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Spectroscopic and photometric studies of main sequence M stars and a search for late-type dwarfs in the solar vicinity

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The University of Arizona, 1992

SPECTROSCOPIC AND PHOTOMETRIC STUDIES OF

MAIN SEQUENCE M STARS

AND A SEARCH FOR LATE-TYPE DWARFS IN THE SOLAR VICINITY

by

Joseph Davy Kirkpatrick

———————————

A Dissertation Submitted to the Faculty of the
DEPARTMENT OF ASTRONOMY
In Partial Fulfillment of the Requirements
For the Degree of
DOCTOR OF PHILOSOPHY
In the Graduate College
THE UNIVERSITY OF ARIZONA

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THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE


As members of the Final Examination Committee, we certify that we have

read the dissertation prepared by___Joseph Davy Kirkpatrick_____

entitled ___SPECTROSCOPIC AND PHOTOMETRIC STUDIES OF MAIN SEQUENCE M____

___STARS AND A SEARCH FOR LATE-TYPE DWARFS IN THE SOLAR VICINITY___

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and recommend that it be accepted as fulfilling the dissertation

requirement for the Degree of ___Doctor of Philosophy_____

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| Donald W. McCarthy, Jr. | 9/9/92 <br> Date |
| Conard C. Dahn | 9/9/92 <br> Date |
| James W. Liebert | 9/9/92 <br> Date |
| John T. McGraw | 9/9/92 <br> Date |
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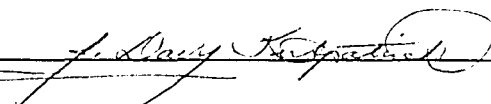direction and recommend that it be accepted as fulfilling the dissertation
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SIGNED:

# DEDICATION

This thesis is dedicated to four individuals to whom I will always be indebted...

My ninth grade physical science teacher, Marilyn Morrison, said she saw something "special" in me and wanted to know if I had plans for my future. I told her that I wanted to become an astronomer, and she informed me that I would have to take a lot of physics and math and that I would most likely have to major in those subjects in college. The idea of taking a lot of physics classes didn't appeal to me, but since Mrs. Morrison held an advanced degree and was also a teacher of physics and math at our local community college, I knew that her opinion was based on facts... and seven years later I finally held that degree in mathematics and physics/astronomy which enabled me to enter graduate school. Because of her, my education always had a clearly defined path, and I thank her especially for making me feel that *I* had special talents.

My aunt Mag was just like a best friend to me. We always had a great time cracking jokes around (and especially *about*) one another and finding joy in the simplicity of the Southern way of life. She taught me about compassion and about values. She, too, made me feel special, and she unwaveringly gave of herself. She was always supportive of my academic pursuits and made me feel that I would make something of myself. I only wish she could have lived long enough to see me get this degree. Mag, I'll always think the world of you, and thanks for not trading me "for all the cows in Texas"!

Finally, there are my amazing parents. There's my Dad who, on the one hand, would tell me that my pile of Vanderbilt homework would "take care of itself," yet, on the other hand, would pull out on those rare occasions his poignant and *horrible* phrase "Let your conscience be your guide." Dad, whenever I'm faced with a dilemma, I think of that saying. There's my Mom who instilled in me the importance of reading and of acquiring a good education; she showed me that learning was fun, and besides it made you a better Jeopardy player and crossword puzzle worker! Mom, I'll always regard you as one of the smartest people in the world. I don't know how they did it — they never seemed to push me — but they saw me all the way through to the completion of this degree. Thanks for your undying support both emotionally and financially. I owe everything to you, and I love you both.

# ACKNOWLEDGEMENTS

Those people listed below helped make this thesis possible, kept me sane during graduate school, or both. To all of you, I extend my sincerest thanks.

I would like to thank my advisor, Don McCarthy, for his frequent and useful insights, for financial assistance, and for being my weight-room partner over the past several years; Todd Henry for innumerable scientific discussions and for assistance with Chapters 3.1 and 3.3; Jim Liebert for financial assistance and for careful readings of Chapters 3.2, 3.3 and 4; Conard Dahn for invaluable help in acquiring and reducing (along with Hugh Harris) the calibration photometry of Chapter 4 and for his many useful suggestions regarding that chapter; John Mc-Graw for conceiving of the CTI concept and for maintaining that the CTI data are of high quality; Doug Kelly for his 50% co-authorship of Chapter 3.2; George Rieke for financial assistance and for overseeing the development of Chapter 3.2; France Allard and Rainer Wehrse for providing unpublished theoretical spectra and for careful readings of Chapter 3.2; Betsy Green for useful discussions regarding the calibration in Chapter 4; Patricia Boeshaar for many unpublished spectral types tabulated in Chapter 5 and for her continued support of my scientific endeavors; and finally my sister Ann Kirkpatrick for (voluntarily!) assisting me in the cross-checking of columns 1 and 3 of Table 5.1.

There are a number of behind-the-scenes people I would also like to thank: Tom Hess, Charles Bridges, Brian Schmidt, Lisa LaFlame, Anne Lierman, and Lexi Moustakas for their assistance in CTI related matters; the crew at the MMT, particularly the telescope operators Janet Robertson, Carol Heller, Bill Kindred, and John McAfee, for surviving my acquistion of over 300 spectra; and Conard and Carol Dahn for providing me a room at their house during my two stints in Flagstaff over the summer of 1992.

With Joan (see you in Texas) Morrill, Diana (Mythica Q.) Johnson, and Sally ("pahl-EEZE!") Oey I have shared good times both during and outside of Astronomy Camp. I am grateful for my friendship with each of you. I am also grateful to those who have unselfishly given their time and talents to help me in my photographic pursuits, particularly Todd Henry, Michael ("I'm always 2nd") Merrill, Tom ("hey, buddy") Connor, and Jorden ("well, dog my cats") Woods.

As for Katy Moore and Kim Dow, they have always been willing to lend an ear when I needed consoling and have provided me with some very interesting diversions. Katy, thanks for listening to me gripe and moan, and maybe someday soon we'll do that joint art exhibition! Kim, I admire your compassion and your unbelievably high energy level. In fact, if the two of you didn't own cats, you'd be darn near perfect!

Lastly, I would like to tell Todd Henry how much I appreciate his friendship. Graduate school would have had a distinctly different flavor had I not met you, Todd. You've given me some of the most memorable and enjoyable experiences I've ever known — our trips to California, our crazy poolside chats, our movie rankings, our overanalyzing of almost any subject! Thanks for being there for me. Life wouldn't be the same without you...

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# ABSTRACT

As any introductory astronomy student knows, M dwarfs are the most common stars in the Galaxy and are the faintest of the core hydrogen burners. A comprehensive study of these faint objects is crucial to our understanding of the stellar composition of the Galaxy and necessary for a more complete knowledge of the transition between main sequence M stars and their slightly less massive counterparts, the brown dwarfs, which never achieve hydrogen burning in their cores.

In this thesis, a spectroscopic catalog of 125 K and M dwarfs is first presented. This catalog covers the wavelength range from 6300 to 9000 Å, near where these objects emit most of their light. Eight of these spectra, covering classes M2 through M9, are combined with infrared spectra from 0.9 to 1.5 $\mu$m to create a second catalog. The two sets of spectra are used to search for temperature-sensitive atomic lines and molecular bands, which are then used in fitting the observed spectra to a sequence of theoretical models. As a result, a new temperature scale for M dwarfs is determined, and this scale is more accurate than previous determinations which have depended on blackbody energy distributions. The sequence of spectra is also used to compare the spectrum of the brown dwarf candidate GD 165 B to known M dwarfs. Furthermore, the spectral catalog is used in an attempt to separate the spectra of faint companions from their M dwarf primaries in systems where the two objects are too close for conventional spectroscopy to resolve the individual components.

A survey for faint M dwarfs is also launched using the data acquired through the CCD/Transit Instrument (CTI) on Kitt Peak, Arizona. Follow-up spec-

troscopy is presented for 133 of these objects, and several more very late M dwarfs are identified. This spectroscopy combined with photometric data from the CTI are used to construct a luminosity function for M dwarfs which is in excellent agreement with determinations from previous surveys.

Finally, possible avenues for future work are discussed. These include spectroscopic follow-up of the reddest of Luyten's proper motion objects — the first results from which have uncovered, in just twelve observations, two objects of type M7 and one of type M8, among the coolest objects yet recognized. Future searches, such as an all-sky survey for objects of extremely high proper motion, are also outlined.

# CHAPTER 1

## INTRODUCTION

Thou know'st 'tis common.
— William Shakespeare, Hamlet, Act I, scene ii, line 72 (1600)

This thesis is an in-depth study of the most common stars in the Galaxy —
the so-called "M dwarfs" — and while this might ordinarily mean that the subject
matter would be interesting only in an academic context, my reasons for studying
this subject are deeply rooted in my early perceptions of a science in which I read
frequently about the making of discoveries and the uncovering of new puzzles.
The puzzle explored in these pages can be stated as follows: although M dwarfs
are the commonest of stars in the Milky Way, and because one would guess *a
priori* that the less massive M dwarfs would be even commoner still, very few
of these lowest mass objects are currently recognized. Unless the presumptions
about our own local galactic milieu are in error, these objects must exist in
hordes. Yet, this myriad of low-mass stars awaits positive detection. Finding the
answer to this problem provides the impetus behind this thesis...

I remember in particular a clear, moonless night from my childhood when,
while riding on the hay wagon *en route* to one of our frequent "wienie roasts" in
the Old Field, I asked my father, "Daddy, what's the name of that star?" His
response was, "I don't know." Undaunted, I found another and asked, "What's

the name of *that* star?" His answer was the same. Nonetheless, this experience left me with a passion for wanting to find out what those stars were called. Lesson #1: I *had* to know.

Later, in the second grade, I was introduced to my elementary school's library, and eventually I was able to locate the five or six books that comprised the library's astronomy section. Unfortunately, some of the books were too advanced for me to read, but there were two, both by H. A. Rey, that were written at my level. As I flipped through them, I found, much to my delight, that the stars names were all listed! Lesson #2: Research pays off.

Then there was the summer afternoon as a teenager when my order from Dover Books arrived: a three volume set called *Burnham's Celestial Handbook.* Noteworthy objects in every constellation were described in detail. I literally couldn't put the books down. There were so many fascinating discoveries there — I could scarcely imagine what other exciting discoveries might lie hidden in the Universe just waiting to be uncovered by some probing astronomer. As I "rounded up" the cows that day for their afternoon milking, I took the first volume along with me. The cows were up at the pond, and I remember being somewhat annoyed at having to climb the steep hill which led there because I wasn't able to walk and read simultaneously. It was then that I began to think seriously about making a career out of astronomy; besides, if I did things right, I wouldn't have to sweat in the hot and humid tobacco fields of Middle Tennessee the rest of my life! Lesson #3: I was hooked...

And so with this thesis I begin an astronomical quest: a search for the intrisically faintest stellar members of our Galaxy. It seems a paradox that we can identify countless quasi-stellar objects lying on the outskirts of the Universe,

yet are unable to find the vast numbers of low-luminosity stars and possibly substellar objects which undoubtedly lie within a few parsecs of our own Sun. In an interesting twist to my childhood conundrum, we now know the name of a certain class of "star" — those that never achieve hydrogen burning in their cores — but have no examples to serve as illustrations. If I were to ask my father today, "Dad, are any of those points of light up there brown dwarfs?", he could honestly reply, "I don't know... and neither does anybody else."

## 1.1: THE MISSING MASS

Consider a population of kinematically well mixed stars. Using observational measurements, the density and velocity distribution of those stars as a function of distance from the galactic plane can be computed. The more total matter there is concentrated close to the plane, the stronger the gravitational potential will be and the more rapidly will the density of the "tracer" stars drop with increasing distance from the plane. Thus, based on the observations, the density of total matter in the plane of the Galaxy can be estimated.

Oort (1932, 1960) pioneered this kind of analysis, and his results showed that a substantial fraction of the derived total mass could not be accounted for by observed matter. That is, the data suggested a large amount of "missing mass" to reside in the solar neighborhood — mass which must be associated with an unseen, "dark" component of the disk. Using updated observations and better theoretical techniques, Bahcall (1987, and papers referenced therein) showed that half of the mass in the solar neighborhood must reside in the form of unobserved matter. The scale height of this material was computed to be less than 700 pc, and if the constituents are objects having masses under 0.1 $M_\odot$, then the nearest one would be about 1 pc away and would have a proper motion exceeding 1 arcsecond per annum.

Recent results have begun to cast doubt upon the reality of this "missing mass," however. Bienaymé, Robin, & Crézé (1987) use a technique based on star counts to obtain a local mass density of 0.09 to 0.12 $M_\odot pc^{-3}$, consistent with the observed value of 0.10 to 0.11 $M_\odot pc^{-3}$ (Bahcall 1984). Kuijken & Gilmore (1989a), using data on K dwarfs near the south galactic pole (SGP), conclude

that there is no missing mass in the solar vicinity, with the same result being found when a re-analysis of data on F dwarfs and K giants is used (Kuijken & Gilmore 1989b). Kuijken (1991) confirms these results using a nearby sample of K dwarfs in addition to the SGP sample.

In response to these claims, Bahcall, Flynn, & Gould (1992) use data on K giants at the SGP to produce a local mass estimate in which the systematic and random uncertainties are well understood. In a "one-experiment" run, they find that a model having no dark matter is inconsistent with the data at an 86% confidence level. These authors give a critical analysis of the Kuijken & Gilmore (1989a, b) mass determinations and conclude that a more robust analysis of the same data would imply a substantial fraction of missing matter. The inhomogeneity in the Bienaymé, Robin, & Crézé (1987) star count sample, as well as in the combined K dwarf sample of Kuijken (1991), should be treated, according to Bahcall, Flynn, & Gould (1992), with caution, as this may introduce unwanted systematic errors.

Clearly, the last has not been written on this subject. If there *is* missing mass, the best possibilities would appear to be very low luminosity degenerates, faint M dwarfs, or brown dwarfs. Liebert, Dahn, & Monet (1988) have shown, however, that the contribution to the local space density by low luminosity white dwarfs is negligible. This has led researchers to begin new surveys in an attempt to identify previously unrecognized M dwarfs and brown dwarfs of faint absolute magnitude.

## 1.2: A COMPANION TO THE SUN?

Inadequate knowledge about the low-luminosity membership of our own so-
lar neighborhood was reflected in a recent study to come out of the field of marine
palaeontology. Raup & Sepkoski (1984) studied marine fossil records throughout
the Phanerozoic (the last 600 million years) and found, as they were expecting,
evidence that mass extinctions have occurred many times, but to their surprise,
the extinctions appeared to be cyclical with a period of 26 Myr, at least over
the last 240 Myr (Lewin 1983). Two major, competing hypotheses were then
born. The first, advocated by Rampino & Stothers (1984), introduced the idea
that the oscillatory motion of the solar system about the plane of the Galaxy
would allow for large clouds of gas and dust to perturb the Oort comet cloud.
Such a scenario would send comets showering into the inner solar system, and
some of these would strike the earth, eradicating many forms of life as global
climactic conditions changed abruptly. A variation of this idea is put forth by
Schwartz & James (1984), but they argue, based on the sun's current position,
that the extinctions occur when the solar system is at its extreme points *away*
from the plane, and here the extinction would be caused, perhaps, by biospheric
alterations induced by larger doses of cosmic or X rays.

The second hypothesis invokes a companion to the sun as the perturber of the
Oort cloud (Davis, Hut, & Muller 1984; Whitmire & Jackson 1984). According to
Davis, Hut, & Muller (1984), this companion, which they dub "Nemesis," has a
moderately eccentric orbit, a period of 26 Myr, and is currently near its aphelion
distance of ~0.7 pc. As a brown dwarf, its presence in the solar vicinity could
have gone unnoticed because of faint apparent magnitude. As an M9 dwarf, it

would have an apparent magnitude of $m_V = 13.5$, but negligibly small proper motion since it is at aphelion. Only its parallax of 1.4 arcseconds would reveal its true identity, leading Perlmutter et al. (1986) to begin a parallax survey of all faint red stars catalogued by the Dearborn Observatory.

As this sample serves to illustrate, our census of objects near the sun is admittedly incomplete — we are currently unable to rule out the existence of a possibly stellar companion which would lie even closer to the sun than Proxima Centauri! Furthermore, our knowledge of brown dwarfs is based on theoretical grounds only; we have only the crudest idea what the apparent magnitude of such a solar companion might be or what it might look like spectroscopically.

## 1.3: A RECENT HISTORY OF SEARCHES FOR VERY LOW-MASS STARS AND BROWN DWARFS

This renewed interest in the original Oort missing mass problem, as well as speculation about an undiscovered solar companion, has helped to spark new surveys, implementing new techniques and technologies, to search for brown dwarfs and the faintest M dwarfs. Imaging fields around nearby stars (Jameson, Sherrington, & Giles 1983; Skrutskie, Forrest, & Shure 1989) is being done to detect possible faint companions. Advances in infrared speckle imaging are enabling astronomers to search nearby M dwarfs for companions as close as 0.2 arcsecond to their primaries and fainter by up to 6 magnitudes at $H$ and $K$ (Henry & McCarthy 1990; Henry 1991; see also Mariotti & Perrier 1991); this technique is providing positive confirmation for some companions first detected during astrometric searches (see, e.g., Lippincott 1978). Obtaining photometry of white dwarfs is continuing in an attempt to detect possible infrared excesses which might indicate the presence of low-mass, very red companions (Probst & O'Connell 1982; Probst 1983a, b; Kumar 1985; Shipman 1986; Kumar 1987; Zuckerman & Becklin 1987a; Becklin & Zuckerman 1988; Zuckerman & Becklin 1992). Photometric studies aimed primarily at discovering young, hot brown dwarfs are focusing on young star clusters and star formation regions such as the Taurus Molecular Cloud (Forrest et al. 1989), the $\rho$ Ophiuchi complex (Rieke, Ashok, & Boyle 1989; Rieke & Rieke 1990), the Pleiades (Stauffer et al. 1989; Jameson & Skillen 1989; Hambly, Hawkins, & Jameson 1991; Simons & Becklin 1992), and the $\alpha$ Persei cluster (Prosser 1992; Rebolo, Martín, & Magazzù 1992). Other studies have instead looked into nearby, older clusters such as the Hyades

(Leggett & Hawkins 1989; Bryja et al. 1992), since for older clusters it should be easier to distinguish on a color-magnitude diagram between brown dwarfs and stars settling toward the main sequence. Other photometric searches have used molecular clouds merely as backdrops to define a well-determined sample volume (Jarrett 1992). Photometric studies have begun in the field, often on much larger areas of sky (Reid & Gilmore 1982; Gilmore, Reid, & Hewett 1985; Boeshaar & Tyson 1985; Boeshaar, Tyson, & Seitzer 1986; Chester et al. 1986; Hawkins 1986; Hawkins & Bessell 1988; Tinney, Mould, & Reid 1992; this thesis). Proper motions are also being measured for faint stars in the Southern hemisphere (Ruiz et al. 1988), and very accurate radial velocity studies are being conducted for (mainly) nearby stars (Campbell, Walker, & Yang 1988; Marcy & Benitz 1989; Latham et al. 1989; Marcy & Butler 1992). Brown dwarfs and planets are now being reported as companions to neutron stars (Fruchter et al. 1990; Bailes, Lyne, & Shemar 1991 — but retracted by Lyne at the 1992 AAS Meeting in Atlanta; Wolszczan & Frail 1992), as possible maser-causing sources in red giants (Struck-Marcell 1988), and as the cause of purported gravitational micro-lensing effects (Irwin et al. 1989). In the past year, quasar searches have even begun to uncover faint, late-M dwarfs and brown dwarf suspects (Schneider et al. 1991; Irwin, McMahon, & Reid 1991).

Despite all of these efforts, however, only six objects (see §3.3) have been identified which are distinctly later in spectral type, and presumably lower in luminosity, than van Biesbroeck 10 discovered in 1944! Why haven't previous searches found these objects in great numbers?

## 1.4: GOALS FOR THIS THESIS

In the chapters which follow, I pursue three different approaches to the continuing search and study of these objects at the end of the main sequence. My original idea was to begin a new, large area survey of these stars using the data base provided by the CCD/Transit Instrument (CTI), described in Chapter 2. After some research into the literature on the subject, though, I found that no comprehensive compendium of late M dwarfs and brown dwarf candidates existed. Furthermore, no one had sought to observe each of these objects in a systematic way so that differences and similarities within the group could be studied. The most obvious tool for such a study is low-resolution spectroscopy. Unfortunately, this, too, presented a problem — standard spectral classification had always been done in the ordinary photographic region, but these objects emit most of their light in the red and infrared portions of the spectrum. Blueward of this, many are beyond the detection limit of even the largest telescopes.

Thus, the first approach became obvious — establishing a new spectral classification scheme for these objects at wavelengths where they were more easily observable. This work is presented in Chapter 3.1. With the development of this spectral sequence, other possibilities arose, such as extending the sequence into the infrared and comparing it to newly produced stellar atmospheric models (Chapter 3.2), obtaining a spectrum of the best brown dwarf candidate known to see if it differed from other spectra in the sequence (Chapter 3.3), and introducing new spectroscopic tools which make it possible for the spectrum of a faint component in a binary system to be studied (Chapter 3.4).

With the establishment of this spectral sequence, the second approach could

begin, and this uses both photometric *and* spectroscopic criteria to study faint, red objects found in the CTI data archives. With this information, a luminosity function (LF) for M dwarfs is produced. Comparisons to other determinations of the LF, as well as an examination of the stellar initial mass function, will help answer the question "Why haven't more of the very lowest mass objects been found?" This work is presented in Chapter 4.

The third approach involves a detailed outline for future research in this area. Spectroscopic acquisition of very red objects already catalogued could reveal many more late dwarfs; a larger sample is badly needed if the gross properties characterizing the population are to be distinguished from the subtle differences existing from spectrum to spectrum. This proposed survey is highlighted in Chapter 5.1. In the context of obtaining a more detailed picture of the makeup of the solar neighborhood, the potential pay-offs of an all-sky survey for high proper motion objects is discussed in Chapter 5.2. The rewards of an all-sky photometric survey are also briefly addressed in Chapter 5.3

In Chapter 6, the major conclusions of this thesis are summarized.

# CHAPTER 2

## THE CCD/TRANSIT INSTRUMENT (CTI)

Astronomy compels the soul to look upwards
and leads us from this world to another.
— Plato, The Republic, book VII, 529 (c. 428 - c. 348 B.C.)

The photometric data base used in the determination of the luminosity function (Chapter 4) is the result of an on-going survey conducted by the CCD/Transit Instrument, otherwise known as CTI. Descriptions of this telescope, its data acquisition, and its archives are given in §2.1. Many astronomical investigations are possible with such a data base, as discussed in §2.2, and the results of the author's previous blue object/emission-line object survey are briefly highlighted as an example. In §2.3 the CTI's role in this thesis is outlined.

### 2.1: TELESCOPE AND DATA BASE

The CTI is a 1.8-m, f/2.2 meridian-pointing telescope located on Kitt Peak, Arizona. It has no moving parts, but utilizes two 320×512 RCA charge-coupled devices (CCDs) aligned with columns in the east-west direction and operated in a "time-delay and integrate" (TDI) mode at the apparent sidereal rate to form an image of the transitting sky (McGraw, Cawson, & Keane 1986). The strip is 8.25-arcminutes wide (north to south) and spans the full range of right ascension.

The telescope is pointed at a declination of +28°, where it can monitor, for example, both the central portion of the Coma Berenices galaxy cluster and areas contained within the Taurus Molecular Cloud. Figure 2.1 shows the course of the CTI strip through galactic coordinates. Note that the strip passes nearly through the North Galactic Pole (NGP), crosses the plane of the galaxy twice, and probes as far south of the plane as $b \approx -35°$. Figure 2.2 shows a typical field near the NGP. This can be compared to Figure 2.3, which shows a field near the galactic plane. In a year's time the CTI surveys about 45 square degrees.

Photometric precision is enhanced by utilization of the TDI technique which averages all spatial instrumental corrections into more stable linear functions. In the space of about 1 minute, an object will traverse 512 lines on the CCD, sampling the flat field vertically as it transits the detector. In such a system, only a flat-field *line* needs to be measured, and this averaging results in a flatter flat field. Bias acquisition is done similarly. Calibration of the CTI photometry will be discussed in Chapter 4.

One of the two CCDs in the focal plane always observes through a $V$ filter while the other observes through $B, R$, or $I$ depending upon the sky brightness. Because it is necessary to maintain a uniform optical path length through the filters so that the CTI will remain in focus regardless of filter choice, the CTI filter system is slightly different from the Johnson/Cousins $BVRI$ system, with each filter having a thickness of 3 mm (McGraw, Cawson, & Keene 1986). The nightly limiting magnitude is $V \approx 21$.

The pixel data are searched to find every detectable object, and photometric parameters are calculated for each. These parameters become part of a "Pool List" and a "Master List" which contain the best estimate for each parameter,

and a "History List" for each color which maintains a light curve for every detected object. (A step-by-step description of the CTI data reduction process can be found in Cawson, McGraw, & Keane 1986a). The "Pool List" contains information on every detection, sorted by right ascension. The "Master List" is a subset of the "Pool List" containing only those objects having a high likelihood of being real. The data listed for each object are variance-weighted mean parameters determined using all available, reduced nights of photometry. Each entry lists, among other parameters, the right ascension and declination (for the 1987.5 equinox) of the object, the average magnitude and magnitude error in each detected bandpass, the number of observations in each bandpass, the image area on the CCD, the ellipticity of the image, the image's peak surface brightness, and pointer numbers referring to its entries in the various "History Lists." There is a "History List" for each bandpass containing the object's coordinates, the individual magnitudes and errors for each detection, and the dates for each individual magnitude determination. The software which is used to interrogate these data bases is described in Cawson, McGraw, & Keane (1986b).

## 2.2: SCIENTIFIC PROGRAMS

The number of scientific programs which can be pursued with the data base is almost limitless. A few examples are listed below.

Extragalactic Astronomy:

● Galaxies — The distribution of galaxies in the surveyed strip can be determined. The density function of Tyson & Jarvis (1979) predicts that 1000 galaxies

are detected per night down to $V = 18$ and that there are some 40,000 total in the strip down to a limiting magnitude of $V = 21$.

• Supernovae — Using the supernova production rate per average galaxy of Tammann (1977), it is predicted that one or more bright supernovae ($V < 16$) will be detected before maximum each year and that some 15 supernovae can be detected per year in galaxies brighter than $V = 18$. Using the data base, the light curves of these supernovae can be monitored and the supernova production rate can be measured.

• Quasars — Complete samples of quasars, based both on color and on variability, can be selected (McGraw *et al.* 1988). The density function of Schmidt & Green (1979) predicts that there are over 500 quasars with $V \leq 20$ in the CTI strip. With this sample the space density and luminosity function as functions of redshift can be determined, and the hypothesis that all quasars are luminosity variables can be studied (McGraw, Angel, & Sargent 1980).

Galactic Astronomy:

• Galactic structure — The structure of our galaxy can be studied to faint magnitudes by investigating the distribution of stars via multi-color star counts.

• Variable stars — The data bases can also be used to study many kinds of variables and specifically to identify and study novae and dwarf novae.

• White dwarfs — Large samples of white dwarfs can be obtained to study scale height and to determine the distribution of white dwarf spectral classes.

• Proper motion stars — By comparing the CTI positional data to a digitized version of the same area of sky taken from the 1950 Palomar Sky Survey (Humphreys, Pennington, & Zumach 1989), previously unknown nearby stars

of faint apparent magnitude can be discovered. In fact, as the CTI continues
to collect data, its own timeline of positions can be searched to discover proper
motion objects (Benedict *et al.* 1991).

o M dwarfs — See §2.3.

Between 1987 and 1989, the author undertook a survey of blue and emission-
line objects in the CTI data base. Some of the more interesting objects uncovered
by this investigation were white dwarfs, blue subdwarfs, quasars, a starburst
galaxy, a Seyfert galaxy, a planetary nebula, and a dMe star. These objects
are listed in Table 2.1 in order of right ascension. The first column gives the
CTI positional designation using equinox 1987.5; columns 2 and 3 give the 1950
coordinates of the object; column 4 gives the $V$ magnitude; and column 5 gives
the object's spectral type. Spectra and finder charts for these objects are available
from the author upon request. This preliminary survey illustrates the potential
which exists for pure astronomical discovery in the CTI strip.

## 2.3: CTI'S ROLE IN THIS THESIS

In the present study, the CTI data base will be used to define a photometri-
cally selected sample of M dwarfs to faint limiting magnitudes. Specifically, the
$R - I$ color will be used as the selection criterion, with $V - I$ also being used
when $V$ magnitudes are available. Since in general only a single color is used
for selection, contamination by background giants, which becomes more prob-
lematic near the galactic plane, cannot be estimated with the usual color-color
diagrams. Instead, the percentage of contamination by giants is estimated by
spectroscopically observing a subset of the photometrically selected objects. The

CTI data base is also used to check for the long-term, high-amplitude variability characteristic of all M giants of type M5 and later.

Dwarf stars of type M6 and later are very important to our understanding of the end of the main sequence, and CTI is a valuable tool for uncovering more of these objects. Spectroscopic follow-up is used to verify all CTI objects suspected through their $R - I$ colors to be of extremely late spectral type. To recognize these objects and to differentiate them from their higher luminosity counterparts, a series of standard spectra has first been obtained. These standard observations are reported in Chapter 3 along with some of the subsequent investigations which have arisen based upon the establishment of the standard spectral sequence. In Chapter 4 the photometrically selected CTI sample of M dwarfs is discussed, and the faint end of the stellar luminosity function is calculated.

TABLE 2.1

OBJECTS DISCOVERED DURING A PRELIMINARY SURVEY
FOR BLUE AND EMISSION-LINE OBJECTS

| CTI Object No. | RA (1950) | Dec | $V$ | Sp. Type |
|---|---|---|---|---|
| 001249.6+280414 | 00:10:52.9 | +27:51:43 | 19.3 | Quasar (z=2.34) |
| 004226.5+275906 | 00:40:26.4 | +27:46:47 | 19.4 | Quasar (z=2.31) |
| 012903.9+280046 | 01:26:58.7 | +27:49:09 | 18.6 | DA |
| 013255.2+280041 | 01:30:49.6 | +27:49:09 | 18.8 | DA |
| 014501.4+275847 | 01:42:54.5 | +27:47:31 | 18.6 | DA wk |
| 015332.9+280203 | 01:51:25.1 | +27:51:00 | 19.5 | DB |
| 015809.8+280132 | 01:56:01.5 | +27:50:36 | 18.7 | DA |
| 015836.1+280551 | 01:56:27.7 | +27:54:56 | 19.2 | DB |
| 015844.7+275957 | 01:56:36.4 | +27:49:02 | 18.9 | Quasar (z=0.75) |
| 020125.3+275914 | 01:59:16.7 | +27:48:24 | 19.2 | DA |
| 021331.9+280443 | 02:11:22.1 | +27:54:13 | 19.2 | DA |
| 035037.2+280044[a] | 03:48:19.5 | +27:53:59 | 18.1 | DA |
| 045934.1+280335[a] | 04:57:13.1 | +28:00:15 | 17.1 | DA |
| 054326.7+280448 | 05:41:04.8 | +28:03:50 | 18.6 | DA |
| 054438.5+280224[a] | 05:42:16.6 | +28:01:30 | 17.9 | DA |
| 062219.2+280323 | 06:19:57.3 | +28:04:32 | 18.4 | DA |
| 102739.6+280341 | 10:25:33.7 | +28:15:11 | 17.6 | Quasar (z=0.36) |
| 104847.9+275823[a,b] | 10:46:44.3 | +28:10:28 | 15.3 | DA |
| 120403.9+275822[c] | 12:02:09.0 | +28:10:54 | 15.5 | Seyfert I galaxy (z=0.165) |
| 125858.5+275856 | 12:57:09.9 | +28:11:04 | 17.6 | DC:(?) |
| 134910.5+275904[d] | 13:47:27.4 | +28:10:13 | 16.3 | sdB |
| 134927.6+275849 | 13:47:44.5 | +28:09:58 | 17.3 | Quasar (z=0.70) |
| 135700.6+280448[a] | 13:55:18.3 | +28:15:45 | 17.0 | DA |
| 135755.3+280057 | 13:56:13.1 | +28:11:53 | 16.8 | dMe |
| 142500.4+280449 | 14:23:20.9 | +28:14:57 | 18.3 | Quasar (z=1.85) |
| 143808.4+275934[a] | 14:36:30.1 | +28:09:15 | 17.8 | DA |
| 144827.0+280525 | 14:46:49.6 | +28:14:44 | 17.8 | Starburst galaxy(z=0.030) |
| 163440.3+280306[a] | 16:33:09.9 | +28:07:42 | 17.0 | DA |
| 175353.4+280005[e] | 17:52:24.8 | +28:00:27 | 12.6 | Planetary nebula |
| 184708.4+280127 | 18:45:39.2 | +27:58:56 | 17.4 | sdB |
| 195027.4+275957[a,f] | 19:48:55.7 | +27:54:11 | 18.5 | DA |

TABLE 2.1 — continued

Notes:

[a] See Kirkpatrick & McGraw 1988.

[b] Given as WD 1046+281 (Ton 547) in McCook & Sion 1987.

[c] Given as QSO 1202+281 (GQ Com) in Hewitt & Burbidge 1980.

[d] Shows a proper motion of $\sim 0.25$ arcsecond/yr; also known as G 150-43.

[e] Given as PK 053+24.1 (Vy 1-2) in Perek & Kohoutek 1967.

[f] Shows a proper motion of $\sim 0.20$ arcsecond/yr.
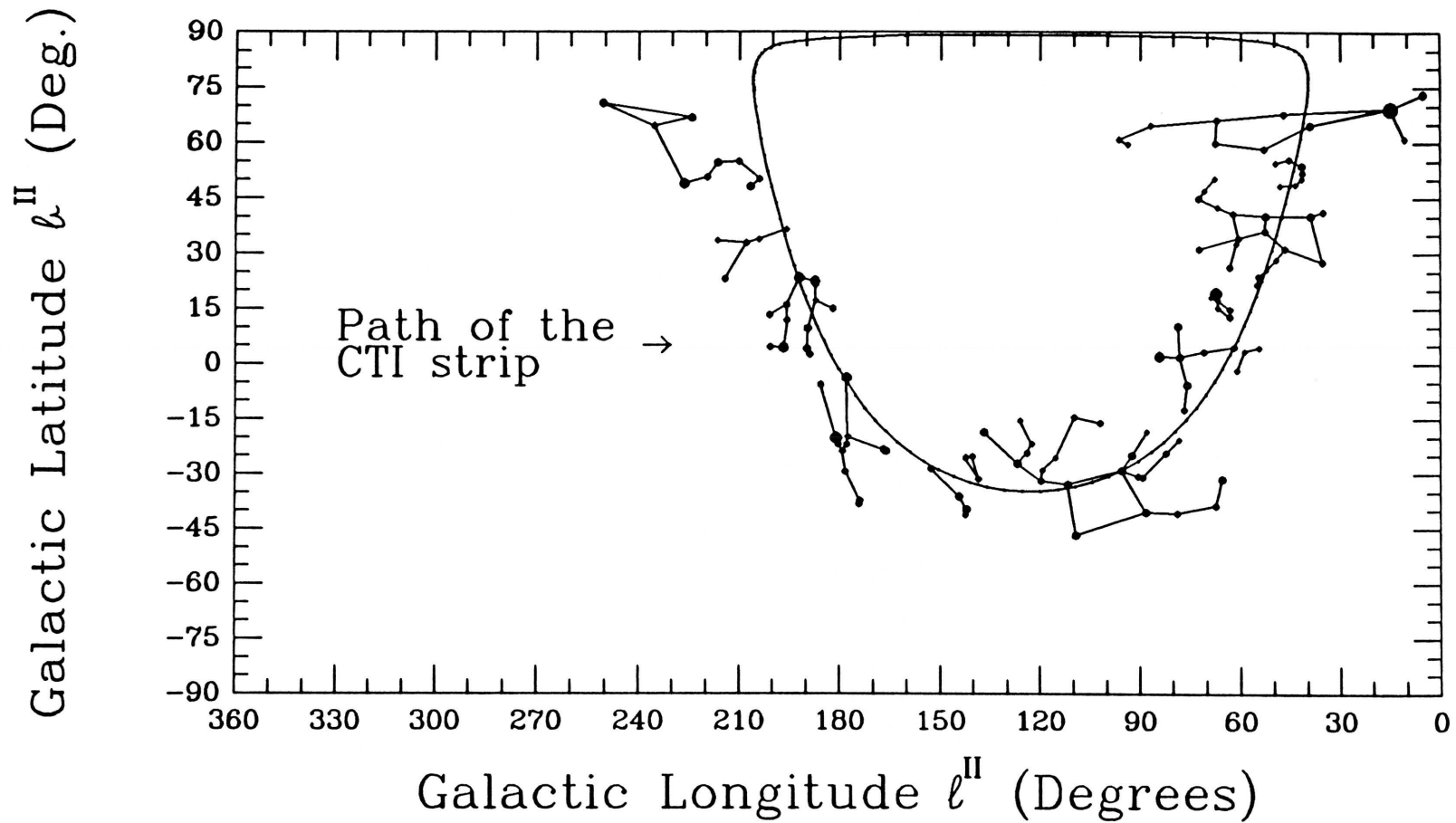
FIG. 2.1. — The path of the CTI survey in galactic coordinates. Familiar constellations are shown along its course. Note that the strip crosses nearly through the North Galactic Pole, crosses the plane of the Galaxy twice (in Cygnus and again in Gemini/Taurus), and probes as far south as $b \approx -35°$. Note also that Pollux ($\beta$ Geminorum) and Scheat ($\beta$ Pegasi) fall in the strip, with Albireo ($\beta$ Cygni) falling just outside.
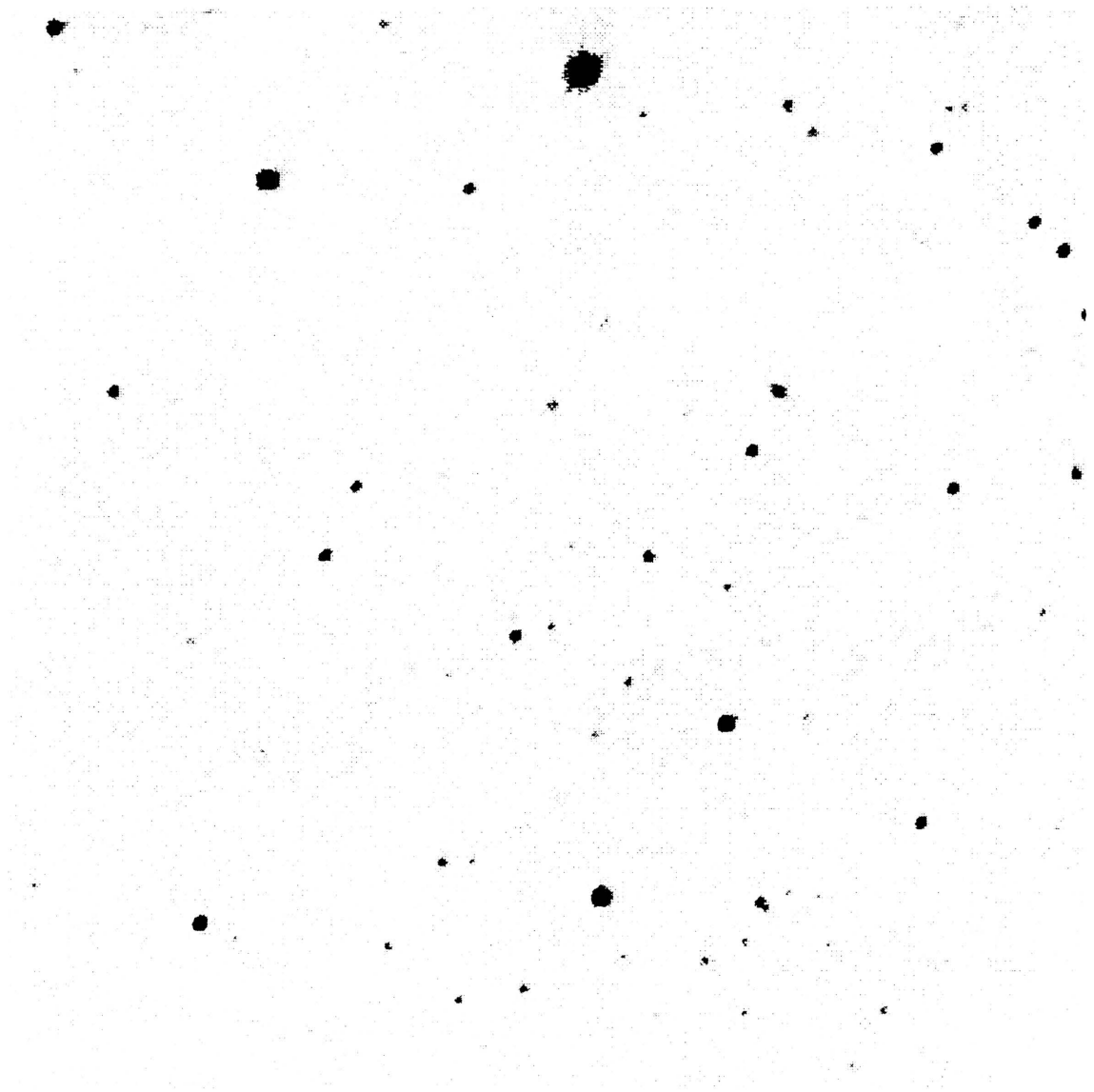
FIG. 2.2. — A typical 1-minute CTI exposure (8.25-arcminutes on a side) in Coma Berenices near the North Galactic Pole. This frame was taken with the "clear" filter and is centered at RA (1950) 12:21:51. North is up, with east to the left. Note the paucity of objects.
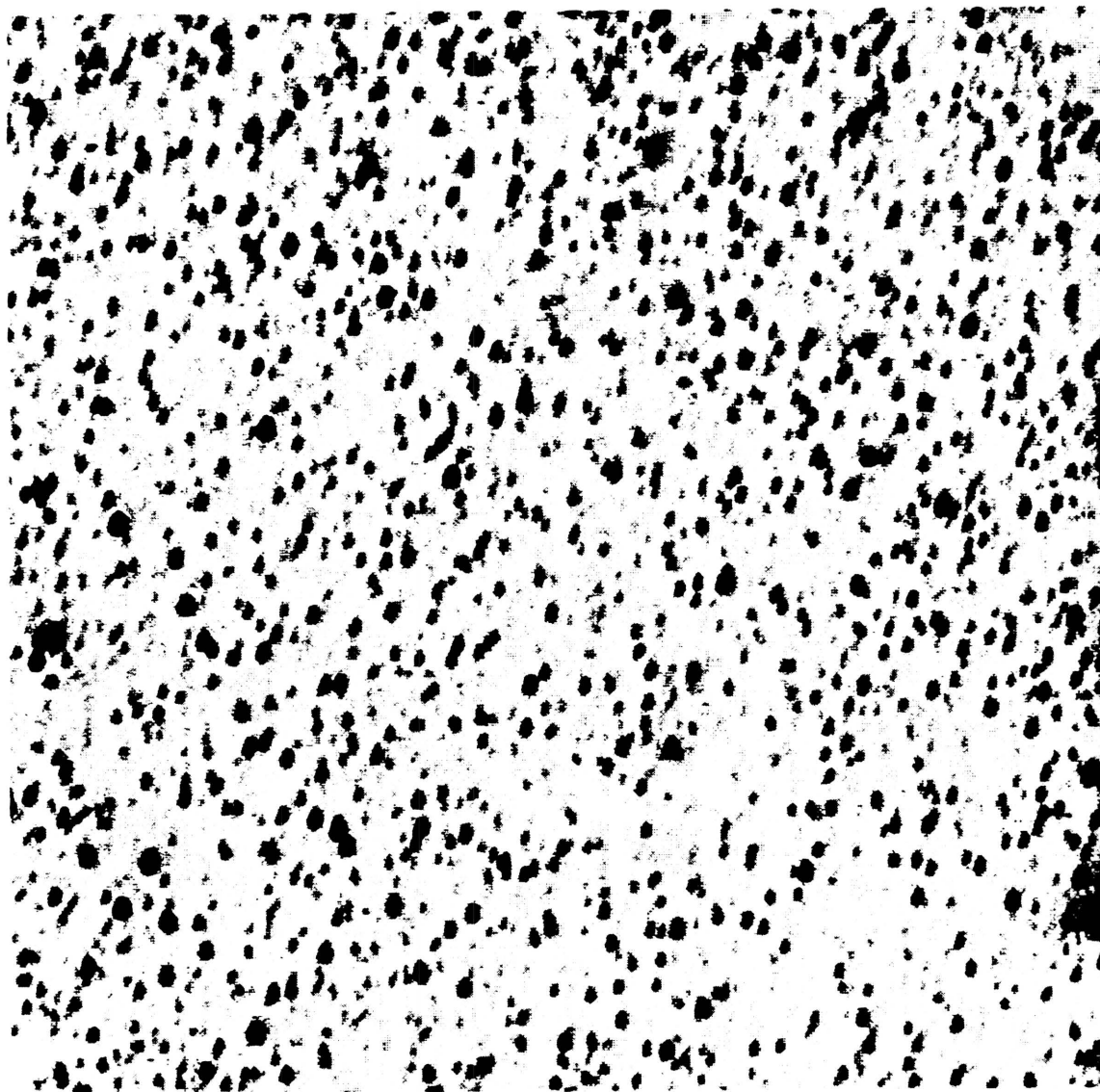
FIG. 2.3. — A typical 1-minute CTI exposure (8.25-arcminutes on a side) in the galactic plane in Cygnus. This frame was taken with the *I* filter and is centered at RA (1950) 19:43:47. Again, north is up, with east to the left. Note the plethora of objects.

# CHAPTER 3

## RED/INFRARED SPECTROSCOPY OF LOW-MASS OBJECTS

Ice is the silent language of the peak;
and fire the silent language of the star.
— Conrad Aiken, And in the Human Heart, Sonnet 10 (1940)

In this chapter, a better understanding of low-mass objects will be obtained by studying their language — that is, their spectra — in a variety of contexts: What spectral characteristics do these objects possess? Can they be differentiated from giants of the same temperature? How does the spectral signature change with decreasing temperature? What *are* the temperatures of these objects? Do there exist spectral characteristics which can discriminate between a low mass stellar object and an even lower mass brown dwarf? Can we establish an empirical relation between a dwarf's spectral class and its mass? If so, what is the smallest mass for which the empirical relation is known? How many objects are currently known which reside near the end of the main sequence?

Specifically, this chapter originated as a necessary first step in checking the photometric results from CTI. Obtaining spectra aids in the investigation of the kinds of objects found in the CTI data base and how well the colors are correlated with spectral type. Nearby, very cool dwarfs will be intrinsically faint, so a large telescope is needed for the acquisition of their spectra. Furthermore,

because these dwarfs are very red, only a small percentage of their total flux will be found at visible wavelengths, where traditional spectroscopy has been done. Obtaining spectra closer to the peak of the energy distribution will allow for shorter integration times and a wider sampling of objects. With current CCDs, adequate throughput is possible out to around 9000 to 10000 Å (0.9 to 1.0 $\mu m$). Recent advances in infrared spectroscopic instrumentation, though revolutionizing the field, still leave the fainter objects unobservable.

Unfortunately, a uniform set of spectral standards has never been acquired in the region longward of H$\alpha$ (6563 Å). So, to place the spectra of the CTI objects on a standard classification system means that a set of spectral standards will have to be observed over the same wavelength range. This standard sequence is presented in §3.1. Some scientific by-products from this spectral sequence are given in subsequent sections: In §3.2 spectra of some of the brighter objects are combined with near-infrared (0.9 to 1.5 $\mu m$) spectra and compared to recent theoretical models to establish temperatures for M dwarfs down to M9. In §3.3 the spectral sequence is used to verify that the spectrum of GD 165 B, the best current brown dwarf candidate, is unlike that of any M dwarf, although its temperature, estimated from the data in §3.2, and its luminosity place it near the end of the stellar main sequence on the H-R Diagram. In §3.4 very high signal-to-noise spectra are presented for some of the objects listed in §3.1, and differential spectroscopy is performed on five composites to obtain spectra of the lower mass secondaries. The results of this chapter are summarized in §3.5.

## 3.1: SPECTRAL LIBRARY FOR K AND M STARS FROM 6300 TO 9000 ÅNGSTROMS

A well-defined standard sequence for late-type stars in the red/near infrared is useful in many astrophysical applications including spectral classification, spectral definition of subdwarf objects, calibration of the temperatures of late-type stars, definition of the end of the main sequence, detection and deconvolution of close binary systems, and development of the stellar luminosity function for the reddest stars, which is currently not well determined.

An extensive spectral catalog from class K5 to M9 is provided here. There are 108 spectra of dwarfs alone, with an additional 17 spectra of objects from other luminosity classes. For classification purposes, obtaining as large a spectral range as possible was the main priority, so the region from 6300 to 9000 Å was chosen. This region encompasses a number of titanium oxide (TiO) bands, useful in classifying early M dwarfs, and a number of vanadium oxide (VO) bands, useful in classifying late M dwarfs (see, e.g., Keenan and Schroeder 1952). The short-wavelength cutoff at 6300 Å provides overlap with the system of Boeshaar (1976), who used features out to 6800 Å and whose dwarf spectral classification system is used in this paper. The B-system band of the CaH molecule, useful as a discriminant between M dwarfs and M subdwarfs (Ake and Greenstein 1980), falls at 6385 Å, near the cutoff. The long-wavelength cutoff at 9000 Å occurs where telluric water absorption begins to dominate the spectrum. This spectral region corresponds more closely than do the bluer systems with the blackbody peaks of M dwarf stars, whose temperatures range from 4000 to 2400 °K (Berriman and Reid 1987; Liebert, Boroson, and Giampapa 1984; a revision of this temperature

scale in given in §3.2).

This large spectral range enables us to investigate whether there are any gross differences among the spectra of the latest M dwarfs which might help discriminate between two distinct groups — late-type stars and hot brown dwarfs. These spectra also provide an important link between optical and near infrared spectra, the latter of which are quickly approaching the resolution of broadband optical spectra used for spectral-typing purposes.

The kinds of objects chosen and the rationale behind their selection is discussed in §3.1.1. The observation and reduction procedures for all spectroscopic data are presented in §3.1.2. A detailed line identification list, including over 50 features useful in describing the spectra of late-type stars, is given in §3.1.3. The method for classifying the spectra, using a combination of spectral features and spectral slope, is outlined in §3.1.4, and a justification for the late-type (M6.5 and later) dwarf classification used here is provided in §3.1.5. The criteria used for luminosity classification are discussed in §3.1.6. Subsequent spectra, not listed as either primary or secondary standards, are presented and classified in §3.1.7. In §3.1.8, the relation between spectral class and mass for dwarf stars is presented, illustrating that mass estimates can be made for main-sequence stars based on an object's spectral class alone. The results are summarized in §3.1.9.

### 3.1.1: Object Lists

Primary dwarf spectral standards were taken from the lists of Boeshaar (1976), Keenan and McNeil (1976, 1989), Turnshek et al. (1985), Boeshaar and Tyson (1985), Giampapa and Liebert (1986), McCarthy et al. (1988), and

Henry and Kirkpatrick (1990). All of these references use the classification system of Boeshaar (1976). Because most of the standards from Boeshaar (1976) are unobservable in the summer months, spectra of a number of M dwarfs from Gliese (1969) and other sources including Luyten (1979) were obtained and reclassified against the primary standards to generate a list of secondary standards.

The primary reason for observing giants and supergiants was to verify that these higher luminosity stars could be reliably distinguished from the dwarfs at the resolution of our data. Standards were taken from the lists of Turnshek et al. (1985), Jacoby, Hunter, and Christian (1984), and Keenan and McNeil (1976, 1989). Classification of giants presents a problem in that giants later than M5 are spectrum variables and are thus unsuitable as spectral standards (Merrill, Deutsch, and Keenan 1962; Abt 1963); the same is true of the latest supergiants although attempts at classifying both have been made (*e.g.,* Solf 1978). No giant or supergiant stars later than M5 have been observed in this study.

M subdwarfs present a different problem. Part of the difficulty lies with the taxonomy itself, *i.e.,* the term "subdwarf" encompasses any number of characteristics including photometric, spectral, or kinematic properties, and a star, whether it fits only one or several of these characteristics, may still be dubbed a "subdwarf." Subdwarfs include stars which are underluminous with respect to the dwarf sequence (an effect which may be due to various line or molecular blanketing effects); stars which are metal poor, indicative of an old halo (population II) origin; and stars with velocities placing them in the halo population. For example, Barnard's Star (GL 699) is sometimes listed as a subdwarf (Veeder 1974), although its gross spectral characteristics, at least in the range covered by our data, do not distinguish it from a dwarf star. (See, however, discussions by

Mould (1976) and Mould and McElroy (1978) on the use of CaH to TiO band ratios as discriminants between old disk dwarfs and halo subdwarfs.) There is also a class of subdwarfs with very strong metallic hydride bands (Bessell 1982). Other stars in our survey which have been classified as subdwarfs in the past include GL 275.2 A (Eggen and Greenstein 1965), GL 213 (Joy and Abt 1974), GL 643 (Veeder 1974), and GJ 2155 (Gliese and Jahreiss 1979). In this paper, we will use the term subdwarf to refer only to those stars whose gross *spectral* characteristics distinguish them to be such. The spectrum of two such subdwarfs, LHS 515 and LHS 2067, are presented here.

### 3.1.2: Observations and Data Reduction

#### a) Dwarf Standards

Tables 3.1 and 3.2 summarize the observations of 77 dwarf spectral standards. All but three were observed with the Red Channel Spectrograph, equipped with a TI CCD, on the Multiple Mirror Telescope (MMT — effective aperture 4.5 m) on Mt. Hopkins, Arizona. A 270 line $mm^{-1}$ grating with an LP-495 order blocking filter was used to cover the range from 6300 to 9000 Å at a resolution of 18 Å. The remaining three dwarfs were observed on 1989 July 24 at the Steward Observatory 2.3-meter telescope with the setup described in §3.1.2b. To assure placement of very faint objects in the aperture, we used a 2.0-arcsec wide slit. It was not deemed necessary to rotate the slit to counteract the effects of atmospheric refraction because even at an airmass of 2.00, the differential refraction between 6500 Å and 9000 Å is only 0.5 arcsecond (Filippenko 1982). Most of these spectra were taken at airmasses of less than 1.2, where the differential

refraction over this wavelength range is less than 0.2 arcsecond.

In the tables, GL (Gliese 1969) numbers are given in the first column and other names are listed in the second column. The third column gives each object's published spectral type, and the fourth gives the spectral type determined here. The date of observation and the length of integration are given in the final two columns.

Figures 3.1 and 3.2 show the spectra of all objects listed in Tables 3.1 and 3.2. Reduction of all spectroscopic data was done with the Image Reduction and Analysis Facility (IRAF) as follows. Each of our MMT observations was contained in a 200 × 800 pixel area on the CCD chip. To determine the bias to subtract from each row of data, we derived an estimate from 18 overscan pixels per row. The bias strip was first reduced to a one-dimensional image by medianing the pixels along rows; this value was then subtracted from the data frame, row by row. To eliminate the pixel-to-pixel variations in the dark current, a median of several dark frames was produced and then subtracted from all object, lamp, flux standard, and flat field frames. Next, to determine the pixel-to-pixel sensitivity variations over the chip, a median of the flat fields was taken and a two-dimensional surface (consisting of a low-order cubic spline along both the rows and the columns) fit to the resultant frame. This surface was then divided into the flat fields, and the resultant flat-field images were divided into each object, lamp, and standard frame.

The spectra of the program objects were not perfectly parallel to the rows of the chip. Therefore, for the sky subtraction, regions typically seven pixels wide just above and below each object spectrum on the chip were fit, along columns, to the background and then subtracted from each spectrum. Because the fit is

done along pixel *columns* (which are not perfectly orthogonal to the dispersion axis of the sky spectrum), these areas were chosen to be close to the object spectrum so that sky subtraction would not be adversely affected. In this way, only those night sky features which are in emission have been removed; removal of absorption features such as the atmospheric A-band has not been attempted.

Next, the spectra were aperture-summed to include all light from the object, and the corresponding lamps were summed over exactly the same area to preserve the wavelength information. Lines in each of the resulting one-dimensional lamp spectra (consisting of helium and argon lines) were then identified to provide a dispersion solution, which was applied to each object and standard star spectrum. Next, the spectra were extinction-corrected using the extinction coefficients for Kitt Peak, which are tabulated in IRAF, and a sensitivity function was derived for each standard spectrum. The standard stars used were from Filippenko and Greenstein (1984). Each spectrum was flux-calibrated in units of $F_\lambda$ using this sensitivity function, and each was inspected for contamination by cosmic rays. Last, each spectrum was normalized to its flux at 7500 Å.

### b) Giant and Higher Luminosity Standards

The giant and higher luminosity standards are given in Table 3.3; the description of the columns is the same as that for Tables 3.1 and 3.2, except that the first column gives the SAO number of the star. These higher luminosity standards (with the exception of SAO 82478, which was observed with the MMT setup described above), as well as the dwarf standards GL 83.1, GL 51, and Gl 866 AB, were observed with the Boller and Chivens Spectrograph with TI CCD

on the Steward Observatory 2.3-m telescope on Kitt Peak, Arizona. A 400 line mm$^{-1}$ grating was employed with a 2-59 order blocking filter to cover the spectral range from 6900 to 9000 Å. This is 600 Å less coverage than obtained at the MMT, but the resolution is improved to 8 Å. The slit width was 2.5 arcseconds.

Figure 3.3 shows the spectra of the 14 objects listed in Table 3.3; the reduction was the same as for the MMT data. The flux standards were from Massey et al. (1988), where an extension, via a blackbody fit to the data, was required for wavelengths longer than 8100 Å. Each spectrum was also normalized to 7500 Å. In Figure 3.3 (as well as for GL 83.1, GL 51, and GL 866 AB in Figure 1) the 2.3-meter data have been rebinned and smoothed to convert them to the same resolution as the MMT data. All subsequent analyses in this paper use these rebinned and smoothed 2.3-meter data.

### c) Miscellaneous Objects

Table 3.4 gives the information on GL 756.2 and LHS 515. Both were taken with the MMT setup described above, and their spectra are shown in Figure 3.4. Details on these two objects are given in §3.1.3c.

### 3.1.3: Line Identifications

An extensive list of features identifiable in the spectra is given in Table 3.5. All obvious atomic and molecular features between 6300 and 9000 Å have been identified using sources dating back to the pioneering work of Öhman (1934). This compilation is presented here to serve as a general reference list for red/near infrared features in late K and M stars of all luminosity classes. The question of

whether each of the listed wavelengths is a laboratory value or a value measured on a spectrum was ignored because of the low resolution (18 Å) employed here. The reader, if concerned about this question, should refer to the paper(s) cited.

Figure 3.5 shows detailed spectra of one supergiant, three giants, three dwarfs, and one subdwarf with line identifications marked. The most obvious lines in these late-type spectra are molecular bands of TiO (and VO for the latest types) and the atomic lines of Ca II, Na I, and K I. Also obvious are the telluric lines of $H_2O$ and the telluric A-band and B-band of $O_2$. In the cooler stars, some of the $H_2O$ absorption is due to the stellar atmosphere, but this is generally overwhelmed by the absorption due to the earth's atmosphere (Spinrad and Newburn 1965; Spinrad et al. 1966).

As can be seen by the spectra in Figure 3.5, supergiants are distinguished by prominent lines of the Ca II triplet and of Fe I and Ti I, as well as prominent bands of CN. In giants of the same spectral type, all of these features are weaker. Dwarfs of similar class have even weaker lines of the Ca II triplet but have much stronger lines of the K I and Na I doublets. The one subdwarf observed shows very strong CaH bands. In short, luminosity classification of the spectra is relatively straightforward except for class II, which is virtually indistinguishable from either class I or class III in this spectral range (Keenan 1957).

As for spectral class, it is clear that K dwarfs, unlike M dwarfs, have little absorption by TiO so that their spectra have much smoother continua. The latest M dwarfs (M7 and later) are distinguished by prominent absorption by VO. Bands of CaH, which are strong in K dwarfs, disappear around spectral class M0 as TiO becomes more prominent. At the resolution of these spectra, $H\alpha$ can be seen in absorption in K dwarfs and occasionally in emission in M

dwarfs. Lines of Fe I and Ca II, which are strong in K through mid-M dwarfs, vanish for late-M dwarfs as absorptions by TiO and VO gain prominence.

Giants, like dwarfs, have little TiO absorption in the K-types, in contrast to mid-M types. The latest M giants are dominated by VO absorption, although none of our giant spectra are late enough to show these VO bands (Keenan and Schroeder 1952). Quantitative criteria for these classifications are given in §3.1.6.

### 3.1.4: Spectral Classification

In this paper we present a different approach to spectral classification than has generally been used in the past. Instead of using only the strengths of the features to determine a spectral type, the slope of the spectrum is also used. This spectrophotometric approach is outlined in §3.1.4a(i) and is compared to the more widely used method in §3.1.4a(ii).

a) Primary Standards

*i) Spectrophotometric Method*

Each of the spectra in Figure 3.1 was run through a least-squares minimization program to determine an ordering for the primary spectra. The program compares one normalized spectrum with each of the other normalized spectra in the list of primary standards by taking the difference between the flux values of the two spectra at 3 Å intervals in wavelength. The sum of the squares of these differences is then obtained for each pair of spectra.

The spectra have been normalized to 7500 Å because there is little absorption

present at this wavelength. However, because there is some level of noise in each of the spectra, the relative normalization for any pair may not be optimal. Therefore, the normalization for each of the spectra in the library is multiplied by a number near 1 (typically between 0.95 and 1.05) until the minimum of the squared differences between it and the spectrum being matched is found.

The minimization program can compute this "least squares" value for any specified spectral region covered by the data. In particular, the program was used to produce least-squares matches based on the data set from 6950 to 8950 Å, on only the *short-wavelength* end of the data (6950 to 7500 Å), and on only the *long-wavelength* end of the data (8400 to 8950 Å). Wavelengths shortward of 6950 Å were not included so that the 2.3-meter data, which begin around 6900 Å, could be compared to the rest of the data.

The matches on the entire data set were useful in determining a rough ordering of the spectra from bluest to reddest, but to obtain the exact ordering in those cases where two or more spectra were very similar to one another, the matches on the ends of the spectra were used. For example, consider two nearly identical spectra. If the normalization for spectrum 1 had to be multiplied by a number *greater* than 1.0 to yield the best match to spectrum 2 at the short-wavelength end, but had to be multiplied by a number *less* than 1.0 to yield the best match to spectrum 2 at the long-wavelength end, then spectrum 1 is clearly redder than spectrum 2. In this way, we ordered the entire catalog of primary standards, from bluest to reddest, and this ordering is given in Table 3.1.

With this ordering, the consistency between the Boeshaar (1976) spectral types and those determined here could be checked. It was found that those spectral types needing revision were changed by only a half spectral subclass at

most. Of the twelve revisions, five were changed by half a subclass, and seven were changed by only a quarter subclass. The distinction between those with a Boeshaar designation of "+" or "-" and those without was not evident, so these designations were dropped from the newly adopted types. Since historically there has been little reason to introduce spectral classes K6, K8, and K9, these designations have also not been used here. In fact, it is found that in this wavelength region the differences between K5 and K7, as well as between K7 and M0, are very slight and do not warrant further subdivisions in spectral class.

For the giants, bright giants, and supergiants, the ordering technique did not result in any necessary changes in spectral class. They are listed from bluest to reddest in Table 3.3.

*ii) "Spectral Features" Method*

The more widely used approach to spectral classification is to use the information contained in the spectral features only and to disregard the overall slope of the spectrum. To do this, the continuum must first be divided out of the data. For the latest stars, there are at best only six points in this spectral range which can possibly be labelled as continuum points: 6530 Å, 7040 Å, 7560 Å, 8130 Å, 8840 Å, and 9040 Å. For each of the spectra in the list of primary standards, a second-order polynomial was fit to the fluxes at each of the six continuum points, and the fit was then divided out of the data to yield a flattened spectrum. The flattened spectra were then run through the least-squares minimization technique described above. In assigning an order and spectral classes to the spectra, this method and the spectrophotometric method are identical,

with three minor exceptions:

(1) The method using spectral features alone indicates the following ordering, from bluest to reddest, of the stars with spectral classes of M3.5 or M4: GL 725 B, GL 273, GL 402, GL 275.2 A, and GL 213. Boeshaar's original spectral classes for these are M3.5, M4, M4, M4+:, and M4+, respectively, showing no discrepancies in ordering. Our adopted spectral types for these stars are M3.5, M3.5, M4, M4, and M4, respectively, also showing no discrepancies in ordering.

(2) The "spectral features" method also indicates that G 208-45 and GL 65 A should be switched in the ordering of Table 3.1 so that the spectral class for G 208-45 is identical to or earlier than GL 65 A. However, in our adopted types, as well as in the literature, G 208-45 has a later spectral class than GL 65 A.

(3) This second method also indicates that LHS 523 and G 51-15 should be switched in the ordering of Table 3.1. This is of little consequence, however, because our classification, as well as that of Boeshaar, is M6.5 for both.

Therefore, the results of the two methods are almost identical. The spectrophotometric method requires that the flux calibrations for the data be relatively accurate so that any errors in the slope of the spectra remain small. The method based only on spectral features can be done without the introduction of flux calibration, but a fit to the continuum of each spectrum must be accomplished. Because the number of continuum points is small and because these are doubtless not true continuum points but rather opacity minima between certain bandheads of TiO, for example, this second method is probably more prone to error than the spectrophotometric method. Hence, the procedure outlined in §3.1.4a(i) will be used for spectral classification throughout the rest of this paper. It is not suggested that this method be used for more distant samples of stars

since for these groups interstellar reddening could affect their classifications. The stars discussed here, however, are all nearby and therefore do not suffer from this problem.

### b) Secondary Standards

Each of the secondary standards was run through the least-squares minimization program to obtain its best match in the list of primary spectra. In this way, each was assigned a spectral type. The newly adopted spectral type was often considerably different from the spectral type quoted in the literature, sometimes by as much as three subclasses. In most cases, the inconsistencies just reflect the differences between the system of Boeshaar (1976) used here and the systems quoted for their spectral types in Gliese (1969). Boeshaar's Table 3 shows several cases of spectral types disagreeing by up to two subclasses between her system and the systems of Joy and Abt (1974) and Kuiper (1938, 1942). In other cases, slight differences may be due to the fact that the current spectra are observed at longer wavelengths than have been used for spectral classification purposes previously. If a faint, unresolved, red companion is present, this may change slightly the subclass of the primary.

By the technique described in §3.1.4a(i), the secondary standards were also ordered from bluest and reddest. The adopted spectral types and ordering are given in Table 3.2. Since the secondary standards have been rigorously typed against the primary standards, both sets serve equally well as spectral standards.

c) Miscellaneous Objects

GL 756.2 was matched via least-squares minimization to the set of giant standards in Table 3.3 (see §3.1.6). Its resulting spectral type is K7 III. LHS 515 was matched against the set of primary dwarf standards, but only over the region from 7050 to 8950 Å in order to exclude the CaH band from 6750 to 7050 Å. The spectrophotometric classification results in a spectral type of sdM2.5, which we have adopted in Table 3.4. When the "spectral features" technique is used over the same wavelength range, however, the resulting type is found to be sdM0.5, indicating that this object has weaker TiO bands, for example, than a dwarf of the same temperature.

### 3.1.5: Extension of the Classification System Beyond M6.5

In the original MKK system of spectral classification, the dwarfs were defined only out to M2 (Morgan, Keenan, and Kellman 1943). The subsequent list of standards, the MK system (Johnson and Morgan 1953), extended the dwarf sequence out to M5 by using Barnard's Star (GL 699) as the reference standard, but this object is now sometimes classified as a subdwarf. The adoption of quantitative classification criteria for dwarfs out to M6.5 was not accomplished until the completion of Boeshaar's (1976) thesis. Before that time, M dwarfs were classified on one of three systems: the Yerkes system of Morgan (1938) and Kuiper (1942), the Mt. Wilson system of Joy (1947) and Joy and Abt (1974), and various authors' attempts at extensions of the MK system.

Unfortunately, astronomers are now presented with a similar problem for spectral classification beyond M6.5. The long-known red objects VB 8 (GL 644

C) and VB 10 (GL 752 B) were not classified by Boeshaar (1976), and subsequent discoveries of objects with even cooler spectra prompted another extension of the classification system. Liebert was the first to obtain spectra of many of these late objects, and Boeshaar was asked for her input in assigning their spectral types. These later types, which are presented in Boeshaar and Tyson (1985), have been used throughout this paper as the basis for the classification of the reddest objects.

In the meantime, Wing was continuing to develop a classification system based on narrow-band photometry of TiO bands. Between M0 and M6, Wing's spectral types are almost identical to those of Boeshaar (Wing and Yorka 1979), but later than this the two systems rapidly diverge. In his system, dwarfs and giants of the same spectral subclass have the same TiO band strengths (Wing 1979). Bessell (1991) has adopted Wing's system and assigns types as late as M10 for giants and as late as M7 for dwarfs. For the coolest dwarfs, he also uses the appearance of VO as an indicator of type, doubtless out of necessity because the TiO bands saturate. A comparison between the latest types used in this paper and those adopted by Bessell (1991) is shown in Table 3.6.

Our reasons for adopting the spectral type extension out to M9 are as follows:

(1) Morgan states that the standards of reference for the MK system "do not depend on values of any specific line intensities or ratio of intensities; they have come to be defined by the appearance of the totality of lines, blends, and bands in the ordinary photographic region" (Morgan and Keenan 1973). Bessell (1991) objects to the use of even the "yellow" portion of the spectrum for late M classification and endorses the use of temperature sensitive features in a region near the maximum flux — a valid point, which is the reason that his spectra

and those of this paper cover nearly the same spectral region. Using TiO band strengths as the sole indicator of spectral type, however, is undesirable because it disregards all of the other information present in the spectrum (the "totality" of which Morgan speaks). Furthermore, Bessell (1991) determines the TiO band strengths by fitting a blackbody curve through the highest "continuum" points. Allard (1990) has calculated M dwarf atmospheres before and after the addition of TiO, $H_2O$, and atomic lines. The depression of the entire spectrum after the addition of these atoms and molecules is striking. Thus, the highest points in an M dwarf spectrum are much below the location of the true continuum, making absolute band strengths unreliable. Ratios are better, and the use of many temperature sensitive ratios is the best.

(2) Note that all of the objects in Table 3.6 have the same Bessell type (M7) except for VB 8 (GL 644 C), which is half a spectral subclass earlier. For the same objects, the classifications in this paper range from M7 to M9. Adopting a system which extends to M9 satisfies the basic tenet which underlies any classification system in any science — things which appear different should be placed into separate categories. The subtle differences in spectral features which distinguish an M0 dwarf from an M1 dwarf may not be immediately apparent from the spectra of Figure 1, but the differences between M7 and M8, or between M8 and M9, are obvious. If spectra which look very similar (like M0 and M1) are segregated, then spectra like those of M7, M8, and M9 should not be placed into the same subclass.

(3) A very fundamental reason for having several subclasses for the coolest spectra, even if few of these objects are currently known, is to search for any peculiarities which could distinguish the spectrum of a brown dwarf from that of

a low-mass star. Above all else, it is these differences that should be noted.

### 3.1.6: Luminosity Classification

The least-squares minimization techniques described in §3.1.3 are very efficient at determining spectral class, but to distinguish between luminosity classes, other criteria are needed: line ratios, flux deficits, or colors. Both line ratios and flux deficits are unsatisfactory because both of these methods require a *continuum* to be drawn to the data — a rather subjective task since M stars exhibit no true continua. Measuring colors, on the other hand, depends only upon the zero-point offset and somewhat upon the resolution of the spectrum. The zero-point dependence is minimized if we take the ratio of two colors which are closely spaced. Therefore, the emphasis here will be placed on color *ratios*.

Examples of useful color ratios are shown in Figure 3.6. The regions over which the flux was summed were wide enough that, despite any shift due to the object's radial velocity, the features examined still fell in the flux regions. Several lines and bands given in Table 3.5 are useful luminosity discriminants: a) the CaH band around 6975 Å is strong in metallic hydride subdwarfs, weaker in dwarfs, and even weaker in giants, b) the Ti I line at 7358 Å is strongest in giants and supergiants, c) the Na I doublet at 8183 Å and 8195 Å is strongest for the dwarfs, and d) the lines of the Ca II triplet (notably the one at 8542 Å which is less contaminated by nearby lines) are strong for giants and supergiants and weak in dwarfs.

For each of the four features mentioned above, a relatively uncontaminated area in the spectrum close to the feature was found to serve as the "continuum"

against which to ratio the flux. In Figure 3.6(a), for example, the flux under the CaH band was integrated from 6960 to 6990 Å, and this was divided into the flux integrated in the nearby "continuum" area of the same width, from 7020 to 7050 Å. The integration limits for each of the color ratios is presented in Table 3.7 along with the features being measured.

All of the stars in Tables 3.1, 3.2, 3.3, and 3.4 are plotted in Figure 3.6 except for the three stars in Table 3.2 which have spectral types earlier than K5. Dwarfs are marked by filled circles, giants by open circles, the bright giant by an open square, and supergiants by crosses. The subdwarf LHS 515 is denoted by a filled square, and GL 756.2 is denoted by an open triangle. As an example, Figure 3.6(a) shows that the metallic hydride subdwarf has the strongest CaH band for its spectral type, followed by the dwarfs and then the higher luminosity stars. Clearly, this criterion separates the luminosity classes very well.

In the remaining graphs of Figure 3.6 — those involving the Ti I line, the Na I doublet, and the Ca II line — there is also a division between luminosity classes. Unfortunately, the dividing line between the dwarfs and the giants is not strong. Note, however, that for two of the graphs in Figure 3.6 the dwarfs fall above the giants in the diagram, and for the other two they fall below. This suggests that ratios of *these* ratios can be constructed to enhance the division between the luminosity classes. These are shown in Figure 3.7. Here, the separations between the dwarfs, giants, and supergiants are much more pronounced, especially in the ratios of the Ca II line at 8542 Å to the Na I doublet, shown in Figure 3.7(d). Any one of the ratios shown in Figure 3.7 would serve as an excellent luminosity discriminant. The values of the ratios used to generate the graphs in Figures 3.6 and 3.7 are listed in Table 3.8.

It should be noted that GL 756.2, marked with a triangle in the figures, shows strong evidence for being a giant star and not a dwarf as published in Gliese (1969) (see Table 3.4). The most convincing evidence for this is shown in Figure 3.7(d), where it is located well above the locus of dwarf stars but below the area occupied by the supergiants. Furthermore, its uncertain parallax is estimated spectroscopically, not trigonometrically, in the Gliese Catalog, and it has negligible proper motion. In addition, Leggett and Hawkins (1988) have noted that this star has red giant colors.

### 3.1.7: Classification of Other Spectroscopic Data

The previous spectra were obtained primarily as the result of a cloudy-night back-up program developed in conjunction with a clear-night program aimed at obtaining spectra of very faint, red CTI objects (Chapter 4). These observational programs concluded in September, 1991, well after the writing of the original paper (Kirkpatrick, Henry, & McCarthy 1991) which introduced the set of 93 spectral standards presented in Tables 3.1-3.4. Since additional cloudy weather was encountered, we had the opportunity to acquire more spectra of brighter objects. These are presented in Table 3.9 and Figure 3.8 and are classified using the techniques discussed in §3.1.3 and §3.1.6. Figure 3.9 plots the color ratios of these objects on the same scale as the plots of Figure 3.7. The values of the ratios used to generate these plots are also listed in Table 3.8. Clearly, most of these objects fall along the locus of dwarfs.

Three objects listed in Table 3.9 are worthy of special mention. The first is LHS 2067, whose companion, LHS 2068, has an earlier spectral type than K5

and is thus not plotted in Figure 3.9 or listed in Table 3.8. LHS 2067 itself is plotted with a filled square in Figure 3.9 and falls away from the area occupied by the dwarfs, much as LHS 515 does in Figure 3.7. For this reason, LHS 2067 is classified here as a subdwarf. A comparison of its spectrum (Figure 3.8) to the spectra just above and below it demonstrates that it has more prominent absorptions by CaH at 6382 - 6389 Å and at 6750 - 7050 Å and by K I at 7665 and 7699 Å. Bessell (1982) lists this star as a metallic hydride dwarf, but curiously mis-identifies it in Bessell (1991), where the spectrum is shown as an M10 giant. The reason for the confusion is that the wrong pair of stars is marked on the finder chart in Luyten & Albers (1979). The real LHS 2067 and 2068 are the two stars ~40 arcseconds to the northeast of the pair that is marked on the chart. Enough time has elapsed since the chart was taken in the 1950's (the Palomar Sky Survey) for current observations to reveal the true pair via its high proper motion, and hence its displacement, relative to the other stars in the field.

The second noteworthy object is Pleiad #2, a brown dwarf candidate detected in the Pleiades by Stauffer et al. (1989, see their table 1). Although classified here as an M5.5 V, this object could, in fact, be a young, hot brown dwarf with spectral characteristics much like that of a normal M dwarf. Pleiad #2 may have slightly enhanced bands of TiO, as compared to other objects of the same spectral class. Its position in the plots of Figure 3.9 is shown by a filled triangle, and it falls in the region occupied by dwarfs for all of the plots except Figure 3.9(b), but this could be spurious due to the fact that the spectrum itself is rather noisy. The spectrum of Ap 0325+4853 (shown in Rebolo, Martín, & Magazzù 1992), a brown dwarf candidate in the $\alpha$ Persei cluster, also appears much like that of an M dwarf. If these are substellar objects and not

stars, the spectral distinction is not obvious. The Li I doublet at 6708 Å has been proposed by Rebolo, Martín, & Magazzù (1992) as a discriminant which could possibly differentiate between brown dwarf an M dwarf spectra. Unfortunately, higher resolution and higher signal-to-noise are necessary before this discriminant can be tested.

The third noteworthy object is RG 0050-2722, which was discovered by Reid & Gilmore (1981). Based upon the strengths of the spectral features — particularly the appearance of VO — this object should be given a designation of M8 (Liebert & Ferguson 1982; Boeshaar 1992). However, the spectrum presented here is clearly redder that GL 752 B (vB 10), the standard M8 dwarf. A comparison of the $I - J$ color of RG 0050-2722 (Reid & Gilmore 1982) and the $I - J$ colors of other M dwarfs (see Table 3.2.5, which gives colors on the same system as that of Reid & Gilmore) shows that this object is redder than vB 10 but not as red as LHS 2924. A comparison of the $J - H$ and $J - K$ colors shows it to be redder than *both* vB 10 and LHS 2924. We hereby assign RG 0050-2722 a spectral class of M8: indicating the discrepancy between its feature strengths and its colors. A comparison of near-infrared spectroscopy of this object and of other late-M dwarfs should prove interesting.

Other objects in Table 3.9 (see §3.1.8) are used in an update of the spectral class versus mass relation originally presented in Kirkpatrick, Henry, & McCarthy (1991), and several of these are discussed in more detail in §3.4. The significance of objects with spectral types later than M6 — which includes four objects in Table 3.9, six objects in Table 3.1, and two objects in Table 3.2 — is discussed in §3.3.

## 3.1.8: Spectral Class versus Mass Relation

In an effort to provide a mass calibration for the dwarf spectral sequence established here, we have examined several M dwarfs in binary systems for which component masses have been determined dynamically (not photometrically). In practice, individual component spectra are difficult to obtain unless the two objects in the system are separated by greater than 2″. Unfortunately, such systems necessarily have long orbital periods and hence poorly determined masses. Nevertheless, seven nearby M dwarfs have separations wide enough to allow the acquisition of component spectra and reasonably accurate masses: GL 65 A and B, GL 166 C, GL 725 A and B, and GL 860 A and B. To this special class of objects we have added eight pairs with separations less than 1″. In six of these, the primary is much more luminous than the secondary so that its light dominates the spectrum: GL 22 AC, GL 234 AB, GL 508 AB, GL 623 AB, LHS 1047 AB, and G 208-44 AB. In addition, the close binaries GL 352 AB and GL 661 AB possess components of nearly equal masses, and presumably the spectral type of the composite is that of the individual stars.

Table 3.10 lists the masses and spectral types of the calibration M dwarfs. The masses are based on new infrared speckle imaging results and on new parallaxes, and the errors given are standard errors which were determined from the literature (Henry 1992). Shown in Figure 3.10 is the spectral class versus mass relation which allows mass estimates for dwarfs to be made based upon spectral class alone. Because only a few objects are available with known masses and spectra on this system, no corrections for age and metallicity effects on spectral types have been attempted.

As can be seen from Figure 3.10, the trend of spectral class with mass is quickly approaching the line which separates the lowest mass stars from the highest mass brown dwarfs (0.08 $M_\odot$). If the trend on this semilog plot is fit with a straight line, it is found that any object with a spectral class of approximately M7 or later can no longer be a star by virtue of its low mass. Interestingly, this is also the point in the spectral sequence where absorption by vanadium oxide becomes apparent (although at higher resolution, VO can be seen at class M5 (Boeshaar (1976)). However, there is no *a priori* reason to believe that the trend in Figure 3.10 is not, for example, asymptotic downward as the mass limit for hydrogen burning is approached. Unfortunately, we cannot presently probe any closer to the brown dwarf line because there are no reliable masses known for objects typed as M6.5 or later. All objects of extremely late spectral class are either single objects (*e.g.*, LHS 2924 and LHS 2065) or are in binaries with very long orbital periods (P $\approx$ 500 years for the GL 569 AB system — Forrest, Skrutskie, and Shure 1988), making accurate mass determinations impossible (see §3.3 of this thesis).

### 3.1.9: Summary

Spectra of 125 late K to late M spectroscopic standards in the region from 6300 to 9000 Å have been presented. Spectral classification has been accomplished by using a spectrophotometric least-squares technique in which both the features and the slope of the spectrum are used. Luminosity classification has been accomplished by identifying luminosity-dependent features in the spectra and creating ratios of narrow-band colors centered on those features. An exten-

sive list of features (from 6300 Å to 9000 Å) identifiable at a resolution of 18 Å in K and M stars of all luminosity classes has been produced. Using dwarfs whose masses are well determined, we have found a tight correlation of mass with spectral class which illustrates that the later M dwarfs are very quickly approaching the brown dwarf limit of 0.08 $M_\odot$. To examine the trend below 0.10 $M_\odot$ requires accurate masses to be determined for stars of class M7 or later.

The spectral sequence will also be used to check against current models of cool-star atmospheres from Allard (1990). The spectra provided here represent a stepping stone between the optical spectral sequences developed in the past and the near infrared spectra which are rapidly approaching resolutions similar to that used for spectral classification. As shown in the next section, moderate resolution spectra of late-type stars from 0.63 to 1.5 $\mu m$ permit definite temperature scales to be assigned to these very red objects. It is hoped that such a calibration will allow a better determination to be made of the location of the end of the main sequence.

# TABLE 3.1

## PRIMARY DWARF SPECTRAL STANDARDS

| Gliese Number | Other Name | Boeshaar Spec. Type[a] | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| 820 A | 61 Cyg A | K5 V[b,c] | K5 V | 1989 Jul 14 | 2 |
| 820 B | 61 Cyg B | K7 V[b,c] | K7 V | 1989 Jul 14 | 2 |
| 380 | HD 88230 | K7 V | K7 V | 1990 Jan 22 | 5 |
| 328 | BD +2°2098 | M0.5 V | M0 V | 1990 Jan 22 | 120 |
| 270 | BD +33°1505 | M0 V | M0 V | 1990 Jan 22 | 597 |
| 846 | HD 209290 | M0.5 V | M0.5 V | 1989 Jul 14 | 5 |
| 229 | HD 42581 | M1 V | M1 V | 1990 Jan 22 | 370 |
| 205 | HD 36395 | M1.5 V | M1.5 V | 1990 Jan 22 | 60 |
| 411 | HD 95735 | M2 V | M2 V | 1990 Jan 22 | 9 |
| 382 | BD −3°2870 | M2 V | M2 V | 1990 Jan 22 | 45 |
| 250 B | BD −5°1844 B | M2.5 V | M2.5 V | 1990 Jan 22 | 600 |
| 381 | G 53-28 | M3 V | M2.5 V | 1990 Jan 22 | 95 |
| 352 AB | BD −12°2918 AB | M3+ V | M3 V | 1990 Jan 21 | 8 |
| 436 | BD +27°28217 | M3 V | M3 V | 1990 Jan 22 | 720 |
| 251 | Wolf 294 | M3.5 V | M3 V | 1990 Jan 22 | 360 |
| 752 A | HD 180617 | M3 V | M3 V | 1989 Jul 10 | 17 |
| 725 A | HD 173739 | M3 V[c] | M3 V | 1989 Jul 14 | 5 |
| 273 | BD +5°1668 | M4 V | M3.5 V | 1990 Jan 22 | 120 |
| 725 B | HD 173740 | M3.5 V[c] | M3.5 V | 1989 Jul 14 | 5 |
| 213 | Ross 47 | M4+ V | M4 V | 1990 Jan 22 | 130 |

TABLE 3.1 (continued)

| Gliese Number | Other Name | Boeshaar Spec. Type[a] | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| 275.2 A | G 107-69 | M4+: V | M4 V | 1990 Jan 22 | 1200 |
| 402 | Wolf 358 | M4 V | M4 V | 1990 Jan 22 | 900 |
| 83.1 | G 3-33 | M4.5 V | M4.5 V | 1989 Jul 24 | 660 |
| 268 AB | Ross 986 AB | M4.5 V | M4.5 V | 1990 Jan 22 | 842 |
| 166 C | 40 Eri C | M4.5 V | M4.5 V | 1990 Jan 20 | 15 |
| 234 AB | Ross 614 AB | M4.5 V | M4.5 V | 1990 Jan 22 | 1980 |
| 51 | Wolf 47 | M5 V | M5 V | 1989 Jul 24 | 960 |
| 866 AB | G 156-31 AB | M5+ V | M5 V | 1989 Jul 24 | 420 |
| — | G 208-44 AB | M5+ V | M5.5 V | 1989 Jul 13 | 75 |
| 65 A | G 272-61 A | M6− V[d] | M5.5 V | 1990 Jan 20 | 25 |
| — | G 208-45 | M6 V[e] | M6 V | 1989 Jul 13 | 225 |
| 65 B | UV Cet | M6− V[d] | M6 V | 1990 Jan 20 | 25 |
| 406 | Wolf 359 | M6 V | M6 V | 1990 Jan 20 | 80 |
| — | LHS 523 | M6.5 V[f] | M6.5 V | 1989 Jul 13 | 600 |
| — | G 51-15 | M6.5 V | M6.5 V | 1990 Jan 20 | 243 |
| 644 C | VB 8 | M7 V[f,g] | M7 V | 1989 Jul 10 | 1200 |
| 752 B | VB 10 | M8 V[c,f,g] | M8 V | 1989 Jul 10 | 1800 |
| 569 B | BD +16°2708 B | M8.5[h] | M8.5 | 1989 Jul 14 | 2100 |
| — | LHS 2924 | M9[f,g] | M9 | 1989 Jul 13 | 1980 |

TABLE 3.1 (continued)

[a] Boeshaar 1976 unless otherwise noted.
[b] Keenan and McNeil 1989.
[c] Turnshek *et al.* 1985.
[d] GL 65 A and GL 65 B typed as one spectrum by Boeshaar 1976.
[e] McCarthy *et al.* 1988.
[f] Giampapa and Liebert 1986.
[g] Boeshaar and Tyson 1985.
[h] Henry and Kirkpatrick 1990.

TABLE 3.2

SECONDARY DWARF SPECTRAL STANDARDS

| Gliese Number | Other Name | Published Spec. Type[a] | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| 764.1 A | HD 184860 | K2 V | < K5 V | 1989 Jul 14 | 21 |
| 250 A | HD 50281 | K6 V | < K5 V | 1990 Jan 22 | 274 |
| 340.3 | HD 80632 | K8 V | < K5 V | 1990 Jan 22 | 45 |
| 775 | HD 190007 | K4 V | K5 V | 1989 Jul 14 | 3 |
| 764.1 B | BD −10°5130 B | K5 V | K7 V | 1989 Jul 14 | 21 |
| 265 A | BD +27°1311 A | M0 V | K7 V | 1990 Jan 22 | 300 |
| 786 | HD 193202 | M0 V | K7 V | 1989 Jul 14 | 10 |
| 748.2 A | BD +1°3942 A | M0 V | K7 V | 1989 Jul 14 | 80 |
| 430 | BD +63°965 | M0 V | K7 V | 1990 Jan 22 | 210 |
| 338 B[b] | HD 79210 | M0 V | K7 V | 1990 Jan 22 | 10 |
| 734 A | HD 230017 | M0 V | M0 V | 1989 Jul 14 | 15 |
| 763 | HD 184489 | M1 V | M0 V | 1989 Jul 14 | 17 |
| 338 A | HD 79211 | M0 V | M0 V | 1990 Jan 22 | 10 |
| 748.2 B | BD +1°3942 B | — | M0 V | 1989 Jul 14 | 80 |
| 839 | G 215-20 | M2 V | M0.5 V | 1989 Jul 14 | 17 |
| — | GJ 2155 | sdM[c] | M0.5 V | 1989 Jul 14 | 25 |
| 761.2 | BD +0°4241 | M1 V | M0.5 V | 1989 Jul 14 | 35 |
| 720 A | BD +45°2743 | M2 V | M0.5 V | 1989 Jul 14 | 20 |
| 767 A | BD +31°3767 A | M1 V | M0.5 V | 1989 Jul 14 | 30 |
| 220 | Ross 59 | M2 V | M2 V | 1990 Jan 22 | 120 |

TABLE 3.2 (continued)

| Gliese Number | Other Name | Published Spec. Type[a] | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| 22 AC | BD +66°34 AC | M2.5 V | M2 V | 1990 Jan 21 | 23 |
| 806 | G 209-41 | M3 V | M2 V | 1989 Jul 14 | 30 |
| 767 B | BD +31°3767 B | M2 V | M2.5 V | 1989 Jul 14 | 30 |
| 226 | G 222-11 | M3 V | M2.5 V | 1990 Jan 22 | 320 |
| 22 B | BD +66°34 B | M4.5 V | M3 V | 1990 Jan 21 | 23 |
| 569 A | BD +16°2708 A | M0 V | M3 V | 1989 Jul 14 | 20 |
| 669 A | Ross 868 | M4 V | M3.5 V | 1989 Jul 10 | 210 |
| 748 AB | Wolf 1062 AB | M4 V | M3.5 V | 1989 Jul 14 | 30 |
| 643 | Wolf 629 | M4 V | M3.5 V | 1989 Jul 10 | 1920 |
| 734 B | BD +10°2734 B | — | M3.5 V | 1989 Jul 14 | 60 |
| 699 | Barnard's Star | M5 V | M4 V | 1989 Jul 10 | 7 |
| 232 | Ross 64 | M6 V | M4 V | 1990 Jan 22 | 900 |
| 791.2 | G 24-16 | M6 V | M4.5 V | 1989 Jul 10 | 210 |
| 669 B | Ross 867 | M5 V | M4.5 V | 1989 Jul 10 | 510 |
| — | LHS 3339 | M5.5 V[d] | M5.5 V | 1989 Jul 13 | 1200 |
| — | LHS 5142 | — | M6.5 V | 1990 Jan 21 | 900 |
| — | LHS 191 | M7: V[d] | M6.5 V | 1990 Jan 21 | 900 |
| — | LHS 2065 | — | M9 | 1990 Jan 21 | 1500 |

[a] Gliese 1969 unless otherwise noted.

[b] Earlier spectral type than its companion, GL 338 A.

[c] Gliese and Jahreiss 1979.

[d] Boeshaar 1992.

TABLE 3.3

## GIANT (AND HIGHER LUMINOSITY) SPECTRAL STANDARDS

| SAO Number | Other Name | Published Spec. Type[a] | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| 52516 | BS 8726 | K5 I[b,c] | K5 I | 1989 Jul 24 | 1 |
| 22994 | HD 13136 | M2 I[b] | M2 I | 1989 Jul 24 | 15 |
| 67559 | $\delta^2$ Lyr | M4 II[d] | M4 II | 1989 Jul 24 | 2 |
| 30653 | $\gamma$ Dra | K5 III[c] | K5 III | 1989 Jul 24 | 3 |
| 21753 | BD +59°128 | K7 III[b] | K7 III | 1989 Jul 24 | 50 |
| 36509 | BS 152 | K7 III[d,e] | K7 III | 1989 Jul 24 | 1 |
| 141052 | $\delta$ Oph | M0.5 III[d] | M0.5 III | 1989 Jul 24 | 4 |
| 127976 | 55 Peg | M1 III[c] | M1 III | 1989 Jul 24 | 4 |
| 91792 | $\chi$ Peg | M2 III[f] | M2 III | 1989 Jul 24 | 4 |
| 28843 | 83 UMa | M2 III[d] | M2 III | 1989 Jul 24 | 1 |
| 63349 | BD +31°2450 | M3 III[b] | M3 III | 1989 Jul 24 | 320 |
| 82478 | HD 110964 | M4 III[b] | M4 III | 1989 Jul 10 | 10 |
| 34651 | BS 8621 | M4 III[g] | M4 III | 1989 Jul 24 | 3 |
| 141344 | HD 151061 | M5 III[h] | M5 III | 1989 Jul 24 | 4 |

[a] Turnshek *et al.* 1985 unless otherwise noted.

[b] Jacoby, Hunter and Christian 1984.

[c] Also from Keenan and McNeil 1989.

[d] Keenan and McNeil 1976.

[e] Listed as K6 III in Keenan and McNeil 1989.

[f] Listed as M2+ III in Keenan and McNeil 1989.

[g] Listed as M4+ III in Keenan and McNeil 1989.

[h] Listed as M5 to M5.5 III in Keenan and McNeil 1989.

TABLE 3.4

MISCELLANEOUS OBJECTS

| Gliese Number | Other Name | Published Spec. Type | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| 756.2 | HD 182196 | K5 V[a] | K7 III | 1989 Jul 14 | 2 |
| — | LHS 515 | sdM0-2[b] | sdM2.5 | 1989 Jul 13 | 1200 |

[a] Gliese 1969.
[b] Giampapa and Liebert 1986.

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TABLE 3.5

FEATURES FOUND IN LATE K TO LATE M
SPECTRA FROM 6300 Å TO 9000 Å

| λ (Å) | Identification | Notes | References |
|---|---|---|---|
| 6322 6358 6448 6512 | TiO | early to late M | 1 |
| 6346 | CaH | strongest in K dwarfs | 1 |
| 6382 6389 | CaH | seen in dwarfs — disappears by mid-M; strong | 2, 3, 4 |
| 6415 | CaOH | (not seen by us — it falls in the bad column on the chip) | 1 |
| 6497 | Ba II blended with Ti, Fe, Ca | seen in K and early-M stars | 5, 6 |
| 6563 | Hα | in absorption in K stars; sometimes in emission in M stars | 6 |
| 6569 6596 6629 6649 | TiO | mid- to late-M stars | 1 |
| 6651 6680 6713 6746 6814 6852 | TiO | mid- to late-M stars | 1 |
| 6708 | Li I | seen in some K and M stars | 7, 8 |

TABLE 3.5 (continued)

| $\lambda$ (Å) | Identification | Notes | References |
|---|---|---|---|
| 6750 | CaH | strongest in early M dwarfs; | 3, 4, 6 |
| 6903 | | particularly strong in metallic | |
| 6908 | | hydride subdwarfs | |
| 6921 | | | |
| 6946 | | | |
| 7050 | | | |
| 6867 | telluric $O_2$ | — | 6, 7 |
| 7000 | (B-band) | | |
| 6979 | Fe I | K and early-M supergiants | 6 |
| 7053 | TiO | found in all; strongest | 1, 6 |
| 7087 | | in early- to mid-M | |
| 7124 | | | |
| 7159 | | | |
| 7197 | | | |
| 7219 | | | |
| 7270 | | | |
| 7186 | telluric $H_2O$ | — | 6 |
| 7273 | | | |
| 7334 | VO | seen only in late-M stars | 6, 9 |
| 7372 | | | |
| 7393 | | | |
| 7405 | | | |
| 7418 | | | |
| 7472 | | | |
| 7534 | | | |
| 7345 | Ti I | obvious in K and early-M | 10 |
| 7358 | | giants and supergiants | |
| 7364 | | | |

TABLE 3.5 (continued)

| λ (Å) | Identification | Notes | References |
|-------|----------------|-------|------------|
| 7389 | Fe I | obvious in K and early-M giants and supergiants | 10 |
| 7411 | Fe I | obvious in K and early-M giants and supergiants | 10 |
| 7589<br>7628 | TiO | found in all; lies in atmospheric A-band | 11 |
| 7594<br>7685 | telluric $O_2$<br>(A-band) | — | 6, 7 |
| 7665<br>7699 | K I | obvious only in dwarfs and subdwarfs; blended with A-band and TiO | 7 |
| 7666<br>7672<br>7705<br>7743<br>7752<br>7783<br>7820<br>7828<br>7861 | TiO | prominent in M stars; strongest at mid-M | 6, 12 |
| 7851<br>7865<br>7897<br>7900<br>7919<br>7929<br>7939<br>7961<br>7967<br>7973 | VO | obvious in late-M dwarfs | 6, 12 |

TABLE 3.5 (continued)

| λ (Å) | Identification | Notes | References |
|---|---|---|---|
| 7878 | CN | obvious in supergiants, | 11 |
| 7895 | | weaker in giants; not seen | |
| 7916 | | in dwarfs | |
| 7941 | | | |
| 7963 | | | |
| 8026 | | | |
| 8044 | | | |
| 8068 | | | |
| 8075 | Fe I | seen in subdwarfs | 13 |
| 8164 | telluric $H_2O$ | — | 6 |
| 8177 | | | |
| 8183 | Na I | found in all; strongest | 6 |
| 8195 | | in dwarfs | |
| 8206 | TiO | found in all; strongest at | 6, 12 |
| 8251 | | mid-M | |
| 8289 | | | |
| 8303 | | | |
| 8335 | | | |
| 8373 | | | |
| 8386 | | | |
| 8420 | | | |
| 8457 | | | |
| 8472 | | | |
| 8506 | | | |
| 8513 | | | |
| 8558 | | | |
| 8569 | | | |
| 8227 | telluric $H_2O$ | — | 6 |
| 8282 | telluric $H_2O$ | — | 13 |

TABLE 3.5 (continued)

| λ (Å) | Identification | Notes | References |
|-------|----------------|-------|------------|
| 8308 8330 | Ti I and Fe I blends | marginally visible in giants and supergiants | 11 |
| 8327 | Fe I | found in K dwarfs | 12, 13 |
| 8388 | Fe I | strongest in K to mid-M stars | 12 |
| 8432 8442 8452 | TiO | prominent in mid- to late-M stars | 12 |
| 8435 | Ti I | obvious in giants and supergiants | 12 |
| 8440 | Fe I | obvious in K and early-M stars; dominated by TiO elsewhere | 13 |
| 8468 | Fe I, Ti I | most obvious in giants and supergiants and K dwarfs | 12, 13 |
| 8498 8542 8662 | Ca II | strongest in late-K through mid-M; strongest in supergiants then giants; weaker in dwarfs | 12 |
| 8514 | Fe I | most obvious in giants and supergiants | 12 |
| 8518 | Ti I | most obvious in giants and supergiants | 12 |

TABLE 3.5 (continued)

| λ (Å) | Identification | Notes | References |
|---|---|---|---|
| 8521 | VO | found only in late-M stars | 9, 12 |
| 8538 | | | |
| 8574 | | | |
| 8597 | | | |
| 8605 | | | |
| 8624 | | | |
| 8649 | | | |
| 8668 | | | |
| 8582 | Fe I | found in K and early- | 13 |
| 8593 | | to mid-M stars | |
| 8599 | | | |
| 8611 | | | |
| 8616 | | | |
| 8622 | | | |
| 8689 | Fe I | strongest in K dwarfs | 7 |
| 8710 | Fe I | strongest in K and early-M | 13 |
| 8713 | | dwarfs and subdwarfs | |
| 8718 | Mg I | strongest in mid-M dwarfs | 13 |
| 8757 | Fe I | strongest in giants and | 13 |
| 8764 | | supergiants | |
| 8793 | Fe I | found in giants and | 13 |
| 8805 | | supergiants | |
| 8807 | Mg I | found in all but late-M stars | 13 |
| 8824 | Fe I | most obvious in mid-M dwarfs | 13 |
| | | and subdwarfs | |

TABLE 3.5 (continued)

| λ (Å) | Identification | Notes | References |
|---|---|---|---|
| 8838 | Fe I | strongest in K giants | 13 |
| 8859<br>8868<br>8937 | TiO | most obvious in mid- to late-M stars | 14, 15 |
| 8867 | Fe I | blended with TiO | 13 |
| 8912<br>8924<br>8927 | Ca II, Mg I blend | weak in K giants | 13 |
| 8952<br>8972 | telluric $H_2O$ | — | 13 |
| 8980<br>8992 | telluric $H_2O$ | — | 13 |

REFERENCES: (1) Faÿ, Stein, & Warren 1974; (2) Ake & Greenstein 1980; (3) Öhman 1934; (4) Öhman 1936; (5) Gahm 1970; (6) Turnshek et al. 1985; (7) Keenan 1957; (8) Keenan & McNeil 1976; (9) Keenan & Schroeder 1952; (10) Davis 1947; (11) Sharpless 1956; (12) Solf 1978; (13) Swensson et al. 1970; (14) Wing, Spinrad, & Kuhi 1967; (15) Phillips 1950.

TABLE 3.6

COMPARISON OF SPECTRAL TYPES FOR VERY LATE "DWARFS"

| Name | Spectral Types | |
| | This paper | Bessell(1991) |
| --- | --- | --- |
| GL 644 C (VB 8) | M7 | M6.5 |
| LHS3002[a] | — | M7 |
| GL 752 B (VB 10) | M8 | M7 |
| LHS 2397a | M8[b] | M7 |
| LHS 2065 | M9 | M7 |
| LHS 2924 | M9 | M7 |

[a] Classified as M7 by Boeshaar 1992.

[b] See §3.1.7.

TABLE 3.7

INTEGRATION LIMITS FOR COLOR RATIOS

| Ratio | Numerator | Denominator | Feature Measured |
| --- | --- | --- | --- |
| A | 7020-7050 Å | 6960-6990 Å | CaH 6975 Å |
| B | 7375-7385 Å | 7353-7363 Å | Ti I 7358 Å |
| C | 8100-8130 Å | 8174-8204 Å | Na I 8183,8195 Å |
| D | 8567-8577 Å | 8537-8547 Å | Ca II 8542 Å |

## TABLE 3.8

## COLOR RATIOS DETERMINED FROM THE SPECTRA

| Object Name | Spec. Type | A | B | C | D | B/A | B/C | D/A | D/C |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Primary Dwarf Spectral Standards (see Table 3.1) | | | | |
| GL 820 A | K5 V | 1.02 | 1.02 | 1.13 | 1.19 | 1.00 | 0.90 | 1.17 | 1.05 |
| GL 820 B | K7 V | 1.02 | 1.01 | 1.12 | 1.20 | 0.99 | 0.90 | 1.18 | 1.07 |
| GL 380 | K7 V | 1.06 | 1.04 | 1.16 | 1.18 | 0.98 | 0.90 | 1.11 | 1.02 |
| GL 328 | M0 V | 1.08 | 1.05 | 1.15 | 1.17 | 0.97 | 0.91 | 1.08 | 1.02 |
| GL 270 | M0 V | 1.08 | 1.04 | 1.14 | 1.14 | 0.96 | 0.91 | 1.06 | 1.00 |
| GL 846 | M0.5 V | 1.11 | 1.03 | 1.17 | 1.20 | 0.93 | 0.88 | 1.08 | 1.03 |
| GL 229 | M1 V | 1.13 | 1.05 | 1.17 | 1.13 | 0.93 | 0.90 | 1.00 | 0.97 |
| GL 205 | M1.5 V | 1.15 | 1.06 | 1.19 | 1.14 | 0.92 | 0.89 | 0.99 | 0.96 |
| GL 411 | M2 V | 1.17 | 1.05 | 1.13 | 1.12 | 0.90 | 0.93 | 0.96 | 0.99 |
| GL 382 | M2 V | 1.17 | 1.06 | 1.18 | 1.13 | 0.91 | 0.90 | 0.97 | 0.96 |
| GL 250 B | M2.5 V | 1.20 | 1.06 | 1.15 | 1.11 | 0.88 | 0.92 | 0.93 | 0.97 |
| GL 381 | M2.5 V | 1.22 | 1.05 | 1.18 | 1.11 | 0.86 | 0.89 | 0.91 | 0.94 |
| GL 352 AB | M3 V | 1.21 | 1.06 | 1.14 | 1.12 | 0.88 | 0.93 | 0.93 | 0.98 |
| GL 436 | M3 V | 1.22 | 1.06 | 1.16 | 1.11 | 0.87 | 0.91 | 0.91 | 0.96 |
| GL 251 | M3 V | 1.24 | 1.07 | 1.18 | 1.10 | 0.86 | 0.91 | 0.89 | 0.93 |
| GL 752 A | M3 V | 1.20 | 1.06 | 1.21 | 1.11 | 0.88 | 0.88 | 0.93 | 0.92 |
| GL 725 A | M3 V | 1.23 | 1.06 | 1.17 | 1.09 | 0.86 | 0.91 | 0.89 | 0.93 |

TABLE 3.8 (continued)

| Object Name | Spec. Type | A | B | C | D | B/A | B/C | D/A | D/C |
|---|---|---|---|---|---|---|---|---|---|
| GL 273 | M3.5 V | 1.25 | 1.08 | 1.18 | 1.08 | 0.86 | 0.92 | 0.86 | 0.92 |
| GL 725 B | M3.5 V | 1.28 | 1.07 | 1.24 | 1.13 | 0.84 | 0.86 | 0.88 | 0.91 |
| GL 213 | M4 V | 1.28 | 1.08 | 1.17 | 1.09 | 0.84 | 0.92 | 0.85 | 0.93 |
| GL 275.2 A | M4 V | 1.30 | 1.08 | 1.22 | 1.09 | 0.83 | 0.89 | 0.84 | 0.89 |
| GL 402 | M4 V | 1.27 | 1.09 | 1.25 | 1.09 | 0.86 | 0.87 | 0.86 | 0.87 |
| GL 83.1 | M4.5 V | 1.36 | 1.09 | 1.28 | 1.08 | 0.80 | 0.85 | 0.79 | 0.84 |
| GL 268 | M4.5 V | 1.31 | 1.08 | 1.24 | 1.06 | 0.82 | 0.87 | 0.81 | 0.85 |
| GL 166 C | M4.5 V | 1.33 | 1.09 | 1.15 | 1.09 | 0.82 | 0.95 | 0.82 | 0.95 |
| GL 234 AB | M4.5 V | 1.37 | 1.08 | 1.26 | 1.07 | 0.79 | 0.86 | 0.78 | 0.85 |
| GL 51 | M5 V | 1.38 | 1.11 | 1.28 | 1.07 | 0.80 | 0.87 | 0.78 | 0.84 |
| GL 866 AB | M5 V | 1.39 | 1.11 | 1.38 | 1.08 | 0.80 | 0.80 | 0.78 | 0.78 |
| G 208-44 AB | M5.5 V | 1.46 | 1.07 | 1.29 | 1.10 | 0.73 | 0.83 | 0.75 | 0.85 |
| GL 65 A | M5.5 V | 1.46 | 1.11 | 1.22 | 1.08 | 0.76 | 0.91 | 0.74 | 0.89 |
| G 208-45 | M6 V | 1.53 | 1.09 | 1.31 | 1.08 | 0.71 | 0.83 | 0.71 | 0.82 |
| GL 65 B | M6 V | 1.43 | 1.09 | 1.22 | 1.09 | 0.76 | 0.89 | 0.76 | 0.89 |
| GL 406 | M6 V | 1.42 | 1.11 | 1.24 | 1.08 | 0.78 | 0.90 | 0.76 | 0.87 |
| LHS 523 | M6.5 V | 1.82 | 1.09 | 1.46 | 1.11 | 0.60 | 0.75 | 0.61 | 0.76 |
| G 51-15 | M6.5 V | 1.53 | 1.11 | 1.24 | 1.11 | 0.73 | 0.90 | 0.73 | 0.90 |
| GL 644 C | M7 V | 1.67 | 1.10 | 1.41 | 1.14 | 0.66 | 0.78 | 0.68 | 0.81 |
| GL 752 B | M8 V | 1.31 | 1.08 | 1.22 | 1.15 | 0.82 | 0.89 | 0.88 | 0.94 |
| GL 569 B | M8.5 | 1.34 | 1.03 | 1.15 | 1.14 | 0.77 | 0.90 | 0.85 | 0.99 |
| LHS 2924 | M9 | 1.28 | 1.02 | 1.05 | 1.04 | 0.80 | 0.97 | 0.81 | 0.99 |

TABLE 3.8 (continued)

| Object Name | Spec. Type | A | B | C | D | B/A | B/C | D/A | D/C |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Secondary Dwarf Spectral Standards (see Table 3.2) | | | | | |
| GL 775 | K5 V | 1.01 | 1.02 | 1.15 | 1.25 | 1.01 | 0.89 | 1.24 | 1.09 |
| GL 764.1 B | K7 V | 1.05 | 1.03 | 1.18 | 1.14 | 0.98 | 0.87 | 1.09 | 0.97 |
| GL 265 A | K7 V | 1.04 | 1.03 | 1.12 | 1.16 | 0.99 | 0.92 | 1.12 | 1.04 |
| GL 786 | K7 V | 1.05 | 1.03 | 1.19 | 1.23 | 0.98 | 0.87 | 1.17 | 1.03 |
| GL 748.2 A | K7 V | 1.04 | 1.02 | 1.14 | 1.15 | 0.98 | 0.89 | 1.11 | 1.01 |
| GL 430 | K7 V | 1.06 | 1.04 | 1.14 | 1.19 | 0.98 | 0.91 | 1.12 | 1.04 |
| GL 338 B | K7 V | 1.08 | 1.05 | 1.13 | 1.16 | 0.97 | 0.93 | 1.07 | 1.03 |
| GL 734 A | M0 V | 1.07 | 1.03 | 1.17 | 1.21 | 0.96 | 0.88 | 1.13 | 1.03 |
| GL 763 | M0 V | 1.08 | 1.03 | 1.12 | 1.14 | 0.95 | 0.92 | 1.06 | 1.02 |
| GL 338 A | M0 V | 1.08 | 1.04 | 1.13 | 1.16 | 0.96 | 0.92 | 1.07 | 1.03 |
| GL 748.2 B | M0 V | 1.06 | 1.01 | 1.14 | 1.18 | 0.95 | 0.89 | 1.11 | 1.04 |
| GL 839 | M0.5 V | 1.08 | 1.04 | 1.15 | 1.24 | 0.96 | 0.90 | 1.15 | 1.08 |
| GJ 2155 | M0.5 V | 1.08 | 1.03 | 1.16 | 1.20 | 0.95 | 0.89 | 1.11 | 1.03 |
| GL 761.2 | M0.5 V | 1.09 | 1.02 | 1.15 | 1.20 | 0.94 | 0.87 | 1.10 | 1.04 |
| GL 720 A | M0.5 V | 1.11 | 1.03 | 1.14 | 1.16 | 0.93 | 0.90 | 1.05 | 1.02 |
| GL 767 A | M0.5 V | 1.16 | 1.03 | 1.16 | 1.15 | 0.89 | 0.89 | 0.99 | 0.99 |
| GL 220 | M2 V | 1.16 | 1.05 | 1.15 | 1.13 | 0.91 | 0.91 | 0.97 | 0.98 |
| GL 22 AC | M2 V | 1.19 | 1.05 | 1.11 | 1.13 | 0.88 | 0.95 | 0.95 | 1.02 |

TABLE 3.8 (continued)

| Object Name | Spec. Type | A | B | C | D | B/A | B/C | D/A | D/C |
|---|---|---|---|---|---|---|---|---|---|
| GL 806 | M2 V | 1.19 | 1.03 | 1.17 | 1.16 | 0.87 | 0.88 | 0.97 | 0.99 |
| GL 767 B | M2.5 V | 1.21 | 1.04 | 1.18 | 1.15 | 0.86 | 0.88 | 0.95 | 0.97 |
| GL 226 | M2.5 V | 1.20 | 1.06 | 1.15 | 1.10 | 0.88 | 0.92 | 0.92 | 0.96 |
| GL 22 B | M3 V | 1.29 | 1.05 | 1.17 | 1.15 | 0.81 | 0.90 | 0.89 | 0.98 |
| GL 569 A | M3 V | 1.22 | 1.05 | 1.19 | 1.12 | 0.86 | 0.88 | 0.92 | 0.94 |
| GL 669 A | M3.5 V | 1.27 | 1.06 | 1.25 | 1.12 | 0.83 | 0.85 | 0.88 | 0.90 |
| GL 748 AB | M3.5 V | 1.26 | 1.06 | 1.19 | 1.13 | 0.84 | 0.89 | 0.90 | 0.95 |
| GL 643 | M3.5 V | 1.32 | 1.07 | 1.27 | 1.10 | 0.81 | 0.84 | 0.83 | 0.87 |
| GL 734 B | M3.5 V | 1.26 | 1.06 | 1.20 | 1.10 | 0.84 | 0.88 | 0.87 | 0.92 |
| GL 699 | M4 V | 1.38 | 1.07 | 1.27 | 1.11 | 0.76 | 0.84 | 0.80 | 0.87 |
| GL 232 | M4 V | 1.32 | 1.07 | 1.21 | 1.08 | 0.81 | 0.88 | 0.82 | 0.89 |
| GL 791.2 | M4.5 V | 1.39 | 1.07 | 1.28 | 1.10 | 0.77 | 0.84 | 0.79 | 0.86 |
| GL 669 B | M4.5 V | 1.35 | 1.07 | 1.26 | 1.06 | 0.79 | 0.85 | 0.79 | 0.84 |
| LHS 3339 | M5.5 V | 1.45 | 1.11 | 1.31 | 1.09 | 0.77 | 0.85 | 0.75 | 0.83 |
| LHS 5142 | M6 V | 1.47 | 1.09 | 1.25 | 1.08 | 0.74 | 0.87 | 0.73 | 0.86 |
| LHS 191 | M6.5 V | 1.63 | 1.10 | 1.32 | 1.10 | 0.67 | 0.83 | 0.67 | 0.83 |
| LHS 2065 | M9 | 1.25 | 1.08 | 1.04 | 1.08 | 0.86 | 1.04 | 0.86 | 1.04 |

TABLE 3.8 (continued)

| Object Name | Spec. Type | A | B | C | D | B/A | B/C | D/A | D/C |
|---|---|---|---|---|---|---|---|---|---|
| Giant (and Higher Luminosity) Spectral Standards (see Table 3.3) | | | | | | | | | |
| SAO 52516 | K5 I | 1.01 | 1.08 | 1.06 | 1.36 | 1.07 | 1.02 | 1.35 | 1.28 |
| SAO 22994 | M2 I | 1.04 | 1.10 | 1.03 | 1.36 | 1.06 | 1.07 | 1.31 | 1.32 |
| SAO 67559 | M4 II | 1.09 | 1.13 | 1.06 | 1.28 | 1.04 | 1.07 | 1.17 | 1.21 |
| SAO 30653 | K5 III | 0.99 | 1.07 | 1.05 | 1.29 | 1.08 | 1.02 | 1.30 | 1.23 |
| SAO 21753 | K7 III | 1.03 | 1.10 | 1.06 | 1.28 | 1.07 | 1.04 | 1.24 | 1.21 |
| SAO 36509 | K7 III | 0.99 | 1.06 | 1.05 | 1.26 | 1.07 | 1.01 | 1.27 | 1.20 |
| SAO 141052 | M0.5 III | 1.00 | 1.09 | 1.11 | 1.28 | 1.09 | 0.98 | 1.28 | 1.15 |
| SAO 127976 | M1 III | 1.01 | 1.08 | 1.09 | 1.30 | 1.07 | 0.99 | 1.29 | 1.19 |
| SAO 91792 | M2 III | 1.02 | 1.09 | 1.07 | 1.26 | 1.07 | 1.02 | 1.24 | 1.18 |
| SAO 28843 | M2 III | 1.01 | 1.09 | 1.10 | 1.31 | 1.08 | 0.99 | 1.30 | 1.19 |
| SAO 63349 | M3 III | 1.03 | 1.10 | 1.10 | 1.26 | 1.07 | 1.00 | 1.22 | 1.15 |
| SAO 82478 | M4 III | 1.13 | 1.12 | 1.07 | 1.18 | 0.99 | 1.05 | 1.04 | 1.10 |
| SAO 34651 | M4 III | 1.08 | 1.12 | 1.06 | 1.28 | 1.04 | 1.06 | 1.19 | 1.21 |
| SAO 141344 | M5 III | 1.12 | 1.18 | 1.05 | 1.25 | 1.05 | 1.12 | 1.12 | 1.19 |
| Miscellaneous Objects (see Table 3.4) | | | | | | | | | |
| GL 756.2 | K7 III | 1.03 | 1.04 | 1.08 | 1.33 | 1.01 | 0.96 | 1.29 | 1.23 |
| LHS 515 | sdM2.5 | 1.56 | 1.01 | 1.21 | 1.21 | 0.65 | 0.83 | 0.78 | 1.00 |

TABLE 3.8 (continued)

| Object Name | Spec. Type | A | B | C | D | B/A | B/C | D/A | D/C |
|---|---|---|---|---|---|---|---|---|---|
| *Other Dwarf/Subdwarf Spectra (see Table 3.9)* | | | | | | | | | |
| GL 301 AB | K7 V | 1.07 | 1.01 | 1.09 | 1.14 | 0.94 | 0.93 | 1.07 | 1.05 |
| GL 338.1 AB | K7 V | 1.05 | 1.01 | 1.08 | 1.14 | 0.96 | 0.94 | 1.09 | 1.06 |
| GL 677 AB | K7 V | 1.01 | 1.03 | 1.13 | 1.17 | 1.02 | 0.91 | 1.16 | 1.04 |
| GL 863.1ABC | K7 V | 1.05 | 1.03 | 1.12 | 1.16 | 0.98 | 0.92 | 1.10 | 1.04 |
| GL 809 | M0 V | 1.12 | 1.04 | 1.11 | 1.15 | 0.93 | 0.94 | 1.03 | 1.04 |
| GL 649 | M0.5 V | 1.14 | 1.05 | 1.19 | 1.15 | 0.92 | 0.88 | 1.01 | 0.97 |
| GL 508 AB | M1 V | 1.13 | 1.03 | 1.11 | 1.13 | 0.91 | 0.93 | 1.00 | 1.02 |
| GL 625 | M1.5 V | 1.23 | 1.04 | 1.20 | 1.16 | 0.85 | 0.87 | 0.94 | 0.97 |
| GL 880 | M1.5 V | 1.14 | 1.05 | 1.14 | 1.16 | 0.92 | 0.92 | 1.02 | 1.02 |
| GL 623 AB | M2.5 V | 1.21 | 1.06 | 1.19 | 1.13 | 0.88 | 0.89 | 0.93 | 0.95 |
| GL 661 AB | M3 V | 1.20 | 1.06 | 1.15 | 1.08 | 0.88 | 0.92 | 0.90 | 0.94 |
| GL 754.1 B | M3 V | 1.26 | 1.07 | 1.22 | 1.11 | 0.85 | 0.88 | 0.88 | 0.91 |
| GL 860 A | M3 V | 1.26 | 1.08 | 1.22 | 1.06 | 0.86 | 0.89 | 0.84 | 0.87 |
| GL 829 | M3.5 V | 1.27 | 1.06 | 1.16 | 1.10 | 0.83 | 0.91 | 0.87 | 0.95 |
| GL 873 | M3.5 V | 1.33 | 1.08 | 1.18 | 1.09 | 0.81 | 0.92 | 0.82 | 0.92 |
| G 117-B15 B | M3.5 V | 1.31 | 1.07 | 1.19 | 1.07 | 0.82 | 0.90 | 0.82 | 0.90 |
| GL 169.1 A | M4 V | 1.24 | 1.06 | 1.19 | 1.05 | 0.85 | 0.89 | 0.85 | 0.88 |
| GL 860 B | M4 V | 1.37 | 1.08 | 1.27 | 1.06 | 0.79 | 0.85 | 0.77 | 0.83 |
| LHS 1047AB | M4 V | 1.32 | 1.06 | 1.19 | 1.09 | 0.80 | 0.89 | 0.83 | 0.92 |
| GL 831 | M4.5 V | 1.29 | 1.07 | 1.22 | 1.07 | 0.83 | 0.88 | 0.83 | 0.88 |

TABLE 3.8 (continued)

| Object Name | Spec. Type | A | B | C | D | B/A | B/C | D/A | D/C |
|---|---|---|---|---|---|---|---|---|---|
| G 77-31 | M5 V | 1.30 | 1.10 | 1.26 | 1.06 | 0.85 | 0.87 | 0.82 | 0.84 |
| LHS 2067 | sdM5 | 1.75 | 1.05 | 1.45 | 1.09 | 0.60 | 0.72 | 0.62 | 0.75 |
| GL 473 AB | M5.5 V | 1.43 | 1.09 | 1.29 | 1.06 | 0.76 | 0.84 | 0.74 | 0.82 |
| GJ 1116 AB | M5.5 V | 1.59 | 1.08 | .28 | 1.08 | 0.70 | 0.84 | 0.68 | 0.84 |
| Pleiad #2 | M5.5 V | 1.50 | 1.03 | 1.05 | 0.94 | 0.69 | 0.98 | 0.63 | 0.90 |
| GL 283 B | M6 V | 1.49 | 1.08 | 1.27 | 1.09 | 0.72 | 0.85 | 0.73 | 0.86 |
| GL 316.1 | M6 V | 1.50 | 1.09 | 1.26 | 1.07 | 0.73 | 0.87 | 0.71 | 0.85 |
| LHS 292 | M6.5 V | 1.62 | 1.07 | 1.31 | 1.10 | 0.66 | 0.82 | 0.68 | 0.84 |
| LHS 2930 | M6.5 V | 1.71 | 1.08 | 1.38 | 1.10 | 0.63 | 0.78 | 0.64 | 0.80 |
| LHS 2397a | M8 | 1.50 | 1.04 | 1.24 | 1.10 | 0.69 | 0.84 | 0.73 | 0.89 |
| RG0050-2722 | M8: | 1.33 | 1.00 | 1.13 | 1.06 | 0.75 | 0.88 | 0.80 | 0.94 |

TABLE 3.9

OTHER DWARF/SUBDWARF SPECTRA

| Gliese Number | Other Name | Published Spec. Type[a] | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| — | LHS 2068[b] | — | <K5 V | 1991 May 07 | 600 |
| 301 AB | BD −13°2439 AB | M0 | K7 V | 1990 Nov 23 | 11 |
| 338.1 AB | BD +77°361 AB | K5 | K7 V | 1990 Nov 23 | 11 |
| 677 AB | BD +29°3029 AB | M0 | K7 V | 1990 Sep 14 | 21 |
| 863.1 ABC | BD +53°2911 ABC | M0 | K7 V | 1990 May 22 | 17 |
| 809 | BD +61°2068 | M2 V | M0 V | 1990 Nov 23 | 10 |
| 649 | BD +25°3173 | M2 | M0.5 V | 1990 May 23 | 240 |
| 508 AB | BD +48°2108 AB | M2 | M1 V | 1990 Nov 23 | 40 |
| 625 | G 202-48 | M2 | M1.5 V | 1990 May 23 | 10 |
| 880 | BD +15°4733 | M2 | M1.5 V | 1990 Nov 22 | 90 |
| 623 AB | G 202-45 AB | M3 | M2.5 V | 1990 May 23 | 120 |
| 661 AB | BD +45°2505 AB | M3-3.5 | M3 V | 1990 May 04 | 4 |
| 754.1 B | — | M5 | M3 V | 1990 Sep 13 | 140 |
| 860 A | BD +56°2783 A | M3 | M3 V | 1990 Sep 13 | 5.6 |
| 829 | Ross 775 | M4 | M3.5 V | 1990 Nov 23 | 20 |
| 873 | BD +43°4305 | M4.5 | M3.5 V | 1990 Nov 22 | 180 |
| — | G 117-B15 B | — | M3.5 V | 1991 May 07 | 300 |
| 169.1 A | Stein 2051 A | M4 | M4 V | 1991 Mar 14 | 900 |
| 860 B | BD +56°2783 B | M4.5 | M4 V | 1990 Sep 13 | 5.6 |
| — | LHS 1047 AB | M4[c] | M4 V | 1990 Nov 23 | 330 |
| 831 | Wolf 922 | M4.5 | M4.5 V | 1990 Nov 23 | 75 |

# TABLE 3.9 (continued)

## OTHER DWARF/SUBDWARF SPECTRA

| Gliese Number | Other Name | Published Spec. Type[a] | Adopted Spec. Type | Date Obs. (UT) | Integ. (sec) |
|---|---|---|---|---|---|
| — | G 77-31 | M5 V[d] | M5 V | 1990 Sep 13 | 130 |
| — | LHS 2067[b] | sdM[e] | sdM5 | 1991 May 07 | 600 |
| 473 AB | Wolf 424 AB | M5.5 | M5.5 V | 1990 May 04 | 105 |
| — | GJ 1116 AB | ~M5? V[f] | M5.5 V | 1990 Nov 23 | 130 |
| — | Pleiad #2[g] | — | M5.5 V | 1990 Jan 20 | 3900 |
| 283 B | LHS 234 | M6 V[h] | M6 V | 1990 Nov 23 | 600 |
| 316.1 | LHS 2034 | M6 V[i] | M6 V | 1990 Nov 23 | 600 |
| — | LHS 292 | M6.5 V[h] | M6.5 V | 1990 Nov 23 | 360 |
| — | LHS 2930 | M6.5 V[i] | M6.5 V | 1991 May 07 | 1200 |
| — | LHS 2397a | M8 V[j] | M8 | 1990 Nov 22 | 1500 |
| — | RG 0050-2722 | M8 V[h] | M8: | 1991 Sep 15 | 3600 |

[a] Gliese 1969 unless otherwise noted.

[b] Wrong star marked on finder chart in Luyten & Albers 1979.

[c] Bidelman 1985.

[d] Boeshaar 1976.

[e] Bessell 1982; mis-identified by Bessell 1991.

[f] Cowley & Hartwick 1982.

[g] Star number 2 in Stauffer et al. 1989.

[h] Boeshaar 1992.

[i] Bessell 1991.

[j] Giampapa & Liebert 1986.

TABLE 3.10

STARS WITH OBSERVED SPECTRA AND KNOWN MASSES

| Object Name | Spectral Type | Mass $(M_\odot)$[a] |
|---|---|---|
| GL 508 AB | M1 V | $0.709 \pm 0.178$[b] |
| GL 22 AC | M2 V | $0.356 \pm 0.046$[b] |
| GL 623 AB | M2.5 V | $0.300 \pm 0.032$[b] |
| GL 725 A | M3 V | $0.370 \pm 0.134$ |
| GL 661 AB | M3 V | $0.262 \pm 0.020$[c] |
| GL 860 A | M3 V | $0.257 \pm 0.029$ |
| GL 352 AB | M3 V | $0.199 \pm 0.062$[c] |
| GL 725 B | M3.5 V | $0.316 \pm 0.115$ |
| GL 860 B | M4 V | $0.167 \pm 0.019$ |
| LHS 1047 AB | M4 V | $0.138 \pm 0.184$[b] |
| GL 234 AB | M4.5 V | $0.180 \pm 0.061$[b] |
| GL 166 C | M4.5 V | $0.155 \pm 0.029$ |
| G 208-44 AB | M5.5 V | $0.118 \pm 0.018$[b] |
| GL 65 A | M5.5 V | $0.097 \pm 0.011$ |
| GL 65 B | M6 V | $0.094 \pm 0.011$ |

[a] Henry 1992.

[b] Light of primary dominates spectrum; mass is that of the primary.

[c] Components are nearly equal in magnitude; mass is the mean of the two.
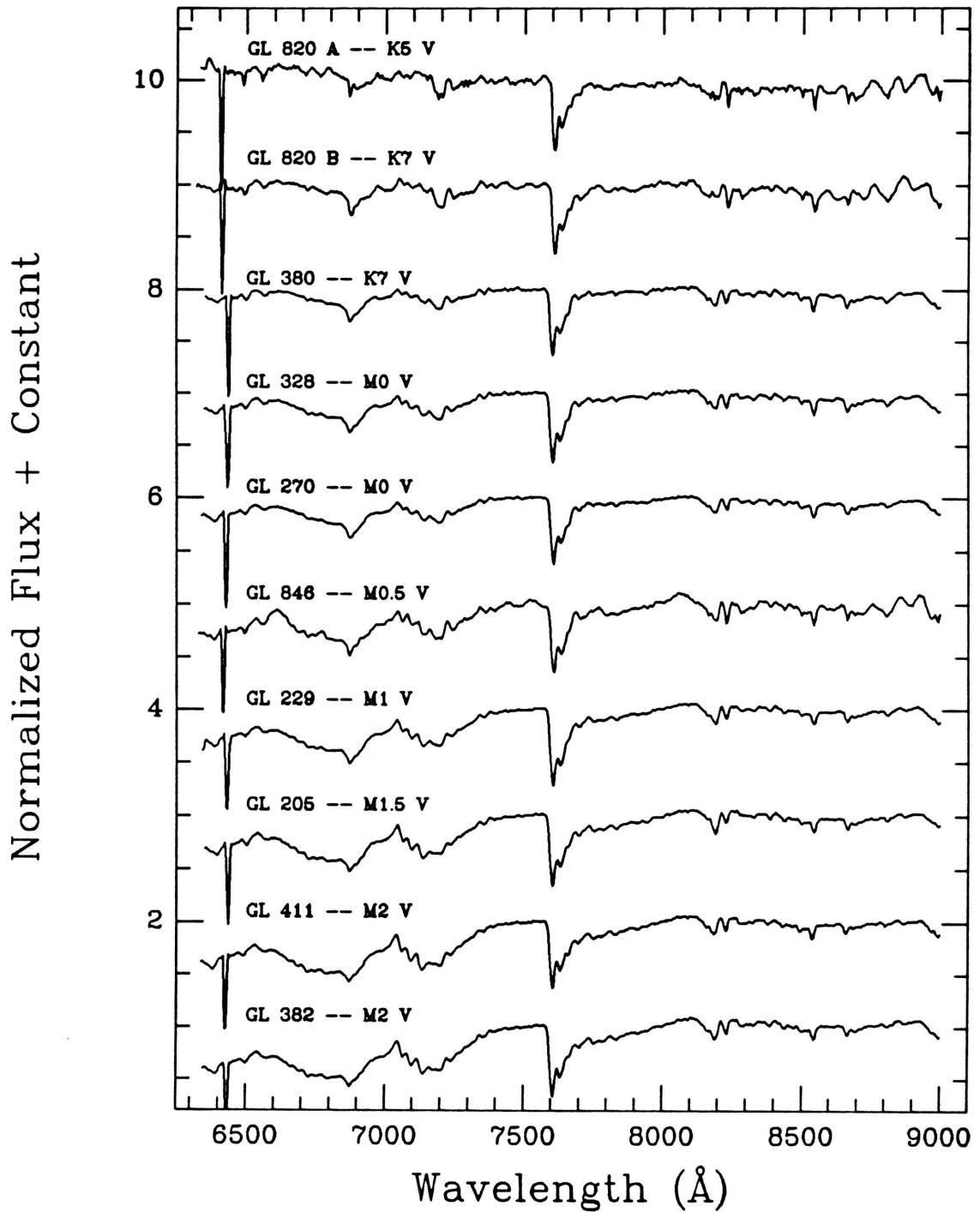
FIG. 3.1. — Spectra of the 39 primary dwarf standards in Table 3.1. All of these were observed at the MMT and have a resolution of 18 Å except for GL 83.1, GL 51, and GL 866 AB which were observed at the Steward Observatory 2.3-meter telescope. These three spectra have been rebinned and smoothed →
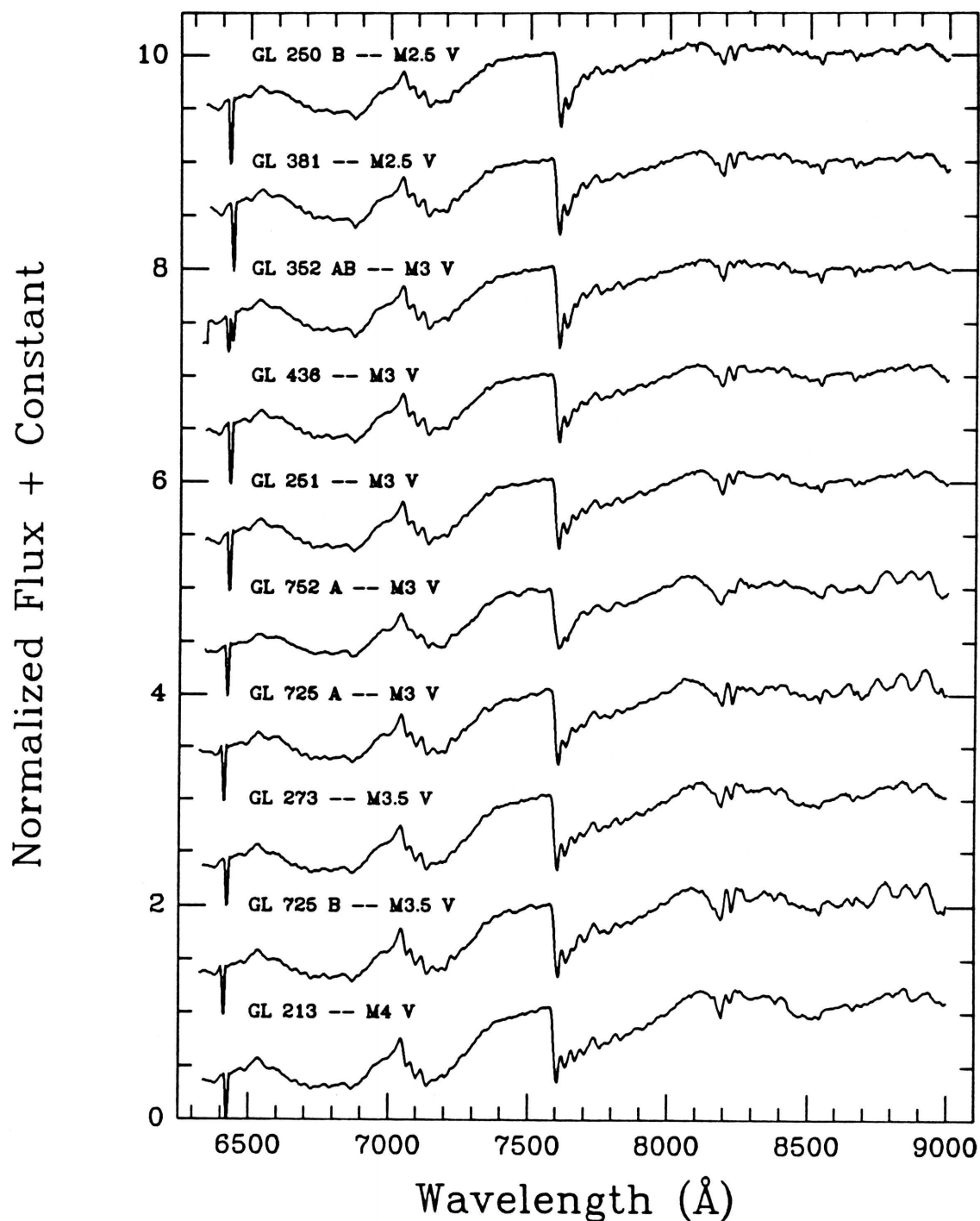
FIG. 3.1. (continued) — so that the resolution matches that of the MMT spectra. Each of the spectra has been normalized to its flux (in units of $F_\lambda$) at 7500 Å and an offset added to separate the spectra vertically. The zero level for each spectrum is its flux value at 7500 Å (which is always an integer) minus 1. For →
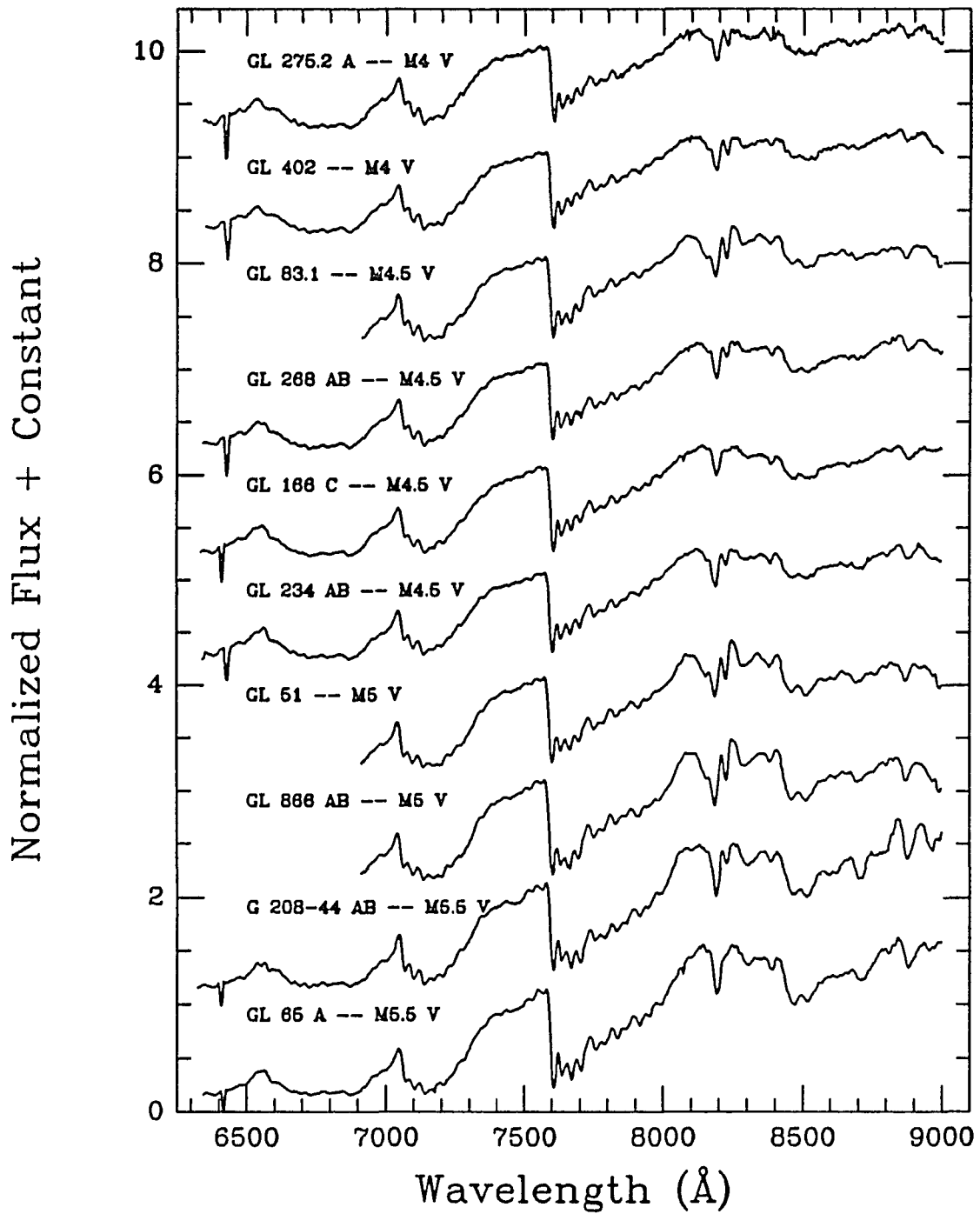
FIG. 3.1. (continued) — example, the zero level for the spectrum of GL 820 A is 9. The "absorption" feature at 6415 Å is due to a dead column on the MMT CCD chip and has not been interpolated over because this is the exact location of a CaOH band. Absorption by telluric $O_2$ and $H_2O$ →
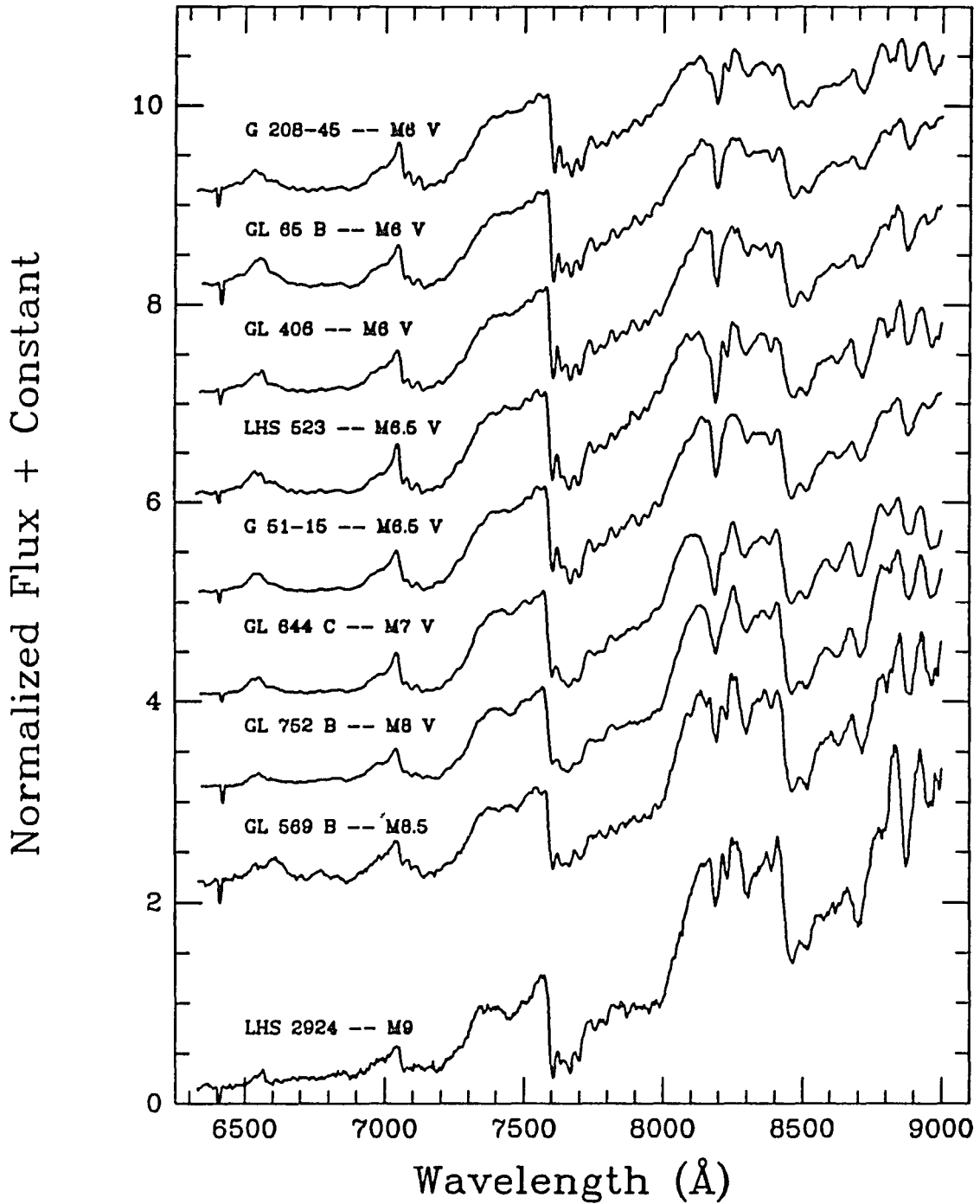
FIG. 3.1. (continued) — has not been removed. GL 569 B and LHS 2924 do not have luminosity classifications given because these objects may not be true stars; they could be brown dwarfs. The same uncertain nature is true of GL 644 C (VB 8) and GL 752 B (VB 10), except that we have retained their designations of luminosity class V for historical reasons.
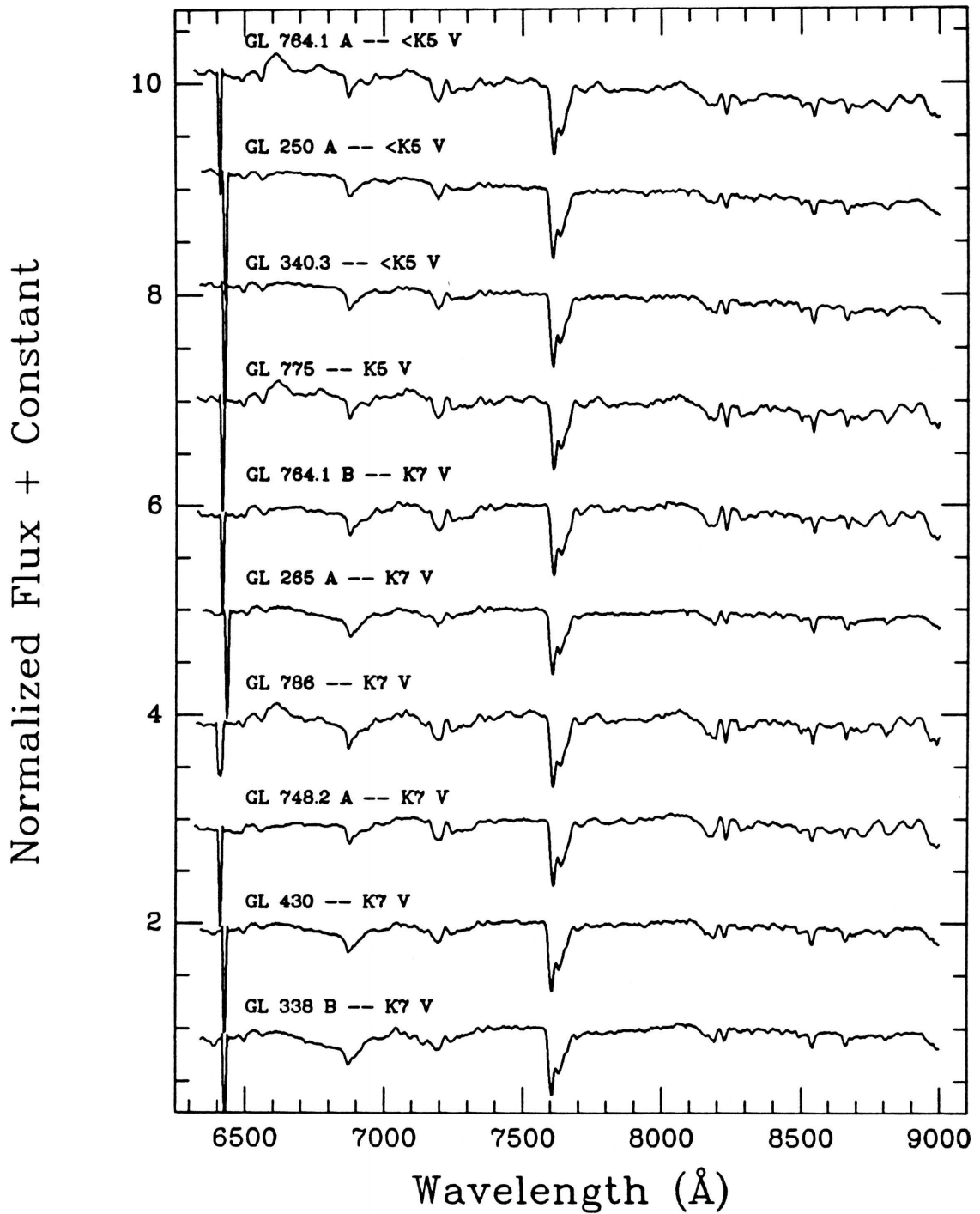
FIG. 3.2. — Spectra of the 38 secondary dwarf standards in Table 3.2. All of these were observed at the MMT and have a resolution of 18 Å. See the caption to Figure 3.1 for more details.
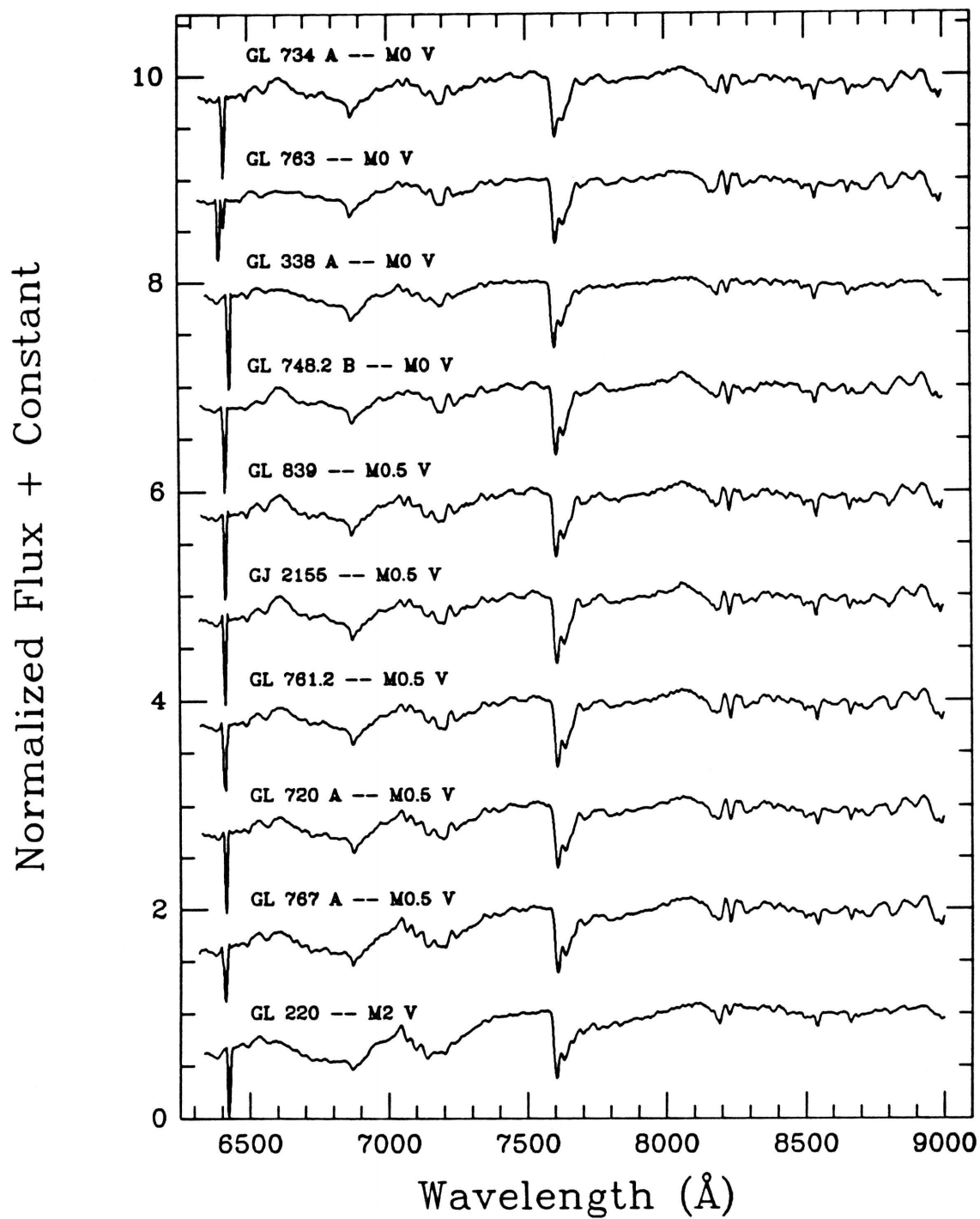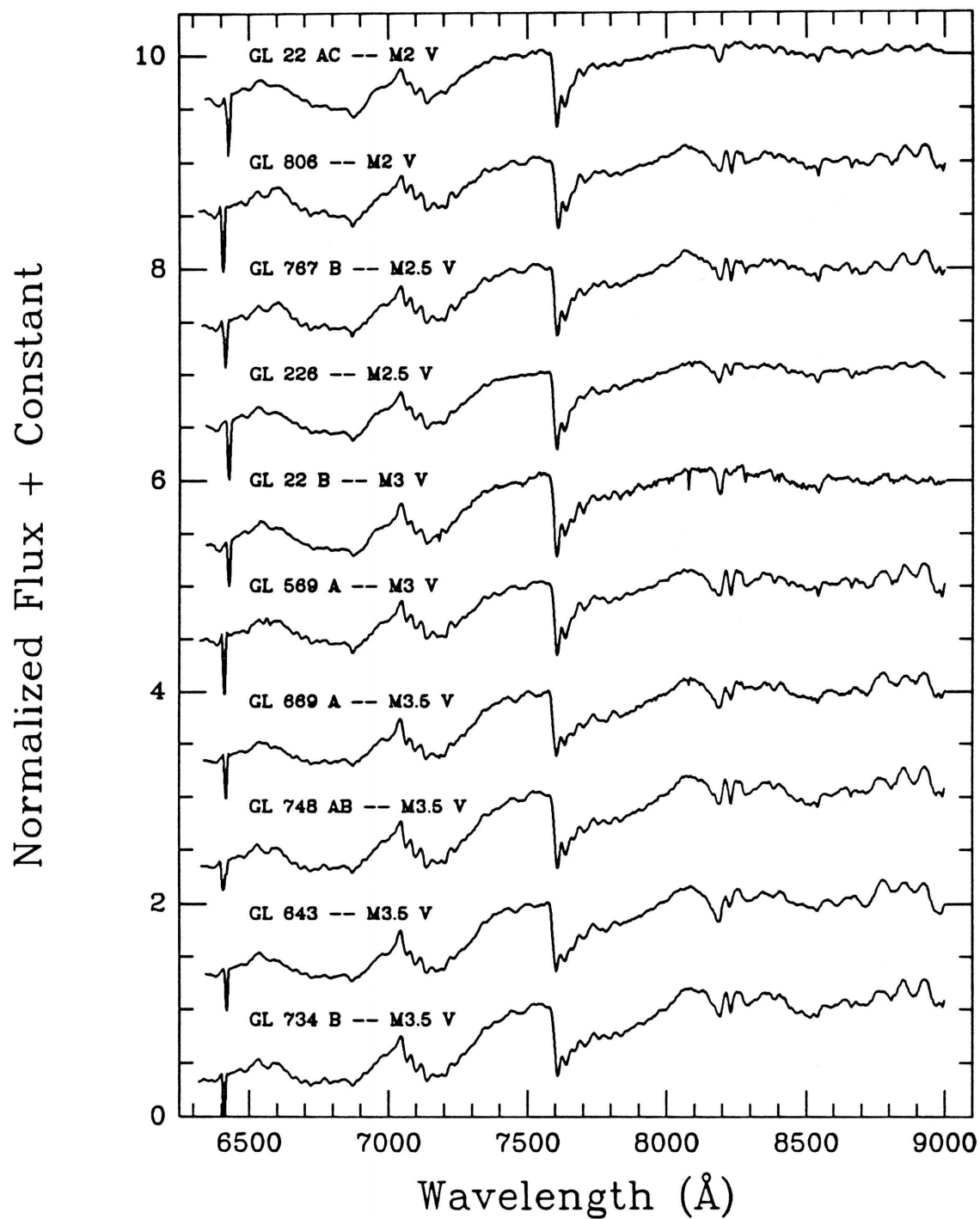
FIG. 3.2. (continued)

FIG. 3.2. (continued)

FIG. 3.2. (continued)

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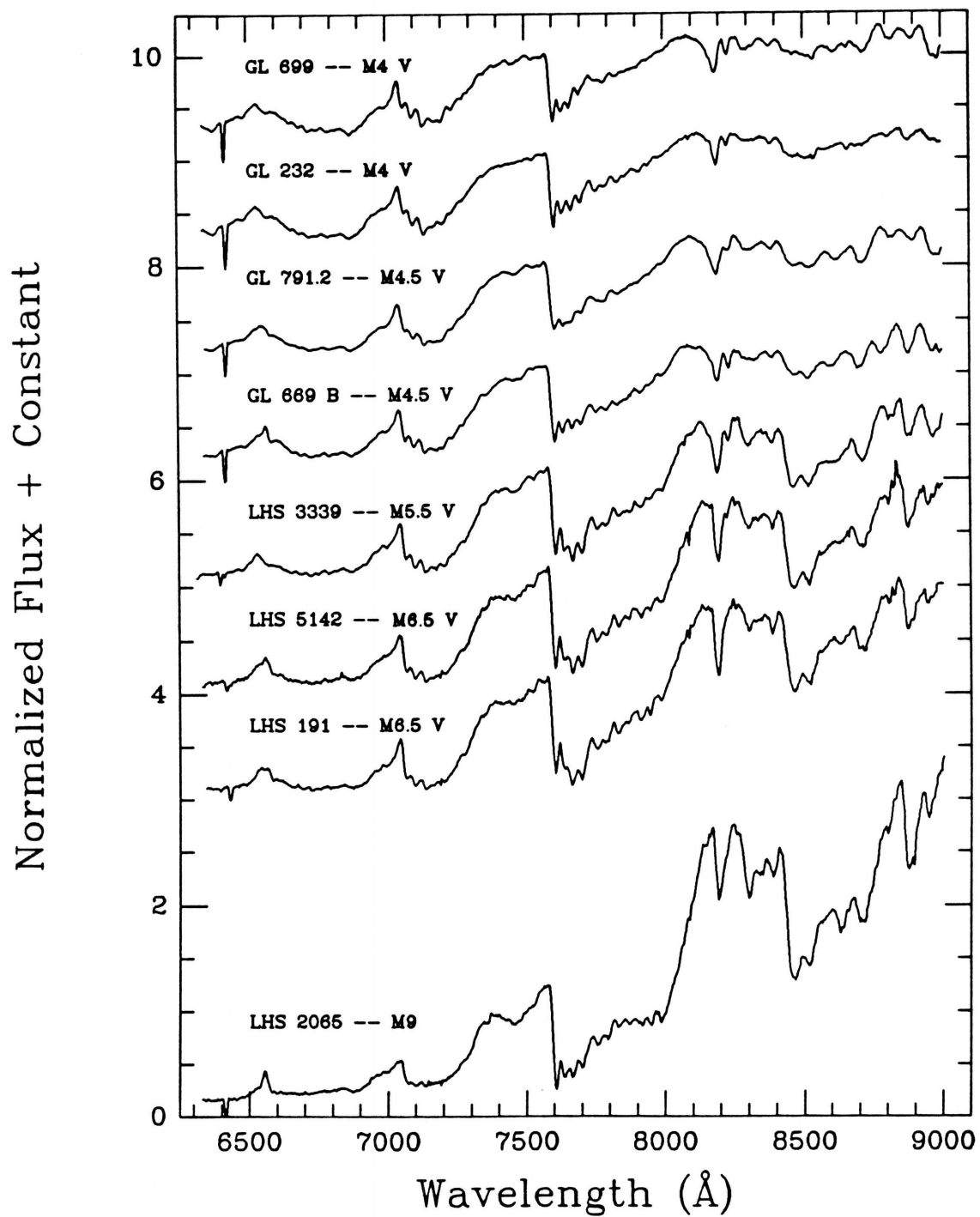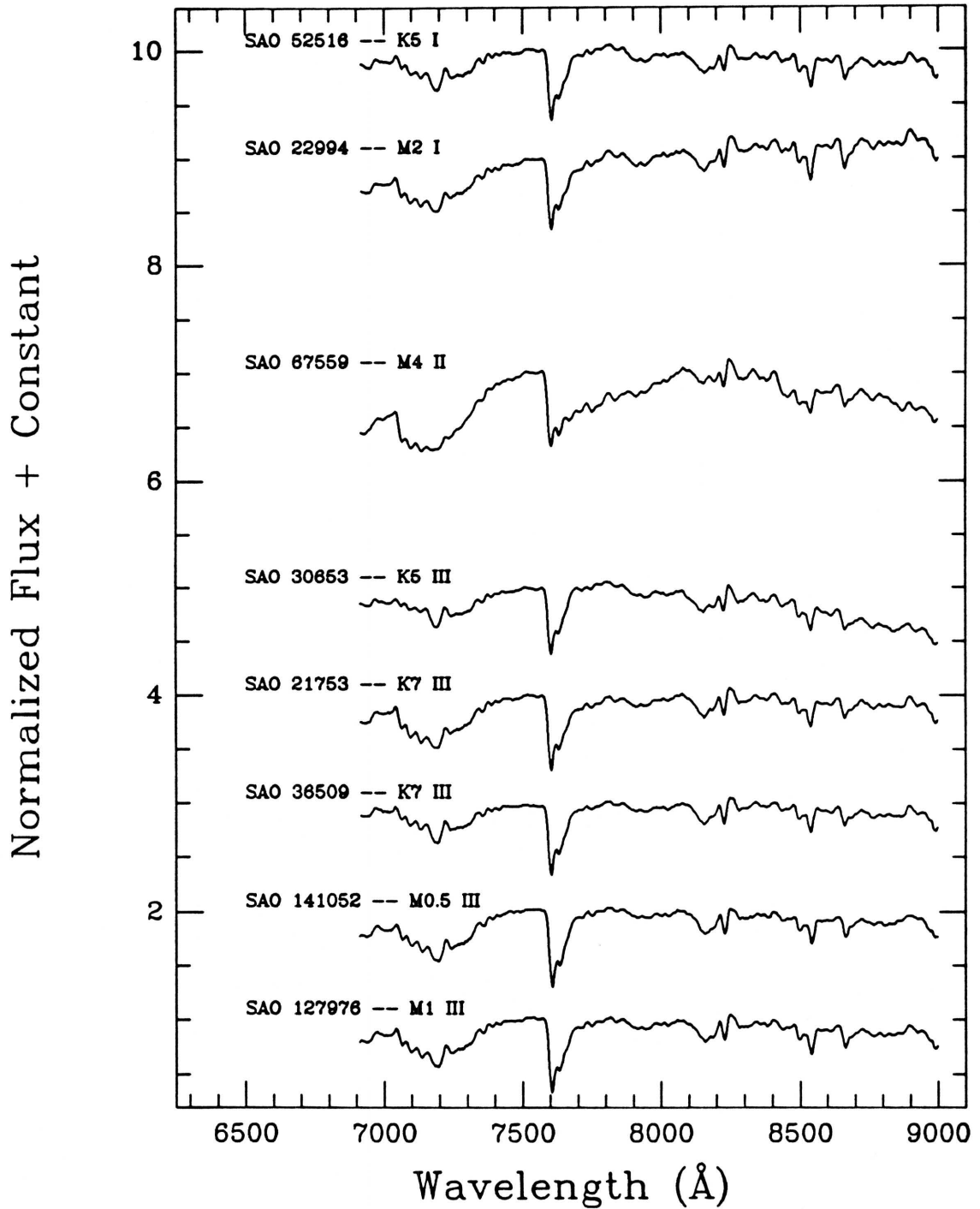


FIG. 3.3. — Spectra of the 14 giant and higher luminosity standards listed in Table 3.3. All but one of these (SAO 82478, taken at the MMT) were observed at the Steward Observatory 2.3-meter telescope, but all have been rebinned and smoothed to match the resolution of the MMT spectra. See the caption to Figure 3.1 for more details.
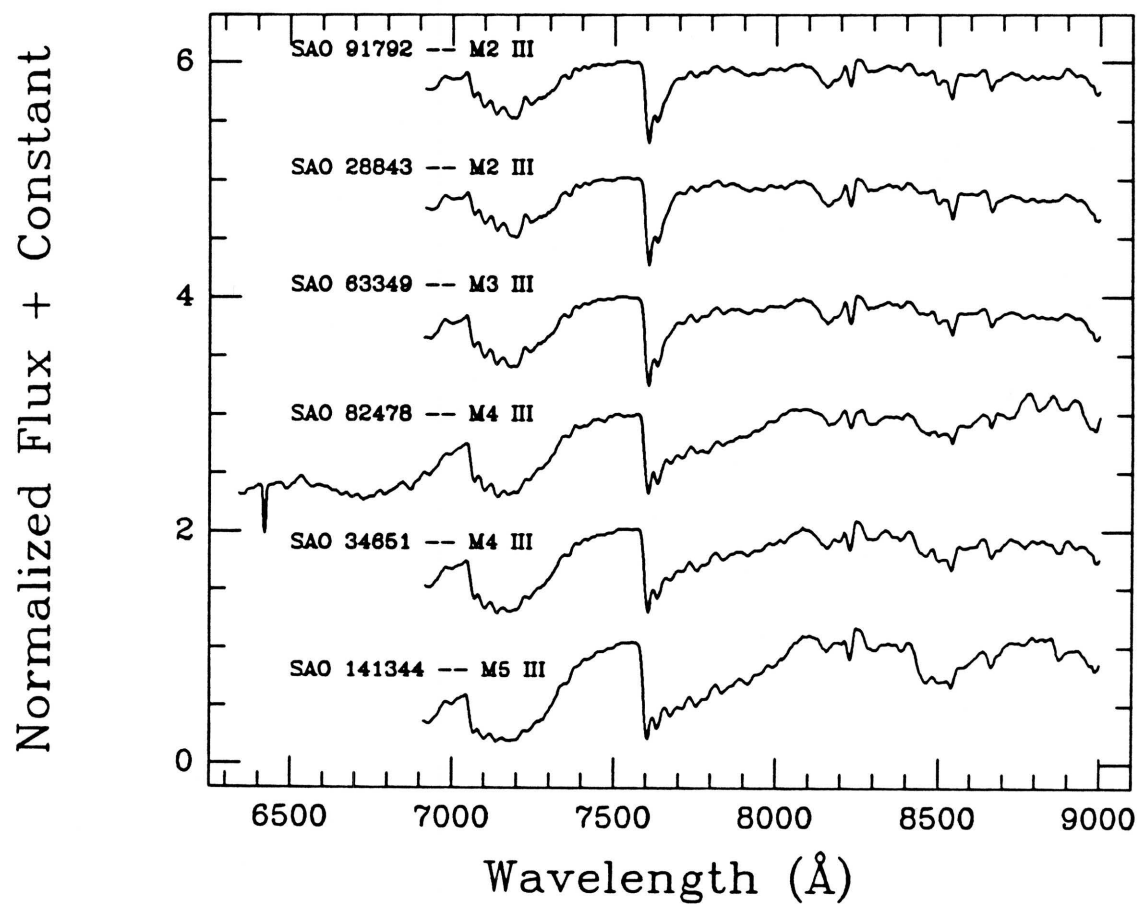
FIG. 3.3. (continued)
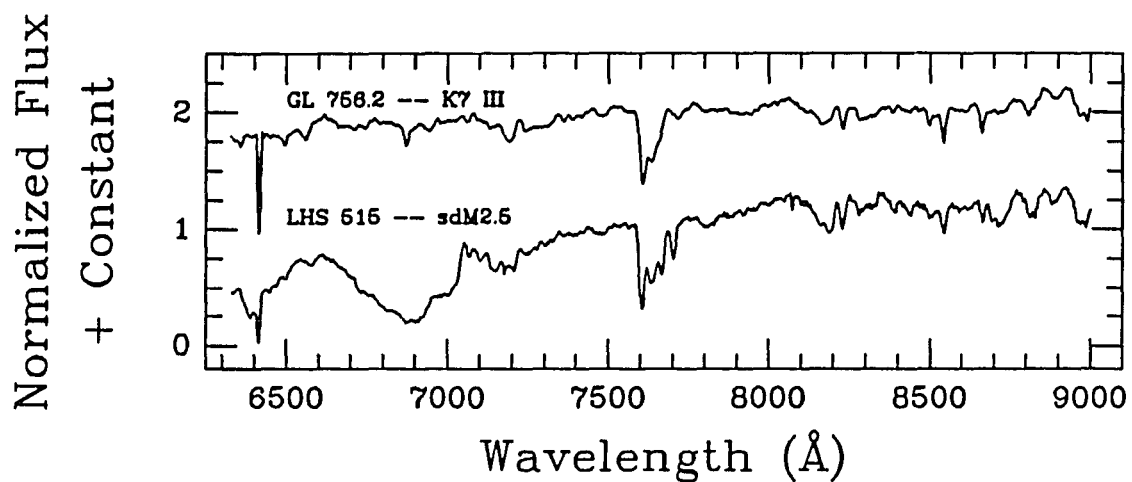
FIG. 3.4. — Spectra of the 2 objects listed in Table 3.4. Both were observed at the MMT and have a resolution of 18 Å. See the caption to Figure 3.1 for more details. Note the prominent absorption lines of the Ca II triplet (8498 Å, 8542 Å, and 8662 Å) in the spectrum of GL 756.2 and the striking absorption feature from 6750 to 7050 Å due to CaH in the spectrum of LHS 515.
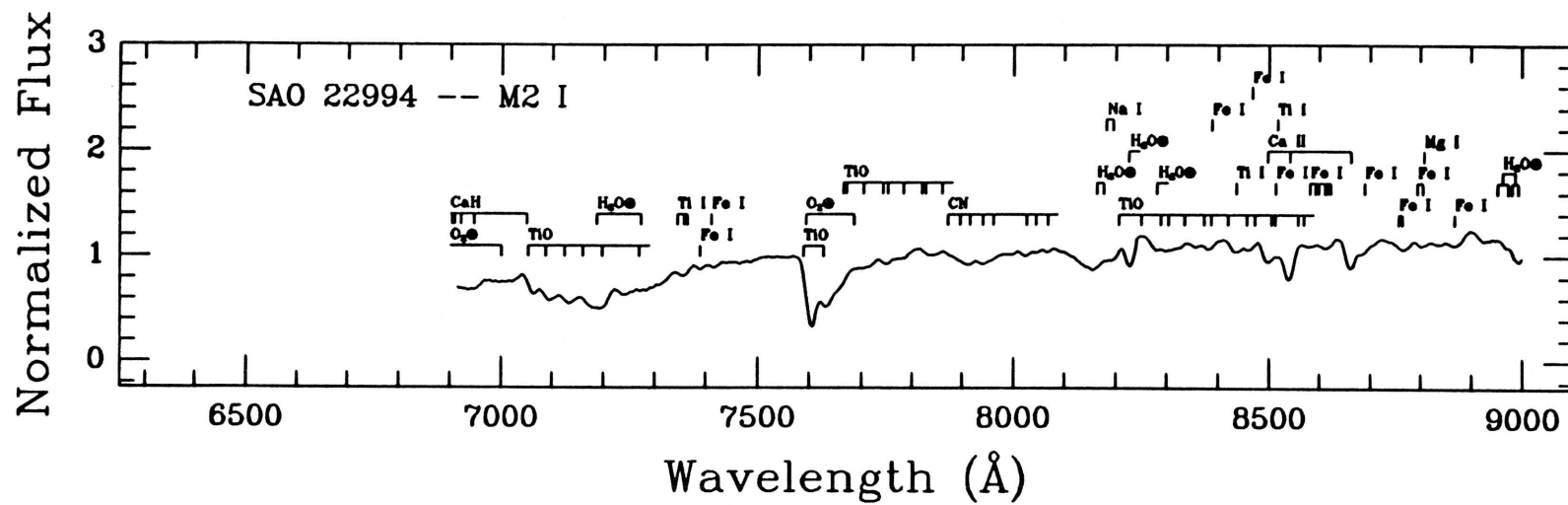
FIG. 3.5. — Detailed spectra of some of the objects in Figures 3.1 through 3.4 with line identifications from Table 3.5 marked. (a) A supergiant of class M2. →
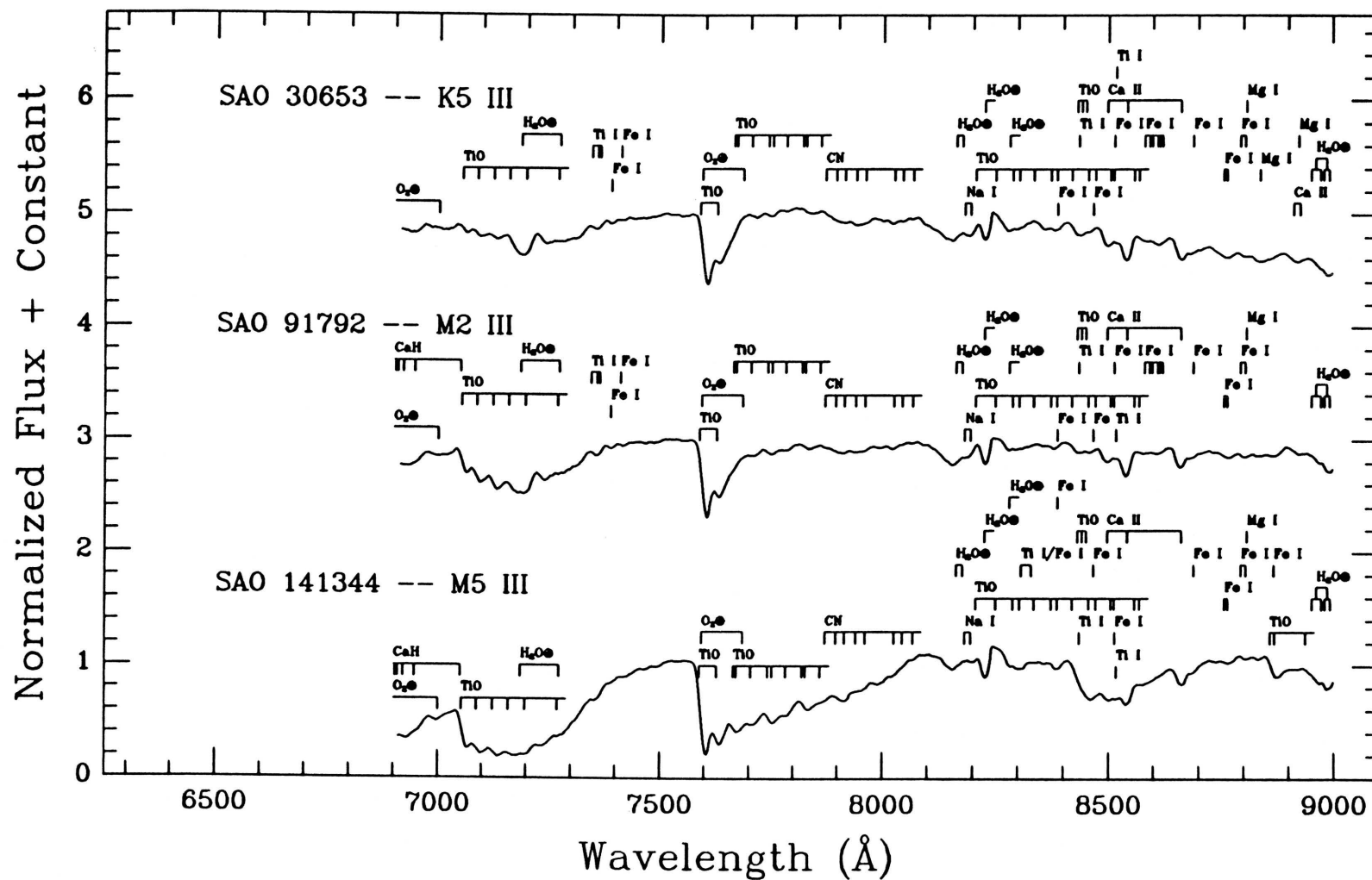
FIG. 3.5. (continued) — (b) Giants of class K5, M2, and M5. In the figure, offsets of two and four have been added to the spectra of SAO 91792 and SAO 30653, respectively, for clarity. →
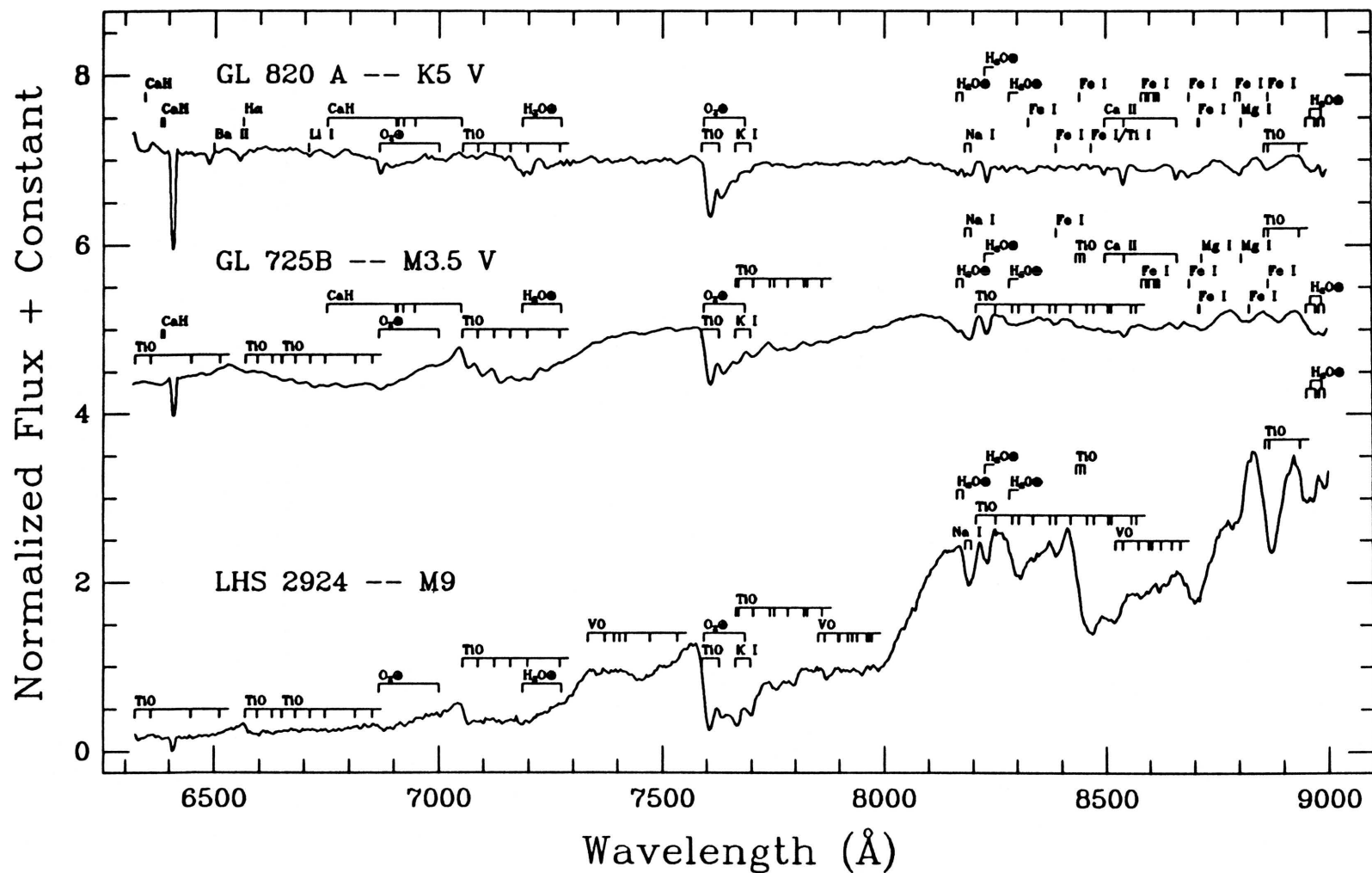
FIG. 3.5 (continued) — (c) Dwarfs of class K5, M3.5, and M9. Offsets of four and six have been added to the spectra of GL 725 B and GL 820 A, respectively, for clarity. →
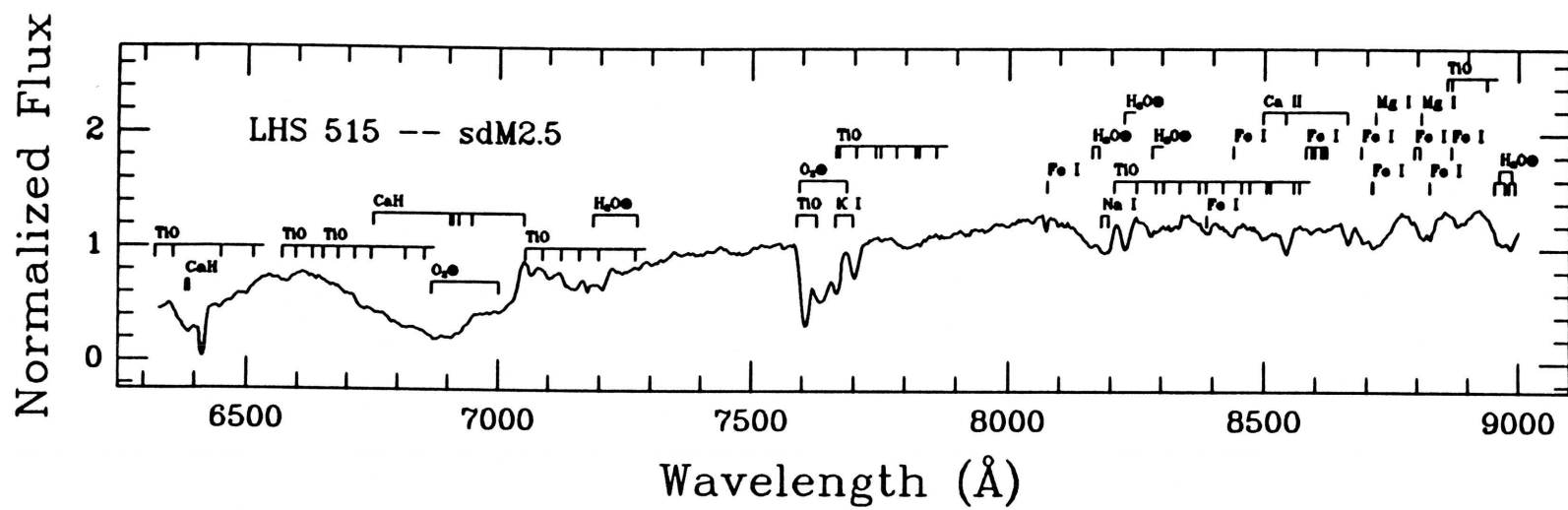
FIG. 3.5. (continued) — (d) A metallic hydride subdwarf of class M2.5.
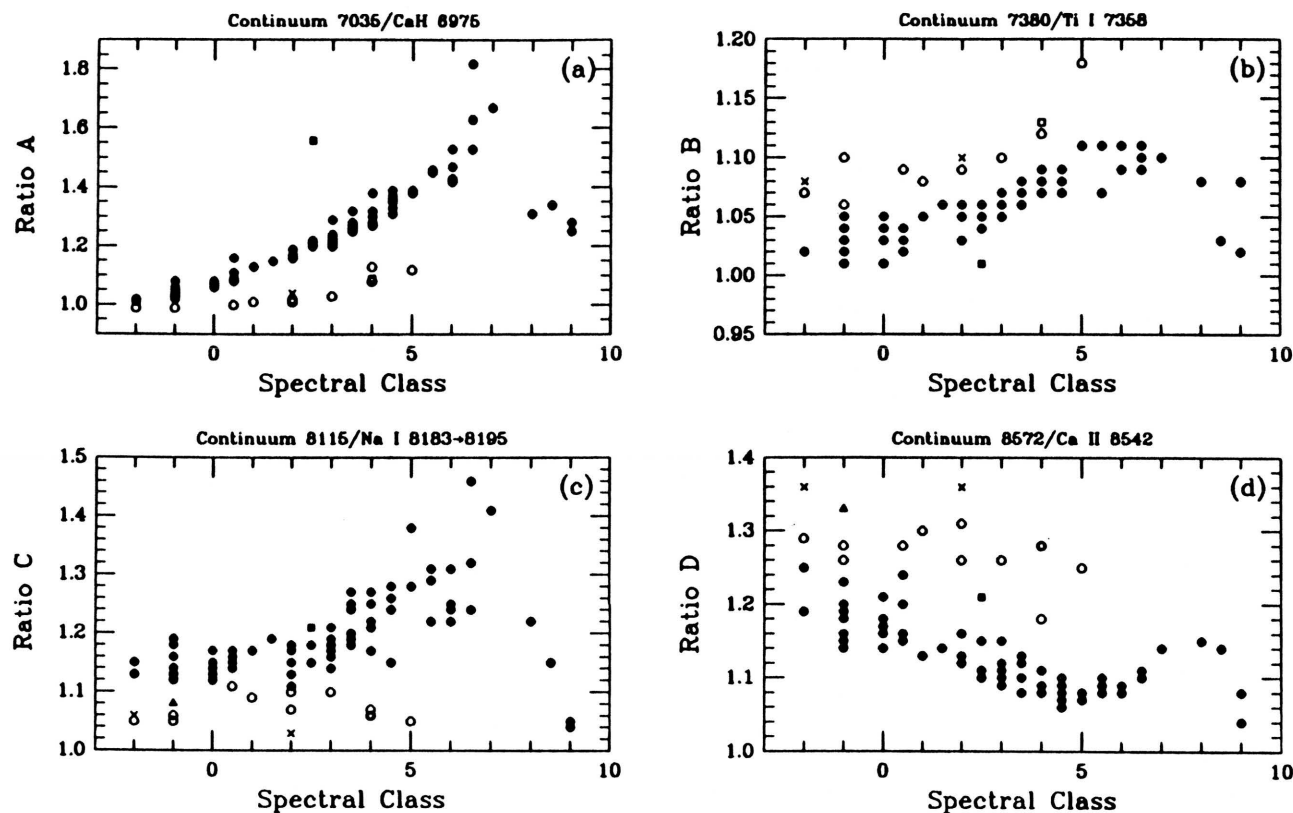
FIG. 3.6. — Color ratios useful as luminosity discriminants. Descriptions of the ratios are given in Table 3.7. Supergiants are marked by crosses, the bright giant by an open square, giants by open circles, and dwarfs by filled circles. The giant GL 756.2 is denoted by an open triangle, and the subdwarf LHS 515 is denoted by a filled square. Along the horizontal axis negative numbers represent K spectral types. K5 is located at the "-2" mark, and K7 is located at the "-1" mark. Positive numbers represent M spectral types; "0" stands for M0, "4.5" for M4.5, etc. The figure shows ratios of four different luminosity dependent lines or bands to nearby "continuum" areas, regions where there is little contaminating absorption.
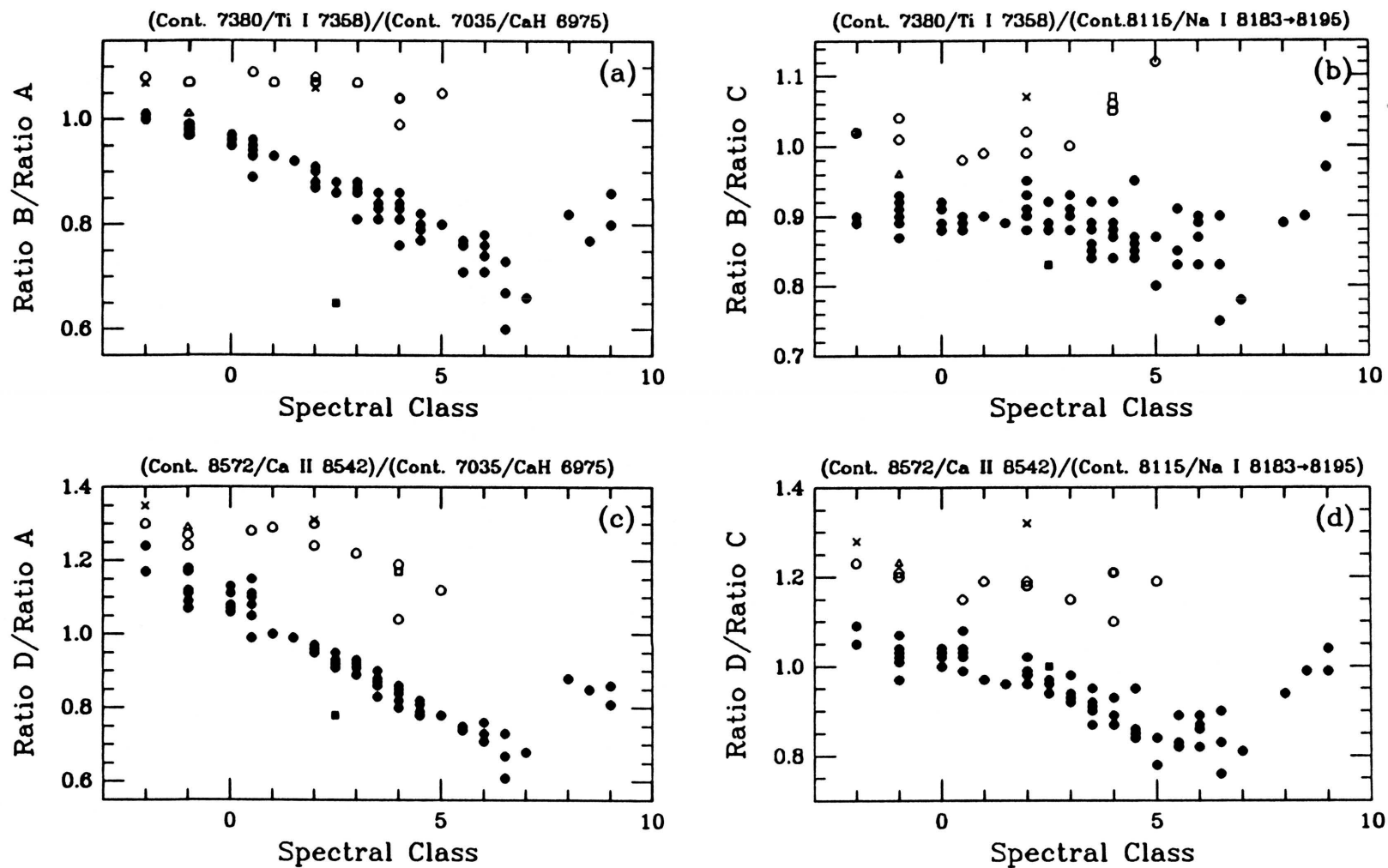
FIG. 3.7. — The same as Figure 3.6, except that the ratios shown are based on the ratios given in Figure 3.6. See text for details.
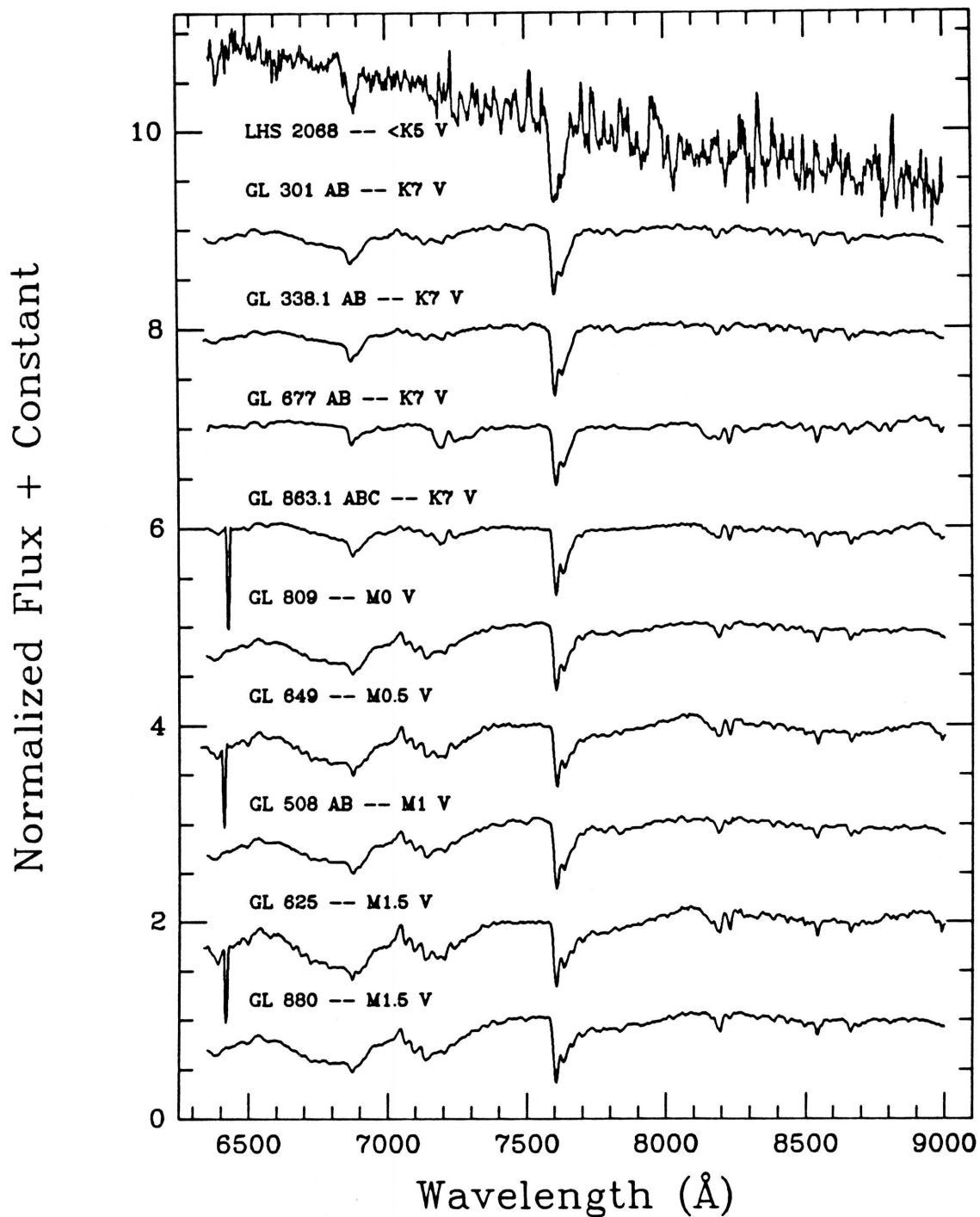
FIG. 3.8. — Spectra of 32 additional objects listed in Table 3.9. All of these were observed at the MMT and have a resolution of 18 Å. See the caption to Figure 3.1 for more details.
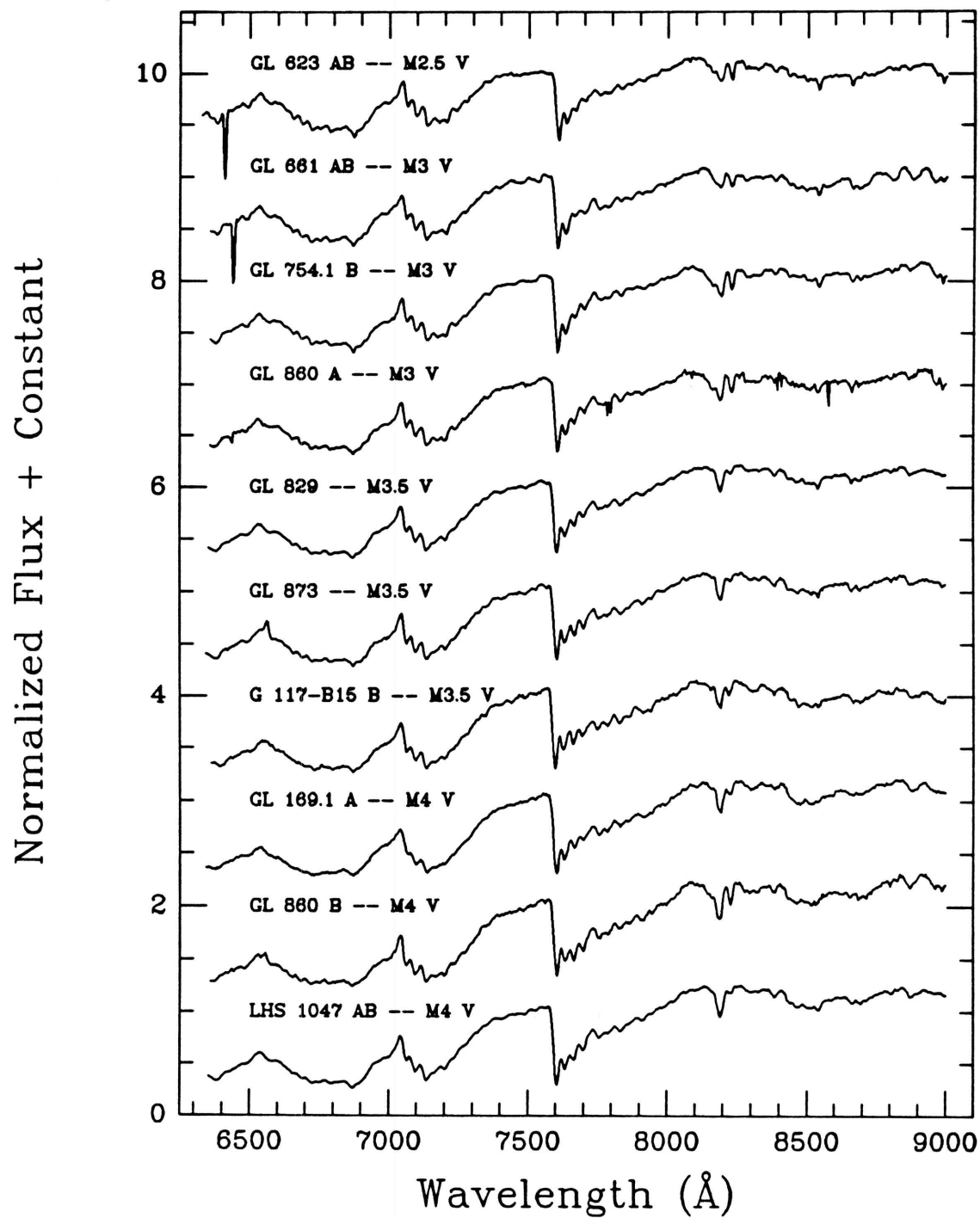
FIG. 3.8. (continued)
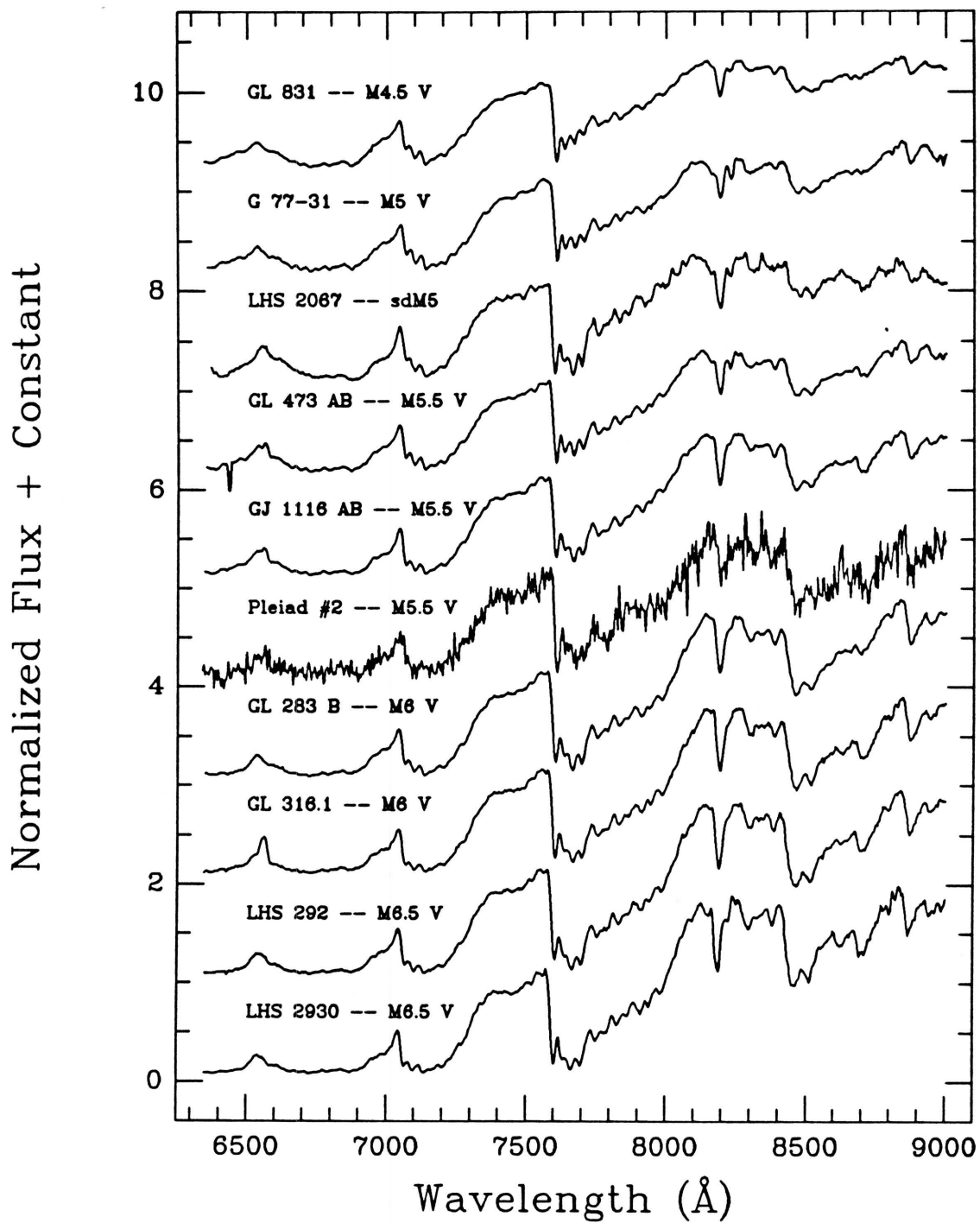
**FIG. 3.8.** (continued)
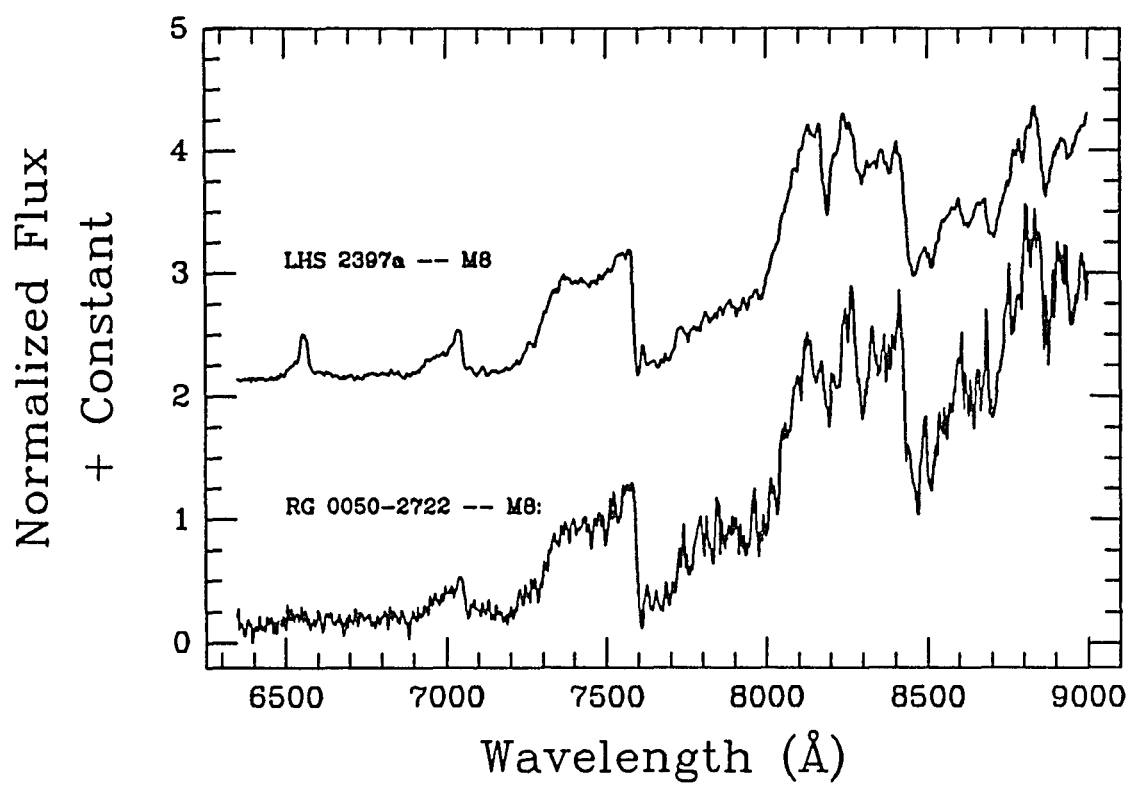
FIG. 3.8. (continued)
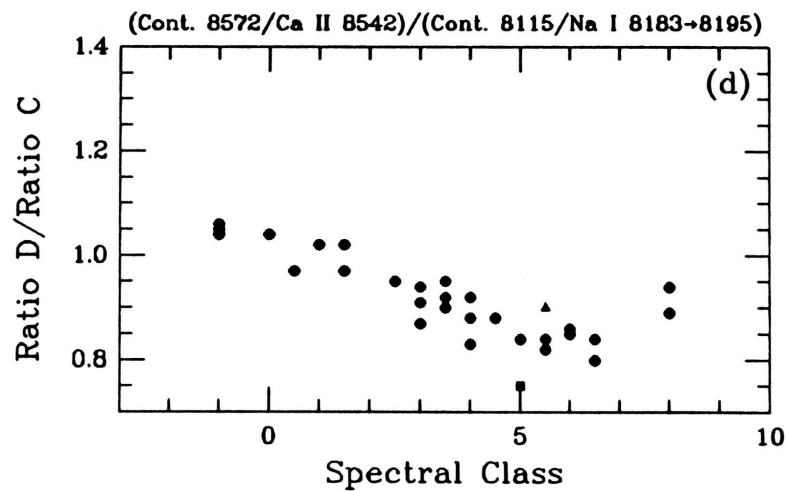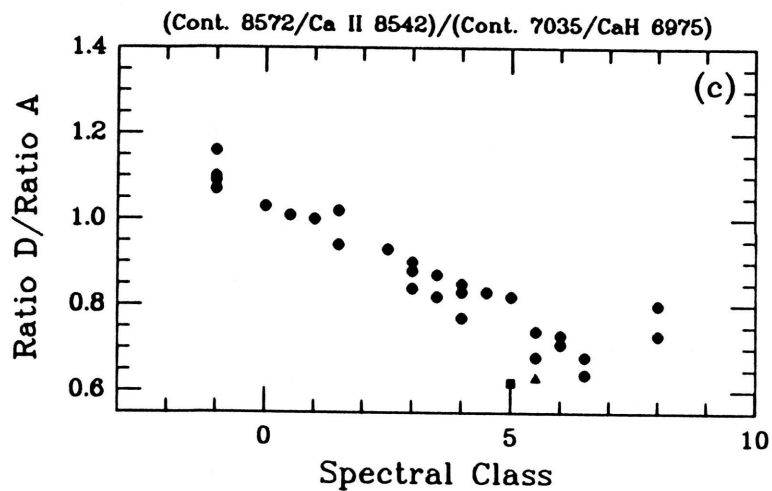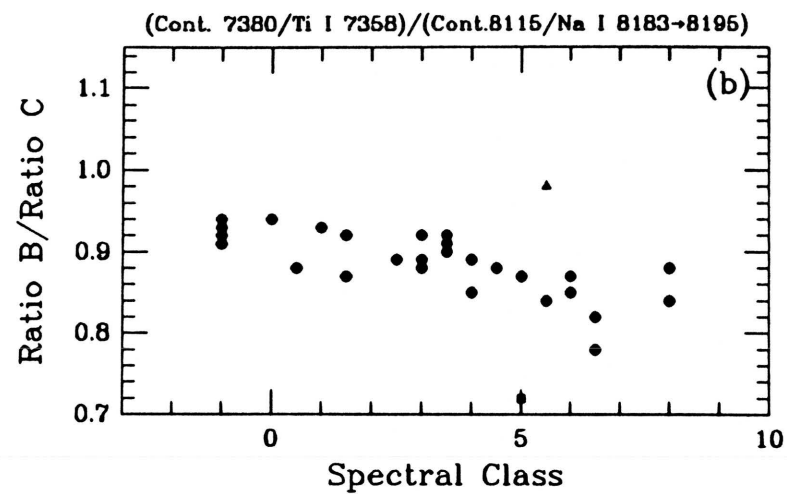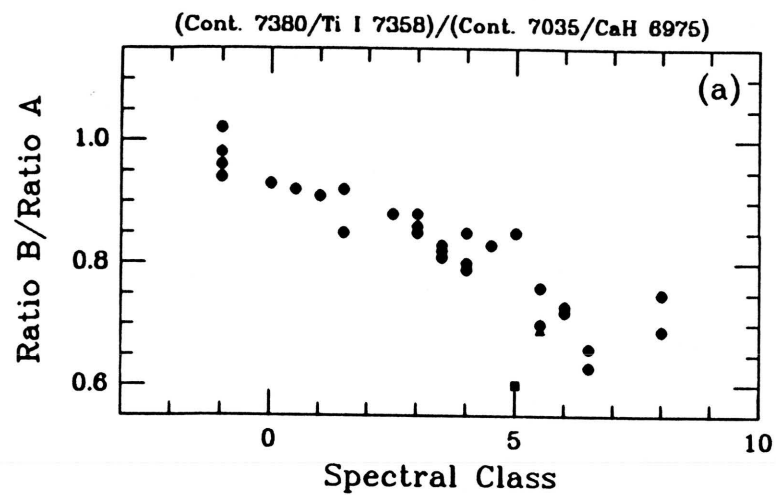
FIG. 3.9. — The same as Figure 3.7, except that the data plotted here are for the stars listed in Table 3.9.
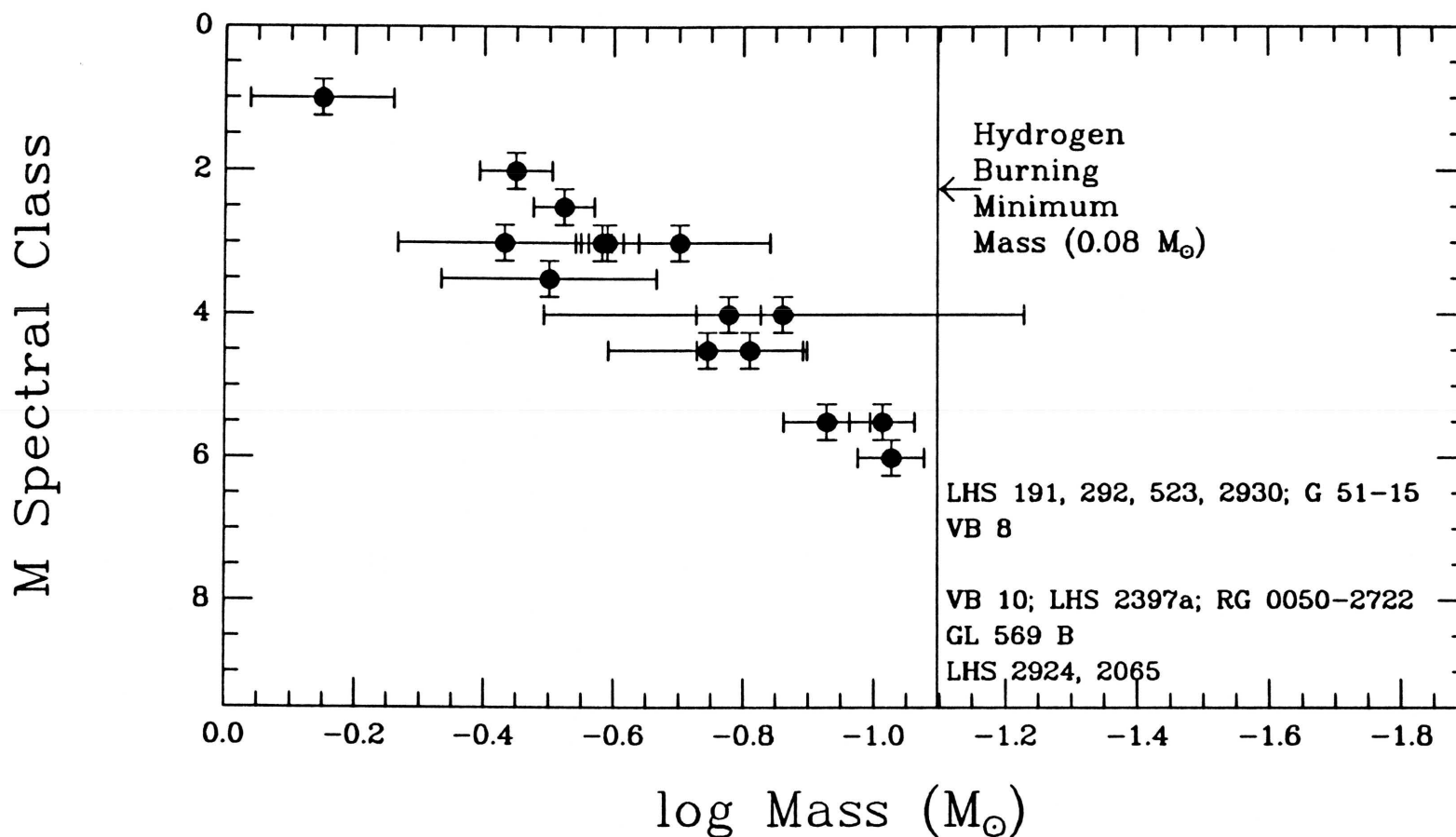
FIG. 3.10. — M spectral class versus the logarithm of the mass for those dwarfs listed in Table 3.10. The vertical line at 0.08 M$_\odot$ represents the minimum mass for core hydrogen burning; objects to the right of the line would be brown dwarfs. The point of highest mass here, representing GL 508 AB, may be spurious; a third member of this system may be present as suggested through radial velocity variations on the order of 10 km/sec (Wilson 1967).

## 3.2: THE TEMPERATURE SCALE FOR M DWARFS DERIVED
## USING SPECTRA FROM 0.6 TO 1.5 MICRONS

M dwarfs are the most common stars in the Galaxy and could be responsible in part for its missing mass; however, these objects are poorly understood physically. Although spectral data provide a wealth of information on such parameters as surface gravities, temperatures, and chemical compositions, it has proven challenging to extract this information because of the difficulty in relating existing data to theoretical models. Traditionally, spectra have been obtained in the visual, but for the coolest stars this has become an obstacle both because they are very faint and because the visual region lies on the Wien side of their blackbody emission, where modelling uncertainties can be very large. As a result, spectral atlases rarely contained data for stars later than M5. Recently, however, high quality spectra of M dwarfs have been obtained in the red and near-infrared, where these objects are emitting their peak fluxes. Spectral sequences are now available for the entire range of M dwarfs, and a comparison between observational and theoretical data can provide more insight into these objects.

Unfortunately, modelling the atmospheres of M dwarfs has proven to be a very complicated problem due to the large number of opacity sources present in their spectra, the uncertainty with which many molecular constants and oscillator strengths are known, and the inability of current models to describe adequately the transition from the radiative layers to the convective ones. (Convection itself, which is the main mode of energy transport in these stars, is fortunately not a major problem, and the high densities force the real temperature gradient

to be very close to the adiabatic one.) The first attempt at modelling these atmospheres was the work of Mould (1976), which included only the early M stars. Two recent PhD theses — Allard (1990) and Ruan (1991) — have attempted to refine these models and to extend them to the temperatures of the coolest dwarfs. The energy distributions from both model grids are quite similar since the majority of subroutines employed was identical.

In this paper we present an M-dwarf spectral sequence against which to check the success of these new models. We have obtained spectra from 0.6 to 1.5 $\mu m$ of well-studied, nearby stars with accurate trigonometric parallaxes. The observations and reductions are presented in §3.2.1. The method for combining the red and the infrared data is given in §3.2.2. Features which serve well as temperature discriminants are discussed in §3.2.3. Model spectra from Allard (1990) are fit to the empirical data and discussed in §3.2.4. The resulting temperature sequence and H-R Diagram for M dwarfs are given in §3.2.5, and the shortcomings of the present models are discussed in §3.2.6. The conclusions are highlighted in §3.2.7.

### 3.2.1: Data Acquisition and Reduction

The objects observed for this project are listed in Table 3.11. Spectral classifications are from §3.1. All of the red spectra were observed at the Multiple Mirror Telescope (MMT) and have a resolution of 18 Å. Spectral coverage, observation date, and integration time are given in columns (4) - (6). Observing setups and reduction procedures can be found in §3.1. Since many of these observations were taken through spotty cloud cover, corrections for atmospheric

absorption were considered unreliable and thus not attempted. Features such as the A- and B-band of telluric $O_2$ are still present.

The infrared spectra were taken at the Steward Observatory 2.3-m telescope using a spectrometer that employs a 2×32 array of germanium photodiode detectors. The spectrometer was used with a pair of round, 6-arcsecond apertures separated by 1 arcminute. The 150 line/mm grating provides sampling every 30 Å, and the observational linewidth is 48 Å. Each grating setting covers about 0.1 $\mu m$, so many settings were needed to cover the spectral range. Each setting had a central wavelength displaced by 0.05 $\mu m$ from the previous one to insure overlap between adjacent spectral pieces. These adjacent pieces were connected by renormalizing one of the two pieces by the median flux ratio in the region of overlap. Dwarf stars of type F and G were observed for flatfielding and flux calibration. Telluric absorption was removed during the flatfielding procedure. However, Paschen absorption features in the spectra of the F and G dwarfs introduced small residual "emission lines" into the spectra of several of the program objects. For a more detailed discussion of the observing procedure and data reduction, see Rix et al. (1990). Spectral coverage, observation date, and total integration time for each object are given in columns (7) - (9) of Table 3.11.

### 3.2.2: Combining the Red and Infrared Spectra

To fit the two parts of the spectrum together, the infrared data for each object were renormalized relative to the red data by using a least-squares minimization technique (described in §3.1) on the overlap region. This procedure takes the difference between the flux values of the two spectra at 3 Å intervals

in wavelength. The sum of the squares of these differences is computed over the overlap region. The infrared spectrum is then shifted vertically up or down relative to the red spectrum, and a new sum is calculated. In this way the shift giving the smallest residual is found. (Because absorption by unremoved telluric $H_2O$ is present, the red spectra were truncated shortward of 0.905 $\mu m$. For each object, the remaining amount of overlap between the red and infrared spectra can be determined from column (7) of Table 3.11.) Once the shift was found, the spectra were renormalized and then connected by averaging the flux values in the overlap region at intervals equivalent to the pixel size for the red data ($\sim$3.5 Å). The resulting spectra are shown in Figure 3.11. Each spectrum is normalized to one (in units of $F_\lambda$) at its peak flux. Since the two pieces of spectra for LHS 2924 do not overlap, their relative normalizations relied solely upon the photometric data discussed below.

The fitted spectra include the regions investigated by broadband $I$ and $J$ filters, so it is possible to extract an $I - J$ color for each spectrum to evaluate the effectiveness of our fitting technique. These extracted $I - J$ colors were compared to values listed in Berriman & Reid (1987, hereafter BR) and Leggett & Hawkins (1988, hereafter LH). The $I$ photometry from both sources is on the Kron-Cousins system. However, BR give $J$ photometry on the AAO system, whereas LH give their $J$ (and $K$) data on the CIT (or CTIO) system. The data sets can be placed on the same system by converting the $J_{CIT}$ values into $J_{AAO}$ values via the equation

$$J_{AAO} = 1.115 J_{CIT} - 0.115 K_{CIT} + 0.004, \qquad (3.1)$$

which can be derived from Elias et al. (1983). The resulting $I_{KC} - J_{AAO}$ colors for the program objects are listed in columns (2) and (3) of Table 3.12. Two of

our objects — GL 411 and GL 406 — had photometry listed in both sources. Column (5) of Table 3.12 gives the difference between the LH and BR colors for these two stars. This comparison demonstrates that the colors agree to within ±0.1 mag.

Photometry on the $I_{KC} - J_{AAO}$ system was then extracted from the spectra of Figure 3.11. The values for $(F_\lambda)_{I_{KC}}$ and $(F_\lambda)_{J_{AAO}}$ were determined over a rectangular bandpass whose cut-on and cut-off wavelengths correspond to the wavelengths at half maximum of the filter. Half power for the $I_C$ ($\sim I_{KC}$) filter occurs at 0.725 and 0.875 $\mu m$ (Bessell 1979), which gives a central wavelength for the rectangular bandpass of 0.80 $\mu m$. For $J_{AAO}$, half power occurs at 1.08 and 1.38 $\mu m$ (Allen & Cragg 1983), giving a central wavelength of 1.23 $\mu m$. The colors measured from the spectra were therefore computed using the formula

$$I_{KC} - J_{AAO} = 2.5\left\{ log\left[ \left( \frac{(F_\lambda)_{J_{AAO}}}{(F_\lambda)_{I_{KC}}} \right) \left( \frac{\lambda_{J_{AAO}}}{\lambda_{I_{KC}}} \right)^2 \left( \frac{(F_{\nu_0})_{I_{KC}}}{(F_{\nu_0})_{J_{AAO}}} \right) \right] \right\}$$

$$= 2.5\left\{ log\left[ \left( \frac{(F_\lambda)_{J_{AAO}}}{(F_\lambda)_{I_{KC}}} \right) \left( \frac{1.23 \ \mu m}{0.80 \ \mu m} \right)^2 \left( \frac{2550 \ Jy}{1640 \ Jy} \right) \right] \right\}. \qquad (3.2)$$

The zero-magnitude fluxes are taken from Berriman & Reid (1987) and Allen & Cragg (1983). The derived colors are shown in column (4) of Table 3.12. Column (6) shows the differences between our photometry and that of LH. The average difference of $\sim$0.08 mag, which is similar to the disagreement found between the BR and LH color data, is small enough that we consider our technique of combining the spectra to be reliable.

Since the red and infrared spectra of LHS 2924 do not overlap, the photometry from LH was used to find the relative normalizations of the two pieces. Since the $I - J$ values derived from the spectra are systematically $\sim$0.1 mag bluer than

the LH values, a value of $I - J = 3.3$ was assumed for the normalization, and, of course, no independent measurement of the color was possible.

For M dwarfs, the purest temperature index of all the red/infrared colors (according to LH) is $I - J$. Table 3.12 shows that $I - J$ increases with increasing spectral type through the M stars, with the possible exception of the G 208-44/45 system. According to our photometry, G 208-44 AB, whose red spectrum is classified as an M5.5 V, is 0.07 mag *redder* in $I - J$ than its sister star G 208-45, whose red spectrum is classified as an M6 V. Although this difference is within the errors determined above, the composite spectrum of G 208-44 AB may be too bright at $J$ for its type due to the contribution from its very red, low-mass secondary, G 208-44 B. The same color effect is found in the photometry presented in McCarthy et al. (1988).

### 3.2.3: Spectral Features

The spectra of Figure 3.11 show many changes in spectral shape and feature strengths along the sequence of M stars. The peak flux (in units of $F_\lambda$) for an M2 star occurs in the red portion of the spectrum, around 0.80 $\mu m$. By M8 and M9, the flux in the infrared portion around 1.1 to 1.2 $\mu m$ greatly dominates. If these peaks corresponded to blackbody maxima, temperatures ranging from 3600 to 2400 K would be derived. Clearly, though, these spectra are far different from those of blackbodies, so a temperature determination based on model fitting and calibration of temperature-sensitive features would be better.

There are several temperature-sensitive atomic lines and molecular bands that are easily visible in this spectral range. Figure 3.12 shows identifications

for an M2 and an M8 spectrum. Most obvious perhaps are the red TiO bands, which gain prominence through the early- and mid-M stars, saturating beyond spectral type M6. At our resolution, VO absorption begins to appear after M6 and is a good indicator of temperature for the latest objects. FeH at 0.99 $\mu m$ begins to appear after M4 and increases with decreasing temperature throughout the sequence. The most obvious temperature-dependent feature in the infrared portion is the $H_2O$ absorption at 1.35 $\mu m$ — by M9 it is the most striking feature in the entire spectrum. Other prominent features are $H_2O$ at 1.14 $\mu m$, OH at 1.20 $\mu m$, and a number of sharp absorption features at 1.169, 1.177, 1.243, and 1.252 $\mu m$ that are likely due to K I. These last four positions are the only features in the 1.1 - 1.5 $\mu m$ solar spectrum which are identified by Livingston & Wallace (1991) as K I, and all four correspond very closely to prominent features found in the spectra of our coolest objects. The 1.177-$\mu m$ line was first identified in the spectrum of R Leo by Spinrad and Wing (1969), who note that the neutral potassium lines are favored at lower temperatures. A more detailed identification of features in the far red portion of the spectrum can be found in §3.1.3.

## 3.2.4: Fits to Theoretical Spectra of M Dwarfs

The spectra of Figure 3.12 can be compared to the theoretical models of Allard (1990). (Additional discussion of Allard's models can be found in Leinert et al. 1990.) Her models cover a grid of metallicities ([M/H] = 0, -1, -2, -3, -4), surface gravities (*log g* = 4, 5, 6), and temperatures (3500, 3250, 3000, 2750, 2500, 2250, 2000 K). Surface gravities for some of the stars in this paper can be determined using radii derived in Lacy (1977) and masses derived from $M_K$

values, and the $M_K$ vs. mass relation, presented in Henry and McCarthy (1990). Independent determinations can be made using the radii and masses given in Caillault and Patterson (1990). The results, which are shown in Table 3.13, indicate that an integral value of *log g* = 5 best describes the stars from type M2 to M6. (The surface gravities of GL 752 B and LHS 2924 are not known since masses have not been determined for either.) Therefore, only the models with *log g* = 5 have been considered further. As for metallicity, the models with [M/H] = -1 have a very striking CaH absorption feature at 0.675 $\mu m$, which is typical of extreme subdwarfs such as LHS 515 (see §3.1.4) and LHS 2045 (see §5.3). Since none of the spectra presented here show this strong feature, only the models with [M/H] = 0 were used.

## a) Fits in the Red Region

As with the observational data, each model spectrum was normalized to unity at its peak flux, in units of $F_\lambda$. By applying the least-squares minimization technique (see §3.1.4) on only the red portion (0.70 - 0.90 $\mu m$), each observed spectrum was compared to each of the model spectra, and the best match in temperature was found. In order to make a finer grid in temperature, a linear interpolation between Allard's spectra was used to produce models with T = 3375, 3125, 2875, 2625, 2375, and 2125 K, giving us a resolution of 125 K.

Figure 3.13 shows each of the red spectra overplotted with the model spectrum that provided the best match. In the case of GL 411, a model warmer than the one at 3500 K would clearly have provided a better match. Generally, the Na I feature at 0.82 $\mu m$ is fit well by the models, as is the slope of the spectrum

between 0.77 and 0.81 $\mu m$ and the relative opacity minimum from 0.69 to 0.72 $\mu m$ that lies between consecutive TiO bands. The similar minimum between 0.64 and 0.67 $\mu m$ is not fit well, nor is the one between 0.73 and 0.76 $\mu m$. For the later spectra ($\geq$ M6), the models predict less flux at 0.90 $\mu m$ than is indicated in the observational data, and the overall appearance of the model spectra is in worse agreement with the true spectra. The temperatures of these fits in the red are given in column (2) of Table 3.14.

## b) Fits in the Infrared Region

When the infrared portion of the spectrum is compared to the models, the discrepancy in the region around 1.00 $\mu m$ is immediately apparent (see Figure 3.14). A small part of this discrepancy arises because Allard (1990) does not include FeH at 0.99 $\mu m$ in her calculations. The models from Ruan (1991), which do include FeH, show substantial discrepancies in the 1.00 $\mu m$ region as well. For example, in both the Allard and Ruan models the VO absorption around 1.05 $\mu m$ is virtually absent. In general it appears that throughout this region there are important opacity sources not yet included in the models.

The general *shape* of the spectral "continuum," however, is traced out well from ~1.08 to the steam feature at 1.35 $\mu m$, even though the models do not include many of the sharp features such as the $H_2O$ absorption at 1.14 $\mu m$ and the OH absorption at 1.20 $\mu m$. To obtain a second set of temperature estimates, the least-square minimization technique was again applied, this time over 1.08 to 1.35 $\mu m$, to find the model providing the best match. Specifically, only the pseudo-continuum and the $H_2O$ feature at 1.35 $\mu m$, both of which are

temperature-dependent, were fit. Absorptions not reproduced in the models (1.10
- 1.12 $\mu m$, 1.13 - 1.145 $\mu m$, 1.165 - 1.18 $\mu m$, 1.19 - 1.215 $\mu m$, and 1.235 - 1.28
$\mu m$) were excluded from the fit. For the latter half of the spectral sequence, at
least as late as M8, the models give a fair match to both the "continuum" and
the 1.35 $\mu m$ steam feature. The best fits are illustrated in Figure 3.15, and the
resulting temperatures are listed in column (3) of Table 3.14. This comparison of
the infrared spectra with theoretical models suggests, even for the coolest stars,
a modeled continuum which is approximately correct but which has a number of
missing absorption species.

As demonstrated in Figure 3.14 (see §3.2.4c), fits that simultaneously match
the red and infrared data give poor results. Nonetheless, when taken *singly*, the
red and infrared portions of the models provide, in many cases, reasonably good
fits to the data. Specifically, good fits are obtained in the red region for stars
earlier than about M6. However, the density of features in the spectra of cooler
objects makes a continuum in the red difficult to identify, and the models are
generally poor fits to the data. These later objects, on the other hand, are fit well
by the infrared portions of the theoretical models, but these same models cannot
be fit reliably to stars earlier that M6 because of the lack of strong temperature-
sensitive features in the infrared. Therefore, the combination of red and infrared
spectra promises to provide improved accuracy in relating the stars to a sequence
of models of differing temperatures.

## c) Synthetic Photometry

Figure 3.14 is plotted so that the best fit to the data in the 1.08 to 1.35 $\mu m$ region is shown. Notice that the red portion (0.70 to 0.90 $\mu m$) of the model should be shifted downward to achieve a better match. Although the least-squares minimization technique found that the same model yielded the best fits in both the red and infrared portions of the spectrum, the normalization of the model in each region was different. This shift cannot be accounted for on observational grounds because, as discussed in §3.2.2, the combined red/infrared spectra successfully reproduce the observational $I - J$ colors. Clearly, the $I - J$ color of the model and that of the true data are in disagreement. To explore this effect further, synthetic $IJHK$ photometry was obtained from the best-fit models and was compared to observed colors. These values are listed in Table 3.15. The $J - H$ and $J - K$ colors were derived using, for $H_{AAO}$ and $K_{AAO}$, respectively, central wavelengths of 1.64 and 2.19 $\mu m$ and zero-magnitude fluxes of 1030 and 650 Jy (Allen & Cragg 1983). For each of the observed spectra, synthetic colors were derived from the model that fit best in the red for spectral types < M6 and from the model that fit best in the infrared for spectral types $\geq$ M6.

For early M dwarfs, the disagreement between the observed and modelled $I - J$ is around 0.05 mag, which is within the uncertainty noted before. However, for later types, the disparity becomes increasingly large; for LHS 2924, the difference between the true $I - J$ and that of the model is 0.86 mag! Part of this discrepancy arises because the modelled $I$ flux is too large due to an underestimate of the opacity around 0.74 $\mu m$. The true $J - H$ and $J - K$ colors increase for later

spectral types, whereas the $J - H$ and $J - K$ colors from the models *decrease* for later spectral types. Despite this backward trend, the $J - H$ color of the models is still in general only $\sim 0.1$ mag different from the true color. For the early M dwarfs, the same difference is seen in the $J - K$ colors, but for later types the discrepancy is $\sim 0.4$ mag.

Allard (1990) derives her own synthetic photometry of the models and notes the same effect presented above, i.e., that $J - H$ and $J - K$ get bluer for the cooler models. This effect can be attributed to gross incompleteness in the opacities, or specifically to the strong influence of water blanketing in the models. Nonetheless, these models are certainly closer to the actual spectra of M dwarfs than are blackbodies and should be used in preference to blackbody curves. The colors of these objects are distinctly unlike those of a blackbody and are likewise not well predicted by the models, especially beyond M5. The best match to the true data is, therefore, achieved by fitting theoretical models to observed *spectra*.

### d) Comparison to Ruan's Models

Ruan (1991) overplots her model spectra with those of Allard (1990). From 0.70 to 0.90 $\mu m$, these two sets of $log\ g = 5$, $[M/H] = 0$ models are virtually identical, convincing us that a temperature scale derived from Ruan's models would give us the same results as Allard's for stars earlier than M6. Ruan's overplots in the infrared show nearly identical $H_2O$ strengths and continuum slopes as well, reassuring us that the same temperature scale would also have been derived for objects of type M6 and later. The major difference between the Ruan and Allard models is the inclusion of 0.99-$\mu m$ FeH in the Ruan set. A

temperature sequence could be derived, potentially, based on this feature alone, as the Ruan models show its strengthening with later type in accordance with observations. Unfortunately, these models do not include either of the obvious absorption species just redward and just blueward of the FeH band, making an accurate fit to the feature impossible. Like Allard, Ruan also notes a blueward trend of $J - H$ and $J - K$ in the models, i.e., that these colors become bluer for later spectral types. Based on this information, we are confident that a temperature scale derived from Ruan (1991) would not differ from that presented here.

### 3.2.5: Temperature Scale

As discussed in §3.2.4b, an accurate temperature sequence can be established for all M dwarfs by using temperatures from red fits for stars earlier than M6 and temperatures from infrared fits for objects of later spectral type. As Table 3.14 demonstrates, the temperatures of the best-fit models in the red and the best-fit models in the infrared are never different by more than 125 K. For objects earlier than type M6, the red and infrared fits assign identical temperatures. In fact, for five of the eight spectra, the same model provided the best fit in both regions. In light of such agreement, we are confident in adopting the temperature determined by the part of the spectrum giving the better fit. These assigned temperatures are listed in column (2) of Table 3.16, where the objects are presented in order of increasing $M_V$. Based on the agreement of the red and infrared fits to the data, we assign an uncertainty in our temperatures of ±125 K.

The luminosities of these objects can be determined from their parallaxes

and from photometry. The parallaxes are listed in column (3) of Table 3.16 and were used to calculate the absolute magnitudes $M_V$, $M_I$, and $M_J$ in columns (4) - (6). A linear interpolation of Bessell's (1991) $M_I$ vs. $BC_I$ relationship gave the values of $BC_I$ (column 7) used to determine the bolometric magnitude in column (8). Notice that these assigned temperatures decrease monotonically with increasing $M_V$, $M_I$, $M_J$ and $M_{bol}$. Finally, luminosities were determined (column 9) assuming that the Sun has $M_{bol} = 4.75$.

As a test of the accuracy of the bolometric corrections, we compared for GL 752 B the flux determined by integration of the $0.6$-$1.5\mu m$ spectrum with the flux determined by trapezoidal integration under the broadband magnitudes. In spite of the strengths of the absorption features in the spectrum, the two techniques agreed to within roughly 5%. For earlier spectral types, the agreement should be much better. Compared to typical uncertainties in distances, the bolometric corrections given by Bessell seem to be fairly reliable. For later spectral types, however, it is clearly preferrable to determine the bolometric flux from spectra rather than from broadband photometry.

Also listed in Table 3.16 are the temperature sequences assigned by BR and by Veeder (1974). To assure a set of data on a standard system, the luminosities of their stars and ours were calculated using parallaxes, photometry, and bolometric corrections from the same sources. Neither the BR or Veeder sequences exhibit the monotonic behavior that ours does, but perhaps this is not too surprising considering the number of data points present in those two sequences, the errors inherent in assigning temperatures from photometric data, and the uncertainties in the parallax. The temperatures assigned by Veeder are determined by fitting a blackbody (by eye) to the observed broad-band colors of each star. Short

wavelengths are assumed to have a certain amount of blocking, but the total flux under the blackbody curve and the total flux observed from the star are required to be equal. BR assumed that no significant backwarming or blanketing occurs at 2.2 $\mu m$. The temperature for each star was determined from the blackbody curve having (1) flux equal to the observed flux at 2.2 $\mu m$ and (2) the same total flux observed from the star. BR quote an uncertainty in their temperatures (which do not differ significantly from the revised temperatures presented in Berriman, Reid, & Leggett (1992)) of ±110 K, whereas Veeder (1974) quotes one of ±150 K.

The temperatures and luminosities from all three sequences are presented in the H-R Diagram of Figure 3.16. The temperatures assigned in this paper are generally *warmer* at a given absolute magnitude than the temperatures assigned by either BR or Veeder, particularly for the lowest-luminosity objects. For $log(L/L_\odot) \leq -3.0$, the difference between our temperatures and those of the other authors is ~500 K. This is not surprising since the models show strong pressure and temperature dependences as well as radiative transfer effects. Figure 3.16(a) shows theoretical tracks of the lower main sequence by D'Antona & Mazzitelli (1985, hereafter DM) and by Burrows, Hubbard, & Lunine (1989, hereafter BHL). The DM curve is for the zero-age main sequence, and the BHL curves are for an age of 10 Gyr. (The BHL curves for an age of 1 Gyr are in very close agreement with those plotted here. Only at the low luminosity end do these tracks deviate noticeably from the 10 Gyr models. Specifically, these younger tracks bring the models *closer* to our plotted positions of GL 752 B and LHS 2924.) Figure 3.16(b) shows the theoretical tracks of Dorman, Nelson, & Chau (1989, hereafter DNC), with the DM curve plotted again for comparison.

The DNC models are also calculated for the zero-age main sequence. Using our temperature scale, the positions of M dwarfs on the H-R Diagram fall closer than previous determinations to theoretical tracks of the lower main sequence.

### 3.2.6: Discussion

This first attempt to fit a sequence of M dwarf spectra with model energy distributions demonstrates clearly that the general slope of the distributions and many of the features can be well reproduced by present-day models. As a result, it is possible to construct an improved temperature scale that is quite consistent with interior models. Shortcomings of the atmospheric models are, however, obvious. For example, the fluxes for wavelengths between major absorption bands are often too high, indicating that additional opacity sources are important but have not yet been included in the calculations (in most cases, due to the lack of laboratory data). It should also be noted that the electronic $f$-values for many bands are of very low accuracy (cf. Bessell & Scholz 1990).

These problems show up in the spectra more strongly when the gradient of the Planck function is steep, i.e., the uncertainties are highest for the coolest models (as can be seen in the comparison of observed and calculated spectra in Figure 3.15) and in a given model are strongest for the short-wavelength, or Wien, portion of the spectrum. This latter point implies that an analysis based on fluxes at wavelengths shorter than that of the maximum flux is rather unreliable (cf. the analogous discussion for limb-darkening by Scholz & Takeda 1987). Therefore, in this paper we draw our main conclusions from the energy distributions in the region of the peak flux.

The differences between the observed and the calculated colors are also largely due to these problems. In particular, the fact that the observed colors involving the $I$ filter are much redder that the calculated ones can be traced back to high fluxes in the 0.74-$\mu m$ region of the models. Additional reasons for the discrepancies could result from uncertainties in the filter functions and the color equations; however, these effects are considered to be small since the synthetic photometry obtained from the combined spectra agrees to within 0.1 mag of the observed colors (see §3.2.2). Furthermore, changes in our adopted filter transmissions do not adversely affect the calculated photometry. For example, when the half-power points of the $J$ bandpass are shifted by $\pm 10\%$ of the filter width, the newly calculated $I - J$ colors of the 2750 K model are only $\sim 0.02$ mag different from the previously derived $I - J$ color. Since these differences are small compared to the differences noted between observed and theoretical photometry, it must be concluded that the biggest factor contributing to the color discrepancy is the absence or uncertain modelling of opacity sources in the models.

### 3.2.7: Summary

This paper presents the first set of 0.6 - 1.5 $\mu m$ spectra for a full sequence of M dwarfs. Strong, temperature-sensitive absorptions by $H_2O$, TiO, VO, OH, K I, and FeH are present. The observed spectra show many more features than are currently included in the models. Identifications have been made of the strongest of these missing absorption species, and follow-up observations are planned at higher resolution.

Using these spectra, a new temperature sequence has been determined for

M dwarfs. Allard's (1990) models have been used for the temperature fits and yield the same results as Ruan's (1991) models. The models present a good fit to dwarfs earlier than type M6 in the region around the $I$ bandpass but are far less successful in reproducing the observed spectra of later dwarfs. Dwarfs of type M6 and later have a significant steam feature at 1.35 $\mu m$ that increases with later spectral type, and the shape of the infrared "continuum" is also temperature-dependent. As a result, these later dwarfs were fit by the models in the region of the $J$ bandpass. The sequence has been established, therefore, by fitting models to the red and infrared portions of the data independently.

Although the red and infrared fits assigned very similar temperatures to the same object, the colors deduced from the models are in sharp contrast with observed colors determined from broad-band photometry. The models predict consistently bluer $I - J$ colors than are observed. Also, the $J - H$ and $J - K$ colors from the models get bluer with later spectral type, in direct contrast to the observed trend. These trends illustrate that it is difficult to assign temperatures to M dwarfs based on colors. The preferred method is to fit models to temperature-sensitive features in the spectra.

The temperatures assigned here are warmer than those of Veeder (1974) and Berriman & Reid (1987), particularly at the lowest luminonsities. When plotted on an H-R Diagram, our sequence is in better agreement with theoretical tracks of the lower main sequence.

TABLE 3.11

LOG OF 0.63 TO 1.50 MICRON SPECTROSCOPY

| | | | Far Red | | | Infrared | | |
|---|---|---|---|---|---|---|---|---|
| Gliese No. | Other Name | Spectral Type | Spectral Range ($\mu m$) | Date Obs. (UT) | Integ. (sec.) | Spectral Range ($\mu m$) | Date Obs. (UT) | Int.[a] (sec.) |
| 411 | HD 95735 | M2 V | 0.63-0.92 | 1990 Jan 22 | 9 | 0.90-1.50 | 1990 Jun 12 | 238 |
| 273 | BD +5° 1668 | M3.5 V | 0.63-0.92 | 1990 Jan 22 | 120 | 0.90-1.60 | 1990 Nov 06 | 904 |
| 213 | Ross 47 | M4 V | 0.63-0.92 | 1990 Jan 22 | 130 | 0.90-1.60 | 1990 Nov 05 | 2515 |
| — | G 208-44 AB | M5.5 V | 0.63-0.92 | 1989 Jul 13 | 75 | 0.85-1.60 | 1989 Sep 20 | 1860 |
| — | G 208-45 | M6 V | 0.63-0.92 | 1989 Jul 13 | 225 | 0.85-1.60 | 1989 Sep 20 | 1800 |
| 406 | Wolf 359 | M6 V | 0.63-0.92 | 1990 Jan 20 | 80 | 0.85-1.51 | 1990 Apr 11 | 1135 |
| 752 B | VB 10 | M8 V | 0.63-0.92 | 1989 Jul 10 | 1800 | 0.85-1.55 | 1989 Sep 17/20 | 2700 |
| — | LHS 2924 | M9 | 0.63-0.92 | 1989 Jul 13 | 1980 | 1.00-1.35 | 1990 Apr 14 | 2190 |

[a] Total integration time for all of the spectral segments.

TABLE 3.12

COMPARISON OF $I - J$ VALUES

| Name | ($I - J$) Reference | | | $\Delta_{I_{KC}-J_{AAO}}$ | |
| | LH[a] | BR[b] | us[c] | LH - BR | LH - us |
| --- | --- | --- | --- | --- | --- |
| GL 411 | 1.13 | 1.23 | 1.04 | -0.10 | +0.09 |
| GL 273 | 1.40 | — | 1.32 | — | +0.08 |
| GL 213 | 1.47 | — | 1.39 | — | +0.08 |
| G 208-44 AB[d] | — | — | 2.11 | — | — |
| G 208 − 45[e] | — | — | 2.04 | — | — |
| GL 406 | 2.31 | 2.27 | 2.24 | +0.04 | +0.07 |
| GL 752 B | 2.74 | — | 2.65 | — | +0.09 |
| LHS 2924[f] | 3.38 | — | — | — | — |

[a] Data from Leggett & Hawkins 1988

[b] Data from Berriman & Reid 1987

[c] Data from this paper

[d] $(I_{KC} - J_{Steward}) = 2.19$ from McCarthy et al. 1988.

[e] $(I_{KC} - J_{Steward}) = 2.15$ from McCarthy et al. 1988.

[f] Because there is no overlap between the far red and the infrared data, Leggett & Hawkins 1988 photometry was used to scale the two spectral pieces. Thus, no independent measurement of $I - J$ was possible.

TABLE 3.13

SURFACE GRAVITIES

| Name | log $g$ (1)[a] | log $g$ (2)[b] |
|------|-----|-----|
| GL 411 | 4.59 | — |
| GL 273 | 4.71 | 5.00 |
| GL 213 | — | 5.11 |
| GL 406 | 5.08 | 5.49 |

[a] Based on data from Lacy 1977 and Henry & McCarthy 1990
[b] Based on data from Caillault & Patterson 1990

TABLE 3.14

TEMPERATURES DERIVED FROM THE BEST FIT TO
ALLARD'S MODEL SPECTRA WITH $[M/H] = 0$, $log\ g = 5$

| Name | Far-red Portion (0.70 - 0.90 $\mu m$) | IR Portion (1.08 - 1.35 $\mu m$) |
|------|------|------|
| GL 411 | >3500 K | >3500 K |
| GL 273 | 3500 K | 3500 K |
| GL 213 | 3375 K | 3375 K |
| G 208-44 AB | 3125 K | 3125 K |
| G 208-45 | 3000 K | 3125 K |
| GL 406 | 2875 K | 3000 K |
| GL 752 B | 2875 K | 2875 K |
| LHS 2924 | 2750 K | 2625 K |

TABLE 3.15

OBSERVED VS. SYNTHETIC COLORS[a]

| Name | Observed Colors | | | Colors from Best-fit Model | | |
|------|-----|-----|-----|-----|-----|-----|
| | $I-J$ | $J-H$ | $J-K$ | $I-J$ | $J-H$ | $J-K$ |
| GL411[b] | 1.13 | 0.54 | 0.75 | — | — | — |
| GL 273 | 1.40 | 0.52 | 0.77 | 1.35 | 0.63 | 0.84 |
| GL 213 | 1.47 | 0.53 | 0.78 | 1.42 | 0.62 | 0.84 |
| G 208-44 AB[c] | 2.19 | 0.52 | 0.89 | 1.64 | 0.59 | 0.82 |
| G 208-45[c] | 2.15 | 0.50 | 0.89 | 1.64 | 0.59 | 0.82 |
| GL 406 | 2.31 | 0.62 | 0.98 | 1.78 | 0.56 | 0.80 |
| GL 752 B | 2.74 | 0.67 | 1.11 | 1.99 | 0.54 | 0.78 |
| LHS 2924 | 3.38 | 0.65 | 1.12 | 2.52 | 0.48 | 0.72 |

[a] Photometry is $I_{KC}$, $J_{AAO}$, $H_{AAO}$, and $K_{AAO}$ from Leggett & Hawkins 1988, unless otherwise noted

[b] None of the models is warm enough to fit this spectrum adequately

[c] Observed colors are from McCarthy et al. 1988 and are not on a standard system

TABLE 3.16

COMPARISON OF TEMPERATURE SEQUENCES

| Name | T(K) | $\pi('')^a$ | $M_V{}^a$ | $M_I{}^b$ | $M_J{}^b$ | $BC_I{}^c$ | $M_{bol}$ | $log(L/L_\odot)^d$ |
|---|---|---|---|---|---|---|---|---|
| | | | This paper | | | | | |
| GL 411 | >3500 | 0.397 | 10.49 | 8.32 | 7.10 | 0.50 | 8.82 | -1.63 |
| GL 273 | 3500 | 0.270 | 11.98 | 9.33 | 7.83 | 0.36 | 9.69 | -1.98 |
| GL 213 | 3375 | 0.168 | 12.73 | 9.86 | 8.30 | 0.30 | 10.16 | -2.16 |
| G 208-44 AB | 3125 | 0.211 | 15.03 | 11.59$^e$ | 9.40$^e$ | 0.00 | 11.59 | -2.74 |
| G 208-45 | 3125 | 0.211 | 15.61 | 12.10$^e$ | 9.95$^e$ | -0.12 | 11.98 | -2.89 |
| GL 406 | 3000 | 0.426 | 16.68 | 12.63 | 10.21 | -0.36 | 12.27 | -3.01 |
| GL 752 B | 2875 | 0.173 | 18.57 | 13.98 | 11.11 | -0.95 | 13.03 | -3.31 |
| LHS 2924 | 2625 | 0.0908$^f$ | 19.37$^g$ | 15.09 | 11.57 | -1.45 | 13.64 | -3.56 |
| | | | Berriman & Reid (1987)$^h$ | | | | | |
| GL 884 | 3650 | 0.130 | 8.46 | 6.79 | 5.80 | 0.61 | 7.40 | -1.06 |
| GL 752 A | 3200 | 0.173 | 10.31 | 7.99 | 6.69 | 0.55 | 8.54 | -1.52 |
| GL 411 | 3250 | 0.397 | 10.49 | 8.32 | 7.10 | 0.50 | 8.82 | -1.63 |
| GL 821 | 3500 | 0.093 | 10.5 | 8.67 | 7.50 | 0.45 | 9.12 | -1.75 |
| GL 643 | 3150 | 0.161 | 12.73 | 10.09 | 8.60 | 0.26 | 10.35 | -2.24 |
| GL 699 | 3100 | 0.552 | 13.25 | 10.50 | 9.04 | 0.19 | 10.69 | -2.38 |
| GL 447 | 3200 | 0.301 | 13.50 | 10.57 | 8.91 | 0.18 | 10.75 | -2.40 |
| GL 866 AB | 2650 | 0.305 | 14.60 | 11.06 | 8.94 | 0.09 | 11.15 | -2.56 |

TABLE 3.16 (continued)

| Name | T(K) | $\pi('')^a$ | $M_V{}^a$ | $M_I{}^b$ | $M_J{}^b$ | $BC_I{}^c$ | $M_{bol}$ | $log(L/L_\odot)^d$ |
|------|------|-------------|-----------|-----------|-----------|------------|-----------|---------------------|
| | | | Berriman & Reid (1987) continued | | | | | |
| GL 406 | 2600 | 0.426 | 16.68 | 12.62 | 10.21 | -0.35 | 12.27 | -3.01 |
| GJ 1111 | 2450 | 0.278 | 17.03 | 12.86 | 10.46 | -0.45 | 12.41 | -3.06 |
| GL 644 C | 2450 | 0.161 | 17.69 | 13.32 | 10.80 | -0.65 | 12.67 | -3.17 |
| | | | Veeder (1974) | | | | | |
| GL 278 C | 3750 | 0.069 | 8.26 | — | 5.16 | — | — | — |
| GL 820 B | 3900 | 0.296 | 8.39 | — | 5.85 | — | — | — |
| GL 717 | 4000 | 0.054 | 8.4 | — | — | — | — | — |
| GL 205 | 3600 | 0.170 | 9.12 | — | — | — | — | — |
| GL 239 | 3650 | 0.104 | 9.71 | 7.85 | 6.71 | 0.56 | 8.41 | -1.46 |
| GL 48 | 3400 | 0.114 | 10.34 | — | — | — | — | — |
| GL 644 AB | 3450 | 0.161 | 10.80 | 7.59 | 6.31 | 0.56 | 8.15 | -1.36 |
| GL 661 A | 3450 | 0.155 | 10.91 | — | — | — | — | — |
| GL 725 A | 3450 | 0.282 | 11.15 | — | 7.45 | — | — | — |
| GL 745 A | 3500 | 0.119 | 11.15 | 8.92 | 7.69 | 0.41 | 9.33 | -1.83 |
| GL 669 A | 3300 | 0.095 | 11.25 | 8.63 | 7.18 | 0.45 | 9.08 | -1.73 |
| GL 829 | 3300 | 0.153 | 11.27 | 8.63 | 7.23 | 0.45 | 9.08 | -1.73 |
| GL 860 A | 3350 | 0.253 | 11.87 | — | — | — | — | — |
| GL 725 B | 3300 | 0.282 | 11.94 | 9.37 | 7.97 | 0.38 | 9.75 | -2.00 |
| GL 285 | 3100 | 0.165 | 12.29 | 9.30 | 7.69 | 0.37 | 9.67 | -1.97 |

TABLE 3.16 (continued)

| Name | T(K) | $\pi('')^a$ | $M_V{}^a$ | $M_I{}^b$ | $M_J{}^b$ | $BC_I{}^c$ | $M_{bol}$ | $log(L/L_\odot)^d$ |
|---|---|---|---|---|---|---|---|---|
| | | | Veeder (1974) continued | | | | | |
| GL 669 B | 3100 | 0.095 | 12.81 | — | — | — | — | — |
| GL 234 A | 3050 | 0.252 | 13.08 | — | — | — | — | — |
| GL 699 | 3250 | 0.552 | 13.25 | 10.50 | 9.04 | 0.19 | 10.69 | -2.38 |
| GL 15 B | 3150 | 0.282 | 13.29 | 10.51 | 9.01 | 0.19 | 10.70 | -2.38 |
| GL 729 | 3000 | 0.345 | 13.3 | 10.34 | 8.89 | 0.22 | 10.56 | -2.32 |
| GL 299 | 3200 | 0.151 | 13.66 | 10.83 | 9.27 | 0.13 | 10.96 | -2.48 |
| GL 51 | 2950 | 0.107 | 13.81 | — | — | — | — | — |
| G 69-47 | 2700 | 0.079 | 14.30 | 10.86 | 8.97 | 0.13 | 10.99 | -2.50 |
| GL 866 AB | 2750 | 0.305 | 14.60 | 11.06 | 8.94 | 0.09 | 11.15 | -2.56 |
| GL 905 | 2800 | 0.318 | 14.80 | 11.41 | 9.39 | 0.03 | 11.44 | -2.68 |
| GL 473 AB | 2800 | 0.231 | 15.09 | 10.80 | 8.79 | 0.14 | 10.94 | -2.48 |
| GL 65 A | 2700 | 0.367 | 15.27 | — | — | — | — | — |
| G 158-27 | 2700 | 0.214 | 15.39 | 11.84 | 9.96 | -0.05 | 11.79 | -2.82 |
| GL 551 | 2700 | 0.761 | 15.45 | — | — | — | — | — |
| GL 406 | 2500 | 0.426 | 16.68 | 12.63 | 10.21 | -0.36 | 12.27 | -3.01 |
| G 51-15 | 2450 | 0.278 | 17.03 | 12.86 | 10.46 | -0.45 | 12.41 | -3.06 |

[a] from Gliese 1969 or Gliese & Jahreiss 1979 unless otherwise noted

[b] calculated using $I_{KC}$ and $J_{CTIO}$ values from Leggett & Hawkins 1988 unless otherwise noted

[c] linearly interpolated from $BC_I$ vs. $M_I$ relation in Table 2 of Bessell 1991

[d] assuming $(M_{bol})_\odot = 4.75$

TABLE 3.16 (continued)

[e] on the Steward system of McCarthy et al. 1988

[f] from Dahn, Probst, & Liebert (unpublished)

[g] from Monet et al. 1992

[h] temperatures do not differ significantly from the revised values presented in Berriman, Reid, & Leggett 1992
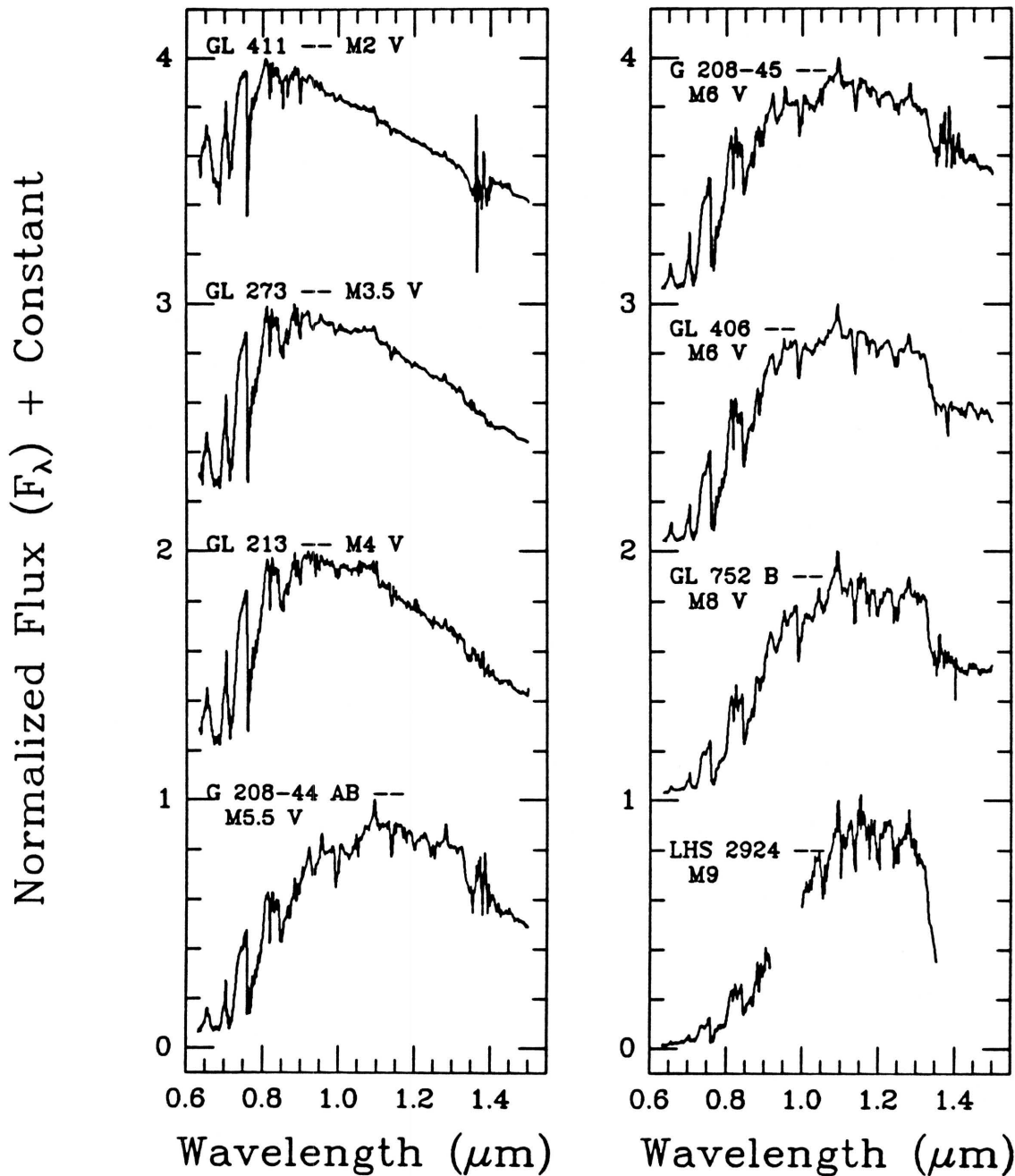
FIG. 3.11. — Spectra of the eight objects listed in Table 3.11. The red portion (0.63 - 0.92 $\mu m$) of the spectra has a resolution of 18 Å, and the infrared portion (0.92 - 1.50 $\mu m$) has a resolution of 48 Å. Each spectrum is normalized to unity at it peak flux (which is in units of $F_\lambda$), and integral offsets have been added to separate the spectra vertically. Note that for early M dwarfs, the infrared region is relatively featureless compared to the red region. For late M dwarfs, many absorption features are seen in the infrared, the most striking of which is the water vapor band at 1.35 $\mu m$.
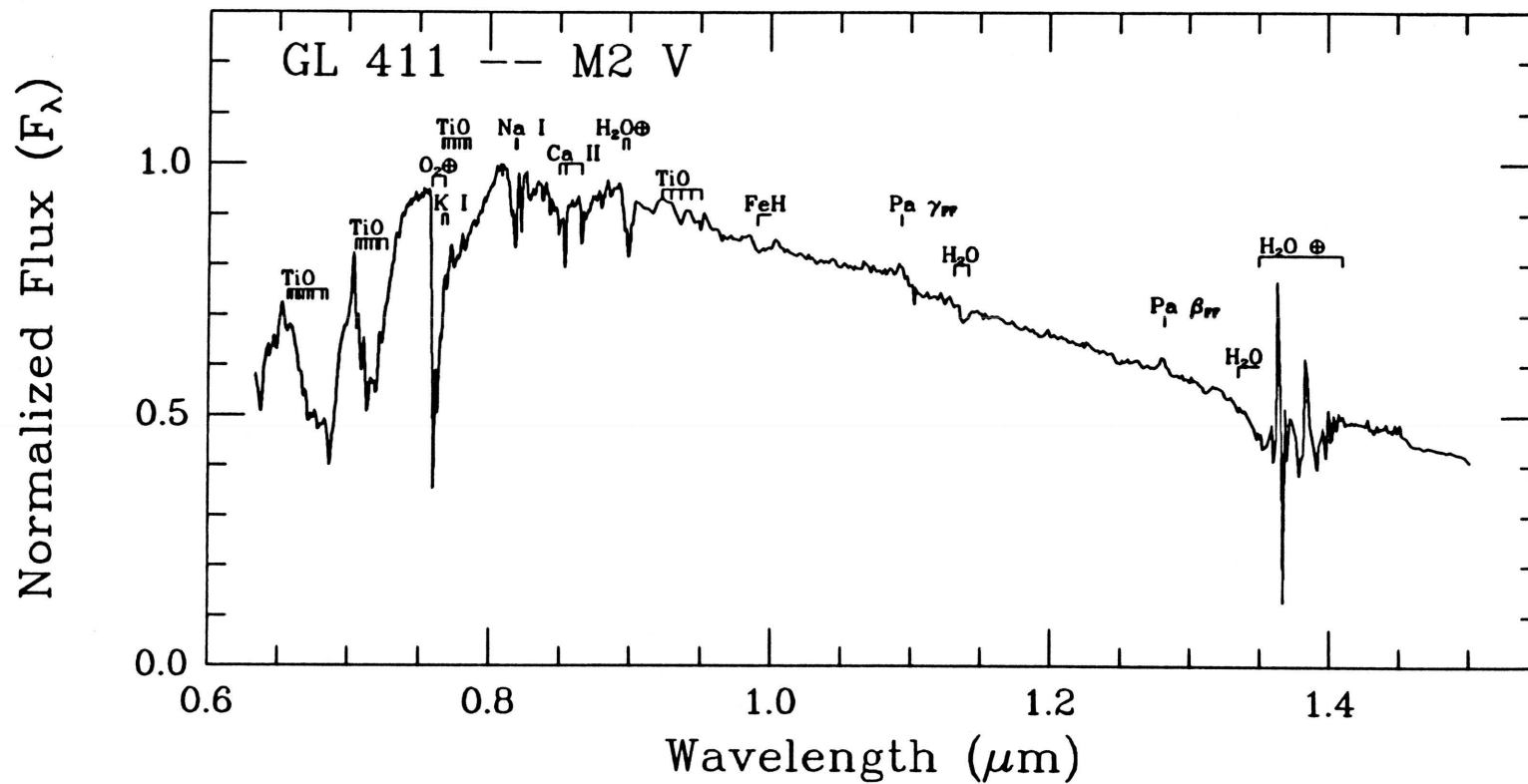
FIG. 3.12. — Identifications of the most prominent features in M dwarf spectra from 0.63 to 1.50 $\mu m$. (a) The spectrum of GL 411 – spectral type M2 V. →
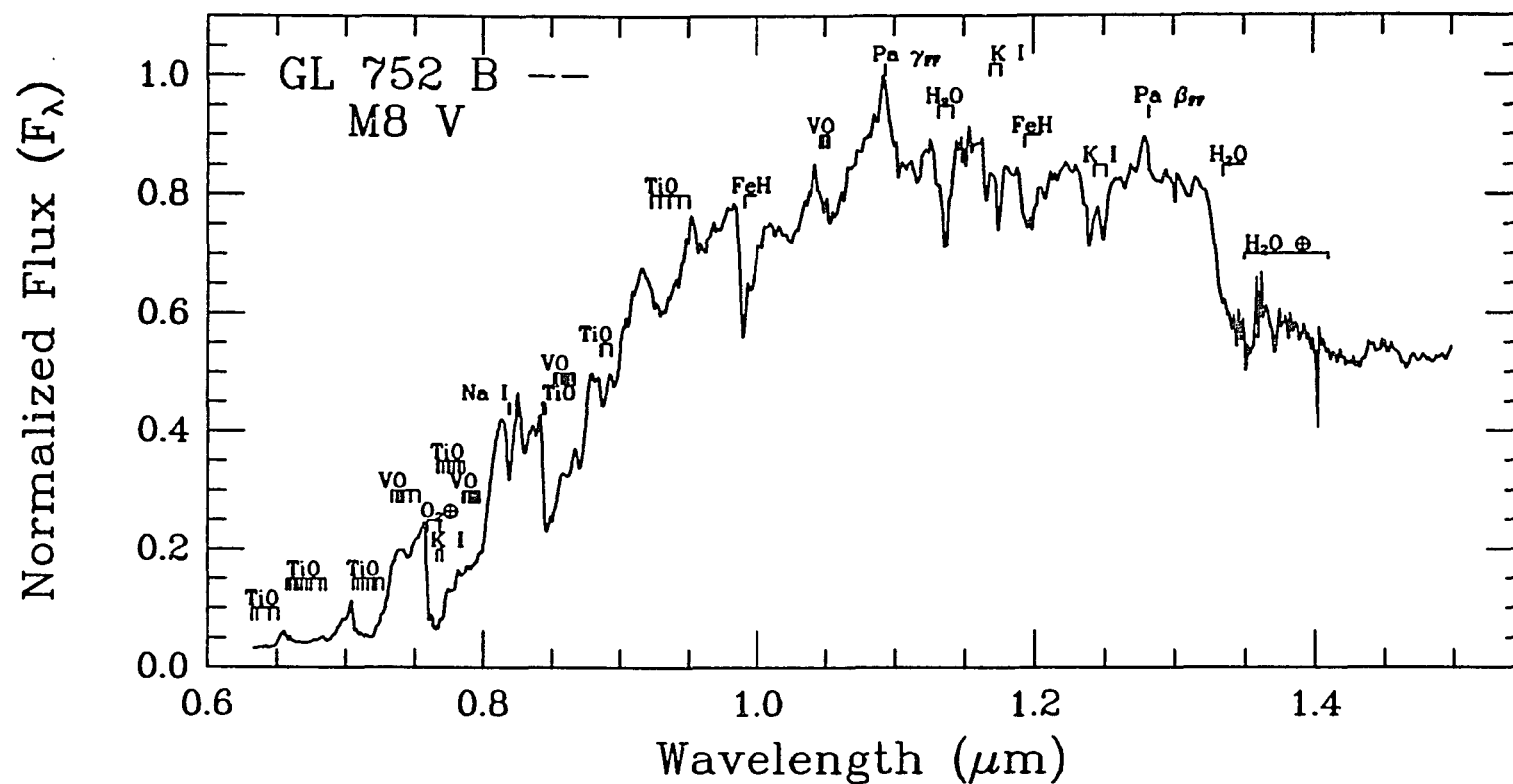
FIG. 3.12. (continued) — (b) The spectrum of GL 752 B (VB 10) – spectral type M8 V. Bands of VO, OH, FeH, and $H_2O$ all serve well as temperature indicators. In both spectra, the subscript "FF" refers to residual Paschen lines, an artifact of flatfielding with F and G stars.
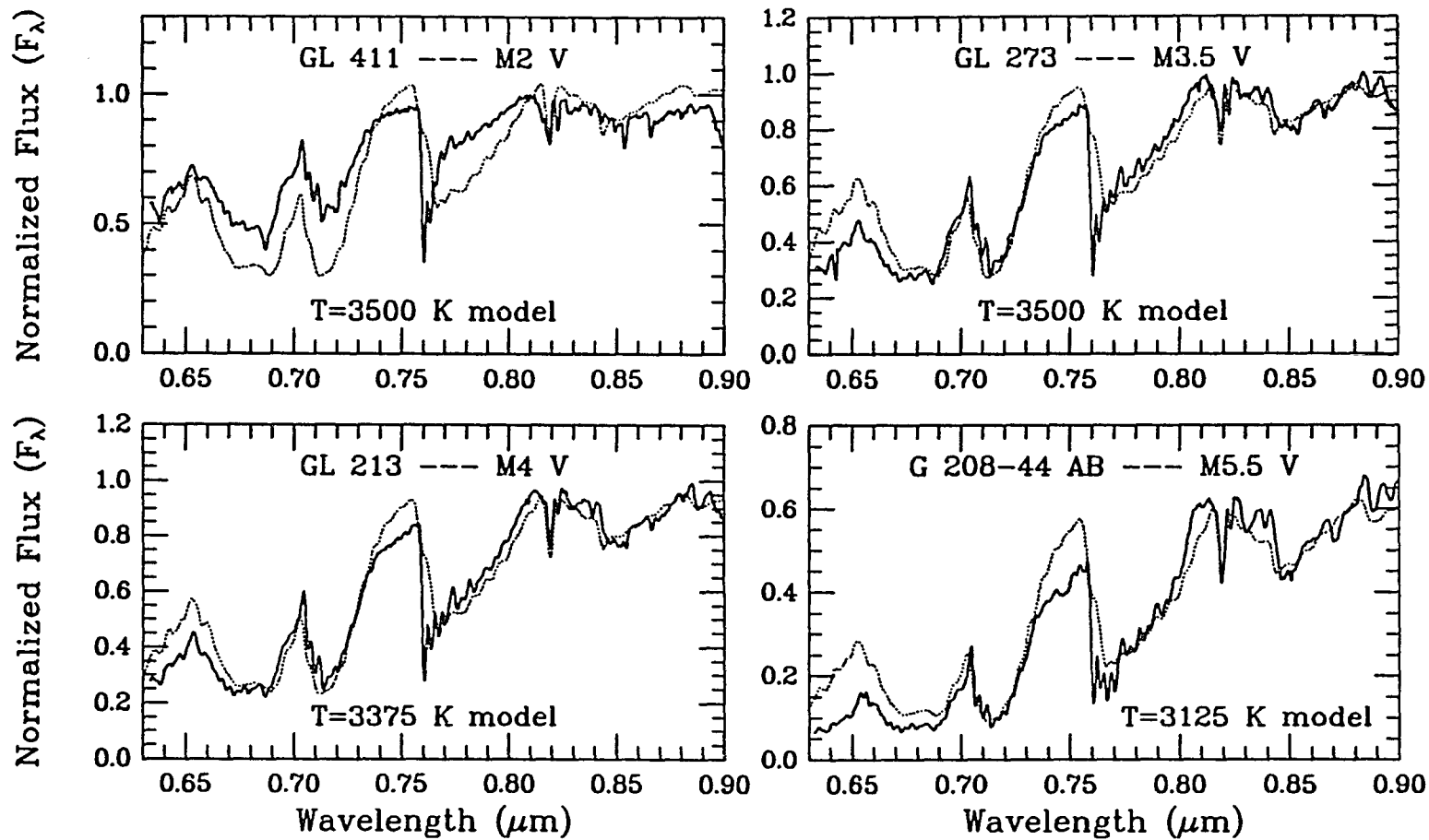
FIG. 3.13. — The best fits to the red spectra. The observational data are shown by the solid lines, and the model data by the dotted lines. The method for determining the best match is explained in the text. The spectrum of GL 411 could be better fit by a warmer model, but the Allard models →
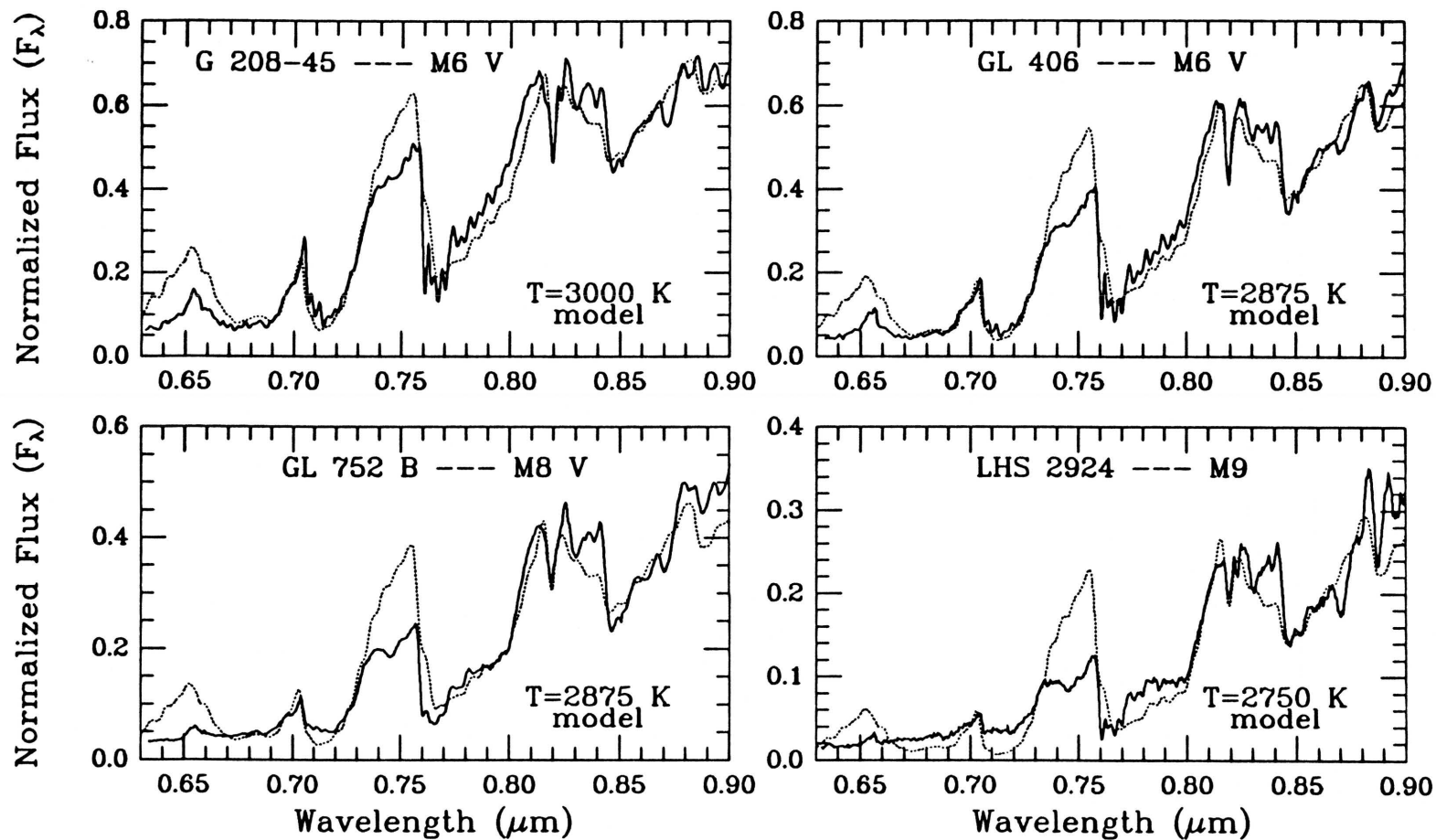
FIG. 3.13. (continued) — do not go hotter than 3500 K. The agreement is generally very good, although the flux near 0.65 and 0.75 $\mu m$ is always overestimated. For cooler objects the disagreement between the true spectra and the predicted ones is much more pronounced.
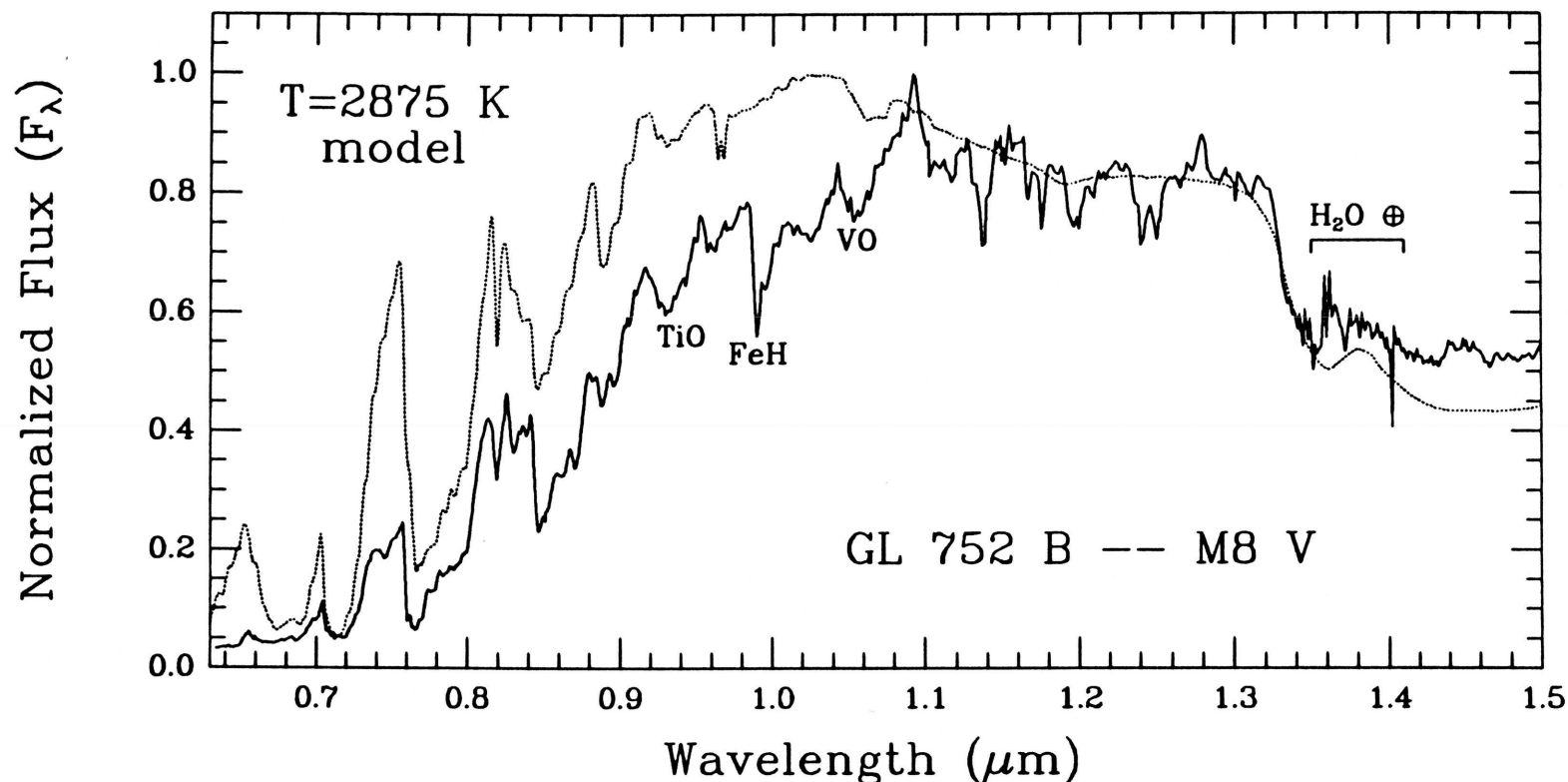
FIG. 3.14. — The spectrum of an M8 dwarf and the model that provides the best fit in the red. Unlike Figure 3.13, each spectrum here is normalized to unity at its peak flux. Note the failure of the model to predict the shape of the stellar "continuum" in the region from 0.9 - 1.1 $\mu m$. Notably absent from the models are FeH at 0.99 $\mu m$ and VO at 1.3 $\mu m$. The strength of the TiO band at 0.93 $\mu m$ is also underestimated. Coincidentally, the least-squares minimization technique finds the 1.08 - 1.35 $\mu m$ fit plotted here to be the best, correctly normalized fit to the $J$ region. This illustrates another point: although the fit at $J$ looks adequate, the same model would have to be shifted downward in the 0.70 - 0.90 $\mu m$ region to achieve a good fit. In other words, $I - J$ colors for the observational and theoretical spectra do not agree. See text for more details.
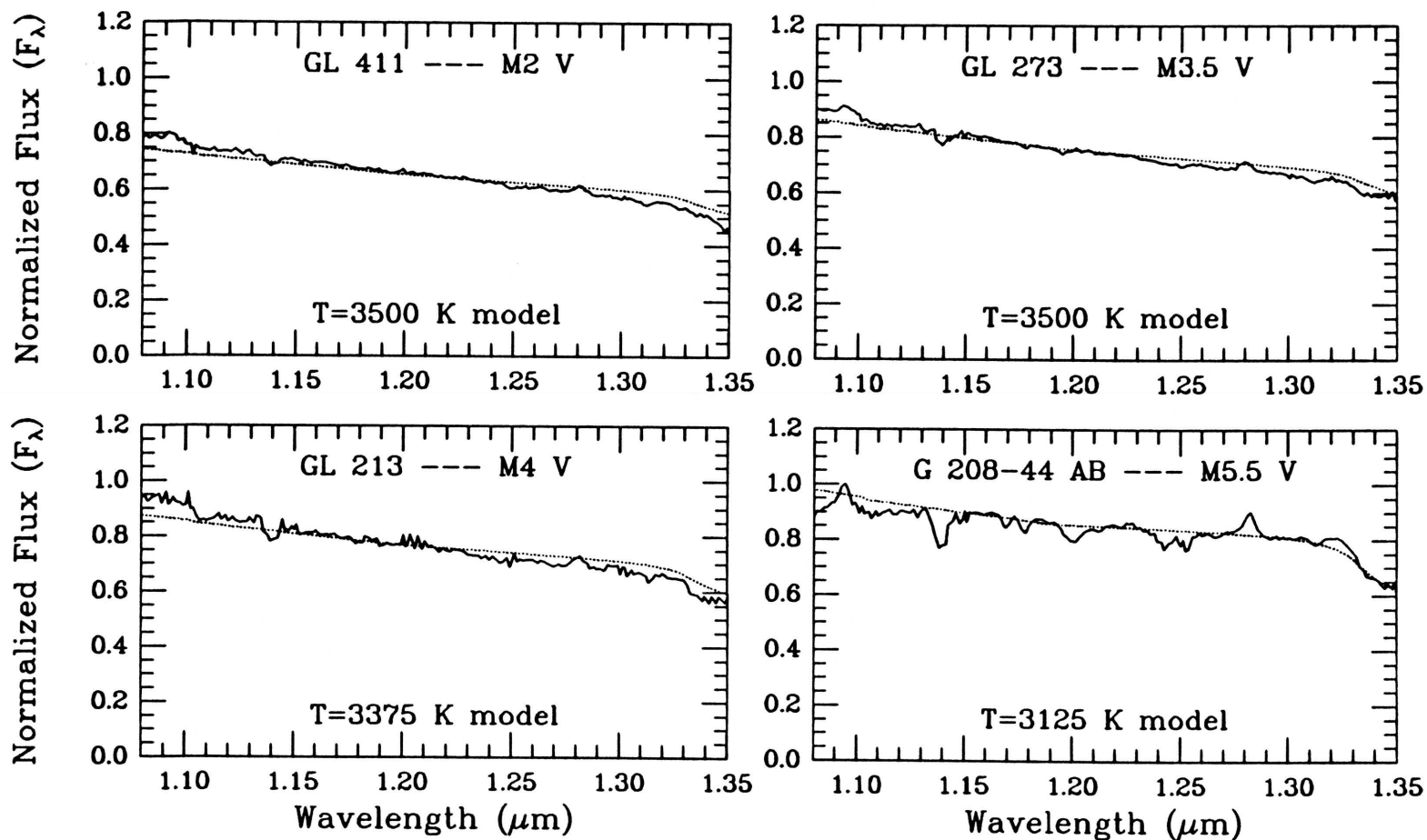
FIG. 3.15. — The best fits to the infrared spectra. The observational data are shown by the solid lines, and the model data by the dotted lines. The method for determining the best match is explained in the text. As in Figure 3.13, →
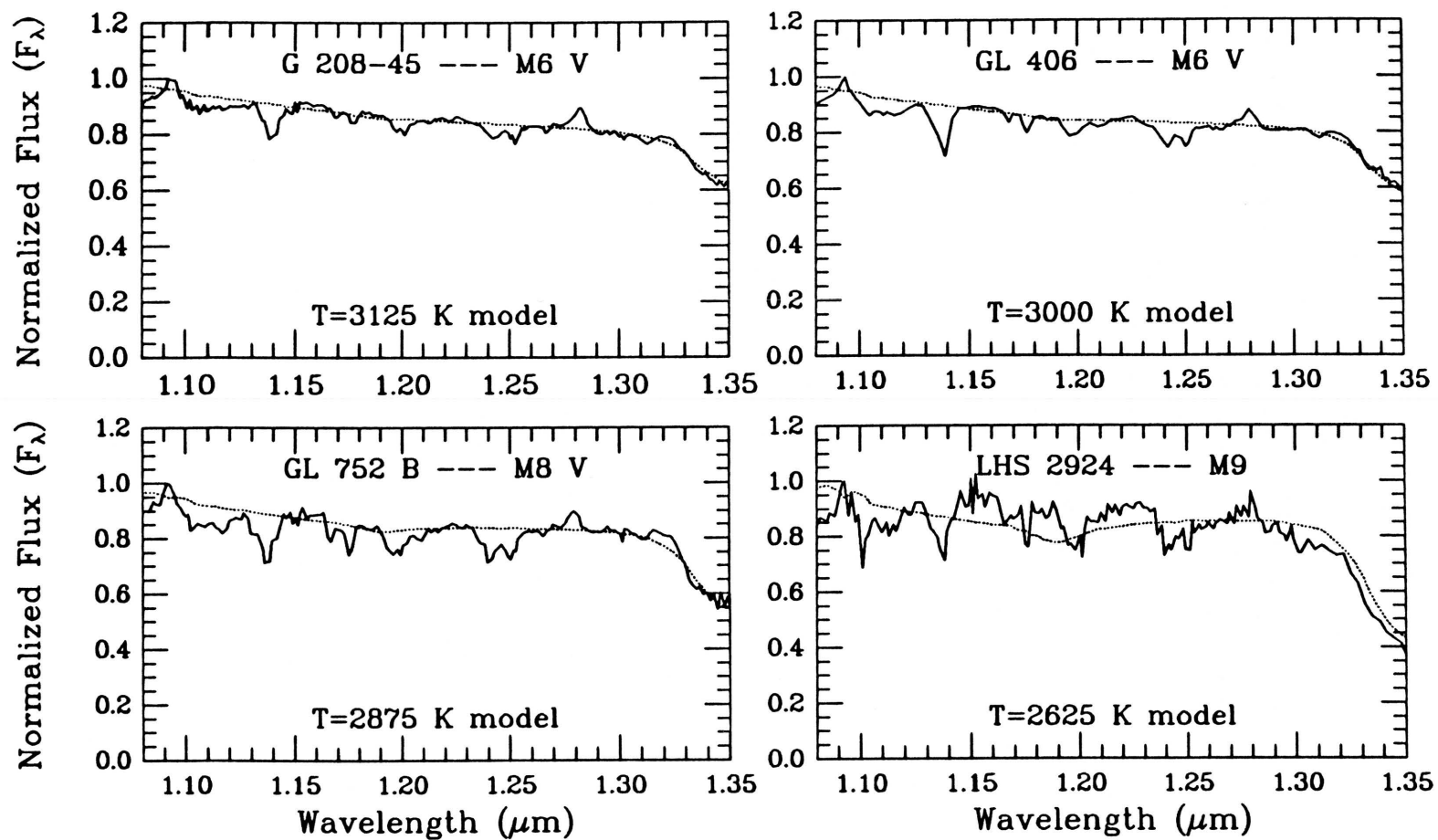
FIG. 3.15. (continued) — the spectrum of GL 411 could be better fit by a warmer model. In general, the steam feature at 1.35 $\mu m$ and the pseudo-continuum are fit well.
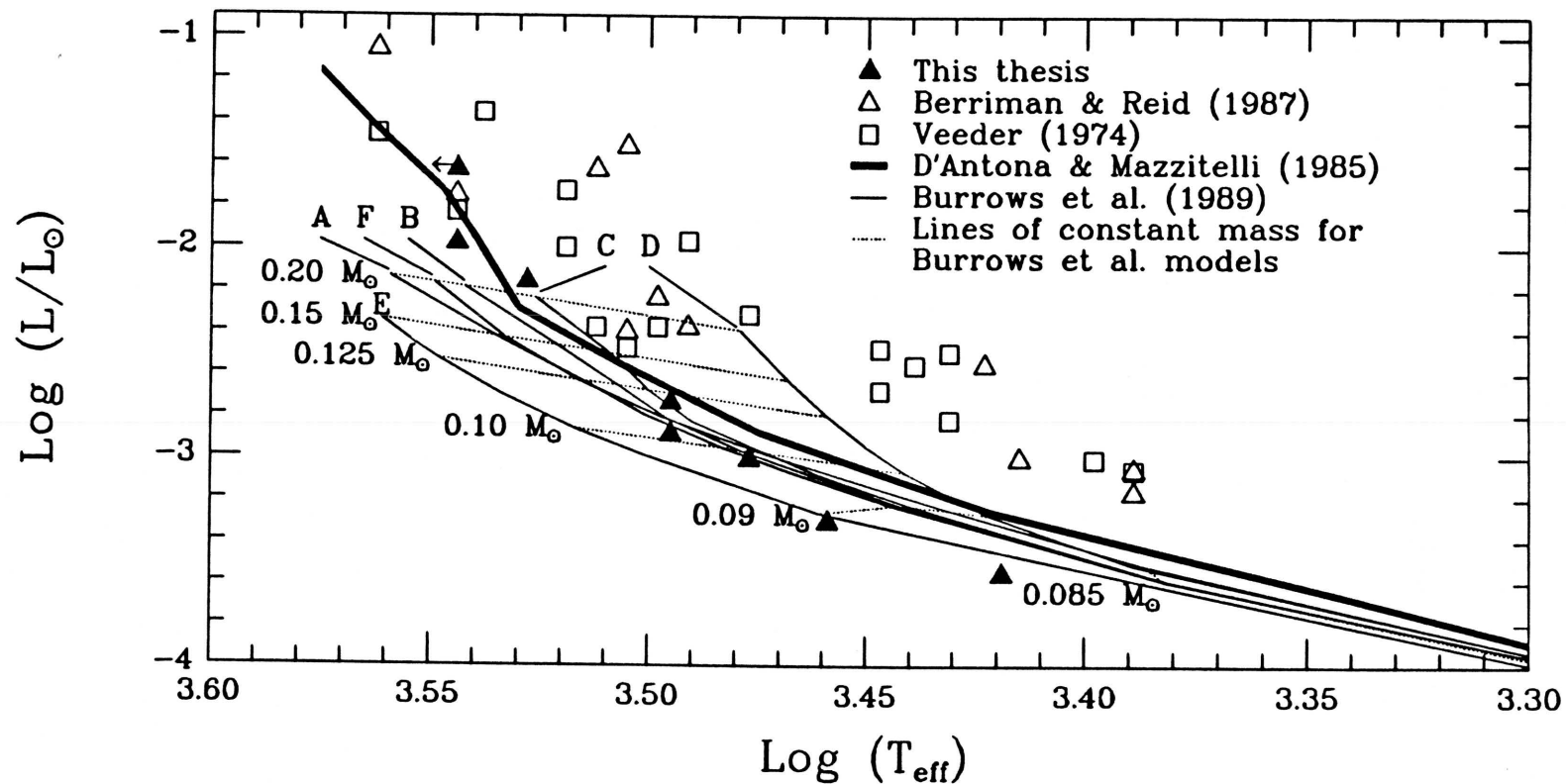
FIG. 3.16. — The H-R Diagram for M dwarfs. Data from this paper are represented by filled triangles, data from Berriman & Reid (1987) by open triangles, and data from Veeder (1974) by open squares. (The data point for GL 411 is indicated with an arrow since our derived temperature is a lower limit.) (a) The theoretical main sequence of D'Antona & Mazzitelli (1985 — heavy line) and the 10 Gyr tracks of models A, B, C, D, E, and F from Burrows, Hubbard, & Lunine (1989 — lighter lines) overplotted with the three temperature sequences. Lines of constant mass (dashes) are indicated on the Burrows et al. models. →
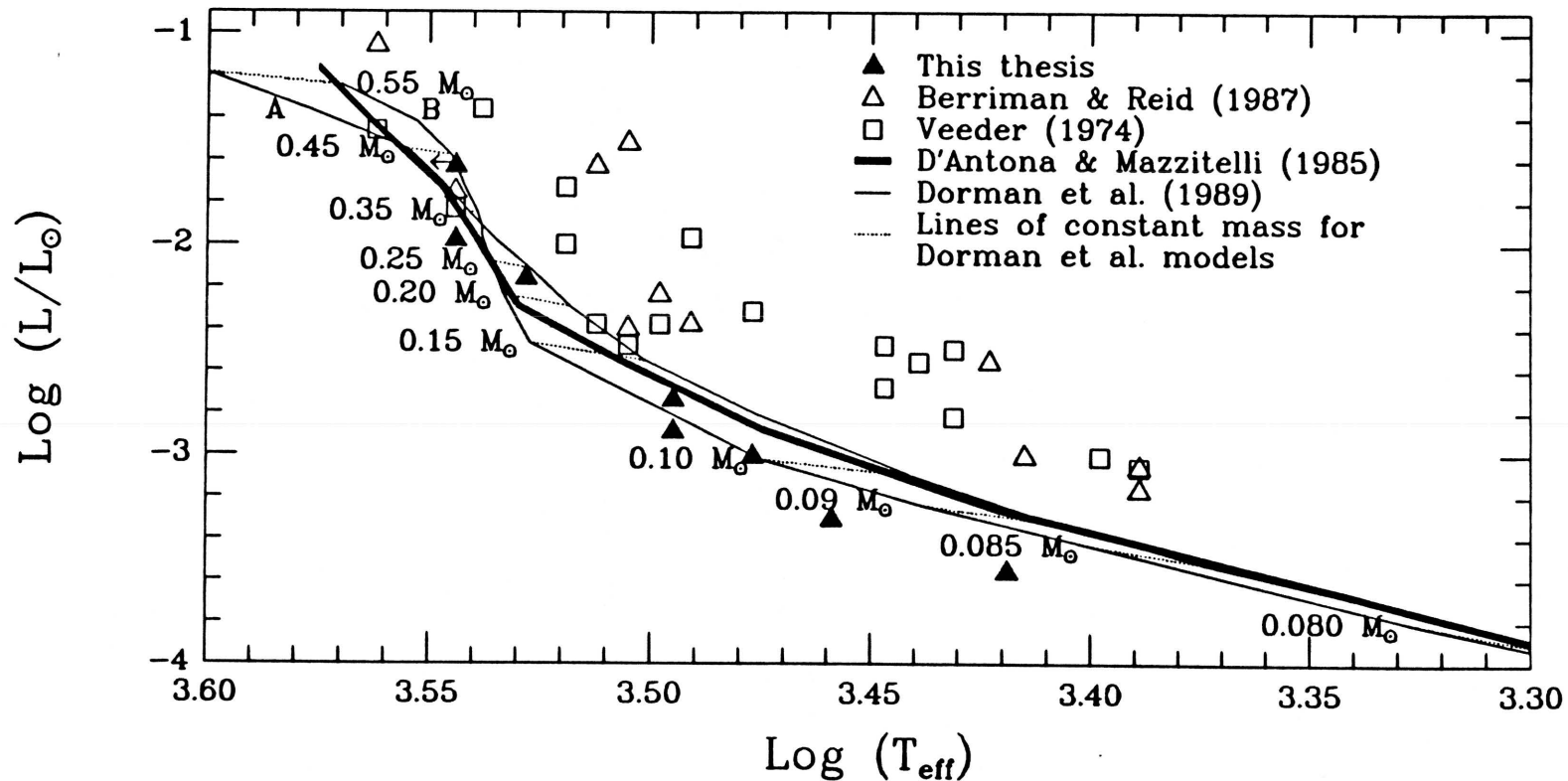
FIG. 3.16. (continued) — (b) The theoretical main-sequence tracks A and B of Dorman, Nelson, & Chau (1989 — lighter lines), with the track of D'Antona & Mazzitelli (1985 — heavy line) and the three temperature sequences shown again for comparison. Lines of constant mass (dashes) are also indicated on the Dorman et al. models. As both figures show, the temperature sequence presented here brings the observed M dwarf track into closer agreement with theoretical tracks. Note that the Burrows et al. and the Dorman et al. models (and also the Burrows et al. models for an age of 1 Gyr) predict all of the objects presented here, even LHS 2924 (M9), to be stellar since they lie within the locus of hydrogen-burning stars ($M \geq 0.08 M_\odot$).

## 3.3: THE UNIQUE SPECTRUM OF GD 165 B — A BROWN DWARF?

After it was first reported that $\sim30-60\%$ of the mass in the solar neighborhood was unaccounted for (Oort 1960; Bahcall 1985), some astronomers proposed that the presence of many faint, previously undetected M dwarfs might explain the discrepancy. If not, there might be a sufficient, additional number of brown dwarfs, first theorized by Kumar (1963), to comprise the remainder of the missing mass. Oddly, until the early 1980's, GL 752 B (VB 10) was still recognized as the lowest-luminosity star, having held that title since its discovery almost 40 years earlier (van Biesbroeck 1944). Three objects discovered during the course of Luyten's survey (see Luyten 1979), however, would later be recognized as objects of even later spectral type: LHS 2924 (Probst & Liebert 1983), LHS 2397a (Liebert, Boroson, & Giampapa 1984), and LHS 2065 (see Reid 1987; Bessell 1991).

Despite new claims that there is far less (or zero) missing mass than previously thought (Kuijken & Gilmore 1989; see alternate viewpoint in Bahcall, Flynn, & Gould 1992), various surveys implementing new techniques and technologies, especially at infrared wavelengths, have begun in the last decade to search for even fainter and redder objects. During a photometric search for low-luminosity objects orbiting white dwarfs, Becklin & Zuckerman (1988; hereafter, BZ) discovered excess infrared radiation from the DA4 (McCook & Sion 1987) white dwarf GD 165. Follow-up infrared imaging verified the presence of a faint companion, designated as GD 165 B, approximately 4 arcseconds distant. At the time of its discovery, there was some question as to whether or not the object were merely a background source falling along nearly the same line of sight as the white dwarf. Fortunately, the large proper motion of GD 165 A (0.25 arcsecond

$yr^{-1}$ — Luyten 1961) has in just a few years lead to the confirmation of the two objects as a common proper motion pair (Zuckerman & Becklin 1992; hereafter, ZB). Because of its extremely red colors and low luminosity, GD 165 B is now generally regarded as the best brown dwarf candidate.

At present, a direct measurement of the mass is the only criterion which can distinguish between a brown dwarf and a star. Unfortunately, the 4-arcsecond separation of the components implies an orbital period on the order of 1600 years, so it will not soon be possible to calculate component B's dynamical mass. However, there may be other, more easily observable parameters which in principle could differentiate between stars and brown dwarfs, specifically red/near-infrared spectra, which have been obtained for many low-luminosity objects. In the case of the GD 165 system, the 4-arcsecond separation is, in another respect, advantageous: a spectrum of the secondary, uncontaminated by the light of the primary, can be acquired and can be compared to the spectra of other very red objects.

Table 3.17 lists all of those known dwarfs which have later spectral types than GL 65 A and B — the reddest dwarfs for which spectra have been acquired *and* for which dynamical masses have been determined (see Table 3.10 and Figure 3.10). GL 65 A and B, also known as L 726-8 and UV Ceti, respectively, have approximately equal masses of $0.095M_\odot$, tantalizingly close to the upper mass limit, $\sim 0.08M_\odot$, for brown dwarfs. (The purported substellar masses for Wolf 424 A and B have been discussed by Henry et al. 1992 and Davidge & Boeshaar 1991. It now appears that the components are most likely stellar.) All dwarfs redder than GL 65 A and B (1) are single, where a dynamical mass is impossible to determine, (2) are in binary or multiple systems with orbital periods of several hundreds to many thousands of years, or (3) have had masses determined from

the technique of infrared speckle imaging — masses which, when the errors are considered, could put them on either side of the M dwarf/brown dwarf dividing line. Several objects in this third class are known, but they are too close to their primaries to yield uncontaminated spectra. These are listed in Table 3.18. Tables 3.17 and 3.18 thus represent the most complete compilation of low-luminosity objects currently known.

This thesis presents spectra of many of the objects in Table 3.17. Since it is not known if the spectrum of a brown dwarf should be fundamentally different from that of a late-M star, it is conceivable that spectra of hot brown dwarfs already exist in the literature and have been labelled as M-star spectra. On the other hand, it is possible that differences exist which would distinguish between them; i.e., a brown dwarf at the same temperature as a low-mass star should differ in $\tau$, $log\ g$, and possibly $Z$ — any of which will produce changes in the spectra. To address this issue, a spectrum was obtained of GD 165 B — the coolest, reddest entry in Table 3.17 and thus the most likely object to be a bona fide brown dwarf. The spectroscopic observations and the reduction of the data are detailed in §3.3.1. The spectrum of GD 165 B is compared to the spectra of other low-luminosity objects in §3.3.2. Possible interpretations of the data are discussed in §3.3.3, and conclusions are given in §3.3.4.

### 3.3.1: Observation and Data Reduction

The spectrum of GD 165 B was obtained on UT 1991 May 07 with the Red Channel Spectrograph of the Multiple Mirror Telescope (MMT — effective aperture 4.5 meters). The observing setup is the same as that described in §3.1.2.

Since the object is invisible on the MMT TV acquisition screen, the slit was first centered on the position of GD 165 A, and then the offsets given in BZ were used to move the slit to the position of GD 165 B. The revised values of the offsets given in ZB only differ from the previous values by 0.6 arcsecond in declination. Since the width of the slit employed was 2 arcseconds, this revision did not effect our ability to position the unseen secondary on the slit correctly.

All observations were obtained when the object was near the meridian, so differential refraction effects were negligible. As a result we were free to adjust the position of the slit on the sky to place the much brighter A component as far away from the slit as possible, while still allowing enough displacement along the direction of the slit to separate the spectrum of its spillover light cleanly from the spectrum of B on the CCD. For each exposure, the spectra were displaced on the CCD by 3.2 arcseconds, and component A was ∼1 arcsecond away from the edge of the slit. In all, a sequence of three 40-minute integrations was made. Afterwards, GD 165 A was placed in the slit and a 5-minute integration was taken.

Because of excellent seeing and guiding, the 3.2-arcsecond displacement of spectra on the chip was sufficient to eliminate almost all spillover light from the white dwarf into the spectrum of GD 165 B. The spectra were reduced via the same procedures as those outlined in §3.1.2, except that special care was taken to trace and define the extraction apertures so that this contaminant light was minimized. Only at short wavelengths, where the flux from the white dwarf is highest, is contamination of the GD 165 B spectrum evident, and even here its effects are small. The 120-minute spectrum of GD 165 B and the 5-minute spectrum of GD 165 A are presented in Figure 3.17.

Because of excellent weather conditions on the night of observation, it is possible to extract $I_C$ magnitudes from the spectra in Figure 3.17. Values for $(F_\lambda)_{I_C}$ were determined over a rectangular bandpass whose cut-on and cut-off wavelengths correspond to the wavelengths at half maximum of the $I_C$ filter — 7250 and 8750 Å. These fluxes were then converted to magnitudes by using 2550 $Jy$ as the zero-magnitude flux (Bessell 1979). For a more complete discussion of this procedure, see §3.2.2. The resulting magnitudes are found to be $I_C = 14.2$ and 20.7 for GD 165 A and B, respectively. The parallax of the system is $0.0278\pm0.0034$ arcsecond (ZB), which gives absolute magnitudes of $M_{I_C} = 11.4$ and 17.9 for GD 165 A and B, respectively.

A lower (brighter) limit for the $R_C$ magnitude of GD 165 B can also be made if it is assumed that the mean flux level between 5700 Å (the filter cut-on) and 6350 Å is comparable to the flux level seen in our spectrum from 6350 Å to the filter cut-off at 7200 Å. As mentioned previously, nearly all of the flux seen in our spectrum from 6350 to 7200 Å is contaminant light from the primary, so the true flux of GD 165 B will be substantially less than what is found here. Using a zero-magnitude flux of 3080 $Jy$ (Bessell 1979), it is found that the magnitude must be fainter than $R_C = 21.5$, corresponding to an absolute magnitude of $M_{R_C} > 18.7$. If this object is assumed to have an $R - I$ color comparable to the latest M dwarfs (Leggett 1992 gives $(R - I)_C = 2.4$ for vB 8), then this implies that the absolute magnitude of GD 165 B is $M_{R_C} \sim 20.3$. Photometric surveys like those of Reid & Gilmore (1982), Hawkins & Bessell (1988), Leggett & Hawkins (1988), and this thesis, which have relied mainly upon $R$ and $I$ measurements, would have detected objects like GD 165 B lying only within 9 pc for a limiting magnitude of $R \sim 20.0$ or within 6 pc for a limiting magnitude of $R \sim 19.0$. This illustrates

that objects like GD 165 B have not been missed because they are necessarily rare, but because they are exceedingly dim at these wavelengths.

### 3.3.2: Comparison to the Spectra of Other Low-Luminosity Objects

In Figure 3.18 are plotted the spectra of GD 165 B and three of the lowest luminosity, red objects known: PC 0025+0447, LHS 2065, and LHS 2924. Spectral features are identified for LHS 2924. Observation and reduction procedures for the spectra of LHS 2924 and LHS 2065 have been discussed elsewhere (§3.1.2). The spectrum of PC 0025+0447, an unusual object discovered by Schneider et al. (1991), was acquired on UT 1991 October 17 with the Red Channel Spectrograph at the MMT with the same setup described in §3.3.1 above. Like GD 165 B, this object was invisible on the MMT TV acquisition screen, but in this case the position given in the discovery paper quotes an error of 5 arcseconds. To improve our chances of finding this object, the slit was first centered on a nearby bright star, SAO 109220, then offsets were used to point to the position given in Schneider et al. (1991). A "quick" 5-minute integration on this position revealed no evidence on the CCD of an unseen object, so the slit was moved 2 arcseconds (the slit width) to the east, and another 5-minute integration taken. Again, no spectrum was seen. After several failed attempts to find the object to the west, a faint spectrum was finally revealed at a location 4 arcseconds east of the original position. Believing that the object was perhaps lying near the edge of the slit, the slit was moved another 1 arcsecond east. The spectrum recorded there was, in fact, brighter, so this position was retained for all subsequent exposures. In all, nine 20-minute integrations were made. The spectrum of PC 0025+0447

shown in Figure 3.18 is the addition of all three hours of integration.

PC 0025+0447 is unique in its own right. Based on the fact that its VO bands, most noticeably the one between 7851 and 7973 Å, are somewhat stronger than those of LHS 2924 and LHS 2065, we classify this object as an M9.5. Unlike LHS 2924, which has weak Hα emission, and LHS 2065, which has Hα emission similar in strength to other dMe's, PC 0025+0447 has an Hα equivalent width ten times larger than any dwarf M star known (Schneider et al. 1991). Apart from the unusual emission feature, this object seems, nonetheless, to be a continuation of the spectral sequence to temperatures cooler than that of LHS 2924 and LHS 2065.

It is clear that the spectrum of GD 165 B, however, does not closely resemble the three other spectra in Figure 3.18 or, in fact, any of the spectra of low-mass stars presented in §3.1. (No statement can be made about the presence or absence of Hα emission since no flux attributable to the B component is detected at this wavelength.) Notably absent are the TiO absorptions at 8432 Å and 8859 Å, which are quite strong for late M dwarfs. The close Na I doublet at 8183 and 8195 Å may be present, but this is an uncertain identification since there is also telluric water absorption between 8164 and 8177 Å. Absorptions by TiO may be marginally present at 8303 and 8510 Å, while the obvious absorption at 8624 Å may correspond to VO, although much stronger than the VO absorption seen in an M9 or M9.5. These features could, therefore, be caused by the same molecular species which dominate the spectra of late M dwarfs, only that the absorption profiles and strengths are different due to the lower temperature of this object. On the other hand, it is also possible that new sources of opacity not present in the spectrum of an M9 or an M9.5 are strongly affecting the spectrum

of GD 165 B from 8700 Å to our cutoff of 9000 Å. Before any of these features are adequately identified, a higher signal-to-noise spectrum at higher resolution is required.

Assuming that the object is a cooler version of LHS 2924, the extreme redness and unique appearance of its spectrum would suggest a classification later than M10, since we have classified PC 0025+0447 as an M9.5. Since there are few spectral features on which to base a true spectral classfication and currently no other spectra to bridge the gap between the M9/M9.5 objects and GD 165 B, we are forced to delay classification until other such objects are discovered. Only when the spectral type can be *quantified* should a type be assigned.

### 3.3.3: Discussion

Table 3.19 gives observed colors and absolute magnitudes for GD 165 B and a sequence of M dwarfs. (BZ give $J = 15.75$ for GD 165 B, but this and the other $J$ values in their table are on the CIT system, not the IRTF system (Zuckerman 1992). All infrared photometry listed in Table 3.19 has been transformed to the AAO system using the equations given in Leggett (1992).) These data clearly show that GD 165 B has extremely red colors and extremely low luminosity, indicative of a very cool temperature. Also given for the first eight objects in Table 3.19 are the temperatures determined in §3.2. The models do not currently predict a spectrum like that of Figure 3.17(b), but some idea of the temperature of this object can be estimated by extrapolating the trends of $M_I$ and $M_J$ with temperature to the absolute magnitudes calculated for GD 165 B. These extrapolations are shown in Figure 3.19. A linear least-squares fit is shown

for each graph, where the lower limit to the temperature for GL 411 has been ignored. The trend of $M_I$ vs. temperature suggests T $\approx$ 2250 K for GD 165 B, whereas the trend of $M_J$ vs. temperature suggests T $\approx$ 2350 K. As a result, the rounded value of T = 2300$\pm$100 K will be adopted as the temperature estimate of GD 165 B based on these fits. ZB derive an estimate of the temperature based on blackbody fits to the observed colors with additional allowance for the $H_2O$ blanketing seen in the spectrum taken by Tokunaga et al. (1990 — the spectrum itself is unpublished). Their result is T = 1800$\pm$200 K, cooler by 500 K than the temperature derived here. This discrepancy is not unexpected, however. As noted in §3.2, when compared to temperatures derived from fits to the models, temperatures based on various blackbody fitting techniques, though in good agreement for early M dwarfs, are lower by up to 500 K for late M dwarfs such as GL 752 B (vB 10).

For some range of temperatures, the spectra of cool objects should begin to bridge the gap between the observed spectra of late M dwarfs (dominated in the red and infrared by molecules such as VO, TiO, $H_2O$, and CO) and the observed spectra of Jupiter and Saturn (which are dominated in this region by molecules such as $CH_4$ and $NH_3$). This transition is apparently not a simple one. Absorption by TiO cannot be distinguished in the spectrum of GD 165 B, although VO may still be present. Absorptions by $CH_4$, which appear prominently in the spectra of Jupiter and Saturn, would be present in a broad band extending from 7600 to 8200 Å (Wolstencroft & Smith 1979), in another band extending from 8500 to 8750 Å with a minimum at $\sim$8600 Å, and in another, more prominent band with a sharp cut-on near 8800 Å, a gradual cut-off near 9100 Å, and two minima at $\sim$8825 and 8873 Å (Owen 1969). (For full coverage of this region, refer to

the laboratory spectra of methane in Dick & Fink (1977) and the observational spectra of Jupiter in Taylor (1965).) Although these wavelengths correspond to the same general regions where absorption occurs in the spectrum of GD 165 B, the shape of the bands and the locations of the minima do not match, indicating that methane is not the absorber. Moreover, as Lunine, Hubbard, & Marley (1986) state, the dominant carbon species should switch from CO to $CH_4$ only at temperatures around 1000 K — much cooler than that found for GD 165 B. Absorption by ammonia, though weaker than methane, is also found between 7500 and 9000 Å but is expected only at even lower temperatures. In other words, the molecules found in M dwarf spectra may no longer be prominent, and the molecules found in planetary spectra do not appear at temperatures as warm as GD 165 B. The features found in our spectrum are likely to be new, presently unidentified molecular absorptions.

Until a broader wavelength coverage is obtained for spectra in the infrared, the bolometric luminosity of this object will be difficult to estimate. Greenstein's (1990) best estimate, when updated to reflect the currently accepted distance of 36 parsecs, is $1.2 \times 10^{-4} L_\odot$, in excellent agreement with the estimate of $1 \times 10^{-4} L_\odot$ by ZB, who quote an uncertainty of $\sim 40\%$. Figure 3.20 shows the H-R Diagram for M dwarfs using data from §3.2. Also shown are the theoretical zero-age main sequence of D'Antona & Mazzitelli (1985) and the sequences, based on two different equations of state, of Dorman, Nelson, & Chau (1989). Two positions for GD 165 B are given in Figure 3.20. The first uses the temperature derived here and the second uses the temperature estimated in ZB; for both, the luminosity estimate of $1 \times 10^{-4} L_\odot$ is adopted. Both points fall near the region occupied, according to theory, by stellar objects marking the end of the

main sequence; however, considering the errors in the plotted quantities, both points are near enough to the stellar/substellar dividing line ($\sim 0.08 M_\odot$) to leave the true nature of GD 165 B ambiguous.

### 3.3.4: Summary

It has been shown that the 6300 - 9000 Å spectrum of GD 165 B is unlike that of any known M dwarf. Bands of VO, which appear only in the latest M dwarfs, may be present, though significantly stronger. The estimated temperature is low enough that new molecular absorptions, not found in warmer spectra like that of LHS 2924, may be appearing. The temperature is not cool enough, however, for this spectrum to begin to resemble the observed spectra of the Jovian planets. At present, the precise location of GD 165 B on the H-R Diagram is not known, due to large uncertainties in calculating both the temperature and the bolometric luminosity. The temperature will only be accurately known once theoretical energy distributions are able to reproduce spectra such as this one. This requires accurate identifications of possibly new molecular absorption species. Furthermore, the bolometric luminosity can only be determined once the spectrum is obtained at longer wavelengths, where the object emits most of its radiation. Both problems can be addressed by acquiring high quality spectra of GD 165 B throughout the infrared.

TABLE 3.17

THE COOLEST "DWARF" SPECTRA

| Object Name | Spectral Type[a] | Ref. | Note |
|---|---|---|---|
| H 2118-4342 | — | 1 | Single? |
| LHS 207 | M6.5: | 2 | Single? |
| LHS 1317 | M6.5: | 2 | Single? |
| LHS 523 | M6.5 | 3,4 | Single? |
| G 51-15 (LHS 248) | M6.5 | 3,4 | Single?[b] |
| LHS 191 | M6.5 | 3,4 | Single? |
| LHS 292 | M6.5 | 4 | Single?[c] |
| GL 316.1 (LHS 2034) | M6.5 | 2 | Single? |
| LHS 3332 | M6.5 | 2 | Single? |
| CTI 015607.7+280241 | M6.5 | 4 | Single? |
| CTI 092539.9+280018 | M6.5 | 4 | Single? |
| CTI 153915.6+280446 | M6.5 | 4 | Single? |
| CTI 174729.0+280322 | M6.5 | 4 | Single? |
| LHS 2351 | — | 5 | Single? |
| LHS 2876 | — | 5 | Single? |
| LHS 2930 | M6.5 | 4,5 | Single? |
| LHS 2980 | M6.5 | 4 | Single? |
| LHS 3003 | — | 5 | Single? |
| LHS 5142 | M6.5 | 4 | Single? |
| GRH 2208-2007 | — | 6 | Single? |
| VB 8 (LHS 429) | M7 | 3,4 | Member of quadruple+ system[d], P ~100000?? yr |
| LHS 3002 | M7 | 5 | Single? |
| LHS 2632 | M7 | 4 | Single? |
| LHS 2645 | M7 | 4 | Single? |
| ESO 207-61 | — | 7 | Single? |
| HB 2124-4228 | — | 8 | Single? |
| HB 2115-4518 | — | 8 | Single? |
| BRI 0021-0214 | — | 9 | Single? |
| CTI 115638.5+280002 | M7 | 4 | Single? |

TABLE 3.17 (continued)

| Object Name | Spectral Type[a] | Ref. | Note |
|---|---|---|---|
| VB 10 (LHS 474) | M8 | 3,4 | Member of double system[e], P ~20000? yr |
| LHS 2397a | M8 | 4 | Single? |
| RG 0050-2722 | M8 | 4,10 | Single? |
| LHS 2243 | M8 | 4 | Single? |
| LH 0418+1339 | — | 11 | Single? |
| GL 569 B | M8.5 | 4,12 | Member of double system, P ~500 yr |
| CTI 012657.5+280202 | M8.5 | 4 | Single? |
| LHS 2065 | M9 | 3,4 | Single? |
| LHS 2924 | M9 | 3,4 | Single? |
| PC 0025+0447 | M9.5 | 4,13 | Single? |
| GD 165 B | *very* late | 4 | Member of double system, P ~1600 yr |

[a] Given on an extension of the Boeshaar 1976 system, as reported in Kirkpatrick, Henry, & McCarthy 1991 and this thesis.

[b] No companions detected to $M_K = 11.3$ at separations of 1 to 10 AU via infrared speckle imaging (Henry 1991).

[c] No companions detected to $M_K = 11.1$ at separations of 2 to 10 AU via infrared speckle imaging (Henry 1991).

[d] This is the fourth, widely separated component (GL 644 C) in the system with GL 643 and GL 644 AB. No companions detected to $M_K = 11.8$ at separations of 2 to 10 AU via infrared speckle imaging (Henry 1991).

[e] This is the low-luminosity, widely separated secondary of the GL 752 AB system. No companions detected to $M_K = 12.1$ at separations of 5 to 10 AU via infrared speckle imaging (Henry 1991).

REFERENCES TO SPECTRA IN THE LITERATURE. — (1) Hawkins 1986; (2) Boeshaar 1992; (3) Kirkpatrick, Henry, & McCarthy 1991; (4) This thesis; (5) Bessell 1991; (6) Gilmore, Reid, & Hewett 1985; (7) Ruiz, Takamiya, & Roth 1991; (8) Hawkins & Bessell 1988; (9) Irwin, McMahon, & Reid 1991; (10) Reid & Gilmore 1981; (11) Leggett & Hawkins 1989; (12) Henry & Kirkpatrick 1990; (13) Schneider et al. 1991.

TABLE 3.18

LOW-MASS COMPANIONS FOR WHICH SPECTRA DO NOT EXIST

| Name | Mass ($M_\odot$) | Note | Ref. |
|------|------|------|------|
| GL 623 B (LHS 417 B) | $0.115\pm0.040^a$, | P = 3.73 yr | 1 |
| | $0.078\pm0.008$ | | 2 |
| Ross 614 B (GL 234 B) | $0.080\pm0.025$ | P = 16.60 yr | 1 |
| G 208-44 B (GJ 1245 C) | $0.075\pm0.015$ | P = 15.22 yr | 1 |
| LHS 1047 B (GJ 1005 B) | 0.060:, | P = 4.63 yr | 1 |
| | $0.055\pm0.032$ | | 3 |
| G 29-38 B | unknown | Dust? | 4,5,6,7,8 |

[a] Derived using speckle and astrometric data.

MASS REFERENCE. — (1) Henry & McCarthy 1992; (2) Marcy & Moore 1989; (3) Ianna, Rohde, & McCarthy 1988; (4) Zuckerman & Becklin 1987; (5) Greenstein 1988; (6) Tokunaga, Becklin, & Zuckerman 1990; (7) Graham et al. 1990; (8) Barnbaum, Misch, & Zuckerman 1992.

TABLE 3.19

COLORS, ABSOLUTE MAGNITUDES, AND TEMPERATURES FOR A SEQUENCE OF M DWARFS[a]

| Name | Sp.Type | $I-J$ | $J-H$ | $J-K$ | $M_I$ | $M_J$ | Temp (K) |
|------|---------|-------|-------|-------|-------|-------|----------|
| GL 411 | M2 V | 1.13 | 0.54 | 0.75 | 8.32 | 7.10 | > 3500 |
| GL 273 | M3.5 V | 1.40 | 0.52 | 0.77 | 9.33 | 7.83 | 3500 |
| GL 213 | M4 V | 1.47 | 0.53 | 0.78 | 9.86 | 8.30 | 3375 |
| G 208-44 AB[b] | M5.5 V | 2.19 | 0.52 | 0.89 | 11.59 | 9.40 | 3125 |
| G 208-45 | M6 V | 2.15 | 0.50 | 0.89 | 12.10 | 9.95 | 3125 |
| GL 406 | M6 V | 2.31 | 0.62 | 0.98 | 12.63 | 10.21 | 3000 |
| GL 752 B | M8 V | 2.74 | 0.67 | 1.11 | 13.98 | 11.11 | 2875 |
| LHS 2924 | M9 | 3.38 | 0.65 | 1.12 | 15.09 | 11.57 | 2625 |
| GD 165 B | *very* late | 4.8 | 1.09 | 1.84 | 17.9 | 13.2 | see text |

[a] For data on the first eight objects refer to §3.2; see text for data on GD 165 B. $I$ magnitudes are given on the Kron-Cousins system; $J$, $H$, and $K$ magnitudes have been transformed to the AAO system. (The $J$ magnitudes listed in Table 1 of Becklin & Zuckerman 1988 are on the CIT system, not the IRTF system, despite what is implied by their second footnote (Zuckerman 1992).)

[b] Composite spectrum, colors, and magnitudes assumed to be dominated by the A component.
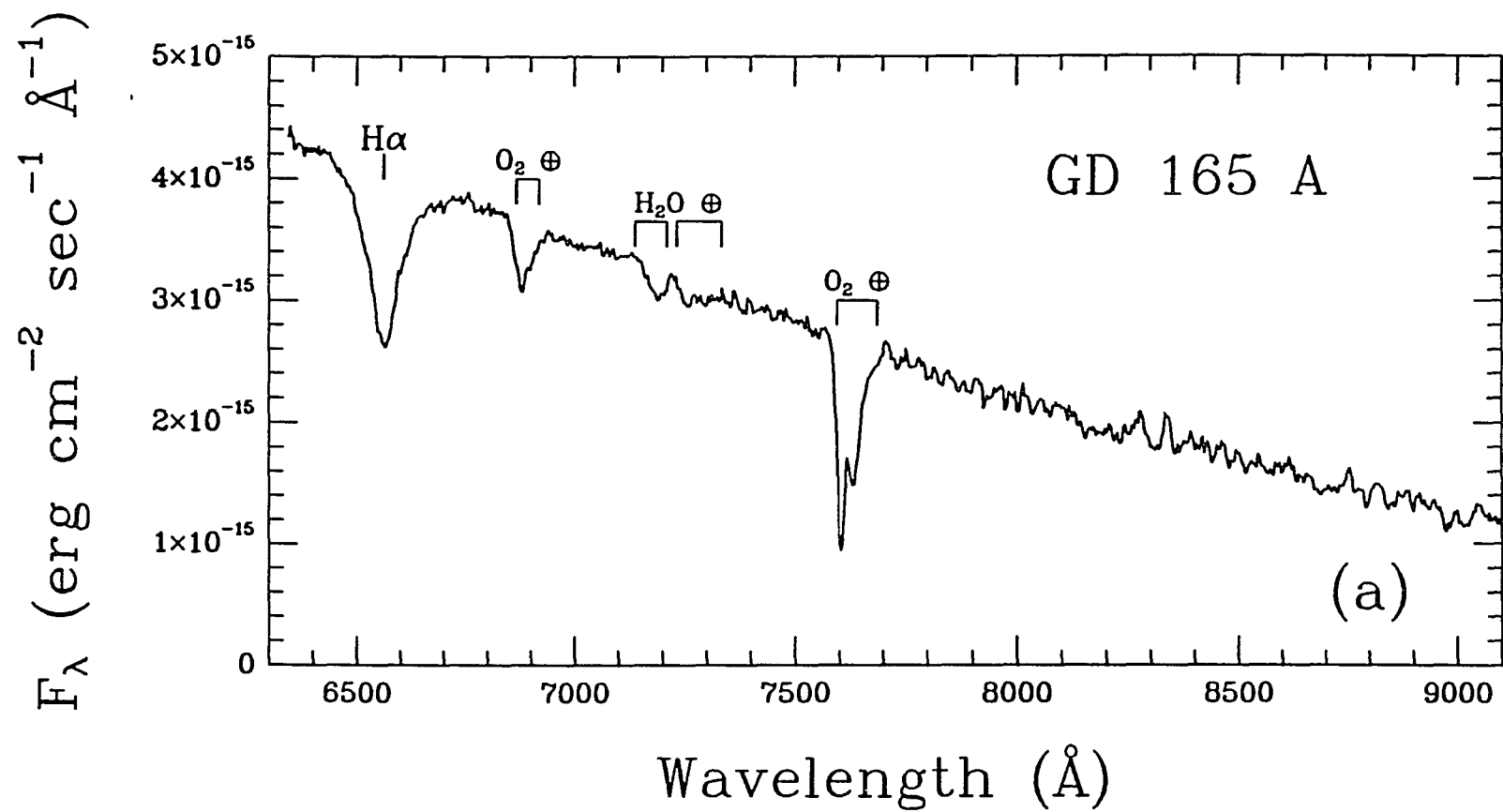
FIG. 3.17. — Spectra of the GD 165 system taken with the Red Channel Spectrograph of the Multiple Mirror Telescope. The resolution is 18 Å. Telluric absorption features have not been removed. (a) The spectrum of the DA4 white dwarf GD 165 A. The broad Hα absorption is labelled. →
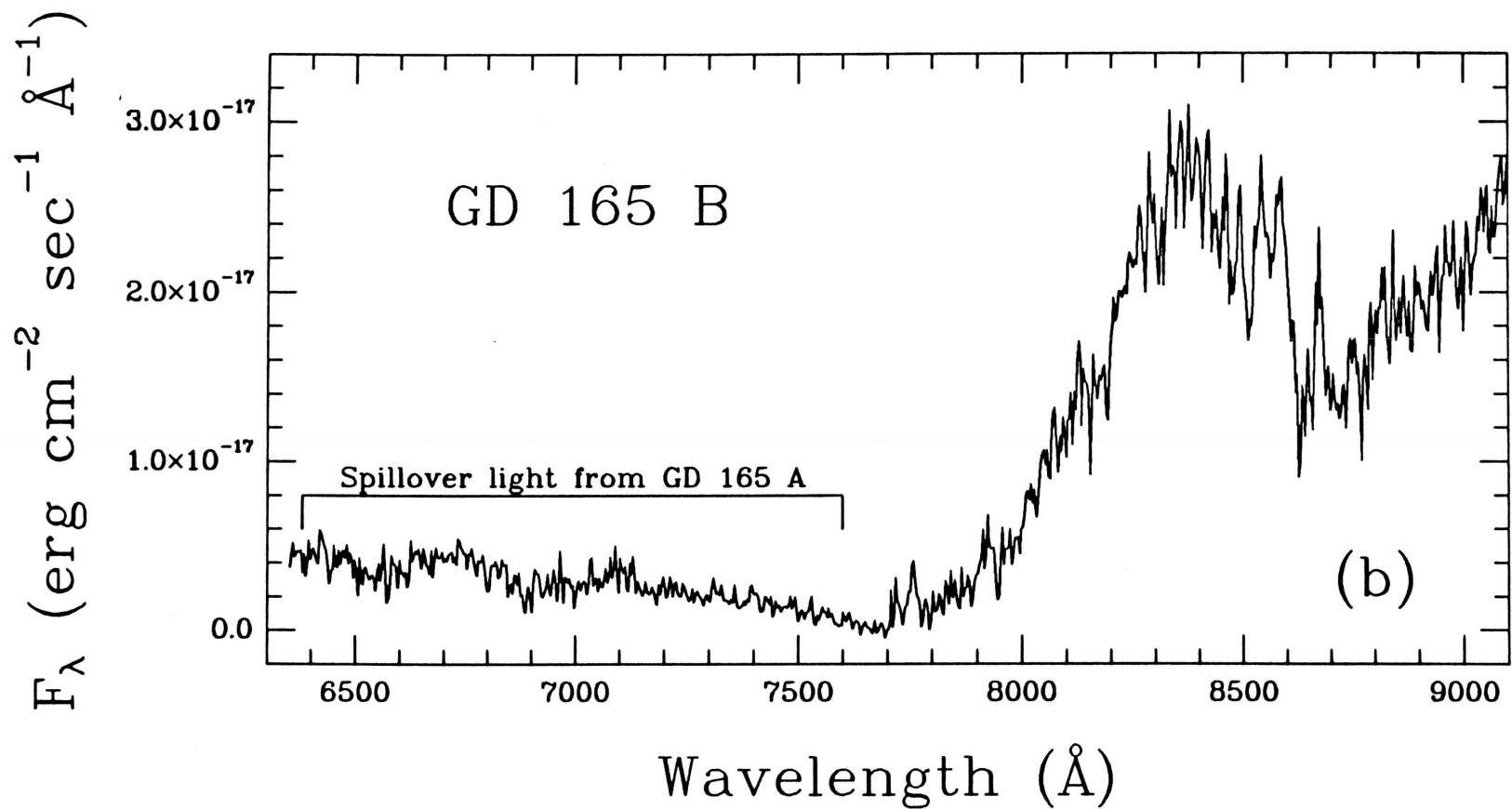
FIG. 3.17. (continued) — (b) The spectrum of the brown dwarf candidate GD 165 B. Spillover light from GD 165 A can be seen at the shortest wavelengths presented here. By 7500 Å, this flux has dropped to almost zero, demonstrating that at longer wavelengths the spectrum of GD 165 B is uncontaminated by the light of the primary.
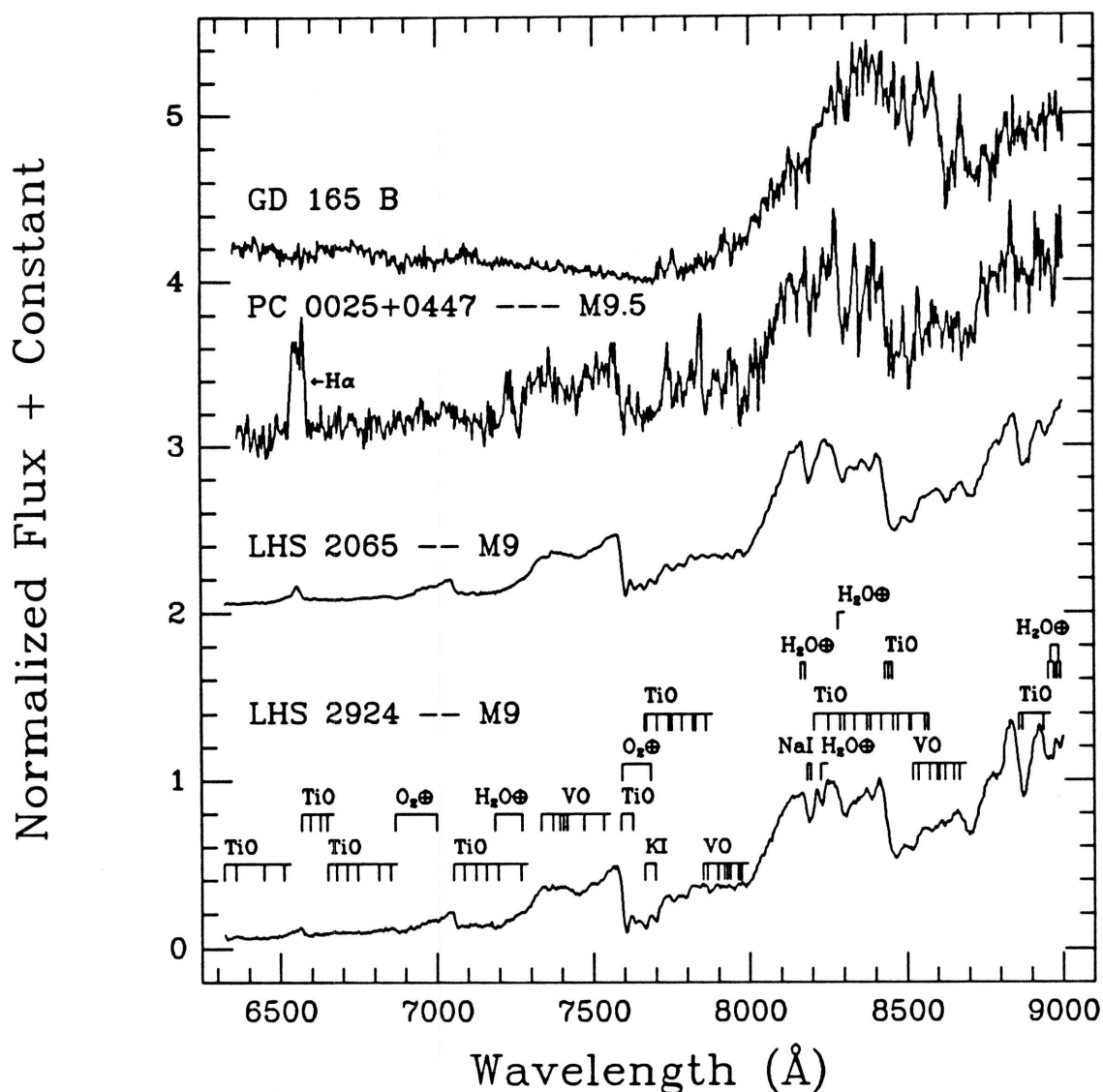
FIG. 3.18. — Spectra of the four latest "dwarfs" known. The spectra were taken at the Multiple Mirror Telescope and have a resolution of 18 Å. The flux (in units of $F_\lambda$) for each spectrum has been normalized to unity at 8250 Å (where there seems to be a common opacity minimum), and integral offsets have been added to separate the spectra vertically. Absorptions by telluric $O_2$ and $H_2O$ have not been removed. Features listed in §3.1.3 are identified in the spectrum of LHS 2924. Note the continuation by PC 0025+0447 of the familiar M dwarf sequence to even cooler temperatures, as evidenced by increased absorption by VO. Also note the lack of similarity between the spectrum of GD 165 B and any of the other spectra presented here.
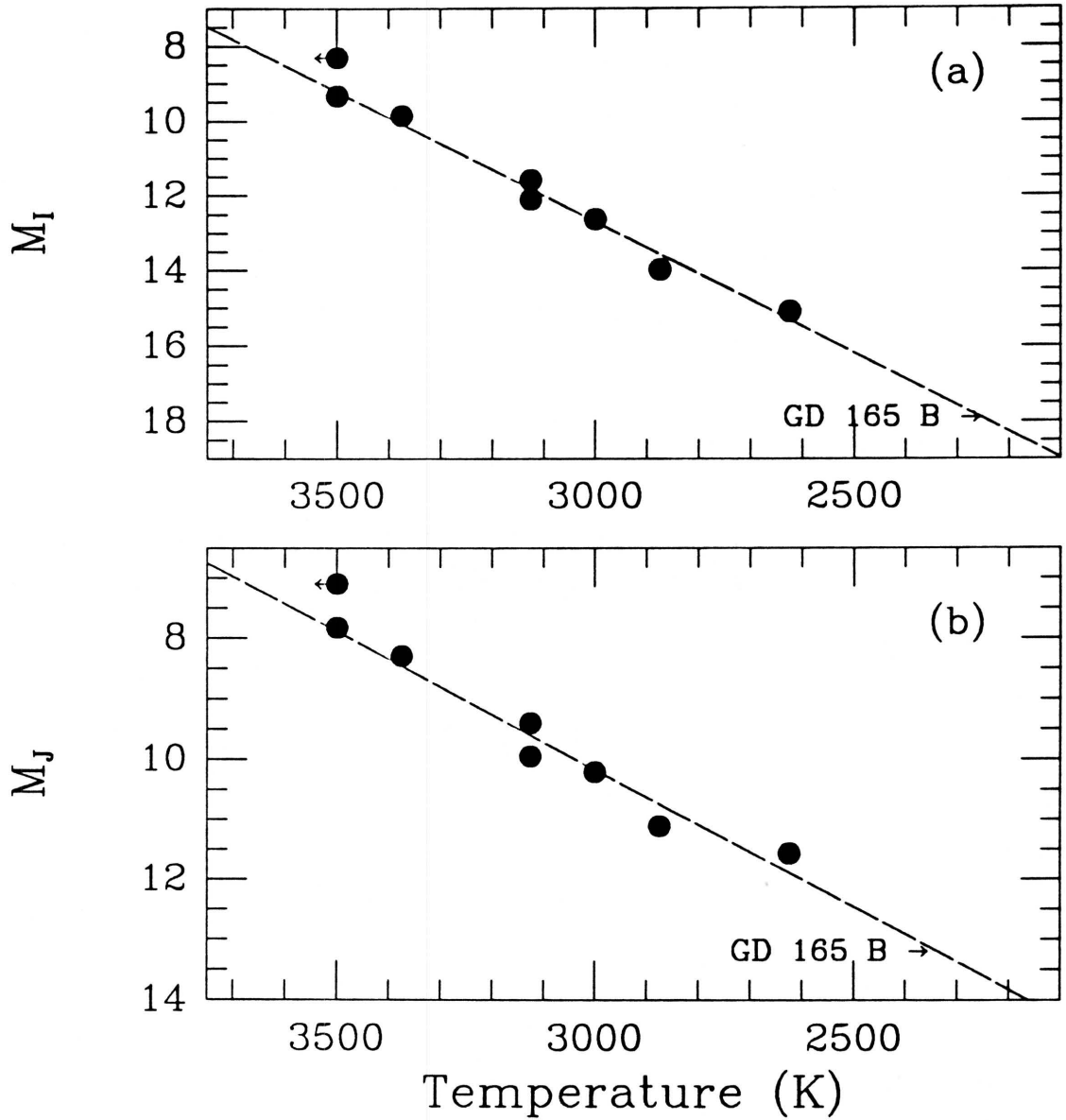
FIG. 3.19. — Absolute magnitude versus temperature for those dwarfs presented in Table 3.19. The dashed line represents a linear least-squares fit to the data, excluding the upper-limit point for GL 411. The absolute magnitude of GD 165 B is indicated with an arrow. (a) $M_I$ vs. temperature. The extrapolation gives T $\approx$ 2250 K for GD 165 B. (b) $M_J$ vs. temperature. The extrapolation gives T $\approx$ 2350 K for GD 165 B.
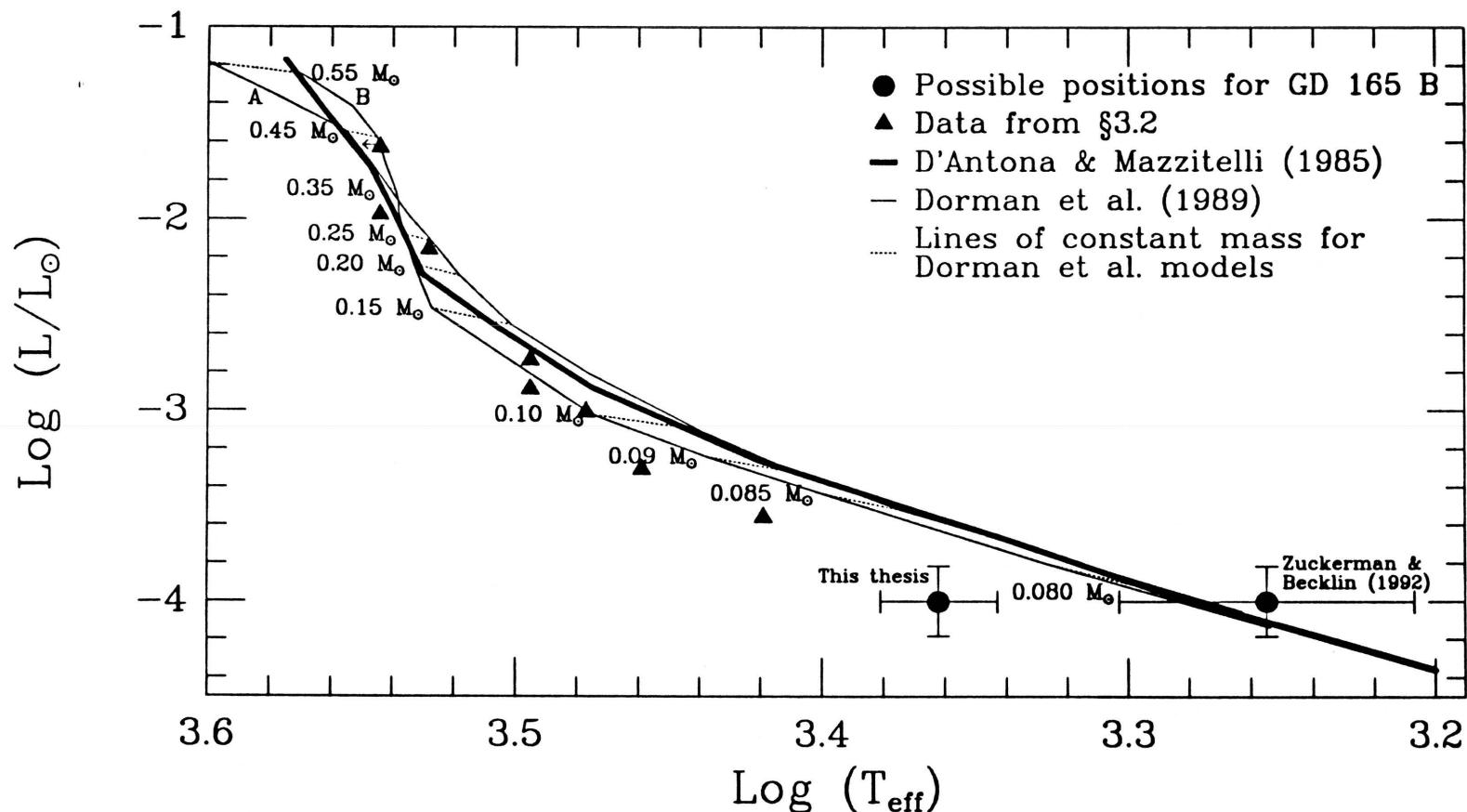
FIG. 3.20. — H-R Diagram for M dwarfs and GD 165 B. This figure is an adaptation of Figure 3.16. Indicated are the theoretical zero-age main sequences of DM (1985 — heavy line) and of DNC (1989, models A and B — lighter lines). Lines of constant mass are indicated by dashes on the DNC models. Triangles represent the first eight objects listed in Table 3.19, and the circles give two possible locations for GD 165 B. The circle at higher temperature uses the luminosity estimated in Greenstein (1990) and temperature derived from the fits in Figure 3.19. The circle at lower temperature uses data calculated in ZB. Both points place GD 165 B at the end of the main sequence at a mass of $\sim 0.08 M_{\odot}$, the dividing line between stars and brown dwarfs.

## 3.4: SPECTRA OF LOW-MASS COMPANIONS

The results of the last three sections have introduced several very interesting astrophysical questions: What are the masses of dwarfs which are typed as M7 and later? Do these mases fall in the stellar or substellar regime, or does the familiar M dwarf sequence, perhaps, correspond only to objects near the end of the main sequence, with brown dwarfs being characterized by qualitatively different spectra — like that of GD 165 B?

In an attempt to address these issues, high signal-to-noise spectra have been obtained of some of the composite systems in Table 3.18. Each of the composites consists of an M dwarf primary and an object whose dynamical mass places it near the brown dwarf limit of 0.08 $M_\odot$. From data acquired through speckle imaging techniques, the percentage of flux attributable to each of the components is known. The spectral type of the primary star can also be deduced from the speckle data. Thus, the spectrum of the low-mass secondary can be "acquired" by subtracting (in the correct percentage from the composite) a spectrum of a single star having the same spectral type as the primary. The power of this technique lies with the facts that for each of the composite systems, (1) its status as a binary is well-established and (2) in a given bandpass the fraction of flux corresponding to the fainter secondary has been measured or can be estimated based on existing data.

The objects chosen for this analysis are listed in §3.4.1, where the acquisition and reduction of the spectroscopic data are also described. The composite systems are addressed individually in §3.4.2, and differential spectroscopy is performed on each. In §3.4.3 these results are discussed, and the conclusions are

given in §3.4.4.

## 3.4.1: Data Acquisition and Reduction

Five composite systems were targeted during this investigation: GL 234 AB, LHS 1047 AB, GL 22 AC, GJ 1081 AB, and G 250-29 AB. The composite spectra of these objects range in type from M2 V for GL 22 AC to M4.5 V for GL 234 AB, so spectra of single M dwarfs were obtained over the same range. In total, 6300-to-9000 Å spectra of two single stars at each half spectral subclass were obtained with the MMT Red Channel on 1991 November 13 using the same setup described in §3.1.2. These objects are listed in Table 3.20. Brighter objects were selected so that high signal-to-noise could be acheived, and as a result many short exposure were taken to avoid saturation effects on the CCD. The integration times listed in Table 3.20 are the sums of the short exposures. Individual spectral types are from §3.1. Because this set of spectra will be used to perform the differencing, it is essential that none of these objects is a binary itself; also included in the table are the references to the observations indicating that the stars are single. The data reduction techniques are identical to those outlined in §3.1.2.

Many short exposures were also taken of the composite systems, which are listed in Table 3.21. The slit width employed was 2 arcseconds — wide enough so that in all cases the spectrum acquired is a true composite of the two members in the system. The spectral types were taken from §3.1 for GL 22 AC, LHS 1047 AB, and GL 234 AB; for G 250-29 AB and GJ 1081 AB the types were assigned using the least-squares minimization technique. References to the duplicity of

each of these systems is given in the last column of Table 3.21. Each of these double systems is discussed in detail in the following section.

### 3.4.2: Differential Spectroscopy of the Composite Systems

### a) GL 234 AB (Ross 614 AB)

The variable proper motion of this star was first recognized by Reuyl (1936), and the companion was confirmed photographically by Baade (Lippincott 1955). Probst (1977) remeasured 285 photographic plates taken between 1928 and 1975 and recomputed the masses of the components: $0.13\pm0.04$ $M_{\odot}$ for GL 234 A and $0.07\pm0.02$ $M_{\odot}$ for GL 234 B. The mass of the secondary falls very close to the hydrogen-burning limit of $0.08$ $M_{\odot}$, indicating that this object could be a brown dwarf. A recent reanalysis using infrared speckle observations results in a similar mass of $0.080\pm0.025$ $M_{\odot}$ for GL 234 B (Henry 1992).

Table 3.22 lists the magnitude differences between the components at $V$, $R$, $I$, $J$, $H$, and $K$. The values of $\Delta J$, $\Delta H$, and $\Delta K$ were derived by Henry (1992) as a result of infrared speckle observations. Probst (1981), in an analysis of late-type dwarf stars and resolved binaries, determined mean magnitude-difference relations of $\Delta R/\Delta V = 0.83$, $\Delta I/\Delta V = 0.67$, $\Delta J/\Delta V = 0.56$, $\Delta H/\Delta V = 0.55$, and $\Delta K/\Delta V = 0.53$, which in this case have been used to generate $\Delta V$, $\Delta R$, and $\Delta I$ for GL 234 AB. Leggett (1992) has reported (Johnson-Cousins-CIT) $VRIJHK$ joint photometry of the pair, which is listed as colors in Table 3.23 and as absolute magnitudes, using the parallax of $0.2432\pm0.0020$ arcsecond determined by Probst (1977), in Table 3.24. The colors of the stars in Leggett's

(1992) compilation are the means of many different measurements from various researchers. She states that the mean error for colors involving $V$ or $R$ is typically 5%. For colors involving $IJHK$, the error in $\sim$3%.

Since the magnitude differences, $\Delta m_1$ and $\Delta m_2$, are known, it can be shown that the color $(m_1 - m_2)$ for star A is given by

$$(m_1 - m_2)_A = (m_1 - m_2)_{AB} + 2.5 \log \left( \frac{1 + 10^{\frac{-\Delta m_1}{2.5}}}{1 + 10^{\frac{-\Delta m_2}{2.5}}} \right), \qquad (3.3)$$

where $(m_1 - m_2)_{AB}$ is the color of the composite system, which is also known. Then, the $(m_1 - m_2)$ color for the B component is simply

$$(m_1 - m_2)_B = (m_1 - m_2)_A + \Delta m_1 - \Delta m_2. \qquad (3.4)$$

Colors of the individual components (GL 234 A and GL 234 B) have been determined and are listed beneath the composite colors in Table 3.23.

Likewise, the absolute magnitudes of star A and component B are

$$M_A = M_{AB} + 2.5 \log \left( 1 + 10^{\frac{-\Delta m}{2.5}} \right); \qquad (3.5)$$

$$M_B = M_A + \Delta m, \qquad (3.6)$$

where the absolute magnitude of the composite, $M_{AB}$, in known. The absolute magnitudes of the individual components are given in Table 3.24.

To perform the differential spectroscopy, the correct spectrum of the primary needs to be subtracted from the composite spectrum. It is not known *a priori* what the spectrum of the primary is, but using the photometry given in Tables 3.23 and 3.24, an estimate of its spectral type can be made. To complement these two tables, Tables 3.25 and 3.26, which give mean colors and mean absolute magnitudes as a function of spectral type, are presented. Again, photometry is

kept on the standard system used in Leggett (1992), and spectral types are on the standard system presented in §3.1. In the last column of Table 3.25 is given a list of the objects whose photometry was used in computing the means for both tables; the values in parentheses after each averaged color or absolute magnitude represent the number of data points used in calculating that average. Only single objects were used to construct Tables 3.25 and 3.26. The standard deviation for the mean colors at each half spectral subclass in Table 3.25 is typically ~0.03 magnitude; the standard deviation for the mean absolute magnitudes in Table 3.26 ranges typically from 0.10 to 0.60 magnitude. This large dispersion is due primarily to the large effect that small uncertainties in the parallax have on the determination of the absolute magnitudes. The parallaxes used are those listed in Leggett (1992).

As can be seen from Table 3.25, the $R - I$ and $I - J$ colors increase monotonically with later spectral types and cover a large range of values. The $V - R$ color is also a good indicator of spectral type. A comparison to the colors of GL 234 A in Table 3.23 to the colors given in Table 3.25 clearly demonstrates that the values of $V - R, R - I$, and $I - J$ for GL 234 A are consistent with this object's having a spectral type around M4 or M4.5. A comparison of the absolute magnitudes in Table 3.26 to those values for GL 234 A in Table 3.24 suggests that the primary has a spectral type between M4 and M5, in agreement with the colors. However, considering the uncertainties in the absolute magnitudes, the colors should be considered more reliable and a better indicator of the spectral type. Therefore, it is concluded that the spectrum of GL 234 A falls roughly around spectral type M4 or M4.5.

There are two spectra in Table 3.20 with type M4 V and two with type

M4.5 V: GL 169.1 A, GL 213, GL 83.1, and GL 166 C. Leggett (1992) presents photometry of GL 213, GL 166 C, and GL 83.1, which can be compared directly to the values derived for GL 234 A in Table 3.23. This comparison demonstrates that GL 83.1 is $\sim$0.10 magnitude redder than GL 234 A in both (V - R) and (R - I), with GL 213 being bluer in the same colors by 0.05 magnitude and GL 166 C bluer by only 0.03 magnitude. No photometry is given for GL 169.1 A, but it is presumed to be bluer by virtue of its M4 V classification. Because only the colors of GL 213 are significantly different from those of GL 234 A, three attempts can be made at extracting the spectrum of GL 234 B from the composite.

The spectra presented here span the range including the $I$ bandpass, and since $\Delta I = 1.99$ for GL 234 AB, then the A component contributes $\sim$86% (or a fraction $[1 + 10^{-\Delta I/2.5}]^{-1}$) of the total light of the composite spectrum at $I$. Each of the single M4 or M4.5 V spectra has been subtracted from the spectrum of GL 234 AB individually so that the flux in the $I$ bandpass of the remainder is 14% of the $I$ flux in the composite. These resulting spectra are plotted in Figure 3.21, below the observed spectrum of GL 234 AB. The differenced spectra in Figure 3.21b-d are the results of subtracting out the spectra of, from top to bottom, (b) GL 169.1, (c) GL 213, and (d) GL 166 C. The spectra of both Figure 3.21b and c resemble normal M dwarf spectra; that of Figure 3.21d is anomalous in that it appears to show VO absorption at 7450 Å (though nowhere else) like a late M dwarf, but the slope of the spectrum has the appearance of a much earlier object. The Na I doublet ($\sim$8190 Å) also appears much too strong. These features could result in differing metallicities between GL 166 C and GL 234 A. Furthermore, the appearance of H$\alpha$ changes wildly from spectrum to spectrum. GL 234 AB is listed as a dMe in Gliese (1969), as is GL 166 C. Sometimes, the H$\alpha$ emission

is of comparable strength and subtracts out well (Figure 3.21d), but since GL 169.1 A and GL 213 are not dMe stars, the Hα emission remains in the difference (Figure 3.21b and c).

Each of the three differenced spectra was fit to the set of standards in §3.1 via the least-squares minimization technique over the wavelength range from 6950 to 8950 Å. The region shortward of 6950 Å was excluded from the fit (1) because low flux levels here make the subtraction process less certain and (2) because of the bad subtraction of the Hα emission. Overplots of these best fits are shown as the dashed spectra in Figure 3.21b-d. The fit to Figure 3.21c is quite good, with the fits to Figure 3.21b and d being less so. As a result of these fits to the differential spectra, a spectral type of ∼M5-6.5 V is adopted for GL 234 B.

A comparison of the derived colors for GL 234 B (Table 3.23) with the averaged colors of Table 3.25 suggests a spectral type for GL 234 B of M5.5-6 V based on $V-R, R-I$, and $I-J$. A similar comparison of the absolute magnitudes of GL 234 B (Table 3.24) with the averages in Table 3.26 also supports a spectral type of M5.5-6 V. Both of these comparisons confirm the result obtained above.

## b) LHS 1047 AB (GJ 1005 AB)

The astrometric perturbation of this system was first noted by Ianna (1979) and the companion was confirmed visually by Heintz (1987). Infrared speckle observations were reported by Ianna, Rohde, & McCarthy (1988), who made the first mass determination of the components — 0.17±0.12 $M_\odot$ for LHS 1047 A and 0.055±0.032 $M_\odot$ for LHS 1047 B. Again, because of the large error in the mass, the secondary could fall on either side of the stellar/substellar dividing

line.

Ianna, Rohde, & McCarthy (1988) determined that $\Delta K = 1.5$, and using the relations from Probst (1981), the magnitude differences in other bandpasses can be estimated. These results are shown in Table 3.22. Ianna, Rohde, & McCarthy (1988) also give $VRIJHK$ photometry for the composite (on the same photometric system used in the last section) and list the parallax as 0.189±0.005 arcsecond. Observed colors for LHS 1047 AB are listed in Table 3.23, and absolute magnitudes are given in Table 3.24. Using the formulae given above, colors and absolute magnitudes for LHS 1047 A and LHS 1047 B have also been computed and entered into the tables.

A comparison of the colors of LHS 1047 A to the color given in Table 3.25 show that the values of $V - R$ and $R - I$ are consistent with this object's having a spectral type of M3.5 V. The $I - J$ color is more consistent with a type of M3 V. Of the four single stars in Table 3.20 having a type of either M3 or M3.5 V, three have photometry in Leggett (1992). The $V - R, R - I$, and $I - J$ colors of GL 725 A (M3 V) are generally 0.12 magnitude bluer than those of LHS 1047 A, whereas the colors of the M3.5 V stars are in much closer agreement, with GL 873 having identical $V - R$ and $R - I$ colors to LHS 1047 A, although the $I - J$ value differs by 0.07 magnitude.

Since $\Delta I = 1.90$, the A component contributes ~85% of the total light of the composite at I. Using this information, two attempts can be made at extracting the spectrum of LHS 1047 B from the composite. The resulting differential spectra are plotted in the lower portion of Figure 3.22, below the observed spectrum of LHS 1047 AB. The residual "H$\alpha$ absorption" feature in Figure 3.22b results from the fact that the subtracted spectrum (GL 873) is a dMe while the com-

posite spectrum of LHS 1047 AB is not. The least-squares fits of the differential spectra to the set of standard stars is shown again by dashed lines in Figure 3.22b and c. The resulting spectral types are in very close agreement and suggest a spectral type of M4.5-M5 V for LHS 1047 B.

The derived colors for LHS 1047 B suggest a spectral type of M5.5 V, with the exception of the $I - J$ color which indicates a type around M4.5 V. A comparison of the absolute magnitudes for the B component with the averaged values suggests that LHS 1047 B is around type M5.5-6 V based on $M_V, M_R$, and $M_I$, and around type M6-6.5 V based on $M_J, M_H$, and $M_K$. These results indicate that the spectral type determined above could be as much as 1.5 spectral subclasses too early, but again the absolute magnitude information should be given low weight. Nonetheless, to satisfy all of the available data, a type of M4.5-6.5 V is assigned.

## c) GL 22 AC (BD +66° 34 AC)

Parallax measurements of the primary star in the GL 22 A/GL 22 B system revealed the presence of a third member, GL 22 C (Alden 1947). Hershey (1973) published the first orbit for the unseen companion around GL 22 A, and using an infrared speckle camera, McCarthy et al. (1991) were the first to image it, determining masses of 0.36±0.05 $M_\odot$ for GL 22 A, 0.18±0.02 $M_\odot$ for GL 22 B, and 0.12±0.02 $M_\odot$ for GL 22 C.

Magnitude differences between the A and C components of $\Delta H = 2.11$ and $\Delta K = 1.94$ were measured by McCarthy et al. (1991). The other magnitude differences in Table 3.22 were again estimated using the relations from Probst

(1981). No $VRI$ photometry exists for this system (at least none could be found using SIMBAD), although McCarthy et al. (1991) present $JHK$. Unfortunately, the McCarthy data have rather large error bars ($\sim$0.13 magnitude for $H - K$, for example) so typical colors for an M2 V (Table 3.25) have been entered for GL 22 AC in Table 3.23. No determination of the absolute magnitudes of the composite is possible at present. As before, colors for GL 22 A and GL 22 C have been estimated and are also listed in Table 3.23.

A comparison of the colors of GL 22 A to the colors in Table 3.25 demonstrates that GL 22 A must fall around spectral type M1.5 or M2 V. The only single object of Table 3.20 having a spectral type in this range and photometry in Leggett (1992) is GL 806, which has $V - R = 0.99$, $R - I = 1.20$, $I - J = 1.19$, $J - H = 0.59$, and $H - K = 0.22$. Based on this evidence, this object appears to be of slightly later class that GL 22 A. The only other single object of M2 V in Table 3.20 (no M1.5 V spectra were acquired) is GL 220. Eggen (1989) gives $V - R$ and $R - I$ colors for this object, which can be transformed to the Johnson-Cousins system by comparing the Eggen (1979) photometry of GL 205 (M1.5 V) and GL 411 (M2 V) to the Leggett photometry. Because these stars are of nearly identical spectral type to GL 220, a simple linear transformation with no color term can be obtained to convert the Eggen colors to the Johnson-Cousins system. When this is done, values of $V - R = 0.95$ and $R - I = 1.13$ are acquired for GL 220. These colors are a good match to the colors of GL 22 A given in Table 3.23.

Since $\Delta I = 2.51$, GL 22 A contributes $\sim$91% of the light of the composite spectrum at $I$. Figure 3.23b shows the result of differencing the GL 220 spectrum from the GL 22 AC spectrum. The composite itself is shown in Figure 3.23a. The

best least-squares match (dashed line) to the differential spectrum has spectral type M5.5 V. However, the differential spectrum has negative flux from 6350 to 7100 Å, indicating perhaps that too large a percentage of the spectrum of GL 220 was subtracted from the composite. If the assumption is made that GL 22 A contributes only 85% of the light at $I$ (which would correspond to $\Delta I = 1.88$, significantly smaller than the measured value), then the result is a differential spectrum having mainly positive flux at the short wavelength end and having a somewhat earlier spectral type of M4.5 V. In this case, the match to the spectral standard is more convincing (see Figure 3.23c). Additionally, this exercise illustrates that a small error in the magnitude difference does not seriously affect the resulting spectral type of the secondary — the difference here being only one spectral class. It should be noted that subtracting off a spectrum with type earlier than M2 makes the problem of negative flux worse.

The derived colors for GL 22 C (Table 3.23), when compared to the values in Table 3.25, suggest a spectral type between M4 and M5.5 V. Based on this evidence, together with the evidence presented in Figure 3.23, a type of M4-5.5 V is adopted.

Curiously, the values of $M_J, M_H$, and $M_K$ given in McCarthy et al. (1991) would suggest a spectral type of M3 V for GL 22 AC, which is a full spectral class later than that of the observed spectrum. Using these absolute magnitudes with the $\Delta J$, $\Delta H$, and $\Delta K$ quoted above, it is found that GL 22 C would have $J - H = 0.74$ and $H - K = 0.48$, supporting a type of M8 or M9, which is in conflilct with the above results. To understand this system better, $VRI$ photometry should be acquired and the infrared magnitudes and magnitude differences should be measured, if possible, with higher precision.

d) GJ 1081 AB (G 96-45 AB)

Astrometric perturbations were first noted for GJ 1081 by Routly (1972) and Behall & Harrington (1976), and the latter authors determined masses of 0.27 $M_\odot$ for GJ 1081 A and 0.10-0.16 $M_\odot$ for GJ 1081 B. The companion was verified through infrared speckle imaging by McCarthy (1986).

The magnitude difference at $K$ is rather uncertain, but is $\sim$0.10 magnitude (McCarthy 1992). Using Probst's (1981) relations, the other magnitude differences in Table 3.22 can be estimated. Weis & Upgren (1982) present $VRI$ photometry of this system, which can be transformed to the Johnson-Cousins system by utilizing the formulae presented in the appendix of Leggett (1992). The resulting colors are entered in Table 3.23. Using a parallax of 0.063±0.003 (Behall & Harrington 1976), absolute Johnson-Cousins $VRI$ magnitudes have likewise been computed (Table 3.24). Using the estimated magnitude differences, the colors and absolute magnitudes for GJ 1081 A and GJ 1081 B have also been computed and entered in Tables 3.23 and 3.24.

The $V - R$ and $R - I$ colors of GJ 1081 A are consistent with a spectral type of M3-3.5 V (Table 3.25). Of the M3 and M3.5 V single stars in Table 3.20, three have Leggett (1992) photometry: GL 725 A has $V - R = 1.07$ and $R - I = 1.39$, both of which are 0.08 magnitude bluer than the colors of GJ 1081 A; GL 725 B has $V - R = 1.12$ and $R - I = 1.43$, which are only 0.03-0.04 magnitude bluer than GJ 1081 A; and GL 873 has $V - R = 1.17$ and $R - I = 1.52$, making it later in type than GJ 1081 A. The fourth star, GL 22 B, is assumed to have similar colors to GL 725 A since both are spectral type M3 V. Therefore, based on this argument, the spectrum of GL 725 B would be the best

match to the primary's spectrum. Interestingly, though, the spectral type of GL 725 B (M3.5 V) is later than that of the GJ 1081 AB composite, which would lead to the secondary spectrum having a type earlier than the primary. This is clearly aphysical.

The photometry of the composite may not be accurate enough to use in this application. A comparison of these values of $V - R$ and $R - I$ with the colors in Table 3.25 would suggest that GJ 1081 AB has a type of M3.5 V. This is half a subclass later than the observed type. If the colors for an M3 V in Table 3.25 are chosen for GJ 1081 AB instead of the transformed Weis & Upgren values (a similar assumption was made for GL 22 AC above), then the colors (especially $R - I$) for GJ 1081 A are more consistent with an object like GL 226 or GL 767 B (M2.5 V).

Since $\Delta I = 1.26$, GJ 1081 A contributes $\sim 76\%$ of the flux to the composite spectrum at $I$. Use of this number results in the residual spectra shown in the lower panels of Figure 3.24, with the composite spectrum of GJ 1081 AB shown in the upper panel. The best least-squares matches to the standard spectra are shown by the dashed lines. In both cases, a spectral type of M5 is the best fit.

The colors of GJ 1081 B in Table 3.23 are consistent with a spectral type of M4.5-5 V. This agrees well with the determination above, so a type of M4.5-5 V is hereby adopted for GJ 1081 B.

### e) G 250-29 AB (LHS 221 AB)

The binary nature of this system was first recognized by Borgman and subsequent observations led to the visual confirmation of the secondary (Heintz 1986).

The companion was also verified through infrared speckle imaging (McCarthy 1986), and a determination of $\Delta K = 1.0$ was made (McCarthy 1992). Refer to Table 3.22 for the estimated magnitude differences in other bandpasses. The orbit and masses for this system have not yet been calculated.

Leggett (1992) does not present photometry of this object, so the colors given in Table 3.23 are the averages for an M2.5 V listed in Table 3.25. The derived colors for G 250-29 A are consistent with a spectral type of M2-2.5 V. Dawson & Forbes (1989) present $VRI$ photometry for G 250-29 AB which, together with the parallax of 0.091±0.04 determined by Heintz (1986), can be used to calculate the absolute $VRI$ magnitudes in Table 3.24. (The $V - R$ and $R - I$ colors adopted in Table 3.23 are 0.08 and 0.10 magnitude bluer, respectively, than the Dawson & Forbes $V - R$ and $R - I$ colors, which suggest an erroneous spectral type of M3-3.5 V for the composite. This difference is doubtless the result of a small but unknown offset between the Dawson & Forbes photometry and the Johnson-Cousins system. However, several tenths of a magnitude separate the absolute magnitudes for each half spectral subclass in Table 3.26, so the unknown offset is considered negligible when comparing the values for G 250-29 AB in Table 3.24 to the averaged values in Table 3.26.)

Leggett (1992) gives $V - R$ and $R - I$ colors for two of the four M2-2.5 V stars in Table 3.20. Both of the colors for GL 226 (M2.5 V) are somewhat redder (by 0.05-0.08 magnitude) than those in Table 3.23 for G 250-29 A, but the colors of GL 806 (M2 V) are only slightly bluer (by 0.02). Therefore, the spectra of the M2 V stars (GL 220 and GL 806) will be used to perform the differential spectroscopy.

Because $\Delta I = 1.26$, G 250-29 A contributes $\sim 76\%$ of the $I$ flux to the composite spectrum. Using this value for both of the M2 V spectra results in the differenced spectra shown in Figure 3.25b-c, with the spectrum of the G 250-29 AB composite shown in Figure 3.25a. The best least-squares matches to the standard spectra indicate spectral types of M5 and M4.5 V for these differenced spectra.

The colors of G 250-29 B in Table 3.23 are consistent with a spectral type in the range M3.5-4.5 V. The absolute magnitudes given in Table 3.24 are consistent with a type of M4 V. Therefore, a spectral type in the range M3.5-5 V is adopted for G 250-29 B.

### 3.4.3: Results

Based on the lines of evidence presented in earlier sections of this chapter, one might have expected that the spectra of these low-mass secondaries, some of which are viable brown dwarf candidates, would resemble the spectra of very late objects like vB8, vB10, and LHS 2924 or perhaps even resemble that of GD 165 B, the best substellar candidate known. Astonishingly, the latest spectral type found for any of the secondaries is M5-6.5 V — for the low-mass object GL 234 B; LHS 1047 B, also having a very low mass, was similarly typed as an M4.5-6.5 V.

The results of the previous section are summarized in Table 3.27 and are plotted as open symbols on the spectral type vs. mass diagram of Figure 3.26. These new points confirm the trend noted in Figure 3.10. In fact, GL 234 B and LHS 1047 B, despite having masses which place them very near or just off the

end of the main sequence, have spectral types in the mid-M range — between M4.5 and M6.5 V. This indicates that objects of type M7 and later, because they would presumably have even *smaller* masses, are likely to be brown dwarfs.

If this supposition is correct, then it implies that the break between low-mass stars and brown dwarfs, according to Table 3.26, falls near $M_K \sim 9.7$, which is also the point at which the infrared $(M_K)$ luminosity function of Henry & McCarthy (1990) is seen to plummet. Furthermore, it means that astronomers have already discovered 21 brown dwarfs (because the last 21 objects in Table 3.17 are all of type M7 or later). This hypothesis must, however, be tested — researchers must begin to scrutinize these 21 objects to see if any are members of short-period binary systems. Only then can dynamical masses be calculated for these objects, whose true nature remains unknown.

### 3.4.4: Summary

Differential spectroscopy has been performed on five composite systems containing an early- to mid-M type primary star and a low-mass secondary. In each case, information acquired through speckle imaging techniques was essential in determining the correct spectral type of the primary and in determining the percentage that its spectrum contributes to the composite.

The surprising result of this differencing is that all of the secondaries were found to have a spectral type of M6.5 or earlier. If any of these is a brown dwarf, which is a possibility for at least two of the secondaries, then its spectrum does not obviously differentiate it from the familiar M dwarf sequence. Furthermore, objects of later type $(\geq M7)$ presumably have lower masses and are even more

likely to be brown dwarfs. Confirmation awaits the direct measurement of a dynamical mass for an object of type M7 V or later.

TABLE 3.20

SPECTRA OF SINGLE M DWARFS OBTAINED ON
1991 NOVEMBER 13

| Object Name | Other Name | Spectral Type | Integ. (sec) | Single status suggested via speckle observations by... |
|---|---|---|---|---|
| GL 220[a] | Ross 59 | M2 V | 570 | — |
| GL 806 | G 209-41 | M2 V | 990 | 1 |
| GL 767 B[b] | BD +31°3767 B | M2.5 V | 1260 | — |
| GL 226[c] | G 222-11 | M2.5 V | 480 | — |
| GL 725 A[d] | HD 173739 | M3 V | 250 | 1, 2 |
| GL 22 B | BD +66°34 B | M3 V | 915 | 3 |
| GL 725 B[d] | HD 173740 | M3.5 V | 250 | 1, 2 |
| GL 873[e] | BD +43°4305 | M3.5 V | 345 | 1, 4 |
| GL 169.1 A[f] | Stein 2051 A | M4 V | 840 | 4 |
| GL 213 | Ross 47 | M4 V | 2400 | 4 |
| GL 83.1 | G 3-33 | M4.5 V | 2010 | 2 |
| GL 166 C | 40 Eri C | M4.5 V | 870 | 2 |

[a] No mention of periodic residuals in the astrometric measurements by Heintz 1988.

[b] Astrometric measurements by Mesrobian, Griese, & Titter 1972 show "no deviation from linearity within the scatter of the observations".

[c] Astrometric measurements by Heintz 1973 show "no systematic run of residuals in 12 years."

[d] Heintz 1987 shows that the astrometric data show no periodic residuals which would indicate a third member in the GL 725 A and B system.

[e] The possible multiplicity of this object (EV Lac) is still a matter of debate: van de Kamp & Worth 1972 find astrometric evidence for a second body with a period of 28.9 years, and Roïzman 1984 finds evidence for an eclipsing body having a period coincident with the photometric period of 4.378 days. In both cases, the derived masses of the other bodies fall between 0.01 and 0.04 $M_\odot$ — if either is real, contribution to the light of the primary would be negligible. Curiously, Weis, Nations, & Upgren 1983 find no significant trends in their astrometric residuals, and Marcy & Benitz 1989 see no radial velocity variations to the $\sigma = 0.24$ km/sec level over 694 days.

[f] Suspected companion disproven via higher quality data by Heintz 1990.

SPECKLE REFERENCES. — (1) Blazit, Bonneau, & 1987; (2) Henry & McCarthy 1990; (3) McCarthy et al. 1991; (4) Henry 1991.

## TABLE 3.21

### SPECTRA OF COMPOSITE SYSTEMS (M DWARF + LOW-MASS SECONDARY) OBTAINED ON 1991 NOVEMBER 13

| Object Name | Other Name | Spectral Type | Integ. (sec) | Duplicity of system established by... |
|---|---|---|---|---|
| GL 234 AB | Ross 614 AB | M4.5 V | 1500 | 1, 2 |
| LHS 1047 AB | GJ 1005 AB | M4 V | 1380 | 3, 4, 5 |
| GL 22 AC | BD +66°34 AC | M2 V | 915 | 6, 7 |
| GJ 1081 AB | G 96-45 AB | M3 V | 720 | 8 |
| G 250-29 AB | LHS 221 AB | M2.5 V | 540 | 8, 9 |

DUPLICITY REFERENCES. — (1) Lippincott 1955; (2) Davey et al. 1989; (3) Ianna 1979; (4) Heintz 1987; (5) Ianna, Rohde, & McCarthy 1988; (6) Hershey 1973; (7) McCarthy et al. 1991; (8) McCarthy 1986; (9) Heintz 1986.

TABLE 3.22

MAGNITUDE DIFFERENCES FOR THE COMPONENTS OF THE
FIVE COMPOSITE SYSTEMS

| Object Name | $\Delta V$ | $\Delta R$ | $\Delta I$ | $\Delta J$ | $\Delta H$ | $\Delta K$ |
|---|---|---|---|---|---|---|
| GL 234 AB | 2.97[a] | 2.47[a] | 1.99[a] | 1.71[b] | 1.66[b] | 1.51[b] |
| LHS 1047 AB | 2.83[a] | 2.35[a] | 1.90[a] | 1.58[a] | 1.56[a] | 1.50[c] |
| GL 22 AC | 3.75[a] | 3.11[a] | 2.51[a] | 2.10[a] | 2.11[d] | 1.94[d] |
| GJ 1081 AB | 1.89[a] | 1.57[a] | 1.26[a] | 1.06[a] | 1.04[a] | 1.0[e] |
| G 250-29 AB | 1.89[a] | 1.57[a] | 1.26[a] | 1.06[a] | 1.04[a] | 1.0[e] |

[a] Estimated using the magnitude-difference relations from Probst 1981.

[b] From Henry 1992.

[c] From Ianna, Rohde, & McCarthy 1988.

[d] From McCarthy et al. 1991.

[e] From McCarthy 1992.

TABLE 3.23

COLORS OF THE COMPOSITE SYSTEMS

| Object Name | $V - R$ | $R - I$ | $I - J$ | $J - H$ | $H - K$ |
|---|---|---|---|---|---|
| GL 234 AB | 1.31 | 1.71 | 1.68 | 0.60 | 0.29 |
| GL 234 A | 1.27 | 1.66 | 1.64 | 0.59 | 0.26 |
| GL 234 B | 1.77 | 2.14 | 1.92 | 0.64 | 0.41 |
| LHS 1047 AB | 1.21 | 1.58 | 1.42 | 0.57 | 0.29 |
| LHS 1047 A | 1.17 | 1.52 | 1.37 | 0.57 | 0.28 |
| LHS 1047 B | 1.65 | 1.97 | 1.69 | 0.59 | 0.34 |
| GL 22 AC[a] | 1.00 | 1.17 | 1.19 | 0.59 | 0.21 |
| GL 22 A | 0.97 | 1.13 | 1.15 | 0.59 | 0.19 |
| GL 22 C | 1.61 | 1.73 | 1.56 | 0.58 | 0.36 |
| GJ 1081 AB[b] | 1.15 | 1.47 | — | — | — |
| GJ 1081 A | 1.10 | 1.40 | — | — | — |
| GJ 1081 B | 1.41 | 1.71 | — | — | — |
| GJ 1081 AB[a] | 1.05 | 1.36 | 1.32 | 0.59 | 0.24 |
| GJ 1081 A | 1.00 | 1.29 | 1.27 | 0.58 | 0.23 |
| GJ 1081 B | 1.32 | 1.60 | 1.47 | 0.60 | 0.27 |
| G 250-29 AB[a] | 1.06 | 1.29 | 1.33 | 0.56 | 0.24 |
| G 250-29 A | 1.01 | 1.22 | 1.28 | 0.55 | 0.23 |
| G 250-29 B | 1.33 | 1.53 | 1.48 | 0.57 | 0.27 |

[a] Values are adopted from Table 3.25. See text for discussion.

[b] Values are based on Weis & Upgren 1982 photometry. See text for details.

TABLE 3.24

ABSOLUTE MAGNITUDES OF THE COMPOSITE SYSTEMS[a]

| Object Name | $M_V$ | $M_R$ | $M_I$ | $M_J$ | $M_H$ | $M_K$ |
|---|---|---|---|---|---|---|
| GL 234 AB | 13.01 | 11.70 | 9.99 | 8.31 | 7.71 | 7.42 |
| GL 234 A | 13.08 | 11.81 | 10.15 | 8.51 | 7.92 | 7.66 |
| GL 234 B | 16.05 | 14.28 | 12.14 | 10.22 | 9.58 | 9.17 |
| LHS 1047 AB | 12.88 | 11.67 | 10.09 | 8.66 | 8.09 | 7.80 |
| LHS 1047 A | 12.96 | 11.79 | 10.26 | 8.89 | 8.32 | 8.04 |
| LHS 1047 B | 15.79 | 14.14 | 12.16 | 10.47 | 9.88 | 9.54 |
| GJ 1081 AB[b] | 11.21 | 10.06 | 8.59 | — | — | — |
| GJ 1081 A | 11.39 | 10.29 | 8.89 | — | — | — |
| GJ 1081 B | 13.28 | 11.86 | 10.15 | — | — | — |
| G 250-29 AB[c] | 10.82 | 9.69 | 8.29 | — | — | — |
| G 250-29 A | 11.00 | 9.92 | 8.59 | — | — | — |
| G 250-29 B | 12.89 | 11.49 | 9.85 | — | — | — |

[a] GL 22 AC lacks any $VRI$ photometry and is hence not listed here.

[b] Values are based on Weis & Upgren 1982 photometry. See text.

[c] Values are based on Dawson & Forbes 1989 photometry. See text.

TABLE 3.25

## MEAN COLORS AS A FUNCTION OF SPECTRAL TYPE FOR M DWARFS

| Spec. | $V-R$ | $R-I$ | $I-J$ | $J-H$ | $H-K$ | Objects used in the mean |
|---|---|---|---|---|---|---|
| M0 V | 0.87(3) | 0.86(1) | 1.03(3) | 0.65(3) | 0.15(3) | GL 270, 328, 763 |
| M0.5 V | 0.87(3) | 0.91(3) | 1.03(4) | 0.65(4) | 0.16(4) | GL 720 A, 761.2, 839, 846 |
| M1 V | 0.96(1) | 1.05(1) | 1.13(1) | 0.63(1) | 0.20(1) | GL 229 |
| M1.5 V | 0.97(1) | 1.10(1) | 1.14(1) | 0.68(1) | 0.19(1) | GL 205 |
| M2 V | 1.00(3) | 1.17(3) | 1.19(3) | 0.59(3) | 0.21(3) | GL 382, 411, 806 |
| M2.5 V | 1.06(2) | 1.29(2) | 1.33(2) | 0.56(2) | 0.24(2) | GL 226, 381 |
| M3 V | 1.05(4) | 1.36(4) | 1.32(4) | 0.59(4) | 0.24(4) | GL 251, 436, 725 A, 752 A |
| M3.5 V | 1.15(4) | 1.51(4) | 1.47(4) | 0.56(4) | 0.24(4) | Gl 273, 643, 669 A, 725 B |
| M4 V | 1.21(3) | 1.59(3) | 1.52(4) | 0.54(4) | 0.26(4) | GL 213, 232, 402, 699 |
| M4.5 V | 1.32(4) | 1.71(4) | 1.65(4) | 0.57(4) | 0.27(4) | GL 83.1, 166 C, 268, 669 B |
| M5 V | 1.43(2) | 1.89(2) | 1.82(2) | 0.59(2) | 0.29(2) | GL 51; GJ 1057 |
| M5.5 V | 1.59(1) | 2.01(1) | 2.03(1) | 0.52(1) | 0.37(1) | GJ 1245 A |
| M6 V | 1.80(3) | 2.17(3) | 2.25(4) | 0.56(4) | 0.37(4) | GL 283B,316.1,406;GJ 1245B |
| M6.5 V | 2.03(2) | 2.30(2) | 2.31(4) | 0.57(4) | 0.34(4) | GJ 1111; LHS 191, 292, 523 |
| M7 V | 2.15(1) | 2.41(1) | 2.47(1) | 0.58(1) | 0.37(1) | GL 644 C |
| M8 V | — | — | 2.95(2) | 0.70(2) | 0.45(2) | GL 752 B; LHS 2397a |
| M9 V | — | — | 3.29(2) | 0.71(2) | 0.51(2) | LHS 2065, 2924 |

## TABLE 3.26

## MEAN ABSOLUTE MAGNITUDES AS A FUNCTION OF SPECTRAL TYPE FOR M DWARFS

| Sp. Type | $M_V$ | $M_R$ | $M_I$ | $M_J$ | $M_H$ | $M_K$ |
|---|---|---|---|---|---|---|
| M0 V | 8.68(3) | 7.80(3) | 6.94(3) | 5.92(3) | 5.26(3) | 5.11(3) |
| M0.5 V | 8.89(4) | 7.96(3) | 7.08(4) | 6.05(4) | 5.40(4) | 5.24(4) |
| M1 V | 9.33(1) | 8.37(1) | 7.32(1) | 6.19(1) | 5.56(1) | 5.36(1) |
| M1.5 V | 9.14(1) | 8.17(1) | 7.07(1) | 5.93(1) | 5.25(1) | 5.06(1) |
| M2 V | 10.16(3) | 9.16(3) | 7.99(3) | 6.80(3) | 6.21(3) | 6.00(3) |
| M2.5 V | 10.45(2) | 9.40(2) | 8.11(2) | 6.78(2) | 6.23(3) | 5.99(2) |
| M3 V | 10.84(4) | 9.79(4) | 8.43(4) | 7.11(4) | 6.52(4) | 6.29(4) |
| M3.5 V | 12.05(4) | 10.90(4) | 9.39(4) | 7.92(4) | 7.36(4) | 7.12(4) |
| M4 V | 12.95(4) | 11.57(3) | 10.12(4) | 8.60(4) | 8.06(4) | 7.80(4) |
| M4.5 V | 13.04(4) | 11.73(4) | 10.02(4) | 8.34(4) | 7.80(4) | 7.53(4) |
| M5 V | 13.95(2) | 12.52(2) | 10.63(2) | 8.82(2) | 8.23(2) | 7.94(2) |
| M5.5 V | 15.10(1) | 13.51(1) | 11.50(1) | 9.47(1) | 8.95(1) | 8.58(1) |
| M6 V | 16.49(4) | 14.56(3) | 12.48(4) | 10.22(4) | 9.66(4) | 9.29(4) |
| M6.5 V | 17.14(4) | 15.13(2) | 12.82(4) | 10.51(4) | 9.94(4) | 9.60(4) |
| M7 V | 17.76(1) | 15.61(1) | 13.20(1) | 10.73(1) | 10.15(1) | 9.78(1) |
| M8 V | 18.76(2) | — | 14.10(2) | 11.15(2) | 10.45(2) | 10.01(2) |
| M9 V | 19.29(2) | — | 14.93(2) | 11.65(2) | 10.94(2) | 10.43(2) |

TABLE 3.27

RESULTS OF THE DIFFERENTIAL SPECTROSCOPY

| Object Name | —Spectral Type Determined— | | Adopted Sp. Type | Calculated Mass ($M_\odot$) |
|---|---|---|---|---|
| | Spectroscopically | Photometrically | | |
| GL 22 A | — | M2 V | M2 V | 0.36±0.05 |
| G 250-29 A | — | M2 V | M2 V | unknown |
| GJ 1081 A | — | M2.5 V | M2.5 V | 0.27(±0.06) |
| LHS 1047 A | — | M3.5 V | M3.5 V | 0.17±0.12 |
| G 250-29 B | M4.5-5 V | M3.5-4.5 V | M3.5-5 V | unknown |
| GL 234 A | — | M4-4.5 V | M4-4.5 V | 0.13±0.04 |
| GL 22 C | M4.5-5.5 V | M4-5.5 | M4-5.5 V | 0.12±0.02 |
| GJ 1081 B | ~M5 V | M4.5-5 V | M4.5-5 V | 0.13±0.03 |
| LHS 1047 B | M4.5-5 V | M4.5-6.5 V | M4.5-6.5 V | 0.055±0.032 |
| GL 234 B | M5-6.5 V | M5.5-6 V | M5-6.5 V | 0.080±0.025 |
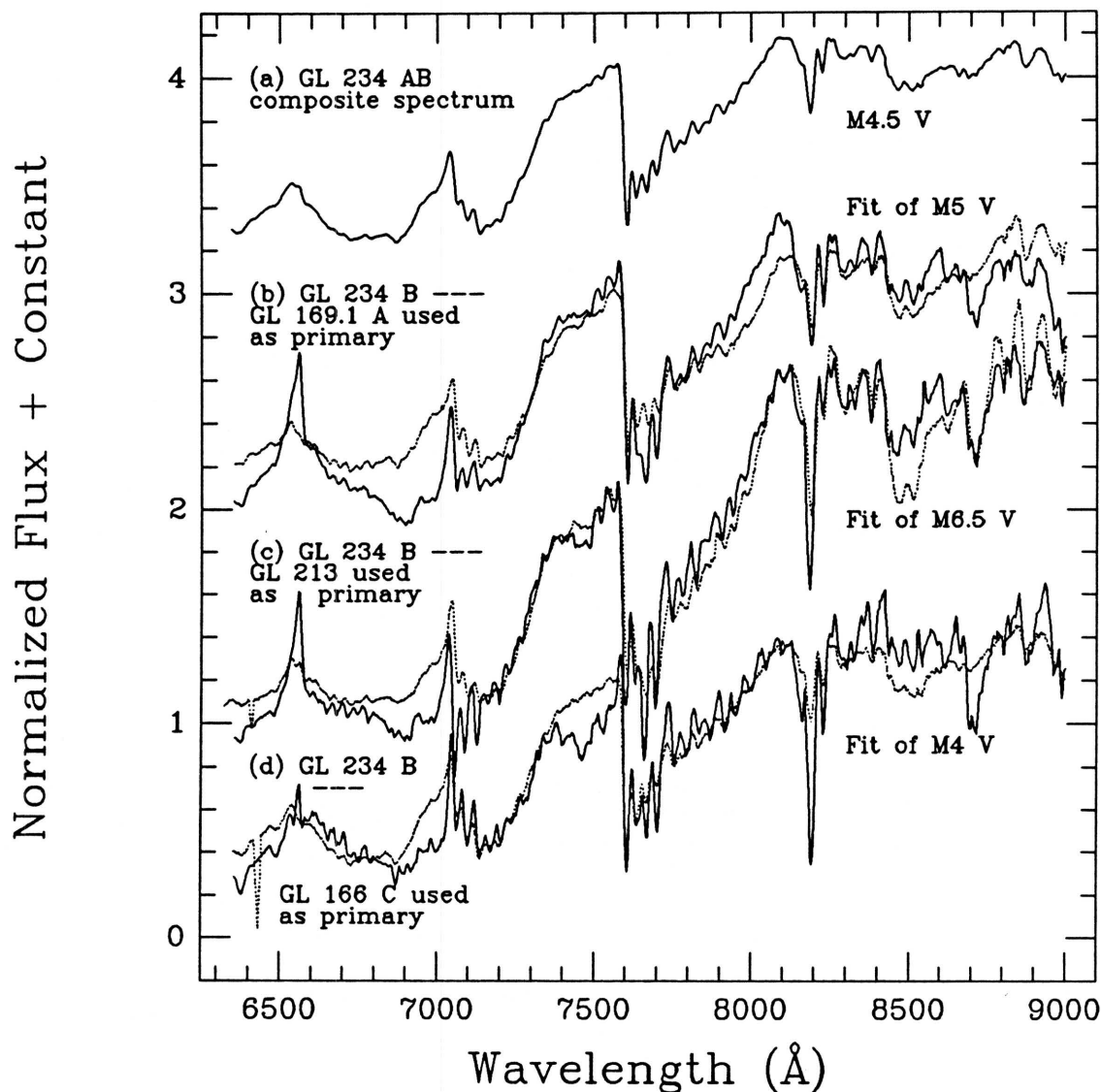
FIG. 3.21. — (a) The composite spectrum of GL 234 AB. (b) The resulting spectrum of GL 234 B, where the spectrum of GL 169.1 A has been subtracted as the spectrum of GL 234 A. The best fit, shown by the dashed line, gives a spectral type of M5 V for the secondary. (c) The resulting spectrum of GL 234 B, where the spectrum of GL 213 has been subtracted as the spectrum of GL 234 A. The best fit, which represents a very good match to this spectrum, gives a spectral type of M6.5 V. (d) The resulting spectrum of GL 234 B, where the spectrum of GL 166 C has been subtracted as the spectrum of GL 234 A. This spectrum is quite peculiar and is fit best by an M4 V — which is half a spectral subclass earlier that GL 166 C itself. See text for discussion. Integral offsets have been used in (a)-(c) to separate the spectral vertically.
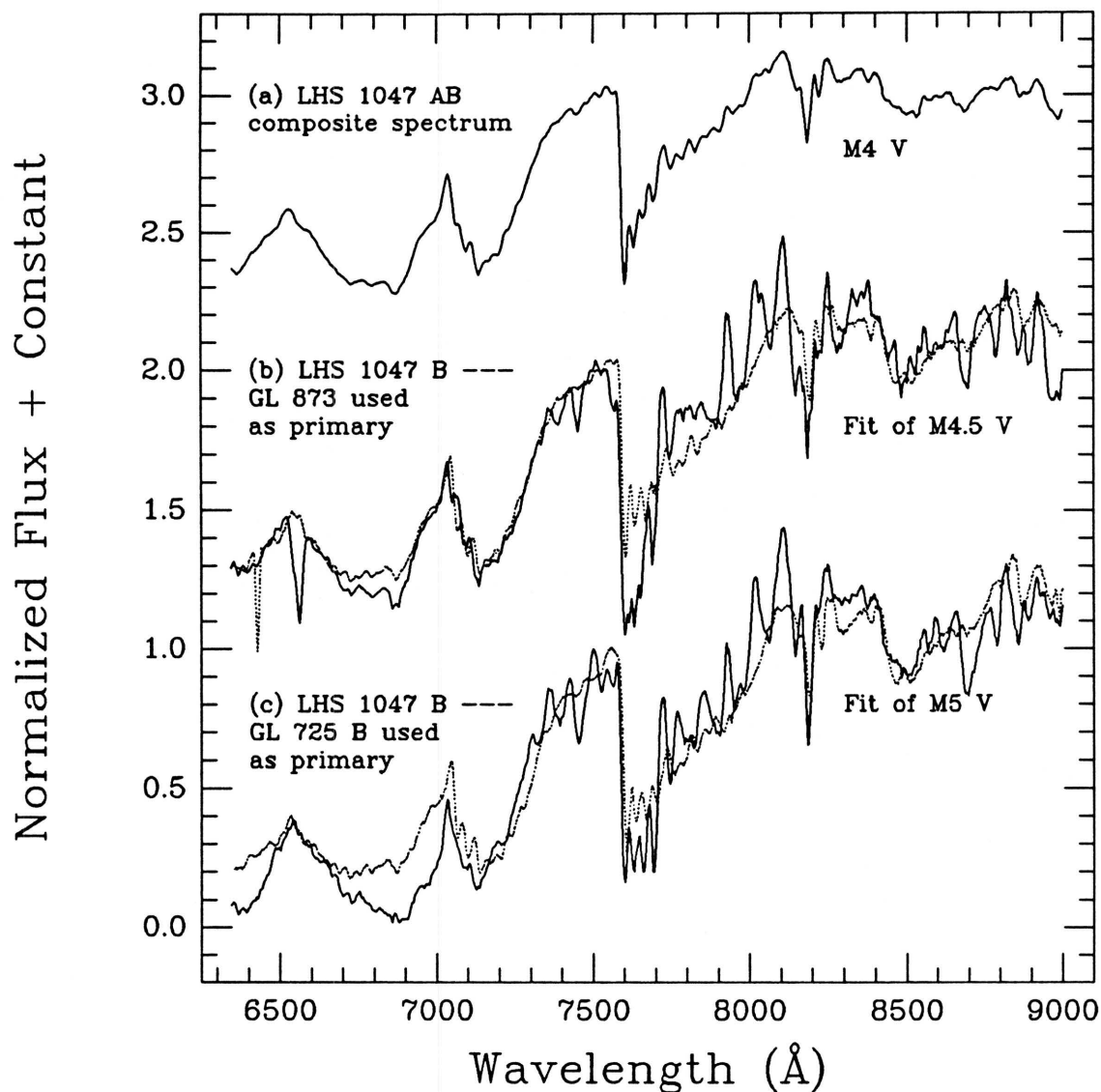
FIG. 3.22. — (a) The composite spectrum of LHS 1047 AB. (b) The resulting spectrum of LHS 1047 B, where the spectrum of GL 873 has been subtracted as the spectrum of LHS 1047 A. The best fit, shown be the dashed line, is a good general match to the spectrum and suggests a spectral type of M4.5 V. (c) The resulting spectrum of LHS 1047 B, where GL 725 B has been subtracted as the spectrum of LHS 1047 A. The best fit to this spectrum suggests a type of M5 V. Integral offsets have been used to separate the spectra vertically.
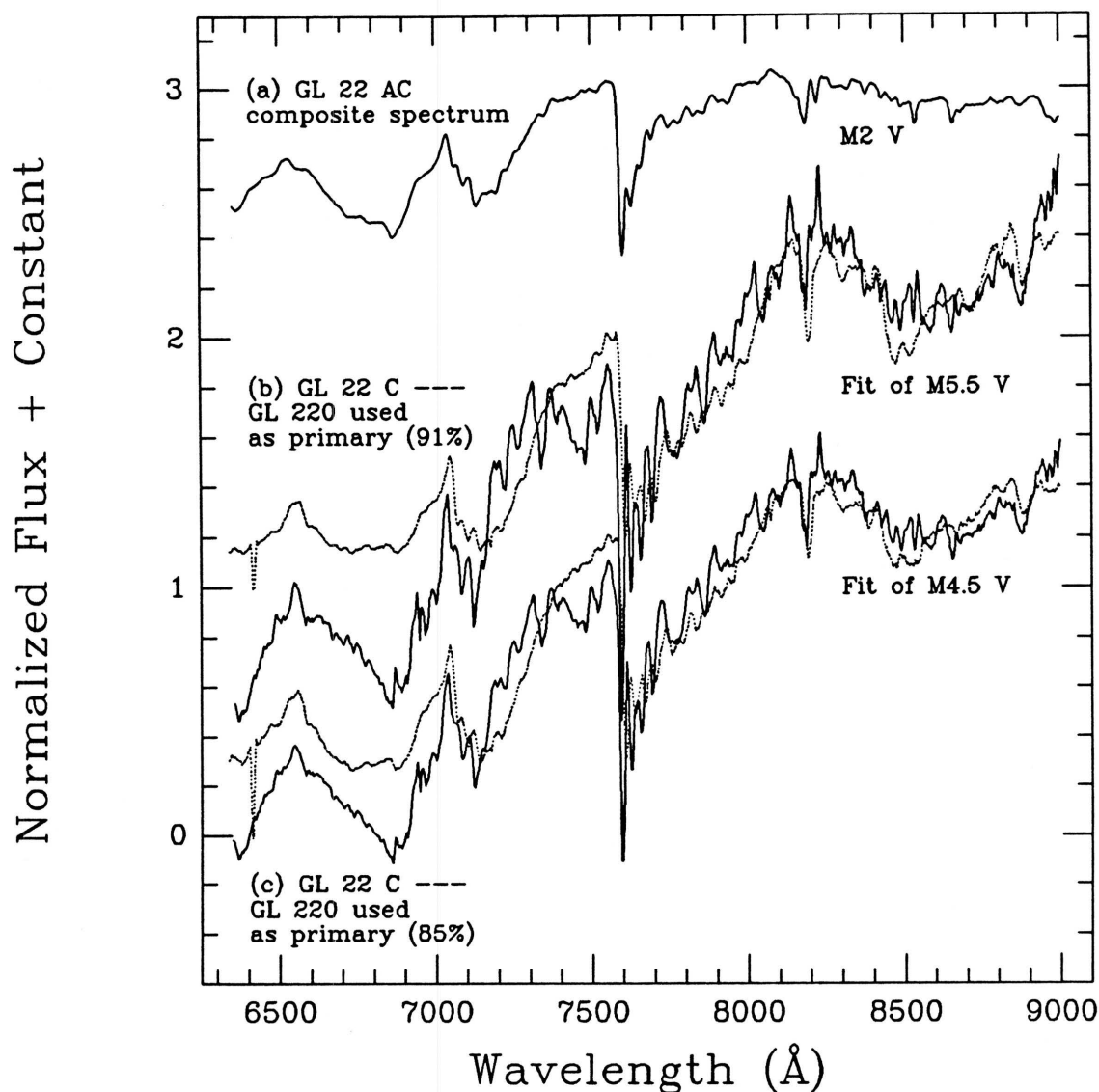
FIG. 3.23. — (a) The composite spectrum of GL 22 AC. (b) The resulting spectrum of GL 22 C, where the spectrum of GL 220 has been subtrated as that of the primary star, which is assumed to be contributing 91% of the flux in the $I$ bandpass. The spectrum representing the best match (M5.5 V) does not fit the differenced spectrum below 7500 Å, largely because the flux for GL 22 C falls below zero for part of this region. (b) The resulting spectrum of GL 22 C, again using GL 220 as the primary. In this case, the primary is assumed to contribute only 85% of the total flux at $I$. The spectrum of GL 22 C now has mainly positive flux, and the best-fit spectrum (M4.5 V) provides a more convincing match. Integral offsets have again been used for clarity.
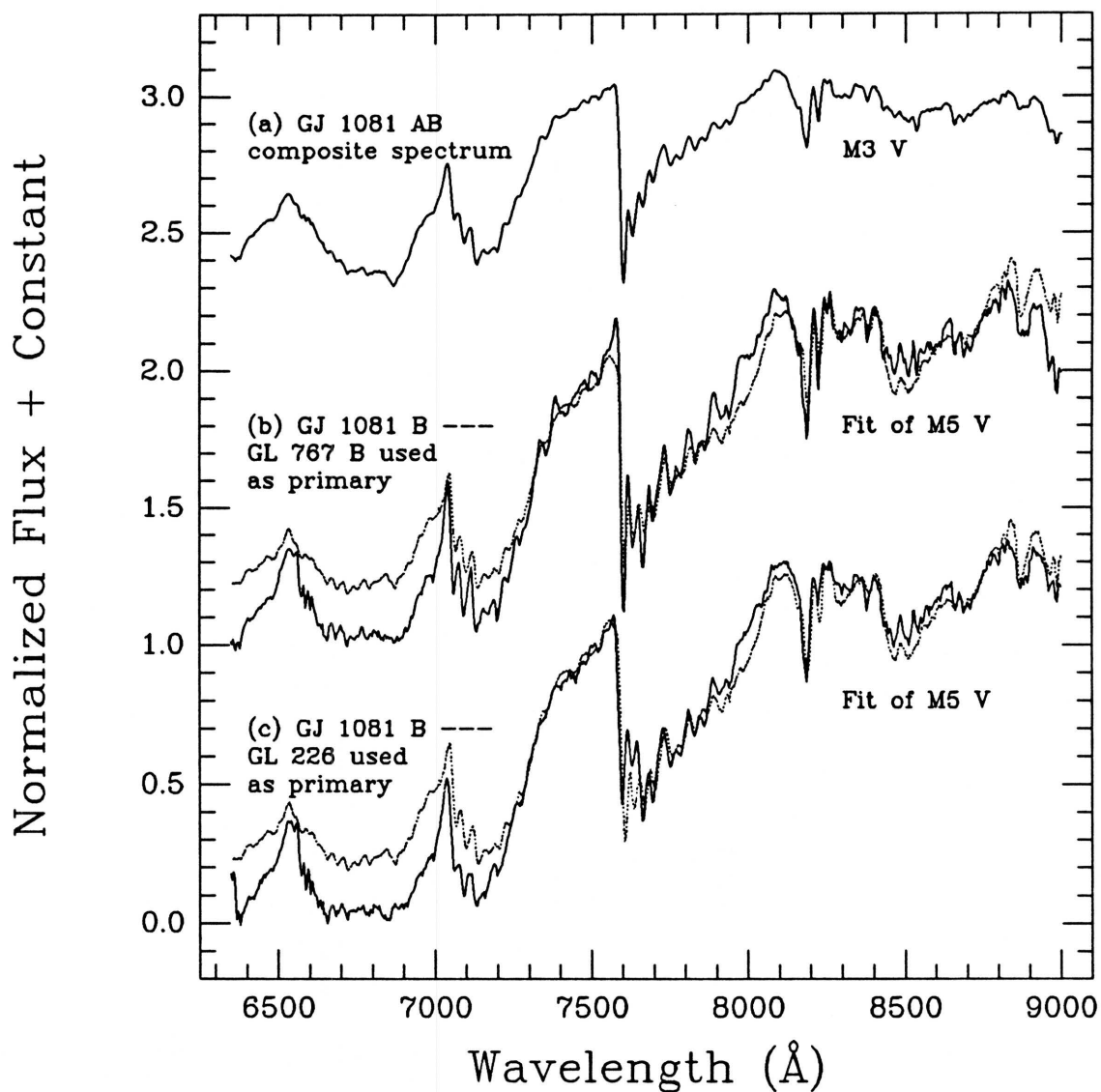
FIG. 3.24. — (a) The composite spectrum of GJ 1081 AB. (b) Thes resulting spectrum of GJ 1081 B, where the spectrum of GL 767 B has been subtracted as the spectrum of GJ 1081 A. The best fit (dashed line) gives a spectral type of M5 V. (c) The resulting spectrum of GJ 1081 B, where the spectrum of GL 226 has been subtracted as the spectrum of GJ 1081 A. The best fit here also gives a spectral type of M5 V. Again, integral offsets have been used for vertical separation.
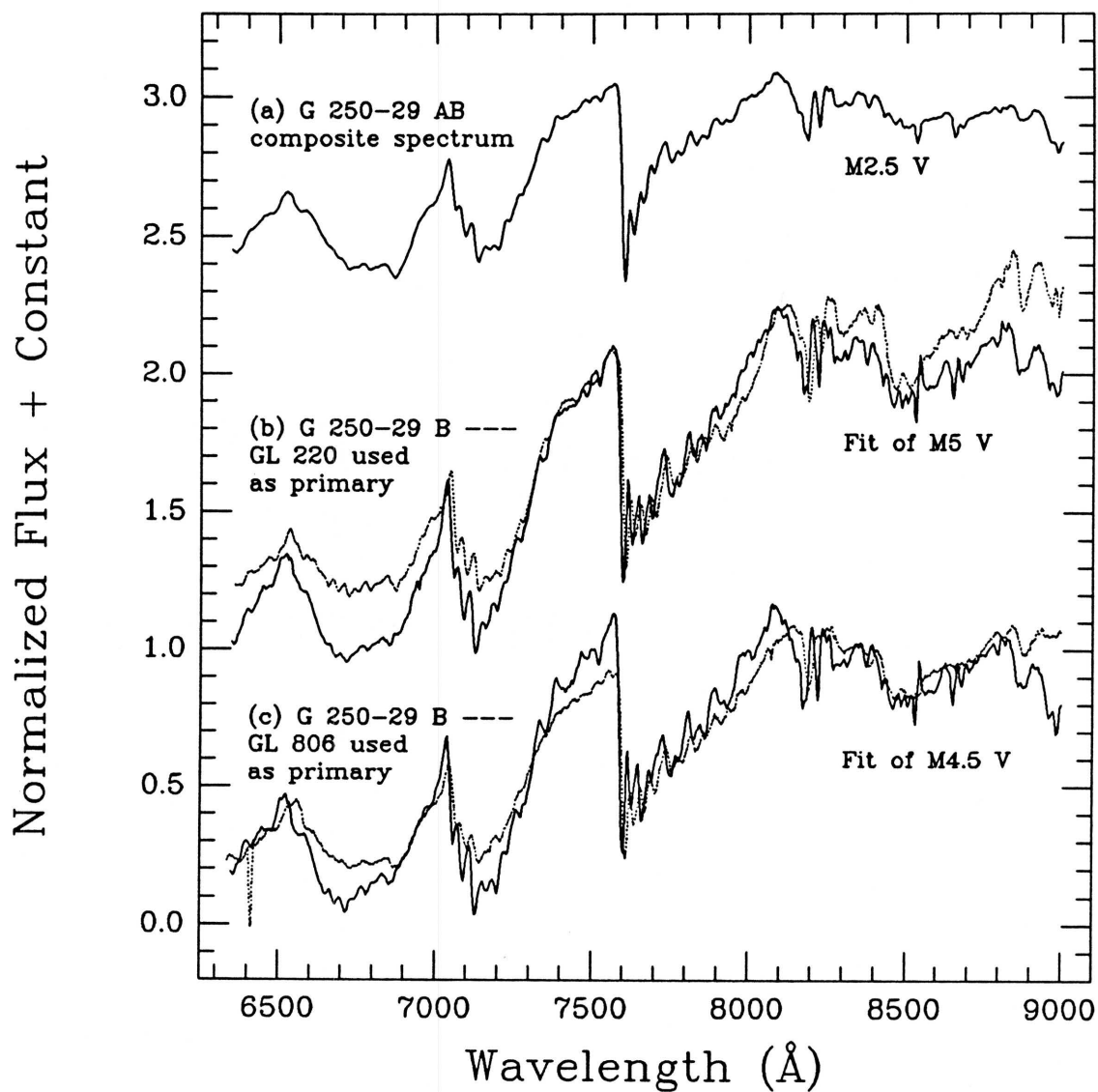
FIG. 3.25. — (a) The composite spectrum of G 250-29 AB. (b) The resulting spectrum of G 250-29 B, where the spectrum of GL 220 has been subtracted as the spectrum of G 250-29 A. The dashed line shows the best fit to the spectrum, suggesting a type of M5 V. (c) The resulting spectrum of G 250-29 B, where the spectrum of GL 806 has been subtracted as the spectrum of G 250-29 A. The best fit suggests a type of M4.5 V. Integral offsets have been added to separate the spectra vertically.
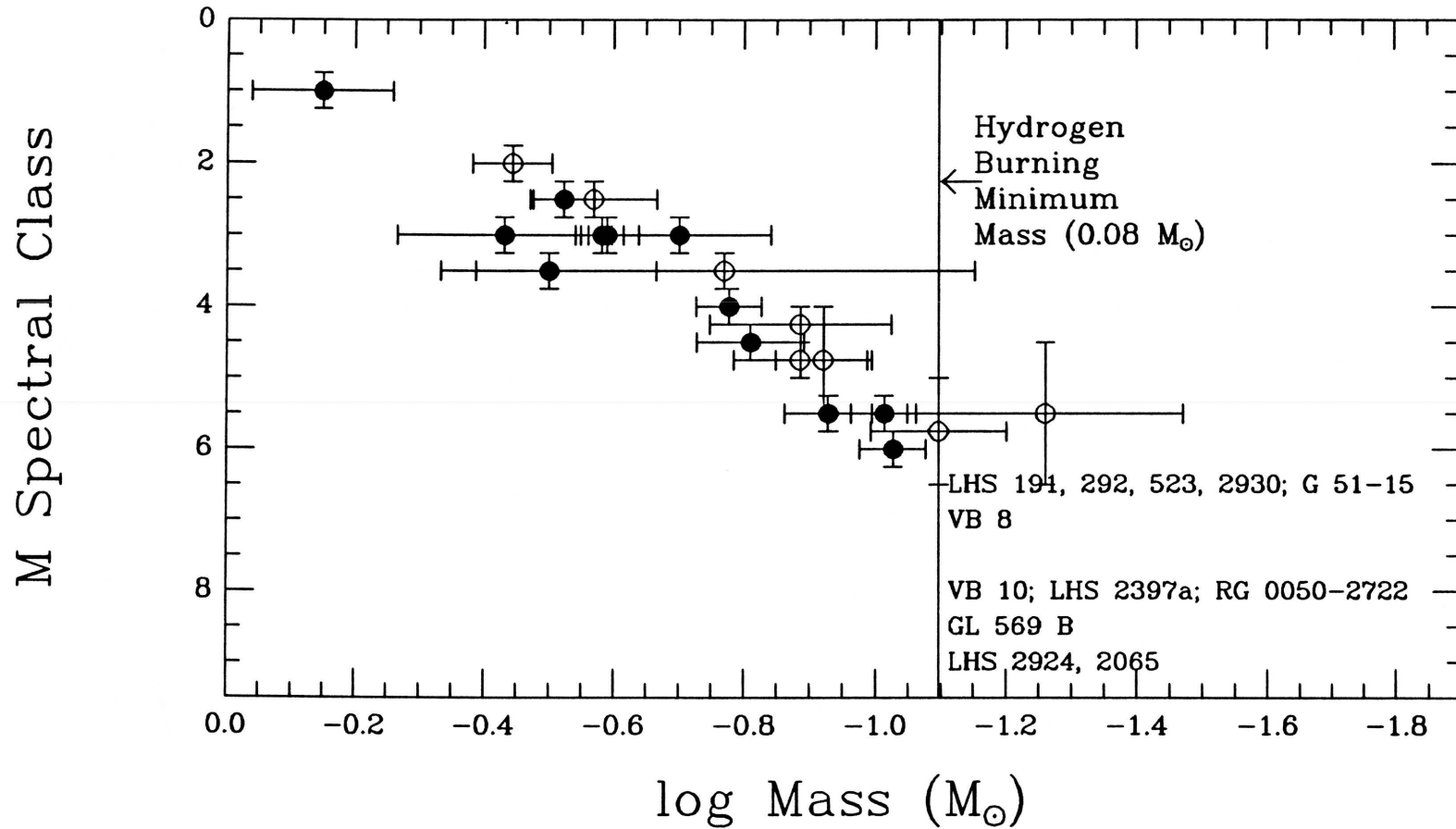
FIG. 3.26. — An adaptation of the spectral class versus mass relation for M dwarfs from Figure 3.10. The solid points are borrowed directly from Figure 3.10 except that the composite points for GL 234 AB, LHS 1047 AB, and GL 22 AC have been omitted. The open points are from Table 3.27 and represent the results of the differential spectroscopy. The aforementioned trend is confirmed based on the new data alone, and combined with the previous results suggests even more strongly that dwarfs of spectral class ~M7 and later are not stars but are actually brown dwarfs.

## 3.5: CONCLUSIONS

The results of this chapter can be briefly summarized as follows:

• An M dwarf spectral sequence from 6300 to 9000 Å has been established, and detailed identifications have been presented for features throughout this region. Temperature-sensitive and luminosity-sensitive ratios have been used to produce quantitative classification criteria.

• The M dwarf spectral sequence has been extended into the infrared (out to 1.5 $\mu$m), and theoretical spectra have been fit to the observed 0.63-to-1.50 $\mu$m data to establish a new temperature scale for M dwarfs. The new scale agrees better with theoretical calculations of the main sequence than do previous calculations based on black-body fits.

• The 6300-to-9000 Å spectrum of GD 165 B has been obtained and compared with spectra of the other lowest luminosity objects known: LHS 2924, LHS 2065, and PC 0025+0447. Its spectrum does not resemble those of the other three objects and as such is a striking deviation from the familiar M dwarf spectral sequence. Future observations throughout the infrared are required before this object can be accurately positioned on the H-R Diagram and its true nature can be revealed.

• Differential spectroscopy has been performed on five composite systems containing a low-mass secondary. The surprising result is that these objects near the stellar/substellar break are found to have spectral types no later than M6.5, suggesting that objects of type M7 and later are bona fide brown dwarfs.

# CHAPTER 4

## A SEARCH FOR OTHER LOW-MASS OBJECTS

Ye little stars! Hide your diminshed rays.
— Alexander Pope, Moral Essays, Epistle III, l. 282 (1731-1735)

This chapter describes the search — using photometric data provided by the CCD/Transit Instrument (CTI) — for stars of extremely low mass. The reddest objects discovered in the data bases have also been targeted spectroscopically in an attempt to assess the accuracy of the CTI photometry near the magnitude limit of the survey and to identify previously unknown, very late M dwarfs in the solar neighborhood. The selection of spectroscopic targets and the follow-up observations are discussed in §4.1.

Using this complementary spectroscopic information together with CTI photometry of all stars in the strip, a luminosity function for M dwarfs is produced. No other recent photometric determination of the faint end of the stellar luminosity function has obtained spectra to check the majority of targets found in the lowest luminosity bins as well as a sampling of stars found in the higher luminosity bins. These data can provide adequate statistics on the percentage of contamination by objects such as M giants and M subdwarfs and can also be used to verify that objects falling in the intrinsically faintest (and most crucial) bins are legitimate objects of extreme type. The derivation of the CTI luminosity

function is detailed in §4.2 along with a comparison to previously published versions of the luminosity function. Implications for the mass function are presented in §4.3. Results of this chapter are summarized in §4.4.

## 4.1: THE SEARCH FOR LATE-M DWARFS IN THE CTI STRIP

A thorough search of the CTI photometric data bases was begun in 1989 to identify late-K to late-M dwarfs. A subset of these objects has been observed spectroscopically with the MMT Red Channel using the setup described in the previous chapter. These spectra are used first to define a sequence of dwarf stars stretching from K5 to late-M so that a calibration of internal CTI $R - I$ and $V - I$ colors (hereafter denoted with the subscript $CTI$) with spectral type could be produced. (The magnitude limits and photometric calibration to a standard system are addressed in §4.3.) Once this correlation is established, an intensive search for stars later than M6 can begin.

### 4.1.1: Object Selection

#### a) Photometric Interrogations of Single-night Data

The data used for this survey rely primarily upon the $R_{CTI}$ and $I_{CTI}$ photometry, with $V_{CTI}$ being utilized whenever available. During the search for spectroscopic targets, $R_{CTI}$ and/or $I_{CTI}$ data had not yet been entered into the data bases for $4^h30^m \leq$ RA $\leq 6^h30^m$ and $20^h00^m \leq$ RA $\leq 22^h30^m$, both of which are areas in and around the galactic plane. Furthermore, the region having $4^h00^m \leq$ RA $\leq 4^h30^m$ encompasses the Taurus Molecular Cloud complex which, because of the reddening present, was excluded from the search area. Over the remaining sections of right ascension, the CTI data base known as the "pool list" (containing photometric data on all images ever identified during the

reduction process) was used to select the target objects. Objects were first selected over a range of $(R-I)_{CTI}$ color as a means of correlating $(R-I)_{CTI}$ and $(V-I)_{CTI}$ with spectral class. Later, objects with extremely red colors, typically $(R-I)_{CTI} \geq 1.50$, were the primary targets of the data base interrogations, although subsets of stars with $(R-I)_{CTI} < 1.50$ were selected as cloudy night back-up targets since brighter examples of these objects can be found throughout the strip.

After the data base interrogations, the identified red objects were visually identified on the reduced CCD images to check for merges with other objects, for photometric contamination by bright stars, or for objects lying too near the edges of the frame. If the object's image appeared to be free from these effects, a finder chart was produced. The latest object found from this data base interrogation was a dwarf of type M8.5. A color-color diagram using the $(V-I)_{CTI}$ and $(R-I)_{CTI}$ colors of the spectroscopic targets is given in Figure 4.1 to show the locus occupied by main sequence stars.

b) Photometric Interrogation of Coadded Data

Coadditions of many nights of CTI data can also be done to probe deeper than the nightly limiting magnitudes given in the "pool list." Coadditions in $R_{CTI}$, $I_{CTI}$, and sometimes $V_{CTI}$ were performed on $\sim 2^h$ of the $24^h$ total in the strip. This is an extremely time-consuming process, which is why only a total of $2^h$ has been completed. To examine small areas having the most archived CTI data, regions spanning only $\sim 5^m$ in RA were summed at a time. In general, the coadditions at $I_{CTI}$ included no more than 9 nights of (high-quality) data,

those at $R_{CTI}$ had no more that 8, and those at $V_{CTI}$ had as many as 27. It has been found that coadding 9 nights at $I_{CTI}$ enables the survey data to probe $\sim$2.2 magnitudes deeper than a single night's data, and coadding 8 nights at $R_{CTI}$ improves the $R_{CTI}$ limit by $\sim$1.8 magnitudes. However, many of the areas have only 2 or 3 nights of $I_{CTI}$ data and 3 or 4 of $R_{CTI}$, which extends the limit by only one magnitude or less.

The RA centers for each of the $5^m$ coadded regions are $00^h15^m$, $01^h03^m$, $01^h27^m$, $01^h57^m$, $02^h51^m$, $13^h18^m$, $13^h42^m$, $14^h15^m$, $14^h42^m$, $15^h06^m$, $15^h39^m$, $16^h09^m$, $18^h03^m$, $19^h00^m$, $19^h12^m$, $20^h27^m$, $21^h03^m$, $22^h06^m$, $22^h54^m$ and $23^h$ $36^m$. Despite the facts that some of these regions do not have both $R_{CTI}$ and $I_{CTI}$ photometry in the "pool list" and that the regions probe more deeply than the "pool list," very few extremely red stars were found that had not previously been discovered during the data base interrogations. The latest of these were an M6 dwarf and an M6.5 dwarf.

<div style="text-align:center">

c) Other Checks of the Data

</div>

Additional information can also be acquired for these objects. The finder charts can be compared to POSS prints of the same field to check visually for proper motion. This visual check is reliable only for proper motions exceeding $\sim$0.2 arcsec/yr, and then only if the field has a sufficient number of stellar images to use as positional comparisons. For many of the objects observed with the Red Channel, CTI light curves have been produced to check for possible variability. However, because most of the data entered into the data bases have been $V_{CTI}$ measurements, only light curves at $V_{CTI}$ can currently be examined.

## 4.1.2: Spectra of CTI Objects

In total, 133 spectra have been obtained of CTI objects. Appendix A includes finder charts, coordinates, photometric data, spectra, and special notes on variability, proper motion, etc. for each of the spectroscopic targets. Each spectrum is typed using the least-squares minimization technique of Chapter 3, with luminosity classes being assigned through the use of color ratios. Figure 4.2 plots the values of these ratios (defined in Table 3.7) for each of the spectra having signal-to-noise ratios of $\sim$7 or better. For the seventeen spectra having poorer quality data, luminosity classes are assigned by eye — but all have the appearance of dwarfs.

### a) Giants and Subdwarfs

Of the 133 objects, 7 are giants. Six of these lie within $\sim$10° of the galactic plane, and the seventh, at a galactic latitude of $-31°$, has $R_{CTI} \approx 11$. Light curves have been produced for six (the exception is the M4 III star CTI 192853.3+280415), and all show marked variability. These are Mira-like variables, and the brightest one, CTI 190917.7+280305, is listed in the General Catalogue of Variable Stars (Kholopov 1985) as TY Lyrae. The others have not been previously designated as variable stars.

Two of the 133 objects are found to be marginal subdwarfs — CTI 000351.3+280138 and CTI 225431.2+ 280046. No extreme, metallic hydride subdwarfs are found. All of the other 124 spectra have dwarf luminosity classifications.

## b) Very Late M Dwarfs

A total of eighteen spectra have been classified as dwarfs of type M6 or later. There are twelve objects with spectral types of M6 V, four with M6.5 V, one with M7 V (CTI 115638.5+280002), and one with M8.5 V (CTI 012657.5+280202). This last object is one of the reddest dwarfs currently known; only LHS 2924, LHS 2065, PC 0025+0447, and GD 165 B are known to be of later type. Each of these should be studied more closely to see if companions are present, and if so, follow-up studies could eventually lead to all-important mass determinations for the components.

## c) Objects with Large Proper Motion

The comparison of the CTI finder charts in Appendix A to the POSS E prints has revealed a number of proper motion objects with $\mu > 0.2$ arcsec/yr. Confirmation of these motions falls beyond the scope of this thesis, but it is worth noting that a few of these spectroscopic targets may have $\mu > 1.0$ arcsec/yr. As Benedict et al. (1991) have shown, a ten-night set of CTI frames taken over a 3-year baseline would be sufficient to detect stars with proper motions exceeding 0.175 arcsec/yr. Thus, CTI data alone could potentially be used to determine the motions of these high-$\mu$ suspects.

## 4.2: DETERMINATION OF THE LUMINOSITY FUNCTION
## FROM CTI DATA

The first step in determining the luminosity function is to calibrate the photometry to a standard system so that $(R - I)_{CTI}$ color and $I_{CTI}$ magnitude can be transformed into an absolute magnitude and a distance. The completeness limit of the survey must then be judged, and the contamination of the photometric sample by non-dwarf objects must be assessed. Once these parameters are known, the data can be binned to produce a luminosity function.

### 4.2.1: Photometric Calibration

With the spectroscopic data completed, a subset of stars having a range of M dwarf spectral types was chosen for calibration photometry. This CCD photometry was obtained at the USNO 1.0-m reflector on UT 1992 Jun 20 by Conard C. Dahn, on 1992 Jul 1 and 2 by Hugh C. Harris, and on 1992 Jul 5 and 6 by the author in collaboration with Conard C. Dahn. The CTI objects were observed at $V$ and $I$ on the Kron-Cousins system (hereafter denoted by the subscript $KC$) and reduced according to the procedures outlined in Monet et al. (1992). A listing of the USNO photometry and the CTI photometry for each of the objects observed is given in Table 4.1. As a diagnostic check, Figure 4.3 is also presented. Here, M dwarf spectral class is plotted against $(V - I)_{KC}$ and against $(R - I)_{CTI}$. There is a trend of increasing color with later spectral type, as would be expected, on both plots, except that four points have $(R - I)_{CTI}$ colors which deviate from the trend. These same four stars have $(V - I)_{KC}$ colors which are consistent with the rest of the data. Each of these has $R_{CTI} > 19.5$,

and for three of them, the errors on $(R - I)_{CTI}$ exceed 0.5 magnitude. For subsequent analyses, these four objects have been omitted.

The remaining data can be used to determine the transformation between $(R - I)_{CTI}$ and $(V - I)_{KC}$. This is shown graphically in Figure 4.4. A weighted linear least-squares fit to the data yields the equation

$$(R - I)_{CTI} - 1.50 = a + b[(V - I)_{KC} - 3.25], \qquad (4.1)$$

$$\text{where } a = -0.136 \pm 0.019$$

$$\text{and } b = 0.713 \pm 0.022.$$

This fit is shown by the solid line in Figure 4.4.

Using the CCD photometry and parallax data presented in Monet et al. (1992), a transformation from $(V - I)_{KC}$ to $M_{I_{KC}}$ can be made. These data are presented in Figure 4.5. Based on the location of objects on the color-magnitude diagram (Figure 10 of Monet et al. 1992), eighteen objects in their Table 1 have been labelled as subdwarfs and another ten as white dwarfs; these non-dwarfs are omitted from Figure 4.5. Unpublished tables of dwarf photometry covering the other data points in their Figure 10 have been kindly provided by Conard C. Dahn and are also presented in Figure 4.5. In addition, because the CTI strip has no stars as late as M9 and because this is the point at which the $(V - I)_{KC}$ color begins to turn *bluer* with later spectral type, the two M9 V stars LHS 2924 and LHS 2065 have been omitted from Figure 4.5.

These data require a correction which depends upon the size of the errors in the trigonometric parallaxes used to calculate each $M_{I_{KC}}$. A parallax value of $\pi \pm \sigma$ is more likely to represent a star further away $(\pi - \sigma)$ than a star closer $(\pi + \sigma)$ because the volume of space between parallax values of $\pi$ and $\pi - \sigma$ is

larger than that sampled between parallax values of $\pi$ and $\pi + \sigma$. The observed values of $\pi$ are thus larger than the true values, and hence the resulting absolute magnitudes will be systematically too large. Lutz & Kelker (1973) have shown that a correction can be applied which depends only upon the value of $\sigma/\pi$. This correction to $M_{I_{KC}}$ has already been applied to the individual data points in Figure 4.5. (As Lutz & Kelker (1973) have shown, trigonometric parallaxes having $\sigma/\pi > 0.175$ have indeterminate corrections, so points with large parallax errors have been omitted from Figure 4.5.) A second-order least-squares fit to these resulting points gives the relation

$$M_{I_{KC}} - 11.50 = c + d[(V-I)_{KC} - 3.25] + e[(V-I)_{KC} - 3.25]^2, \quad (4.2)$$

$$\text{where } c = -0.816 \pm 0.037,$$

$$d = 2.334 \pm 0.053,$$

$$\text{and } e = -0.107 \pm 0.055.$$

Finally, $I_{CTI}$ can be related to $I_{KC}$. A plot of $\Delta I$ vs. $(V-I)_{KC}$ (data from Table 4.1) is presented in Figure 4.6. A weighted linear least-squares fit, shown by the solid line, represents the trend well. This fit is given by

$$I_{CTI} - I_{KC} = f + g[(V-I)_{KC} - 3.25], \quad (4.3)$$

$$\text{where } f = 0.020 \pm 0.009$$

$$\text{and } g = -0.072 \pm 0.010,$$

showing that the transformation between the two systems requires a small color term. The above sequence of equations transforms the $I_{CTI}$ and $(R-I)_{CTI}$ values for any given object into a value of $M_{I_{KC}}$ and a distance for that object.

A correct transformation of color into absolute magnitude is, however, of utmost importance to an accurate derivation of the luminosity function. Although obvious subdwarfs have been removed from Figure 4.5 before the determination of equation 4.2, the data used to construct this relation are based primarily upon a *kinematically* selected sample of objects (mainly objects chosen from the proper motion lists of Luyten and Giclas). On the other hand, the CTI data to which the transformation will be applied represent a *photometrically* selected sample. To address this bias, U, V, W space motions for many of the objects plotted in Figure 4.5 have been found in Gliese & Jahreiss (1991). According to Mihalas & Binney (1981b), the V space motions of M dwarfs average around -15 to -19 km/sec, whereas subdwarfs have average V space motions of -150 km/sec. Figure 4.7 breaks the stars in Figure 4.5 into three different V velocity bins. Figure 4.7a shows the low-velocity sub-sample (V $>$ $-30$ km/sec); Figure 4.7b shows the intermediate-velocity sub-sample (-100 km/sec $<$ V $\leq$ -30 km/sec); and Figure 4.7c shows the high-velocity sub-sample (V $<$ -100 km/sec). For each part of the figure, the second-order fit from Figure 4.5 is shown. The bright end of the low-velocity sample in Figure 4.7a falls largely *above* the previous relation, whereas the bright end of the high-velocity sample in Figure 4.7c falls largely *below*. Figure 4.8 shows the low-velocity sub-sample of Figure 4.7a and a second-order least-squares fit to the sub-sample, which is given by

$$M_{I_{KC}} - 11.50 = h + j[(V - I)_{KC} - 3.25] + k[(V - I)_{KC} - 3.25]^2, \quad (4.4)$$

where $h = 0.003 \pm 0.014$,

$j = 4.254 \pm 0.044$,

and $k = -0.293 \pm 0.013$.

Because of a lack of data at the faint end, this calibration should only be considered valid for $(V - I)_{KC} < 3.0$.

The calibration given by equation 4.2 is biased towards higher velocity stars; equation 4.4 is biased towards low-velocity stars. Because a photometrically selected sample will choose stars regardless of kinematics, the true calibration needed to convert the CTI colors into absolute magnitudes lies somewhere *between* the calibrations given by these two equations. Therefore, to bracket the true luminosity function, two different luminosity functions should be derived, one using equation 4.2 and the other using equation 4.4.

<u>4.2.2: Completeness and Contamination in the Strip</u>

a) Completeness Limit at $R$

In a search for red objects where the principle criterion for selection is an $R - I$ color, the limit of the survey is dictated by the magnitude limit at $R$. To determine the limiting $R_{CTI}$ magnitude of the strip, objects in a very narrow range of color, $0.99 \leq (R - I)_{CTI} \leq 1.01$ (corresponding to a spectral class of $\sim$M3), have been selected from the "pool list" over the region $0^h \leq \mathrm{RA} < 2^h$. In this region of right ascension, the galactic latitude maintains a nearly constant value of $-35°$. The number of objects for each 0.2-magnitude bin in $R_{CTI}$ is shown by the solid line in Figure 4.9.

For a constant space density of stars, the ratio of star counts in a shell with thickness $\Delta m_1$ to the star counts in the next adjacent shell of thickness $\Delta m_2$ (where $\Delta m$ refers to the change in apparent magnitude between the far and near

sides of the shell) is

$$\frac{V_2}{V_1} = \frac{10^{\frac{3\Delta m_2}{5}} - 1}{1 - 10^{\frac{-3\Delta m_1}{5}}},\qquad(4.5)$$

or $\dfrac{V_2}{V_1} = 10^{\frac{3\Delta m}{5}}$ if $\Delta m_1 = \Delta m_2 = \Delta m$. $\qquad(4.6)$

For star counts out of the plane of the galaxy, however, the space density is not constant for successive shells but drops off as the perpendicular $z$ distance from the plane increases. The density $D(z)$ of stars is well represented by the expression

$$D(z) = D_0 e^{\frac{-|z|}{\beta}}\qquad(4.7)$$

where $D_0$ is the density of stars near the sun, $z$ is the height of the star away from the plane, and $\beta$ is the scale height. For the data examined here, this expression becomes

$$D(z) = D_0 e^{\frac{-d\ sin 35^\circ}{\beta}},\qquad(4.8)$$

where $d$ is the distance to the star from the sun. The scale height of dwarf M stars is given as 350 pc by Mihalas & Binney (1981a) and as 300 pc by Gilmore & Reid (1983). A value of $\beta = 350$ pc is adopted here, but it can be shown that a value of $\beta = 300$ pc does not change the results.

Using these two expressions, the percentage change in star counts from one bin to the next can be predicted. The dotted line in Figure 4.9 is this prediction normalized to the observed counts at $R_{CTI} = 19.1$, and the dashed line shows the prediction when normalized to the observed counts at $R_{CTI} = 18.9$. These predictions demonstrate that the CTI survey is not complete beyond $R_{CTI} = 19.5$. Based on this plot, a magnitude of $R_{CTI} = 19.0$ is chosen as a conservative estimate of the completeness limit of the CTI survey.

## b) Area of Sky Covered

Based on data obtained during the interrogation for spectroscopic targets, the useable portion of the CTI strip is found (by eliminating objects falling too near the north or south edges of the CCD frames) to have an extent of $\sim 8'10''$ in declination. The northern and southern extremes of the strip are roughly $\delta_{south}(1987.5) = 27°58'25''$ and $\delta_{north}(1987.5) = 28°06'35''$. The area encompassed by the strip is given by

$$\text{Area}_{CTI} = \frac{\text{Area}_{CTI} \text{ (steradians)}}{\text{Area}_{sky} \text{ (steradians)}}\text{(Square degrees on celestial sphere)}$$

$$= \frac{\int_{\delta_{south}}^{\delta_{north}} 2\pi\cos\theta d\theta}{4\pi}(41252.96124) \text{ square degrees}$$

$$= 43.3 \text{ square degrees}, \qquad (4.9)$$

where the value of square degrees on a sphere comes from Abell (1982).

Because of interstellar reddening near the galactic plane, the full $24^h$ range of right ascension will not be used. Maps of H I column densities and galaxy counts given in Burstein & Heiles (1982) give the total line-of-sight reddening as a function of galactic latitude and longitude. If the reddening material is assumed to have a scale height of $\sim 100$ parsecs like that of the H I, and if this material is assumed to be uniformly distributed along the line of sight, the total reddening out to a specified distance within the galaxy can be estimated. With these maps and input assumptions, plots of $E(B - V)$ as a function of right ascension along the CTI strip can be produced. These have been kindly provided by Conard C. Dahn. Assuming a distance of 100 pc, $E(B - V)$ never exceeds 0.03 magnitude for right ascensions more than 20° away from the galactic plane ($03^h47^m \leq \text{RA} < 07^h26^m$ and $18^h12^m \leq \text{RA} < 21^h51^m$), except for the region

$3^h <$ RA $< 3^h 30^m$, where the excess reaches 0.06 magnitude. Johnson (1965) presents mean extinction data for various colors along different lines-of-sight, and his average measurement of $\mathrm{E}(R - I)/\mathrm{E}(B - V)$ is 0.80, if the Orion region is excluded. Therefore, only the data having RA $< 3^h 00^m$, $7^h 26^m \leq$ RA $< 18^h 12^m$, or RA $\geq 21^h 51^m$ will be used since in these regions the data have a negligible value of $\mathrm{E}(R - I) \leq 0.02$.

Finally, no $R_{CTI}$ and/or $I_{CTI}$ data exist for $21^h 51^m \leq$ RA $< 22^h 36^m$. This, combined with the above restrictions on RA, reduces the percentage of useable area in the strip to 63.2%, or 27.4 square degrees.

## c) Contamination by Non-dwarfs

Contamination of the CTI photometric data by objects which are not dwarfs has been examined in the previous section. Spectroscopy revealed 2 subdwarfs out of 133 objects. This $\sim$2% contamination by subdwarfs is negligible.

A total of 7 giants was discovered among the 133 spectroscopic targets. Six fall within $\sim$10° of the galactic plane, and the seventh is sufficiently bright that the distance derived using its $(R - I)_{CTI}$ color in the dwarf calibration equations would be conspicuously small. Thus, excluding areas near the galactic plane assures that contamination by giants is also negligible.

## 4.2.3: Analysis of the Photometric Data

### a) Imposed Distance Limit

With the transformations to a standard system established and with completeness and contamination problems assessed, the data bases can now be interrogated. Because of the large area covered by this survey and because of the faint limiting magnitude attained, there will be a sufficient number of objects per bin in the luminosity function even if a distance limit of 100 parsecs is imposed upon the sample of stars. The reason for limiting the sample volume to this radius is twofold:

(1) The drop in star density for areas out of the plane will be negligible at this distance. At the North Galactic Pole, the density of M dwarfs will have dropped to 72% of its value in the solar neighborhood; for areas in the strip which look more obliquely along the galactic plane, the decrease in density at 100 parsecs is even less than this. If objects much greater than 100 parsecs were to be included, the exponential factor, which for a given distance depends upon the galactic latitude and hence upon the right ascension, would have to be incorporated into the star counts to normalize the computed density to the value in the solar neighborhood. This factor depends upon the scale height, which is not accurately known and thus inserts another uncertainty into the calculations.

(2) For distances under 100 parsecs, reddening problems will be minimized. (See discussion in §4.2.2 above.)

b) Scrutiny of the Photometrically Selected Objects via Internal Checks

For the calculation of the luminosity function, the CTI "master list" was used since this data base contains only those objects which have a high probability of being real detections (unlike the "pool list" which includes photometric information for *all* identified objects). The data were searched for all objects having $M_{I_{KC}} \geq 8.00$ and derived distances not exceeding 100 parsecs. This resulted in the discovery of 283 candidates.

The selection of candidates indicates that there are some values of right ascension which occur more frequently than would be expected from a random distribution of M dwarfs along the strip. In particular, there are twelve small regions having a preponderance of red objects, and at each of these regions a nearby, bright star was found. These stars are generally of late type themselves, and they greatly influence the photometric measurements of other objects lying near them on the sky. The identification of these affected areas resulted in the removal of 117 objects. A list of these bright stars is given in Table 4.2. CTI images show the affected region around $\beta$ Geminorum (Pollux) to be $\sim 3^{m} 30^{s}$ long; a smaller area ($< 3^{m}$ long) around $\beta$ Pegasi (Scheat) is also affected. (The other bright star mentioned in Chapter 2, $\beta$ Cygni (Albireo), does not fall in the range of right ascension discussed here.) The fainter stars in Table 4.2 contaminate much smaller regions. If a total area of $\sim 7^{m}$ in right ascension is assumed to be unuseable because of bright stars, then the useable portion of the strip is only 27.2 square degrees, instead of 27.4. This small change in total area would increase the resulting logarithmic space densities by only 0.003, which is considered negligible.

Two additional objects were excluded because their values of $R_{CTI}$ and $(R - I)_{CTI}$ would indicate that $V_{CTI} < 19.0$ for each, yet neither was detected at $V$. These two objects, CTI 002737.2+280025 and CTI 170411.6+280620 are considered spurious and are not considered further. Also, because of the large photometric uncertainties for extremely faint objects, no objects with $R_{CTI} \geq$ 20.0 have been used for the determination of the luminosity function. (Although the *completeness* limit has been taken to be $R_{CTI} = 19.0$, the *limiting magnitude* is chosen to be $R_{CTI} = 20.0$.) This criterion has led to the elimination of another eight objects. Another object, CTI 103415.5+280117, has been excluded because it is merged with another object on the CCD frame.

For the remaining 155 objects, those with $M_{I_{KC}} < 12.0$ all have $I$, $R$, *and* $V$ measurements, so color criteria based on the results of Figure 4.1 can be employed to discard obviously bad data. A plot of $(V - I)_{CTI}$ vs. $(R - I)_{CTI}$ for these objects is shown in Figure 4.10. Objects lying along the locus of main sequence stars (defined by Figure 4.1) are denoted by filled circles, and those points with discrepant photometry are denoted by open circles. (Three additional points are so discrepant that they fall off the plot as shown.) Using this plot, a total of 19 objects is eliminated. To aid in further checking the validity of remaining objects, Figure 4.11 is produced. This plot shows $(B - I)_{CTI}$ vs. $(R - I)_{CTI}$ for those objects in Figure 4.10 having $B_{CTI}$ photometry. At first glance, Figure 4.11 appears to show a second sequence of stars lying beneath the sequence defined by the majority of the objects. This second sequence, however, does not represent a sequence of giants or subdwarfs, as verified by Figure 4.12, which shows the $(B - I)_{CTI}$ vs. $(R - I)_{CTI}$ diagram for spectroscopically observed dwarfs (filled circles) and giants (open triangles). The dwarf targets are shown to have a large

scatter of $(B - I)_{CTI}$ values, and two spectroscopically identified giants having $R_{CTI} > 12.0$ do not distinguish themselves from the dwarfs on this plot. Because M giants are high amplitude variable stars and because CTI cannot acquire $B$ and $I$ (for example) simultaneously, it is not clear what the $(B - I)_{CTI}$ values for these objects actually represent. Over time, with the inclusion of many more nights of data into the data bases, these will reflect the mean colors of the giants over their light curves. Despite this problem with separating the luminosity classes via color-color diagrams, spectroscopy has, as noted previously, already shown that giant contamination is negligible. At a later time, light curves of all selected objects can be produced from CTI data so that any giants which may still be contaminating the counts can be removed.

Of the nine objects having $M_{I_{KC}} \geq 12.0$, seven have been observed spectroscopically and have dwarf spectral types of M6 or later. A spectrum of CTI 022000.5+275933 has not been acquired, but because its finder chart shows it to be free from sources of photometric contamination, it is retained. A spectrum of CTI 153915.6+280445 has also not been obtained, but this object, along with CTI 174729.0+280322 (M6.5 V), falls outside of the distance limit (72 pc) of its absolute magnitude bin (see discussion below).

As a final internal check, Figure 4.13, which plots the number of remaining objects vs. right ascension, is produced. Within the (Poissonian) errors, this histogram is, as one would expect, flat. The total number of objects thus remaining is 136.

c) Scrutiny of the Photometrically Selected Objects via External Checks

As an external check of the completeness of the CTI data, the NLTT Catalogue (Luyten 1979) is used to generate a list of proper-motion selected objects lying in the CTI strip. These objects are given in Table 4.3. Column 1 gives the LP or other name of the 60 NLTT objects falling in the strip; columns 2 and 3 give the magnitudes as listed in the NLTT Catalogue; column 4 lists Luyten's color class of the object; and column 5 gives the proper motion in arcseconds per annum. Incorporating both proper motion as well as precession of the coordinates (using the precession coefficients listed in Lang 1980), the 1950 positions are updated to equinox 1987.5 coordinates (epoch 1987.5) to give a predicted CTI positional designation for each of these objects. These predicted coordinates are listed in columns 6 and 7. The CTI "master list" is then searched for objects near these locations, yielding the corresponding CTI name of the NLTT star as listed in column 8. Columns 9 and 10 list the $R_{CTI}$ and $I_{CTI}$ photometry of the objects.

Of the 60 objects, 58 were clearly detected by the CTI. Of the two not detected, Wolf 411 ($m_r = 11.1$) and LP 340-555 ($m_r = 11.3$) are bright enough so that saturation problems in the CCD system and subsequent CTI photometric analysis have, most likely, failed to distinguish these objects as single entities; $\beta$ Gem, for example, is broken into many photometric segments by the CTI photometry routines, and the segment falling nearest the predicted position has a magnitude of only $V_{CTI} = 10.8$. There is little doubt that stars this bright could have been "missed."

Column 11 of Table 4.3 gives a note indicating if the object is used toward the construction of the CTI luminosity function (Table 4.4) and if not, why it is not used. Some fall outside of the range of RA being used for the analysis, others are too blue ($(R-I)_{CTI} < 0.60$), others are too bright ($R_{CTI} < 12.0$), and others are determined to be beyond the 100-pc cutoff (in which case the derived distance is listed). In total, there are 12 objects out of 60 which satisfy the criteria used for determination of the luminosity function. In summary, this external check shows that the CTI has detected, with 100% success, objects listed in Luyten's volumes. Therefore, the percentage of objects which should have been detected by the CTI but which were missed during photometric reductions is negligibly small. The main reason for missed objects is the incompleteness at very faint ($R_{CTI} > 19.0$) magnitudes.

## 4.2.4: CTI Luminosity Function and Comparison to Others

The final list of objects used in the derivation of the luminosity function is presented in Table 4.4, which is a compendium of sub-tables, one for each of the twelve half-magnitude bins between $M_{I_{KC}} = 8.00$ to 14.00. Listed are the CTI designation for each object, the $R_{CTI}$ magnitude and $(R - I)_{CTI}$, $(V - I)_{CTI}$, and $(B - I)_{CTI}$ colors, the derived absolute magnitudes at $I_{KC}$ and $V_{KC}$, the distance and its propagated error, and the resulting value of $V/V_{max}$. In this last quantity, $V$ is the volume of the sphere having a radius equal to the object's calculated distance, and $V_{max}$ is the maximum value of $V$ for which the object would still be included in the luminosity function — which, for all but the faintest bins, is a volume of 100-pc radius.

The first bin, centered at $M_{I_{KC}} = 8.25$, is incomplete because non-linearity effects in the CCD make photometry for stars with $R_{CTI} < 12.0$ unreliable. The bin centered at $M_{I_{KC}} = 12.25$ is marginally incomplete since an object having $M_{I_{KC}} = 12.50$ and lying 100 parsecs away would have $R_{CTI} = 19.40$, fainter than the completeness limit of the strip. The three lowest luminosity bins are not complete to 100 parsecs even when the limiting magnitude of $R_{CTI} = 20.0$ is considered. These only probe to distances of 97, 72, and 53 parsecs for bin centers of $M_{I_{KC}} = 12.75$, 13.25, and 13.75, respectively.

The average $V/V_{max}$ values for each bin are listed in the footnotes of Table 4.4. For a randomly distributed sample of stars, the $V/V_{max}$ average in each bin should be 0.5 since half of the objects in the bin should lie in the nearer half of the volume, and the rest should lie in the farther half. If this number is not near 0.5, then the sample is either not uniformly distributed or is incomplete. Within the errors, however, all of the bins have $V/V_{max} \sim 0.5$, with the exception of the faintest, which contains only one point. The number of objects found in each bin is summarized in Table 4.5, along with the distance probed by each (the volume is 2782 pc$^3$ for $d = 100$ pc), and the logarithm of the observed luminosity function $\Phi_{obs}$, in units of number per cubic parsec per unit $M_{I_{KC}}$ bin.

This "uncorrected" luminosity function is shown in Figure 4.14 (solid symbols), along with the $M_{I_{KC}}$ luminosity function at the South Galactic Pole (open circles) as determined by Leggett & Hawkins (1988). The error bars represent the square root of the number of stars in each bin. Note that the number of stars predicted by the two samples are virtually the same within the errors. Both luminosity functions show an upturn in the luminosity function beyond $M_{I_{KC}} = 12.5$, though these upturns are based on usually one or two objects per

bin. The upturns are consistent with the theoretically predicted contribution by brown dwarfs to the luminosity function. The dashed line in Figure 4.14 shows the brown dwarf luminosity function calculated by Nelson, Rappaport, & Joss (1986) and normalized so that 0.08 $M_\odot$ $pc^{-3}$ is the total local mass density of substellar objects.

If calibration equation 4.4 (based on low-velocity parallax stars only) is used instead of equation 4.2, this changes the makeup of the first three bins of the luminosity function. The new membership of the first three bins is shown in Table 4.6. This dramatically alters the shape below $M_{I_{KC}} = 10.0$, as shown by the open circles in Figure 4.15. The true luminosity function for $8.00 \leq M_{I_{KC}} \leq 9.50$ falls somewhere between the solid circles and the open circles in the figure.

As presented, none of the luminosity functions in Figures 4.14 or 4.15 has been corrected for the Malmquist effect or Malmquist bias, which can be thought of as the absolute-magnitude analogue of the Lutz-Kelker. For a full description of the Malmquist corrections, see Stobie, Ishida, & Peacock (1989) and Leggett & Hawkins (1988). Once the "uncorrected" luminosity function $\Phi(M)$ has been calculated, the Malmquist correction, which depends upon the first and second derivatives of $\Phi(M)$, can be applied to the star counts in each bin. This is accomplished via the equation

$$\frac{N_{obs}}{N_{true}} = 1 + \frac{\sigma_M{}^2}{2} \frac{1}{\Phi(M)} \left[ 10^{-0.6M} (0.6 \ln 10)^2 \Phi(M) - 1.2 \ln 10 \frac{d\Phi}{dM} + \frac{d^2\Phi}{dM^2} \right],$$

(4.10)

where $N_{obs}$ is the observed number of objects in the bin, $N_{true}$ is the true number of objects, and $\sigma_M$ is the typical error in absolute magnitude. Values for the quantities $\sigma_M$, $N_{obs}/N_{true}$, and $\log \Phi_{true}$ are also given in Table 4.5. The derivatives are computed by using the forward- and central-difference formulas

given in Conte & de Boor (1980). Figure 4.16 compares the uncorrected CTI luminosity function (solid circles and triangles) with the luminosity function once the Malmquist correction has been applied (solid squares). The absolute magnitude errors in the faintest bins are so large that accurate corrections cannot be applied.

Also shown in Figure 4.16 (open squares) is the luminosity function for objects within 5.2 parsecs of the sun and north of $\delta = -20°$ (updated here but originally presented in Dahn, Liebert, & Harrington 1986). For comparison to this version of the CTI luminosity function, the 5.2-parsec sample was recomputed at $I$ (photometry from Leggett 1992) and supplemented with the newest trigonometric parallax data from Gliese & Jahreiss (1991). The data for these objects are given in Table 4.7. All objects with $M_{I_C} \geq 7.0$, $\delta \geq -20°$, and $d <$ 5.2 parsecs listed in Gliese & Jahreiss (1991) are tabulated, with the exception of white dwarfs. GJ 1116 A and B and GL 412 A and B, originally included in the 5.2 parsec census, now fall outside of that volume, and GL 866 is now listed as a double star. Using Probst's equations (Chapter 3.4) together with individual infrared magnitudes determined through speckle observations, the $I$ magnitudes for the close binaries in the list have been de-convolved into their separate components. The trigonometric parallaxes are so well known that the Lutz-Kelker correction is negligible, and the errors in the absolute magnitudes will correspondingly be small, making the Malmquist correction negligible. The largest source of error comes from the paucity of known objects — Poisson errors are indicated in Figure 4.16.

The luminosity function for nearby stars is virtually flat from $M_I = 8.5$ to 11.5 with a gradual decline to $M_I = 13.5$. This form of the luminosity function is

quite different from the CTI determination. One possible reason for this is that binaries are more easily resolved in the nearby sample, and this tends to raise the faint end of the luminosity function as lower luminosity companions are found, while lowering the brighter end as the resolved primaries shift to lower luminosity bins themselves. Henry & McCarthy (1990) argue that the difference between their luminosity function for nearby stars and luminosity functions found during more distant, magnitude-limited surveys is due solely to the inability of the more distant surveys to recognize duplicity. Reid (1991), on the other hand, models the effect of unresolved binaries and finds that this effect can not reconcile the differences between the nearby sample and the more distant ones which rely on photometric parallaxes. He suggests that the solar neighborhood has an excess of low-luminosity objects.

To address this issue, the 5.2-pc sample of Table 4.7 is re-investigated. To convert this luminosity function into a luminosity function like that derived from the CTI data, three effects must be considered. First, the photometrically derived samples are based on a volume with a much larger average distance from the sun. For the 100-pc cut-off, half-volume occurs at 79 pc. If the 5.2-pc sample were moved to this distance, many of the multiple systems would be unresolvable. Second, the 5.2-pc sample relies on accurate *trigonometric* parallaxes to compute distances, whereas *photometric* parallaxes are used in the 100-pc sample. Third, because of the cosmic scatter in the absolute magnitude vs. color relation, some of the objects in the nearby sample will have estimated distances *greater* than 5.2 pc, and some objects outside of the volume will have estimates placing them *within* 5.2 pc. As a result of these three effects, a larger volume of stars needs to be considered; those stars need to be thought of as residing at a larger distance to

determine which composite systems are no longer resolvable; and $(V - I)$ colors and $I$ photometry for each single star or system need to be used to compute absolute magnitudes and distances.

A complete sample of M dwarfs out to 7 pc was selected from Gliese & Jahreiss (1991). (Twenty-five objects, including several binaries, between 7 and 10 pc were also selected, but for none of these did the photometrically derived distance place them within 5.2 pc.) The 7-pc sample includes 74 objects. $V$ and $I$ photometry was provided by Conard C. Dahn or taken from Leggett (1992) for most of these; however, photometry for GJ 1005 AB was taken from Chapter 3.4, and no $I$ photometry was found for either G 99-49 or GL 338 AB. G 99-49 is an M4 dwarf whose trigonometric parallax places it at 5.4 pc; because of its proximity to the 5.2-pc cut-off, a distance for this object derived photometrically could place it within the 5.2-pc sample. GL 338 AB has a trigonometric parallax placing it at 6.2 pc; because this binary would have composite photometry in the more distant sample, it is likely that this object's photometrically derived distance (which would be an underestimate of the true distance) would place it within 5.2 pc. The spectral types of GL 338 A and B presented in Chapter 3.1, however, indicate that this derived absolute magnitude will likely be $M_I < 8.0$, placing it outside of the sample considered here. Regardless, these two systems would add (at most) two more points to the luminosity function described below — one at mid-M types and the other at early M. Exclusion of these does not alter the conclusions which follow.

Once the remaining entries in the 7-pc sample are considered, the resulting luminosity function contains 28 "objects" of which 15 are single stars and 13 are composites (consisting of 12 binaries and 1 triple system). This result is

compared to other luminosity functions in Figure 4.17. This photometrically derived "nearby" luminosity function differs from the true nearby luminosity function in that it now predicts a peak at $M_I \sim 9.5$ (like the CTI luminosity function) and predicts fewer objects at lower luminosities (also like the CTI luminosity function). In fact, this new result is in close agreement with the CTI luminosity function over most of the range of $M_I$. The major, remaining discrepancy between the two occurs at the bin centered on $M_I = 11.5$. Whereas the CTI luminosity function would predict only one object in this bin, it is found that 5 "objects" actually fall there: GL 65 AB, GL 473 AB, GJ 1245 ABC, GL 866 AB, and GL 905. Thus, 80% of the "objects" are composite — the highest frequency of binaries in the other bins is 57%. This preponderance of composite systems, together with the fact that these results involve small numbers, suggests that the overabundance at $M_I = 11.5$ is a mere statistical fluctuation. Were it not for the large number of composites, fewer objects would be found in this bin and more would fall in the adjacent bin at $M_I = 12.5$, where the CTI luminosity function predicts only a lower limit. In this case, the new luminosity function presented here would very closely mimic that from the CTI. Therefore, the true 5.2-pc luminosity function and luminosity functions like the one determined from CTI data are consistent when unresolved binarity and photometric uncertainties are considered.

Using the data presented in Table 4.4, the CTI luminosity function can also be constructed at $V$. This is shown in Figure 4.18 and tabulated in Table 4.8. In Figure 4.18 the CTI derivation (solid symbols) is also compared to Reid & Gilmore's (1982) derivation (open circles) which agrees well with the CTI determination. Both show a peak in the predicted counts around $M_{V_{KC}} = 12.0$

and an increase at faint $(M_{V_{KC}} > 15.5)$ luminosities.

Table 4.6 can also be used to re-derive the brighter end of the luminosity function when equation 4.4 is used instead of equation 4.2. The result (Figure 4.19) is a lowering in the predicted number of stars with $10.0 \leq M_{V_{KC}} \leq 12.5$, with a possible shift in the peak of the luminosity function toward fainter magnitudes. Again, the true function lies somewhere between the solid symbols and the open symbols on the diagram.

The Malmquist correction at $V$ is also given in Table 4.8 and is illustrated by the solid squares in Figure 4.20. This is compared to the Wielen, Jahreiss, & Kruger (1983) luminosity function (open triangles) which is based on objects known within 20 parsecs and which is basically flat for the range $12 < M_V < 17$. The disparity between the CTI sample and a sample based on nearby stars has been discussed above.

## 4.3: IMPLICATIONS FOR THE MASS FUNCTION

The luminosity function can also be used to address the more fundamental question: "Does the density of M dwarfs rise for lower and lower masses and if so, does this increase predict enough mass for the faintest M dwarfs (and even brown dwarfs) to account for the local missing matter?" As basic as this question is to galactic structure, it remains very difficult to answer based on the lack of observational data — and portions of the analysis frequently revert to theory.

Most derivations of the mass function ($\xi$ = number of stars per unit mass interval per unit volume) have relied on converting absolute magnitudes at a particular bandpass into a bolometric absolute magnitude, and then with the help of some form of the mass-luminosity relation have converted these magnitudes into masses. A slightly different approach will be attempted here — one which requires fewer steps and relies only upon empirically derived quantities.

Consider the objects listed in Table 3.10. All of these objects are within 20 parsecs and have well determined parallaxes. Several of these have $I$ photometry listed in Leggett (1992), so absolute magnitudes at $I$ can be computed. Several of these have composite $I$ photometry only, but in the spirit of Table 4.7 these can be de-convolved into component magnitudes based on speckle observations. Where the components are nearly equal in magnitude and mass, the joint $I$ magnitude has been made fainter by 0.75 mag and an average of the two masses taken. In Figure 4.21 these absolute $I$ magnitudes are plotted as a function of mass. Regrettably, this figure has only nine points and some of those have poorly determined masses, but nonetheless, a trend of decreasing mass ($M$) with fainter $M_{I_{KC}}$ is evident. A weighted linear least-squares fit to these data is shown by

the solid line in the figure. Its functional form is

$$\mathsf{M} = 0.646 - 0.046 M_I. \tag{4.11}$$

Solving this equation for the minimum hydrogen-burning mass of $\mathsf{M} = 0.08 M_\odot$ gives $M_I = 12.3$, which is the point where the luminosity function reaches its minimum. This would give credence to the ideas that (1) the rise in the luminosity function noted beyond $M_I = 12.3$ represents the appearance of the brown dwarf component, and (2) as suggested in Chapter 3.4, objects of spectral type $\sim$M7 and later are indeed brown dwarfs.

However, this relation maps $M_I$ linearly into mass, so the shape of the mass function ($\xi$) mimics that of the luminosity function ($\Phi$). This is shown by the solid circles in Figure 4.22. The mass function rises slowly toward $\sim 0.2 M_\odot$, then drops off quickly toward the end of the main sequence. A similar effect, shown by the open circles in Figure 4.22, is seen even when the mass function is derived from the nearby luminosity function of Figure 4.16. One might expect a priori, however, that the mass function should climb steadily for decreasing mass, meaning that lower mass objects are formed in larger numbers than high mass ones throughout the M dwarf regime.

Therefore, a second fit of the $M_I$ vs. mass data is acquired — this time with a weighted second-order least-squares solution. This fit is shown by the dotted line in Figure 4.21 and has the form

$$\mathsf{M} = 1.590 - 0.231 M_I + 0.009 M_I{}^2. \tag{4.12}$$

This mapping of $M_I$ into mass results in the mass function $\xi$ shown by the solid circles in Figure 4.23. Here, $\xi$ increases toward $0.17 M_\odot$, drops toward the

hydrogen burning limit, then begins to increase again after $0.13 M_\odot$. The mass function derived from the nearby luminosity function (open circles) is essentially flat (within the errors) above a mass of $0.17\ M_\odot$ and then increases dramatically towards the hydrogen burning limit. A small change in the form of the absolute magnitude-mass relation has made a substantial difference in the shape of the mass function.

The integrated mass density is nearly identical for the two nearby mass functions presented in Figures 4.22 and 4.23 — $0.014\pm0.001 M_\odot\ pc^{-3}$ for $M_I \geq 8.0$ (masses below $M \sim 0.3 M_\odot$). Unless the upward tail seen in the CTI luminosity function is indicative of a large, previously undetected population of (substellar) objects, the missing mass in the solar neighborhood is not in the form of low-luminosity M dwarfs and brown dwarfs.

## 4.4: SUMMARY

The CTI data base has been used to search for previously unrecognized M dwarfs of extremely late type. In total, eighteen objects having classifications of M6 V or later were found, and the latest of these has a spectral type of M8.5, ranking it with the latest "dwarf" objects known.

The CTI data base has also been used to construct the stellar luminosity function for M dwarfs at both $I$ and $V$. Both exhibit a slow rise for the early M stars, reaching a peak at $M_I \sim 9.5$ ($M_V \sim 12.0$), then declining rapidly to a minimum at $M_I \sim 12.0$ ($M_V \sim 15.5$). At fainter magnitudes there appears to be an increase in the number density which might be caused by a brown dwarf component of the luminosity function.

Comparisons of these luminosity functions to others derived by Leggett & Hawkins (1988) and Reid & Gilmore (1982) show that the same general result is found. The luminosity function for stars within 5.2 and 20 parsecs shows an essentially constant density except for the faintest bins. It has been illustrated that this effect is caused by the resolving of binaries into their individual components for the nearby surveys, whereas for the more distant surveys, these systems show up as single points in higher absolute magnitude bins.

Lastly, unless the upturn seen for the faintest magnitudes of the CTI luminosity function is suggesting a large population of still undetected objects, the missing mass, if there *is* mass missing, is *not* in the form of low-luminosity M dwarfs. Obtaining this result has, however, highlighted the current difficulty in relating the luminosity function to a mass function. Until more observational data points linking absolute magnitude with mass are measured, the difficulty

will remain. This involves the search for and follow-up investigation of more late-type objects — some of which, it is hoped, will be members of close binary systems so that dynamical masses can eventually be determined. These objects will also aid in better defining the faint end of the luminosity function. Proposed directions for this search are outlined in the next chapter.

TABLE 4.1

USNO PHOTOMETRY OF CTI M DWARFS

| CTI Object No. | Spec. | $I_{KC}$ | $(V-I)_{KC}$ | $I_{CTI}$ | $(R-I)_{CTI}$ |
|---|---|---|---|---|---|
| 131541.4+280227 | M4 | 14.098±.019 | 2.976±.043 | 14.15±.01 | 1.21±.01 |
| 135347.7+280418 | M6 | 15.764±.020 | 3.687±.054 | 15.75±.04 | 1.60±.06 |
| 141111.3+280141 | M5.5 | 16.403±.023 | 3.543±.055 | 16.41±.06 | 1.43±.09 |
| 141237.7+280559 | M3 | 14.583±.018 | 2.458±.042 | 14.66±.02 | 0.78±.02 |
| 141329.8+280131 | M2.5 | 14.579±.024 | 2.355±.031 | 14.64±.01 | 0.73±.02 |
| 153915.6+280214[a] | M4 | 18.444±.026 | 2.815±.058 | 18.62±.21 | 2.33±.79 |
| 153915.6+280446 | M6.5 | 17.897±.021 | 4.433±.117 | 17.77±.11 | 1.92±.49 |
| 153945.1+280234 | M1.5 | 14.044±.016 | 2.124±.056 | 14.15±.01 | 0.56±.01 |
| 153948.1+280322 | M2 | 14.737±.016 | 2.213±.026 | 14.83±.01 | 0.65±.02 |
| 154231.3+280401 | M5.5 | 16.705±.034 | 3.620±.062 | 16.71±.20 | 1.81±.28 |
| 160557.4+280437[a] | M3 | 18.191±.037 | 2.501±.096 | 17.96±.20 | 1.55±.28 |
| 161340.2+280011 | M5.5 | 17.306±.022 | 3.916±.062 | 17.32±.29 | 1.77±.41 |
| 170958.5+275905 | M5.5 | 13.903±.024 | 3.674±.031 | 13.88±.02 | 1.58±.03 |
| 171818.0+280512 | M5 | 16.830±.022 | 3.366±.123 | 16.93±.12 | 1.57±.18 |
| 174729.0+280322 | M6.5 | 17.872±.022 | 4.271±.197 | 17.57±.29 | 2.21±.42 |
| 180120.1+280410 | M2.5 | 14.699±.025 | 2.265±.028 | 14.79±.01 | 0.60±.02 |
| 180304.9+280256 | M2.5 | 14.876±.034 | 2.368±.042 | 15.01±.01 | 0.76±.03 |
| 191216.8+280229[a] | M4 | 17.171±.027 | 2.946±.057 | 17.40±.40 | 2.21±.57 |
| 202738.5+280227[a] | M3 | 18.454±.107 | 2.527±.126 | 18.03±.50 | 2.86±.35 |
| 223752.5+275918 | M1 | 14.763±.020 | 2.059±.056 | 14.84±.02 | 0.48±.03 |

[a] Data point has been removed from subsequent analyses. See text for details.

TABLE 4.2

BRIGHT, CONTAMINATING STARS IN (OR NEAR THE EDGE OF)
THE CTI STRIP

| SAO # | RA[a] | (1987.5) Dec[a] | $m_V$[b] | Spec[b] | Total[c] | Note |
|-------|--------|-----------------|----------|---------|----------|------|
| 75137 | 02:05:11.5 | +28:02:31 | 9.0 | K7 | 3 | BD +27°329 |
| — | 02:18:45.9 | +28:00:47 | 11.1[d] | M7 III[e] | 5 | see Appendix A |
| 75520 | 02:40:49.0 | +27:59:35 | 8.8 | K7 | 3 | BD +27°420 |
| 79434 | 07:29:02.1 | +27:56:34 | 5.1 | K0 | 18 | 65 Gem |
| 79666 | 07:44:33.1 | +28:03:25 | 1.2 | K0 | 6 | $\beta$ Gem |
| 80181 | 08:25:42.2 | +27:56:07 | 5.8 | K2 | 7 | $\phi^1$ Cnc |
| 80511 | 08:54:54.8 | +27:58:33 | 5.2 | G5 | 2 | $\rho^2$ Cnc |
| 82706 | 13:11:17.4 | +27:56:28 | 4.3 | G0 | 7 | $\beta$ Com |
| 85220 | 17:34:08.1 | +27:59:50 | 8.8 | K7 | 3 | BD +28°2780 |
| 90732 | 22:42:23.5 | +28:05:30 | 8.9 | M8 | 39 | BD Peg |
| 90981 | 23:03:10.0 | +28:00:53 | 2.6 | M0 | 22 | $\beta$ Peg |
| 91472 | 23:45:10.9 | +28:06:29 | 7.9 | F5 | 2 | BD +27°4614 |

[a] Precessed to equinox 1987.5 and updated to epoch 1987.5 using the proper motion values listed in the SAO Catalog.

[b] Values taken from the SAO Catalog, unless otherwise stated.

[c] Number of objects out of the 283 total whose photometry is affected by this bright star.

[d] $R_{CTI}$ magnitude.

[e] From Appendix A.

## TABLE 4.3

## STARS FROM THE NLTT CATALOGUE WHICH SHOULD BE IN THE CTI STRIP

| LP# | $m_r$ | $m_{pg}$ | col | $\mu$ | RA(1987.5) | Dec$^a$ | CTI Name | $R_{CTI}{}^b$ | $(R-I)_{CTI}$ | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 294-34 | 16.0 | 17.5 | m | .192 | 01:00:04.3 | 27:59:42 | 010005.0+275941 | 15.18 | 0.64±.13 | d=176±11 pc |
| +27°262 | 7.9 | 8.8 | G5 | .534 | 01:38:53.2 | 28:02:55 | 013853.9+280256 | (<11.1) | — | too bright |
| — | 10.5 | 11.6 | k | .240 | 01:42:56.0 | 27:59:38 | 014256.7+275937 | <10.02 | 0.19±.01 | too bright |
| — | 11.8 | 12.9 | k | .240 | 01:42:58.0 | 27:59:26 | 014257.9+275925 | <10.50 | 0.21±.01 | too bright |
| 297-8 | 14.6 | 15.7 | k | .190 | 02:08:59.6 | 28:05:06 | 020859.6+280504 | 13.57 | 0.82±.05 | in Table 4.4 |
| 298-38 | 11.4 | 12.5 | k | .284 | 02:49:29.0 | 28:03:33 | 024929.6+280328 | <10.84 | 0.11±.01 | too bright |
| 298-47 | 10.2 | 11.7 | m | .280 | 02:54:56.0 | 28:04:51 | 025456.4+280449 | <10.18 | 0.26±.01 | too blue |
| 299-34 | 14.5 | 15.6 | k | .223 | 03:11:49.0 | 28:04:45 | 031149.0+280442 | 13.77 | 0.06±.01 | RA excluded |
| 300-18 | 18.2 | 21.1 | m | .193 | 03:35:32.8 | 28:06:10 | 033533.4+280608 | 17.25 | 1.02±.09 | RA excluded |
| 301-16 | 18.9 | 21.0 | m | .184 | 03:57:50.2 | 28:01:10 | 035750.4+280105$^c$ | 17.47 | 1.41±.08 | RA excluded |
| 302-46 | 12.8 | 14.5 | m | .205 | 04:40:41.0 | 27:59:26 | 044041.1+275919 | (13.32) | — | RA excluded |
| R 411 | 11.0 | 12.1 | k | .347 | 05:34:13.3 | 28:05:28 | 053413.5+280529 | (<11.6) | — | RA excluded |
| — | 14.2 | 15.7 | m | .305 | 05:47:25.3 | 28:03:15 | 054725.2+280312 | (14.65) | — | RA excluded |
| 308-14 | 14.0 | 15.5 | m | .197 | 07:02:44.2 | 28:02:19 | 070244.0+280215 | 13.52 | 0.63±.08 | RA excluded |
| $\beta$ Gem | 1.1 | 2.2 | K0 | .625 | 07:44:34.1 | 28:03:28 | 074434.0+280331 | (<10.8) | — | too bright |
| 313-5 | 11.6 | 13.4 | m | .202 | 09:02:10.9 | 28:04:37 | 090210.4+280434 | 11.40 | 0.72±.01 | too bright |
| 314-8 | 16.6 | 18.5 | m | .227 | 09:28:38.2 | 28:06:33 | 092838.3+280629 | 16.03 | 0.80±.06 | d=188±20 pc |
| +28°1779 | 8.9 | 9.8 | G5 | .203 | 09:36:06.8 | 28:01:46 | 093606.5+280149 | <8.61 | — | too bright |
| 314-68 | 14.9 | 15.5 | g | .238 | 09:48:13.5 | 28:03:38 | 094811.7+280337 | 14.19 | -0.07±.01 | too blue |
| 315-63 | 17.4 | 20.9 | m+ | .193 | 10:17:10.5 | 28:02:11 | 101710.9+280213 | 16.75 | 1.11±.03 | d=141±9 pc |

TABLE 4.3 — continued

| LP# | $m_r$ | $m_{pg}$ | col | $\mu$ | RA(1987.5) | Dec[a] | CTI Name | $R_{CTI}$[b] | $(R-I)_{CTI}$ | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| +28°1902 | 6.7 | 7.8 | K0 | .186 | 10:34:08.7 | 28:01:38 | 103407.9+280137 | (<9.3) | — | too bright |
| 317-5 | 15.2 | 16.9 | m | .390 | 10:45:59.2 | 27:58:31 | 104559.5+275829 | 14.46 | 0.15±.02 | too blue |
| — | 12.8 | 14.6 | m | .210 | 10:53:45.7 | 28:02:36 | 105345.9+280235 | <11.88 | 0.38±.02 | too blue |
| 317-36 | 17.8 | 19.7 | m | .223 | 10:59:46.2 | 28:01:19 | 105945.8+280120 | 17.06 | 0.03±.06 | too blue |
| 319-8 | 12.8 | 13.1 | f-g | .182 | 11:38:46.8 | 28:00:14 | 113846.6+280016 | 12.24 | -0.27±.03 | too blue |
| W 411 | 11.1 | 12.6 | M1 | .198 | 12:23:01.5 | 27:59:06 | (not found) | — | — | too bright |
| 321-218 | 17.7 | 19.6 | m | .222 | 12:40:49.4 | 28:02:27 | 124049.5+280231 | 17.02 | 1.34±.04 | d=102±7 pc |
| 321-106 | 15.3 | 16.8 | m | .245 | 12:41:54.1 | 28:06:18 | 124154.1+280620 | 14.69 | 0.05±.02 | too blue |
| 322-403 | 15.1 | 16.6 | m | .185 | 13:01:41.9 | 28:03:53 | 130144.9+280346 | 13.88 | 0.62±.05 | d=101±6 pc |
| 322-1178 | 16.5 | 18.0 | m | .228 | 13:15:40.2 | 28:02:08 | 131541.3+280227[c] | 15.35 | 1.21±.01 | in Table 4.4 |
| 323-25 | 17.9 | 20.3 | m | .500 | 13:20:15.1 | 28:04:06 | 132017.4+280347[d] | 16.76 | 1.20±.03 | d=118±7 pc |
| +28°2242 | 10.4 | 11.0 | G5 | .220 | 13:35:06.2 | 27:59:39 | 133505.7+275945 | (<11.5) | — | too bright |
| — | 16.2 | 16.0 | a | .261 | 13:49:10.6 | 27:59:03 | 134910.5+275904[e] | 15.64 | -0.39±.06 | too blue |
| 324-30 | 18.3 | 20.3 | m | .180 | 13:53:47.3 | 28:04:13 | 135347.7+280419[c] | 17.35 | 1.60±.06 | in Table 4.4 |
| 325-1 | 18.6 | 20.8 | m+ | .186 | 14:11:11.1 | 28:01:37 | 141111.3+280141[c] | 17.84 | 1.43±.08 | d=125±17 pc |
| 325-29 | 18.2 | 20.5 | m | .212 | 14:20:53.5 | 28:02:32 | 142053.4+280234 | 17.68 | 0.92±.08 | d=315±39 pc |
| 327-10 | 17.0 | 18.3 | k-m | .196 | 15:04:58.1 | 28:01:57 | 150457.9+280202 | 16.32 | 1.00±.03 | d=145±8 pc |
| — | 13.3 | 14.8 | m | .377 | 16:00:42.5 | 27:59:25 | 160042.7+275927 | 12.82 | 0.67±.01 | in Table 4.4 |
| 331-4 | 17.7 | 19.4 | m | .220 | 16:49:57.5 | 28:06:37 | 164956.9+280642 | 17.15 | 0.14±.10 | too blue |
| 331-23 | 14.2 | 16.0 | m | .187 | 16:58:13.1 | 28:01:30 | 165812.6+280131 | 13.73 | 0.67±.01 | in Table 4.4 |

TABLE 4.3 — continued

| LP# | $m_r$ | $m_{pg}$ | col | $\mu$ | RA(1987.5) | Dec$^a$ | CTI Name | $R_{CTI}{}^b$ | $(R-I)_{CTI}$ | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 331-41 | 11.7 | 12.3 | g | .278 | 17:04:35.7 | 28:03:10 | 170435.1+280315 | <10.90 | -0.27±.01 | too blue |
| 332-10 | 14.3 | 15.8 | m | .287 | 17:14:17.6 | 28:06:28 | 171417.4+280630 | 13.56 | 0.96±.01 | in Table 4.4 |
| 332-17 | 16.1 | 17.6 | m | .237 | 17:18:34.5 | 28:05:47 | 171834.3+280550 | 14.85 | 0.86±.01 | in Table 4.4 |
| 333-8 | 15.8 | 16.9 | k | .244 | 17:41:21.1 | 28:01:22 | 174121.4+280126 | 15.66 | -0.02±.03 | too blue |
| 333-26 | 14.7 | 16.4 | m | .241 | 17:54:44.0 | 28:03:59 | 175443.4+280405 | 13.51 | 0.77±.01 | in Table 4.4 |
| 334-3 | 16.1 | 17.6 | m | .297 | 18:05:58.2 | 28:04:17 | 180558.5+280419 | 15.51 | 1.15±.02 | in Table 4.4 |
| 334-45 | 17.8 | 19.4 | m | .298 | 18:30:02.2 | 28:05:04 | 183002.4+280506 | 16.35 | 0.09±.11 | RA excluded |
| — | 15.3 | 16.4 | k | .240 | 18:48:17.6 | 28:05:24 | 184817.9+280533 | 13.75 | 0.29±.01 | RA excluded |
| R 712 | 12.6 | 13.2 | g | .270 | 18:49:25.9 | 28:04:56 | 184925.5+280459 | <11.70 | -0.36±.01 | RA excluded |
| 340-555 | 11.3 | 12.8 | m | .243 | 21:04:49.2 | 28:05:03 | (not found) | — | — | RA excluded |
| 342-7 | 14.6 | 16.3 | m | .260 | 21:38:59.2 | 28:02:20 | 213859.6+280219 | (15.14) | — | RA excluded |
| 343-42 | 15.3 | 16.6 | k-m | .183 | 22:17:22.0 | 28:04:41 | 221722.6+280441 | 14.45 | — | RA excluded |
| 344-8 | 11.3 | 11.9 | g | .229 | 22:27:41.2 | 28:02:54 | 222741.1+280253 | 10.36 | — | RA excluded |
| $\beta$ Peg | 2.6 | 4.1 | M0 | .237 | 23:03:10.0 | 28:00:54 | 230310.5+280045 | <10.00 | — | too bright |
| 345-43 | 16.6 | 17.7 | k | .281 | 23:07:06.6 | 28:01:35 | 230706.6+280135 | 15.78 | 0.60±.04 | d=252±23 pc |
| 345-49 | 18.1 | 20.2 | m | .222 | 23:10:13.8 | 28:02:25 | 231013.8+280223 | 17.15 | 1.11±.12 | d=170±31 pc |
| 346-7 | 14.5 | 15.6 | k | .198 | 23:20:16.2 | 28:06:06 | 232016.4+280607 | 13.62 | 0.82±.01 | in Table 4.4 |
| 346-14 | 17.1 | 18.6 | m | .187 | 23:21:33.0 | 28:00:40 | 232133.4+280040 | 16.35 | 1.08±.04 | d=125±10 pc |
| 346-43 | 17.5 | 19.4 | m | .206 | 23:31:33.2 | 28:01:58 | 233133.1+280158 | 16.59 | 1.35±.05 | in Table 4.4 |
| 346-50 | 14.0 | 15.5 | m | .232 | 23:34:51.8 | 27:59:56 | 233452.3+275955 | 13.18 | 0.99±.01 | in Table 4.4 |

TABLE 4.3 — continued

*a* Predicted coordinates for epoch and equinox 1987.5

*b* Parenthetical values refer to $V_{CTI}$ photometry

*c* In Appendix A

*d* Luyten appears to have overestimated this object's proper motion. The CTI star listed in the table has been confirmed from CTI images to be the proper motion object (LP 323-25 = LHS 2723) in question.

*e* In Table 2.1

## TABLE 4.4

## OBJECTS USED IN THE DERIVATION OF THE CTI LUMINOSITY FUNCTION

(a) $8.0 \leq M_{I_{KC}} < 8.5$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 023847.2+280001 | 12.75 | 0.71±.01 | 2.18±.01 | 3.57±.01 | 8.45±.12 | 10.78±.13 | 50±3 | 0.13 |
| 081639.4+280502 | 13.88 | 0.69±.01 | 2.17±.01 | 3.58±.02 | 8.38±.12 | 10.68±.13 | 88±5 | 0.68 |
| 082957.2+275934 | 13.89 | 0.64±.01 | 2.09±.01 | 3.39±.01 | 8.20±.13 | 10.43±.14 | 98±6 | 0.94 |
| 094720.8+280132 | 13.32 | 0.63±.01 | 2.09±.01 | 3.49±.01 | 8.16±.13 | 10.38±.14 | 77±5 | 0.46 |
| 101140.7+275859 | 14.06 | 0.69±.01 | 2.16±.01 | 3.42±.02 | 8.37±.13 | 10.67±.13 | 96±6 | 0.88 |
| 105543.8+275850 | 13.49 | 0.65±.01 | 2.12±.01 | 3.50±.02 | 8.23±.13 | 10.47±.14 | 80±5 | 0.51 |
| 124540.8+275915 | 13.60 | 0.60±.01 | 2.04±.01 | 3.37±.03 | 8.06±.14 | 10.23±.14 | 93±6 | 0.80 |
| 154930.3+280216 | 13.37 | 0.64±.01 | 2.13±.01 | 3.74±.02 | 8.22±.13 | 10.46±.14 | 76±5 | 0.44 |
| 155023.4+280613 | 13.01 | 0.66±.01 | 2.15±.01 | 3.62±.03 | 8.28±.13 | 10.54±.13 | 63±4 | 0.25 |
| 160042.7+275927 | 12.82 | 0.67±.01 | 2.18±.01 | 3.86±.01 | 8.31±.13 | 10.58±.13 | 56±3 | 0.18 |
| 165812.6+280131 | 13.73 | 0.67±.01 | 2.20±.01 | 3.91±.02 | 8.30±.13 | 10.57±.13 | 86±5 | 0.64 |
| 224754.6+280029 | 13.14 | 0.61±.01 | 2.05±.01 | 3.38±.01 | 8.09±.14 | 10.28±.14 | 74±5 | 0.41 |
| 232230.1+280303 | 13.59 | 0.67±.01 | 2.17±.01 | 3.56±.01 | 8.31±.13 | 10.59±.13 | 80±5 | 0.51 |

Average $\frac{V}{V_{max}} = 0.53 \pm 0.03$.

TABLE 4.4 — continued

(b) $8.5 \leq M_{I_{KC}} < 9.0$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 003238.9+280229 | 14.73 | 0.84±.01 | 2.36±.01 | 3.75±.03 | 8.92±.11 | 11.44±.11 | 95±5 | 0.86 |
| 003257.9+280102 | 14.39 | 0.75±.01 | 2.25±.01 | 3.69±.02 | 8.59±.12 | 10.97±.12 | 99±5 | 0.97 |
| 011544.7+280414 | 12.97 | 0.81±.01 | 2.30±.01 | 3.68±.07 | 8.82±.11 | 11.30±.11 | 45±2 | 0.09 |
| 011557.5+275930 | 14.79 | 0.86±.01 | 2.41±.01 | 3.80±.03 | 8.98±.11 | 11.52±.11 | 95±5 | 0.86 |
| 020859.6+280504 | 13.57 | 0.82±.01 | 2.32±.01 | 4.15±.01 | 8.84±.11 | 11.32±.11 | 59±3 | 0.21 |
| 072709.4+280352 | 14.71 | 0.83±.02 | 2.41±.01 | 3.77±.02 | 8.88±.11 | 11.38±.12 | 96±5 | 0.88 |
| 083520.9+280004 | 14.19 | 0.84±.01 | 2.37±.01 | 3.79±.03 | 8.92±.10 | 11.43±.11 | 74±4 | 0.41 |
| 093631.3+280237[a] | 14.49 | 0.84±.01 | 2.37±.01 | 3.87±.02 | 8.92±.10 | 11.44±.11 | 85±4 | 0.61 |
| 111007.3+275952 | 13.96 | 0.80±.01 | 2.30±.01 | 3.68±.02 | 8.77±.11 | 11.23±.11 | 73±4 | 0.39 |
| 114014.1+280624 | 14.81 | 0.85±.02 | 2.42±.01 | 3.91±.06 | 8.93±.11 | 11.45±.12 | 98±5 | 0.94 |
| 134024.0+280508 | 13.92 | 0.79±.01 | 2.39±.01 | 3.75±.02 | 8.72±.11 | 11.16±.12 | 73±4 | 0.39 |
| 135842.2+280642 | 14.16 | 0.84±.01 | 2.43±.01 | 3.82±.07 | 8.90±.11 | 11.41±.12 | 74±4 | 0.41 |
| 140051.1+280653 | 14.55 | 0.80±.01 | 2.36±.01 | — | 8.76±.12 | 11.22±.13 | 96±5 | 0.88 |
| 145115.0+275902 | 13.02 | 0.81±.01 | 2.30±.01 | 3.77±.01 | 8.81±.11 | 11.28±.11 | 46±2 | 0.10 |
| 154107.1+280508 | 13.24 | 0.78±.01 | 2.29±.01 | 3.78±.04 | 8.70±.11 | 11.14±.12 | 54±3 | 0.16 |
| 170759.1+280555 | 14.01 | 0.78±.01 | 2.33±.01 | 4.04±.02 | 8.70±.11 | 11.14±.12 | 78±5 | 0.47 |
| 171834.3+280550 | 14.85 | 0.86±.01 | 2.29±.01 | 3.57±.04 | 8.98±.11 | 11.52±.12 | 98±5 | 0.94 |
| 175443.4+280405 | 13.51 | 0.77±.01 | 2.37±.01 | 3.79±.02 | 8.67±.11 | 11.09±.12 | 63±3 | 0.25 |
| 225113.8+280022 | 14.02 | 0.73±.01 | 2.25±.01 | 3.71±.02 | 8.54±.12 | 10.90±.13 | 86±5 | 0.64 |

TABLE 4.4 — continued

(b) $8.5 \leq M_{I_{KC}} < 9.0$ (continued)

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 231028.2+280452 | 14.50 | 0.84±.02 | 2.38±.01 | 3.78±.03 | 8.90±.12 | 11.41±.12 | 87±5 | 0.66 |
| 232016.4+280607 | 13.62 | 0.82±.01 | 2.36±.01 | 3.75±.02 | 8.84±.11 | 11.32±.12 | 60±3 | 0.22 |
| 233843.5+280219 | 14.40 | 0.77±.01 | 2.29±.01 | 3.76±.02 | 8.67±.12 | 11.09±.12 | 95±5 | 0.86 |

Average $\frac{V}{V_{max}}$ = 0.55±0.02.

[a] Spectrum M3 V.

TABLE 4.4 — continued

$$\text{(c) } 9.0 \le M_{I_{KC}} < 9.5$$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 001956.9+275927 | 15.25 | 0.99±.01 | 2.63±.01 | 3.92±.04 | 9.43±.09 | 12.15±.10 | 90±4 | 0.73 |
| 002151.7+280450 | 14.71 | 1.00±.01 | 2.60±.01 | 3.92±.03 | 9.47±.09 | 12.21±.10 | 69±3 | 0.33 |
| 010332.0+280234[b] | 15.37 | 1.00±.01 | 2.56±.01 | 4.14±.05 | 9.45±.10 | 12.19±.10 | 94±4 | 0.83 |
| 014344.1+280344 | 14.72 | 0.87±.01 | 2.40±.01 | 3.83±.03 | 9.01±.10 | 11.56±.11 | 90±4 | 0.73 |
| 015115.8+280458[b] | 15.05 | 0.99±.01 | 2.57±.01 | — | 9.42±.10 | 12.14±.10 | 83±4 | 0.57 |
| 015723.6+275946 | 13.58 | 0.89±.01 | 2.43±.01 | 3.79±.01 | 9.07±.10 | 11.65±.10 | 51±2 | 0.13 |
| 022228.2+275853 | 14.85 | 0.96±.01 | 2.55±.01 | 3.72±.03 | 9.34±.10 | 12.03±.10 | 79±4 | 0.49 |
| 074104.7+280143 | 15.16 | 0.94±.02 | 2.51±.02 | 3.92±.05 | 9.25±.11 | 11.90±.12 | 96±5 | 0.88 |
| 075350.3+280306 | 14.63 | 0.91±.02 | 2.47±.01 | 3.97±.03 | 9.16±.11 | 11.78±.11 | 79±4 | 0.49 |
| 083524.2+280412 | 15.23 | 1.00±.01 | 2.60±.01 | 3.96±.07 | 9.48±.09 | 12.22±.10 | 87±4 | 0.66 |
| 095541.2+280148 | 14.71 | 1.00±.01 | 2.59±.01 | 4.10±.03 | 9.48±.09 | 12.23±.10 | 68±3 | 0.31 |
| 101912.3+280028 | 15.16 | 0.96±.01 | 2.55±.01 | 4.00±.04 | 9.33±.10 | 12.02±.10 | 91±4 | 0.75 |
| 103555.5+280005 | 15.16 | 0.92±.01 | 2.48±.01 | 3.88±.04 | 9.18±.10 | 11.80±.11 | 100±5 | 1.00 |
| 104642.9+280435 | 14.76 | 0.95±.01 | 2.55±.01 | 4.09±.03 | 9.29±.09 | 11.95±.10 | 78±3 | 0.47 |
| 105707.5+280223[c] | 14.17 | 0.88±.01 | 2.45±.01 | 3.92±.02 | 9.05±.10 | 11.62±.11 | 68±3 | 0.31 |
| 112959.7+280044 | 14.70 | 0.99±.01 | 2.60±.01 | 4.12±.03 | 9.43±.09 | 12.16±.10 | 70±3 | 0.34 |
| 115339.5+280332 | 15.01 | 0.90±.01 | 2.44±.01 | 3.90±.06 | 9.12±.10 | 11.71±.11 | 97±5 | 0.91 |
| 115350.7+280342 | 13.58 | 0.91±.01 | 2.47±.01 | 3.90±.02 | 9.17±.10 | 11.79±.10 | 49±2 | 0.12 |
| 125417.4+280002 | 15.05 | 0.95±.01 | 2.54±.01 | 3.93±.06 | 9.31±.10 | 11.98±.10 | 88±4 | 0.68 |
| 142531.5+280033 | 15.03 | 0.95±.01 | 2.53±.01 | 4.07±.03 | 9.28±.10 | 11.94±.10 | 89±4 | 0.70 |

TABLE 4.4 — continued

(c) $9.0 \leq M_{I_{KC}} < 9.5$ (continued)

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 144455.1+280618 | 14.82 | 0.88±.01 | 2.46±.01 | 3.87±.12 | 9.06±.10 | 11.64±.11 | 92±4 | 0.78 |
| 144708.9+275947 | 14.79 | 0.89±.01 | 2.46±.01 | 4.00±.03 | 9.09±.10 | 11.68±.11 | 88±4 | 0.68 |
| 151814.8+280548 | 14.46 | 0.97±.01 | 2.60±.01 | — | 9.37±.10 | 12.07±.11 | 65±3 | 0.27 |
| 161117.0+280426 | 13.74 | 0.96±.01 | 2.61±.01 | 4.42±.02 | 9.33±.09 | 12.02±.10 | 47±2 | 0.10 |
| 165052.8+275958 | 15.16 | 0.94±.02 | 2.57±.01 | 4.26±.06 | 9.26±.11 | 11.92±.11 | 95±5 | 0.86 |
| 171417.4+280630 | 13.56 | 0.96±.01 | 2.61±.01 | — | 9.34±.09 | 12.03±.10 | 43±2 | 0.08 |
| 180525.2+275914 | 15.17 | 0.97±.03 | 2.75±.01 | 4.47±.07 | 9.36±.13 | 12.06±.14 | 90±5 | 0.73 |
| 230637.3+280228 | 14.57 | 0.95±.01 | 2.53±.01 | 3.87±.03 | 9.30±.10 | 11.97±.11 | 71±3 | 0.36 |
| 233452.3+275955 | 13.18 | 0.99±.05 | 2.63±.04 | 4.03±.01 | 9.44±.09 | 12.18±.09 | 34±1 | 0.04 |
| 233855.8+280517 | 14.69 | 0.97±.02 | 2.58±.01 | 3.99±.03 | 9.37±.11 | 12.07±.12 | 72±4 | 0.37 |
| 234725.1+280306 | 13.15 | 0.87±.01 | 2.38±.01 | 3.76±.01 | 9.02±.10 | 11.58±.11 | 44±2 | 0.09 |

Average $\frac{V}{V_{max}}$ = 0.51±0.01.

[b] Spectrum M3.5 V.

[c] Spectrum M3 V.

TABLE 4.4 — continued

$$(d) \ 9.5 \le M_{I_{KC}} < 10.0$$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 001251.1+280535[d] | 15.43 | 1.03±.02 | 2.67±.01 | 4.32±.18 | 9.56±.10 | 12.34±.11 | 91±4 | 0.75 |
| 002241.4+280145 | 14.86 | 1.07±.01 | 2.73±.01 | 4.33±.03 | 9.71±.09 | 12.55±.09 | 64±3 | 0.26 |
| 005108.5+280103 | 15.58 | 1.06±.01 | 2.71±.01 | 4.18±.05 | 9.66±.09 | 12.48±.10 | 92±9 | 0.78 |
| 021537.7+275838 | 15.20 | 1.09±.01 | 2.91±.01 | — | 9.76±.09 | 12.62±.10 | 73±3 | 0.39 |
| 074001.0+280406 | 15.11 | 1.10±.02 | 2.75±.01 | 4.25±.05 | 9.80±.10 | 12.68±.11 | 70±3 | 0.34 |
| 074046.2+275917 | 14.78 | 1.01±.02 | 2.63±.01 | 4.08±.03 | 9.51±.10 | 12.26±.11 | 69±3 | 0.33 |
| 080302.4+280017 | 15.87 | 1.12±.02 | 2.96±.01 | 4.54±.10 | 9.88±.10 | 12.79±.11 | 93±4 | 0.80 |
| 091237.6+280105 | 15.37 | 1.02±.01 | 2.64±.01 | 3.98±.07 | 9.52±.10 | 12.28±.10 | 91±4 | 0.75 |
| 092641.4+275836 | 15.24 | 1.03±.02 | 2.67±.02 | 3.98±.11 | 9.56±.11 | 12.33±.11 | 83±4 | 0.57 |
| 094558.7+275949 | 14.90 | 1.02±.01 | 2.63±.01 | 4.09±.04 | 9.53±.09 | 12.30±.10 | 72±3 | 0.37 |
| 095536.6+280143 | 14.27 | 1.02±.01 | 2.65±.01 | 4.12±.02 | 9.52±.09 | 12.29±.09 | 54±2 | 0.16 |
| 104631.6+280413 | 14.56 | 1.10±.01 | 2.77±.01 | 4.25±.03 | 9.80±.08 | 12.68±.09 | 53±2 | 0.15 |
| 105315.0+280523 | 15.30 | 1.04±.01 | 2.73±.01 | 4.27±.05 | 9.59±.09 | 12.39±.10 | 84±4 | 0.59 |
| 105539.5+280122 | 14.77 | 1.05±.01 | 2.70±.01 | 4.11±.03 | 9.64±.09 | 12.45±.09 | 64±3 | 0.26 |
| 120408.8+280305 | 15.86 | 1.15±.02 | 2.80±.01 | 4.98±.16 | 9.97±.09 | 12.92±.10 | 87±4 | 0.66 |
| 123808.9+280618 | 15.12 | 1.09±.02 | 2.76±.01 | 4.27±.17 | 9.77±.10 | 12.63±.10 | 70±3 | 0.34 |
| 133707.3+275935 | 14.73 | 1.02±.01 | 2.64±.01 | 4.05±.03 | 9.52±.09 | 12.28±.09 | 67±3 | 0.30 |
| 135210.6+280310 | 15.33 | 1.11±.01 | 2.81±.01 | 4.31±.08 | 9.84±.09 | 12.73±.10 | 74±3 | 0.41 |
| 135755.3+280057 | 15.05 | 1.13±.01 | 2.84±.01 | 4.31±.06 | 9.89±.09 | 12.81±.09 | 63±2 | 0.25 |
| 144733.4+280459 | 15.28 | 1.13±.01 | 2.86±.01 | 4.36±.05 | 9.92±.09 | 12.85±.10 | 69±3 | 0.33 |

TABLE 4.4 — continued

(d) $9.5 \leq M_{I_{KC}} < 10.0$ (continued)

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 154549.6+280140 | 15.58 | 1.07±.02 | 2.75±.01 | 4.16±.09 | 9.69±.10 | 12.52±.10 | 90±4 | 0.73 |
| 165228.8+275955 | 14.58 | 1.03±.01 | 2.73±.01 | 4.51±.04 | 9.56±.09 | 12.33±.10 | 61±3 | 0.23 |
| 165313.8+275950 | 14.62 | 1.06±.01 | 2.79±.01 | 4.61±.05 | 9.67±.09 | 12.49±.10 | 59±2 | 0.21 |
| 170532.0+275926 | 15.04 | 1.09±.01 | 2.88±.01 | 4.85±.07 | 9.78±.11 | 12.65±.11 | 67±3 | 0.30 |
| 172351.3+280248 | 15.57 | 1.09±.02 | 2.79±.01 | 4.54±.17 | 9.76±.10 | 12.62±.11 | 86±4 | 0.64 |
| 175221.7+280329 | 13.43 | 1.02±.01 | 2.77±.01 | 4.58±.02 | 9.54±.09 | 12.21±.09 | 36±1 | 0.05 |
| 180558.5+280419 | 15.51 | 1.15±.02 | 2.91±.01 | 4.76±.10 | 9.97±.10 | 12.92±.10 | 74±3 | 0.41 |
| 225024.0+275956[e] | 15.64 | 1.14±.03 | 2.86±.02 | 4.28±.06 | 9.94±.12 | 12.87±.12 | 80±4 | 0.51 |
| 235133.2+280057 | 15.63 | 1.09±.02 | 2.76±.01 | 4.10±.05 | 9.76±.10 | 12.62±.11 | 89±4 | 0.70 |

Average $\frac{V}{V_{max}}$ = 0.43±0.01.

[d] Double star unresolved by CTI; both spectra are M3.5 V.

[e] Spectrum M4 V.

TABLE 4.4 — continued

$$\text{(e) } 10.0 \le M_{I_{KC}} < 10.5$$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 002142.1+280548[f] | 15.83 | 1.19±.02 | 2.85±.01 | 4.27±.11 | 10.10±.10 | 13.11±.11 | 80±4 | 0.51 |
| 003439.1+280309[f] | 15.83 | 1.18±.02 | 2.84±.01 | 4.24±.41 | 10.07±.09 | 13.06±.10 | 81±3 | 0.53 |
| 005100.5+280430[f] | 15.87 | 1.17±.02 | 2.86±.01 | 4.56±.08 | 10.03±.09 | 13.01±.10 | 84±4 | 0.59 |
| 012703.2+275835 | 16.00 | 1.19±.02 | 2.89±.01 | 4.16±.16 | 10.11±.10 | 13.12±.11 | 86±4 | 0.64 |
| 015714.5+275816 | 16.38 | 1.21±.06 | 2.91±.03 | 3.86±.10 | 10.17±.21 | 13.20±.23 | 98±10 | 0.94 |
| 021050.6+280307 | 16.21 | 1.18±.03 | 2.83±.02 | 4.47±.09 | 10.08±.11 | 13.08±.12 | 96±5 | 0.88 |
| 082852.6+280159 | 15.25 | 1.26±.01 | 3.00±.01 | 4.48±.05 | 10.33±.08 | 13.43±.09 | 53±2 | 0.15 |
| 084047.8+280234 | 15.64 | 1.17±.01 | 2.88±.01 | 4.53±.07 | 10.04±.09 | 13.02±.10 | 76±3 | 0.44 |
| 085556.5+280559 | 14.46 | 1.23±.01 | 3.00±.01 | — | 10.25±.08 | 13.31±.08 | 39±1 | 0.06 |
| 101111.3+275946 | 15.66 | 1.21±.01 | 2.90±.01 | 4.25±.06 | 10.17±.09 | 13.20±.09 | 70±3 | 0.34 |
| 114741.4+280311 | 16.63 | 1.27±.03 | 3.08±.02 | 4.69±.23 | 10.37±.11 | 13.49±.12 | 98±5 | 0.94 |
| 120048.6+275958 | 15.20 | 1.29±.01 | 3.10±.01 | 4.54±.08 | 10.43±.08 | 13.58±.08 | 49±2 | 0.12 |
| 131541.3+280227[f] | 15.35 | 1.21±.01 | 2.93±.01 | 4.64±.09 | 10.16±.08 | 13.19±.09 | 62±2 | 0.24 |
| 133723.8+280206 | 15.24 | 1.22±.01 | 2.94±.01 | 4.39±.05 | 10.21±.08 | 13.25±.09 | 57±2 | 0.19 |
| 133727.4+280628 | 16.37 | 1.20±.03 | 2.91±.02 | 4.31±.06 | 10.15±.13 | 13.17±.14 | 99±6 | 0.97 |
| 142659.1+280657 | 16.00 | 1.20±.04 | 2.92±.02 | — | 10.15±.16 | 13.18±.18 | 83±6 | 0.57 |
| 171253.5+280042 | 16.65 | 1.27±.04 | 3.12±.02 | — | 10.37±.16 | 13.48±.18 | 99±7 | 0.97 |
| 175958.0+280550 | 16.47 | 1.31±.04 | 3.11±.02 | — | 10.50±.15 | 13.67±.16 | 85±6 | 0.61 |
| 225852.9+280043 | 16.33 | 1.25±.04 | 3.25±.03 | 5.36±.39 | 10.31±.15 | 13.40±.17 | 89±6 | 0.70 |
| 225953.7+275905 | 14.57 | 1.18±.01 | 2.89±.01 | 4.68±.03 | 10.06±.09 | 13.05±.09 | 46±2 | 0.10 |

TABLE 4.4 — continued

(e) $10.0 \leq M_{I_{KC}} < 10.5$ (continued)

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 235317.0+280338 | 15.10 | 1.19±.01 | 2.88±.01 | 4.43±.04 | 10.11±.08 | 13.12±.09 | 57±2 | 0.19 |
| 235659.2+280243 | 16.15 | 1.29±.02 | 3.02±.01 | 4.65±.07 | 10.43±.11 | 13.58±.11 | 76±4 | 0.44 |

Average $\frac{V}{V_{max}}$ = 0.54±0.02.

$^f$ Spectrum M4 V.

(f) $10.5 \leq M_{I_{KC}} < 11.0$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 085445.3+280047 | 16.65 | 1.34±.06 | 3.07±.04 | — | 10.61±.20 | 13.83±.22 | 86±8 | 0.64 |
| 141034.2+280158$^g$ | 16.39 | 1.33±.03 | 3.12±.01 | 4.91±.21 | 10.58±.11 | 13.79±.12 | 78±4 | 0.47 |
| 223903.2+280324 | 16.61 | 1.33±.05 | 3.13±.04 | 4.57±.34 | 10.56±.18 | 13.76±.19 | 87±7 | 0.66 |
| 233133.1+280158 | 16.59 | 1.35±.05 | 3.39±.04 | 4.62±.39 | 10.62±.17 | 13.84±.19 | 83±7 | 0.57 |

Average $\frac{V}{V_{max}}$ = 0.59±0.07.

$^g$ Spectrum M4.5 V.

TABLE 4.4 — continued

(g) $11.0 \leq M_{I_{KC}} < 11.5$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 092248.3+280503 | 17.81 | 1.57±.18 | 3.41±.03 | — | 11.34±.58 | 14.87±.63 | 96±26 | 0.88 |
| 124832.6+280502[h] | 16.92 | 1.53±.03 | 3.50±.02 | 4.77±.26 | 11.22±.13 | 14.70±.14 | 68±4 | 0.31 |
| 132116.6+280328 | 17.60 | 1.59±.05 | 3.31±.03 | — | 11.40±.18 | 14.96±.20 | 84±7 | 0.59 |
| 135347.7+280419[i] | 17.35 | 1.60±.06 | 3.47±.02 | — | 11.44±.21 | 15.01±.23 | 73±7 | 0.39 |
| 170958.5+275905[h] | 15.46 | 1.58±.03 | 3.65±.01 | 5.68±.13 | 11.37±.12 | 14.91±.13 | 32±2 | 0.03 |

Average $\frac{V}{V_{max}}$ = 0.44±0.15.

[h] Spectrum M5.5 V.

[i] Spectrum M6 V.

(h) $11.5 \leq M_{I_{KC}} < 12.0$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 015625.5+280135[j] | 17.69 | 1.65±.07 | 3.61±.04 | — | 11.60±.25 | 15.25±.27 | 77±9 | 0.46 |

Average $\frac{V}{V_{max}}$ = 0.46±0.16.

[j] Spectrum M6 V.

TABLE 4.4 — continued

(i) $12.0 \leq M_{I_{KC}} < 12.5$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 004244.4+280140[k] | 19.30 | 1.94±.16 | — | — | 12.50±.55 | 16.56±.60 | 95±25 | 0.86 |
| 011826.7+280514[k] | 19.00 | 1.85±.21 | — | — | 12.23±.69 | 16.16±.75 | 98±31 | 0.94 |
| 015607.7+280241[l] | 18.33 | 1.83±.12 | 3.89±.08 | — | 12.16±.40 | 16.06±.43 | 75±14 | 0.42 |

Average $\frac{V}{V_{max}} = 0.74 \pm 0.38$.

[k] Spectrum M6 V.

[l] Spectrum M6.5 V.

(j) $12.5 \leq M_{I_{KC}} < 13.0$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 000455.2+280301[m] | 18.27 | 1.99±.08 | 4.08±.06 | — | 12.67±.28 | 16.80±.31 | 54±7 | 0.17 |
| 014716.6+280142[m] | 19.12 | 1.95±.21 | — | — | 12.53±.71 | 16.60±.78 | 86±29 | 0.70 |
| 022000.5+275933 | 18.99 | 1.95±.19 | — | — | 12.53±.63 | 16.60±.68 | 81±24 | 0.58 |

Average $\frac{V}{V_{max}} = 0.48 \pm 0.27$, based on $d_{max} = 97$ pc.

[m] Spectrum M6 V.

TABLE 4.4 — continued

(k) $13.0 \leq M_{I_{KC}} < 13.5$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 153915.6+280445[n] | 19.87 | 2.14±.80 | — | — | 13.09±2.64 | 17.42±2.87 | 87±106 | — |
| 174729.0+280322[p] | 19.78 | 2.21±.41 | — | — | 13.30±1.37 | 17.74±1.49 | 74±47 | — |

[n] No spectrum available; photometric errors are very large; object is beyond $d_{max}$ = 72 pc.

[p] Spectrum M6.5 V; object is just beyond $d_{max}$ = 72 pc.

(l) $13.5 \leq M_{I_{KC}} < 14.0$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) | $\frac{V}{V_{max}}$ |
|---|---|---|---|---|---|---|---|---|
| 012657.5+280202[q] | 19.35 | 2.30±.24 | — | — | 13.57±.80 | 18.14±.87 | 51±19 | 0.89 |

Average $\frac{V}{V_{max}}$ = 0.89±0.15, based on $d_{max}$ = 53 pc.

[q] Spectrum M8.5 V.

TABLE 4.5

THE CTI LUMINOSITY FUNCTION AT $I$

| $M_{I_{KC}}$ | # | $d_{max}$(pc) | $\log \Phi_{obs}$ | $\overline{\sigma_M}$ | $\frac{N_{obs}}{N_{true}}$ | $\log \Phi_{true}$ |
|---|---|---|---|---|---|---|
| 8.25 | 13 | 100 | -2.029 | 0.13 | 0.968 | -2.015 |
| 8.75 | 22 | 100 | -1.801 | 0.11 | 0.966 | -1.786 |
| 9.25 | 31 | 100 | -1.652 | 0.10 | 0.996 | -1.650 |
| 9.75 | 29 | 100 | -1.681 | 0.10 | 0.994 | -1.678 |
| 10.25 | 22 | 100 | -1.801 | 0.11 | 1.063 | -1.827 |
| 10.75 | 4 | 100 | -2.541 | 0.17 | 0.858 | -2.475 |
| 11.25 | 5 | 100 | -2.444 | 0.24 | 1.361 | -2.578 |
| 11.75 | 1 | 100 | -3.143 | 0.27 | 0.175 | -2.386 |
| 12.25 | 3 | 100[a] | <-2.666 | 0.55 | — | — |
| 12.75 | 3 | 97[a] | <-2.626 | 0.54 | — | — |
| 13.25 | 0 | 72[a] | — | 0.91 | — | — |
| 13.75 | 1 | 53[a] | <-2.316 | 0.80 | — | — |

[a] Taking a limiting magnitude of $R_{CTI} = 20.0$, one magnitude fainter than the adopted completeness limit.

# TABLE 4.6

## REDISTRIBUTION OF OBJECTS IN THE FIRST THREE BINS OF THE CTI LUMINOSITY FUNCTION WHEN CALIBRATION EQUATION 4.4 IS USED INSTEAD OF EQUATION 4.2 [a]

### (a) $8.0 \leq M_{I_{KC}} < 8.5$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) |
|---|---|---|---|---|---|---|---|
| 011544.7+280414 | 12.97 | 0.81±.01 | 2.30±.01 | 3.68±.07 | 8.05±.16 | 10.52±.16 | 64±50.09 |
| 020859.6+280504 | 13.57 | 0.82±.01 | 2.32±.01 | 4.15±.01 | 8.08±.16 | 10.57±.16 | 83±60.21 |
| 105707.5+280223 | 14.17 | 0.88±.01 | 2.45±.01 | 3.92±.02 | 8.48±.15 | 11.05±.16 | 89±60.31 |
| 145115.0+275902 | 13.02 | 0.81±.01 | 2.30±.01 | 3.77±.01 | 8.02±.16 | 10.49±.17 | 66±50.10 |
| 232016.4+280607 | 13.62 | 0.82±.01 | 2.36±.01 | 3.75±.02 | 8.08±.17 | 10.57±.17 | 85±70.22 |
| 234725.1+280306 | 13.15 | 0.87±.01 | 2.38±.01 | 3.76±.01 | 8.42±.15 | 10.98±.15 | 57±40.09 |

### (b) $8.5 \leq M_{I_{KC}} < 9.0$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) |
|---|---|---|---|---|---|---|---|
| 015723.6+275946 | 13.58 | 0.89±.01 | 2.43±.01 | 3.79±.01 | 8.52±.15 | 11.10±.15 | 66±50.13 |
| 075350.3+280306 | 14.63 | 0.91±.02 | 2.47±.01 | 3.97±.03 | 8.69±.17 | 11.30±.17 | 98±80.49 |
| 104642.9+280435 | 14.76 | 0.95±.01 | 2.55±.01 | 4.09±.03 | 8.92±.15 | 11.59±.15 | 92±60.47 |
| 115350.7+280342 | 13.58 | 0.91±.01 | 2.47±.01 | 3.90±.02 | 8.70±.15 | 11.32±.15 | 60±40.12 |
| 230637.3+280228 | 14.57 | 0.95±.01 | 2.53±.01 | 3.87±.03 | 8.95±.16 | 11.62±.17 | 84±60.36 |

TABLE 4.6 — continued

(c) $9.0 \leq M_{I_{KC}} < 9.5$

| CTI Object Name | $R_{CTI}$ | $(R-I)_{CTI}$ | $(V-I)_{CTI}$ | $(B-I)_{CTI}$ | $M_{I_{KC}}$ | $M_{V_{KC}}$ | dist(pc) |
|---|---|---|---|---|---|---|---|
| 002151.7+280450 | 14.71 | 1.00±.01 | 2.60±.01 | 3.92±.03 | 9.27±.14 | 12.01±.15 | 75±50.33 |
| 015115.8+280458 | 15.05 | 0.99±.01 | 2.57±.01 | — | 9.16±.16 | 11.88±.16 | 93±70.57 |
| 022228.2+275853 | 14.85 | 0.96±.01 | 2.55±.01 | 3.72±.03 | 9.02±.15 | 11.71±.16 | 91±60.49 |
| 083524.2+280412 | 15.23 | 1.00±.01 | 2.60±.01 | 3.96±.07 | 9.28±.15 | 12.03±.16 | 95±70.66 |
| 095541.2+280148 | 14.71 | 1.00±.01 | 2.59±.01 | 4.10±.03 | 9.28±.14 | 12.03±.15 | 75±50.31 |
| 112959.7+280044 | 14.70 | 0.99±.01 | 2.60±.01 | 4.12±.03 | 9.19±.14 | 11.92±.15 | 78±50.34 |
| 151814.8+280548 | 14.46 | 0.97±.01 | 2.60±.01 | — | 9.07±.16 | 11.77±.16 | 74±50.27 |
| 161117.0+280426 | 13.74 | 0.96±.01 | 2.61±.01 | 4.42±.02 | 9.01±.14 | 11.70±.14 | 55±40.10 |
| 171417.4+280630 | 13.56 | 0.96±.01 | 2.61±.01 | — | 9.03±.14 | 11.71±.15 | 50±30.08 |
| 233452.3+275955 | 13.18 | 0.99±.05 | 2.63±.04 | 4.03±.01 | 9.22±.14 | 11.95±.14 | 58±20.04 |
| 233855.8+280517 | 14.69 | 0.97±.02 | 2.58±.01 | 3.99±.03 | 9.07±.18 | 11.77±.18 | 82±70.37 |

[a] These recalibrated data are re-distributed into the first three bins as follows:

6 objects with $8.0 \leq M_{I_{KC}} < 8.5$, yielding $\log \Phi_{obs} = -2.365$,

5 objects with $8.5 \leq M_{I_{KC}} < 9.0$, yielding $\log \Phi_{obs} = -2.444$,

11 objects with $9.0 \leq M_{I_{KC}} < 9.5$, yielding $\log \Phi_{obs} = -2.102$

(or, 1 object with $10.0 \leq M_{V_{KC}} < 10.5$, yielding $\log \Phi_{obs} < -3.143$,

4 objects with $10.5 \leq M_{V_{KC}} < 11.0$, yielding $\log \Phi_{obs} = -2.541$,

4 objects with $11.0 \leq M_{V_{KC}} < 11.5$, yielding $\log \Phi_{obs} = -2.541$,

10 objects with $11.5 \leq M_{V_{KC}} < 12.0$, yielding $\log \Phi_{obs} = -2.143$,

16 objects with $12.0 \leq M_{V_{KC}} < 12.5$, yielding $\log \Phi_{obs} = -1.939$).

TABLE 4.7

LUMINOSITY FUNCTION DATA FOR OBJECTS WITH $M_I \geq 8.0$,
$\delta > -20°$, AND $d \leq 5.2$ PARSECS (WHITE DWARFS EXCLUDED)

| Object | $m_I$ | $\pi$ (arcsec) | $M_I$ |
|---|---|---|---|
| GL 699 | 6.77 | 0.5453±0.0010 | 10.45 |
| GL 406 | 9.39 | 0.4183±0.0025 | 12.50 |
| GL 411 | 5.32 | 0.3973±0.0018 | 8.32 |
| GL 65 A | 8.31 joint | 0.3807±0.0043 | 11.81 |
| GL 65 B | 8.31 joint | 0.3807±0.0043 | 12.15 |
| GL 905 | 8.84 | 0.3156±0.0016 | 11.34 |
| GL 447 | 8.14 | 0.3011±0.0019 | 10.53 |
| GL 866 A | 8.62 joint | 0.2943±0.0035 | 11.72 |
| GL 866 B | 8.62 joint | 0.2943±0.0035 | 11.72 |
| GL 15 A | 5.94 | 0.2895±0.0049 | 8.25 |
| GL 15 B | 8.25 | 0.2895±0.0049 | 10.56 |
| GL 725 A | 6.44 | 0.2861±0.0018 | 8.72 |
| GL 725 B | 7.13 | 0.2861±0.0018 | 9.41 |
| GJ 1111 | 10.53 | 0.2758±0.0030 | 12.73 |
| GL 54.1 | 8.90 | 0.2674±0.0030 | 11.04 |
| GL 273 | 7.16 | 0.2644±0.0020 | 9.27 |
| GL 860 A | 6.91 joint | 0.2519±0.0023 | 9.29 |
| GL 860 B | 6.91 joint | 0.2519±0.0023 | 10.25 |
| GL 628 | 7.40 | 0.2447±0.0063 | 9.34 |
| GL 234 A | 8.06 joint | 0.2421±0.0017 | 10.14 |
| GL 234 B | 8.06 joint | 0.2421±0.0017 | 12.13 |
| GL 473 A | 8.92 joint | 0.2322±0.0043 | 11.45 |
| GL 473 B | 8.92 joint | 0.2322±0.0043 | 11.55 |
| GL 83.1 | 9.17 | 0.2238±0.0029 | 10.92 |
| LHS 292 | 11.20 | 0.2210±0.0036 | 12.92 |
| GJ 1002 | 10.16 | 0.2128±0.0033 | 11.80 |
| GL 687 | 6.72 | 0.2127±0.0020 | 8.36 |
| GJ 1245 A | 9.81 joint | 0.2120±0.0043 | 11.71 |
| GJ 1245 C | 9.81 joint | 0.2120±0.0043 | 13.11 |
| GJ 1245 B | 10.27 | 0.2120±0.0043 | 11.90 |
| GL 876 | 7.45 | 0.2113±0.0048 | 9.07 |
| GL 166 C | 8.32 | 0.2071±0.0025 | 9.90 |
| GL 388 | 6.81 | 0.2039±0.0028 | 8.36 |
| GL 873 | 7.57 | 0.1970±0.0025 | 9.04 |

TABLE 4.8

THE CTI LUMINOSITY FUNCTION AT $V$

| $M_{V_{KC}}$ | # | $d_{max}$(pc) | $\log \Phi_{obs}$ | $\overline{\sigma_M}$ | $\frac{N_{obs}}{N_{true}}$ | $\log \Phi_{true}$ |
|---|---|---|---|---|---|---|
| 10.25 | >6 | 100 | <-2.365 | 0.14 | 1.039 | <-2.382 |
| 10.75 | 9 | 100 | -2.189 | 0.13 | 0.896 | -2.141 |
| 11.25 | 18 | 100 | -1.888 | 0.12 | 1.027 | -1.900 |
| 11.75 | 18 | 100 | -1.888 | 0.11 | 0.931 | -1.857 |
| 12.25 | 28 | 100 | -1.696 | 0.10 | 1.030 | -1.709 |
| 12.75 | 16 | 100 | -1.939 | 0.10 | 0.963 | -1.923 |
| 13.25 | 19 | 100 | -1.864 | 0.12 | 1.038 | -1.881 |
| 13.75 | 7 | 100 | -2.298 | 0.15 | 1.182 | -2.371 |
| 14.25 | 0 | 100 | — | — | — | — |
| 14.75 | 4 | 100 | -2.541 | 0.27 | 1.101 | -2.583 |
| 15.25 | 2 | 100 | -2.842 | 0.25 | 1.595 | -3.045 |
| 15.75 | 0 | 100 | — | — | — | — |
| 16.25 | 2 | 100[a] | <-2.842 | 0.59 | — | — |
| 16.75 | 4 | 100[a] | <-2.541 | 0.59 | — | — |
| 17.25 | 0 | 90[a] | — | — | — | — |
| 17.75 | 0 | 73[a] | — | — | — | — |
| 18.25 | 1 | 60[a] | <-2.477 | 0.87 | — | — |

[a] Taking a limiting magnitude of $R_{CTI} = 20.0$, one magnitude fainter than the adopted completeness limit.
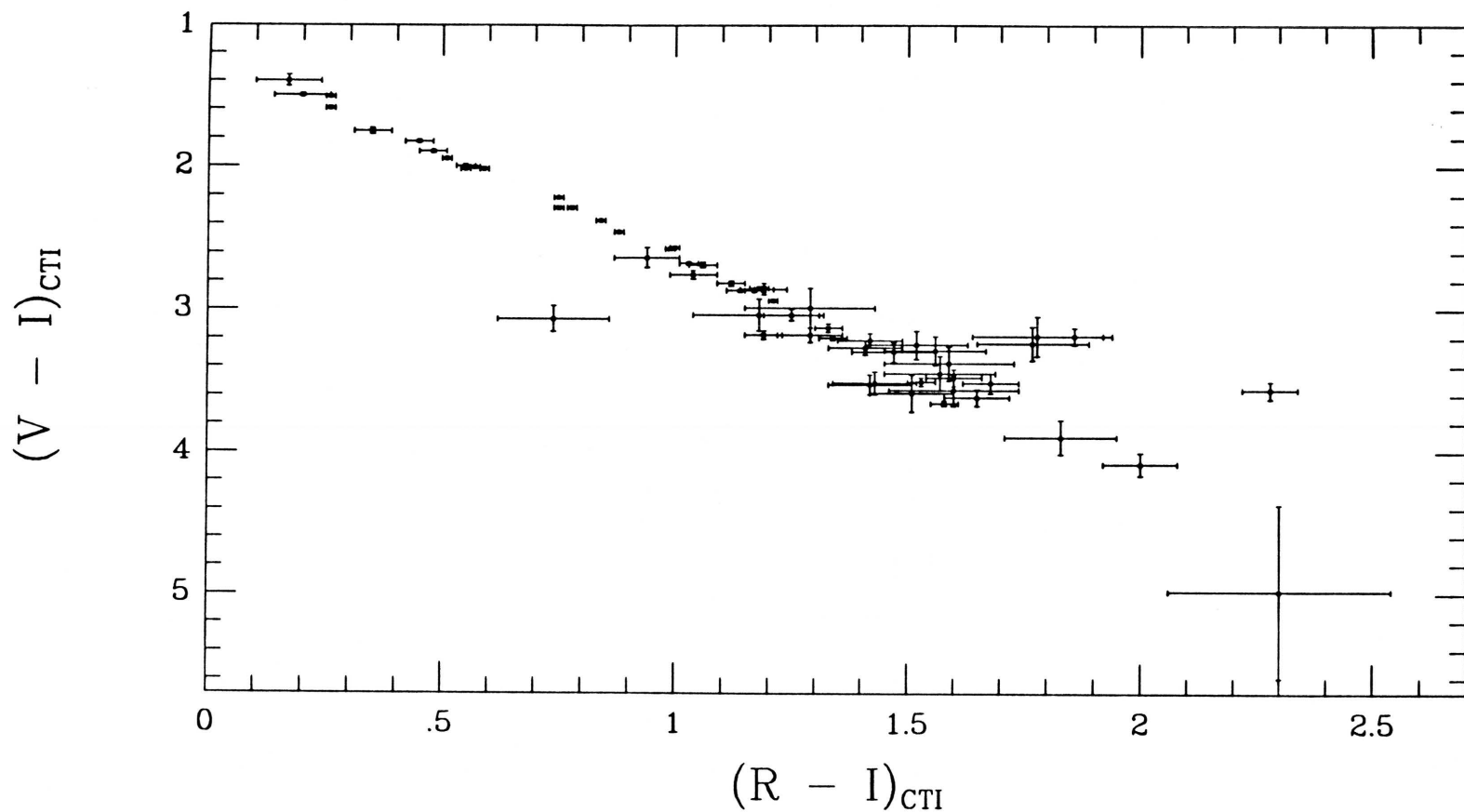
FIG. 4.1. — The $(V - I)_{CTI}$ vs. $(R - I)_{CTI}$ diagram for spectroscopic targets having $(R - I)$ errors of 0.15 magnitude or less. In this diagram, only those objects verified to be dwarfs are plotted. Also plotted at the lower right is the location of the M8.5 dwarf. Its $V_{CTI}$ magnitude was determined through coadditions of multiple nights of CTI data.
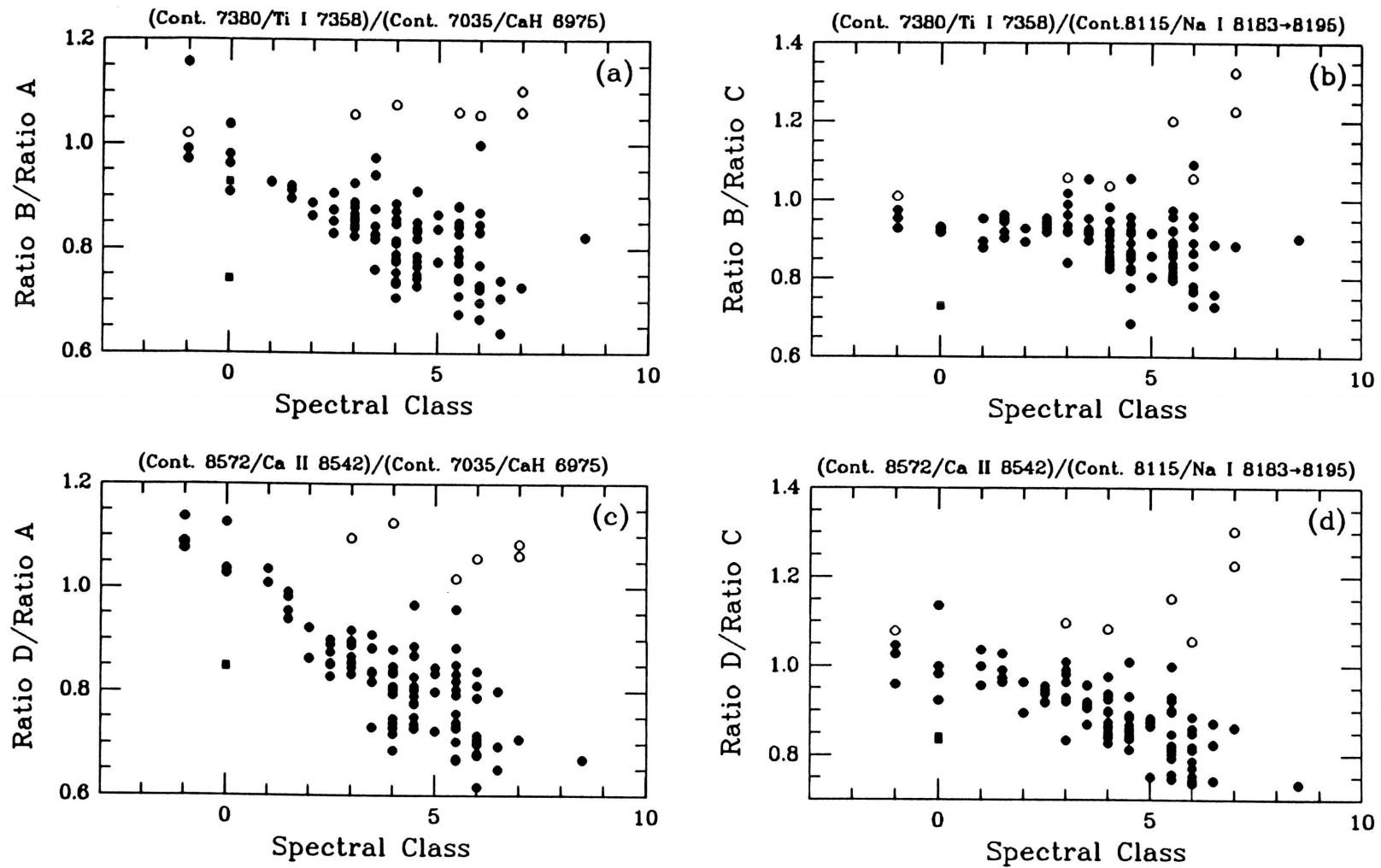
FIG. 4.2. — Color ratios determined from the spectra of the CTI targets. Dwarfs are indicated by the filled circles, giants by the open circles, and subdwarfs by the filled squares.
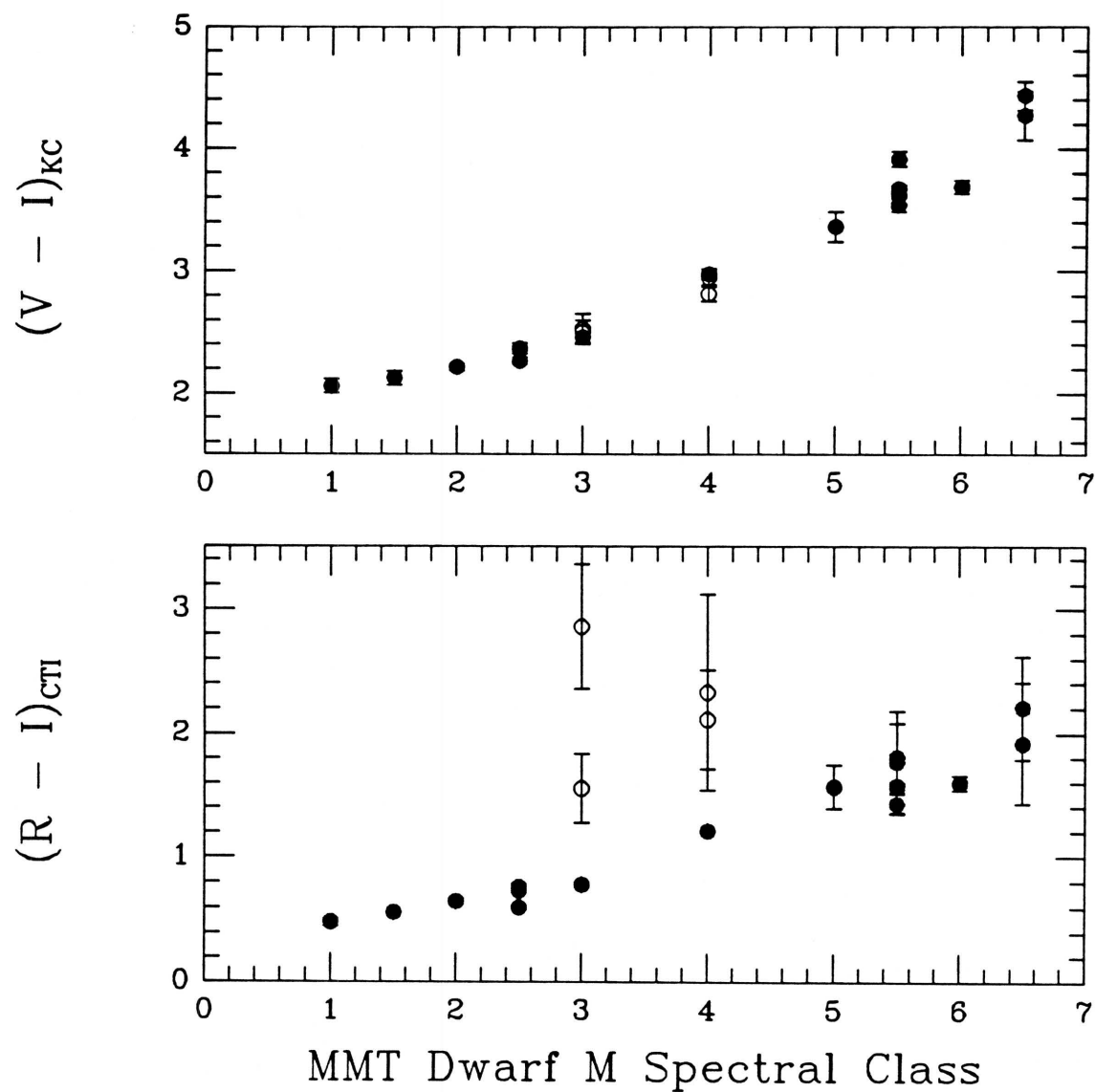
FIG. 4.3. — $(V-I)_{KC}$ and $(R-I)_{CTI}$ vs. M dwarf spectral class for those dwarfs observed photometrically at the U. S. Naval Observatory. The four discrepant points on the $(R-I)_{CTI}$ plot are labelled with open circles on both figures.
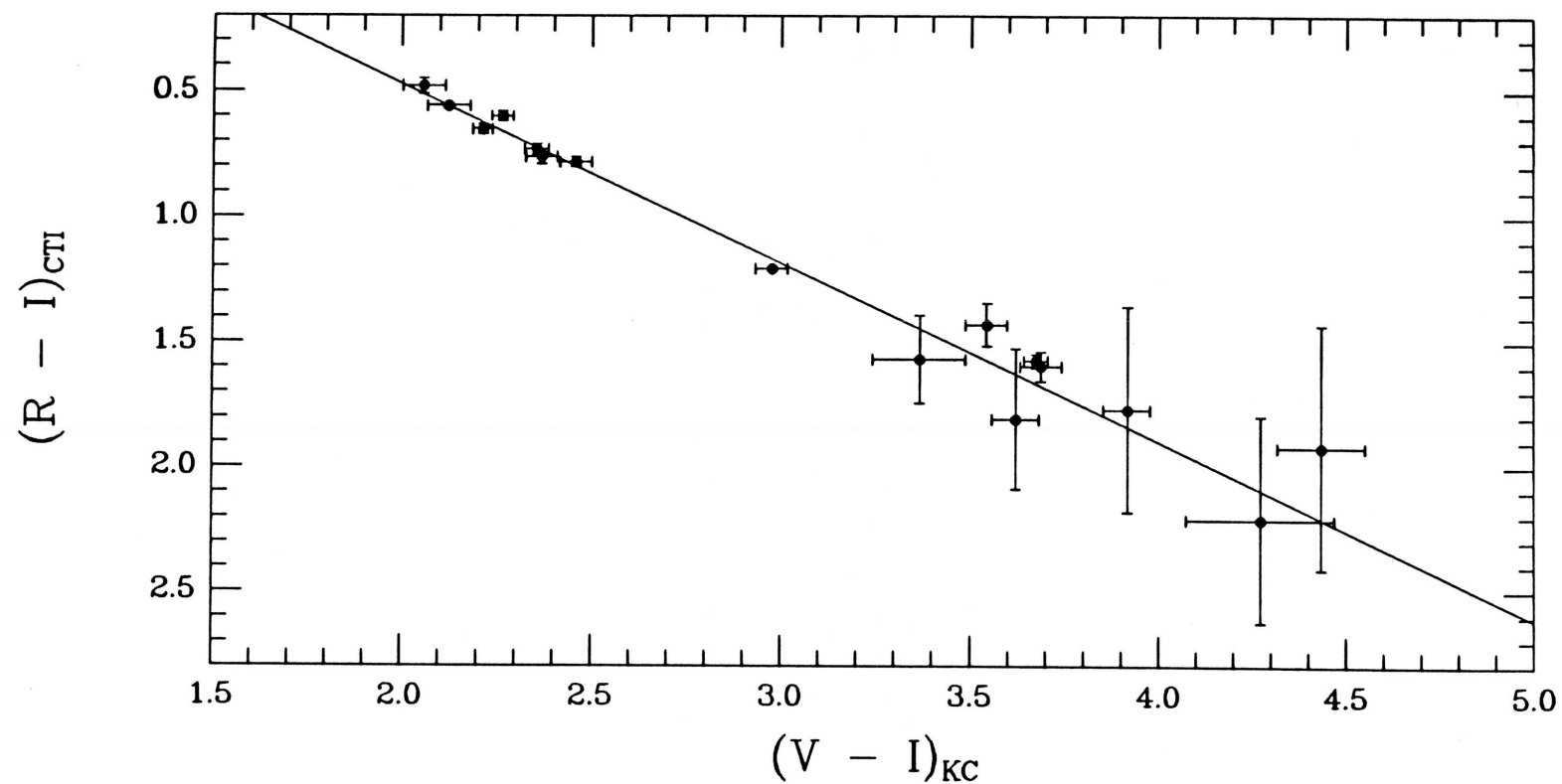
FIG. 4.4. — The $(R-I)_{CTI}$ vs. $(V-I)_{KC}$ relation as determined through photometry taken at the U. S. Naval Observatory. The solid line represents a weighted linear least-squares fit to the data.
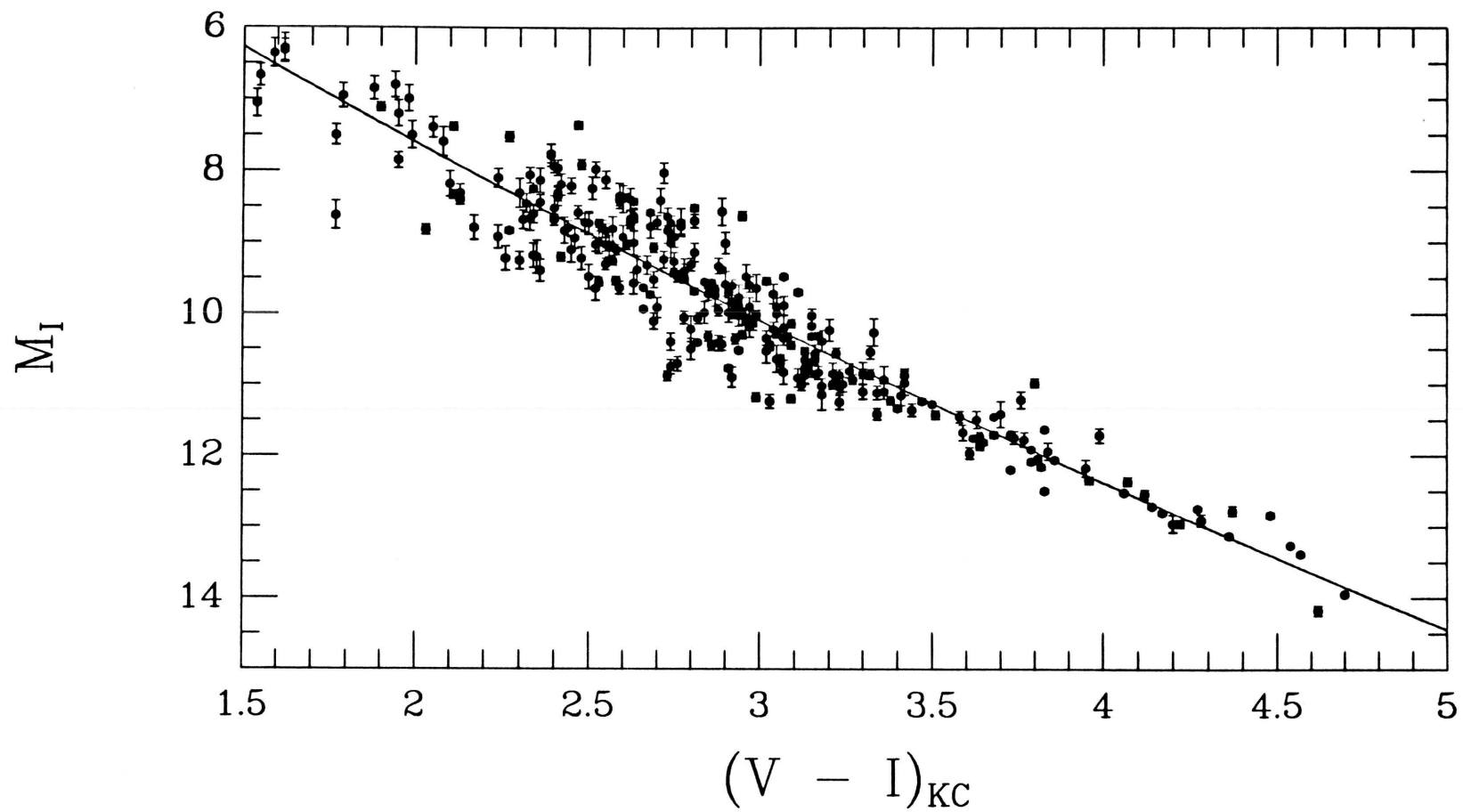
FIG. 4.5. — A plot of $M_{I_{KC}}$ vs. $(V-I)_{KC}$ for USNO parallax stars. The solid line represents a second-order least-squares fit to the data.
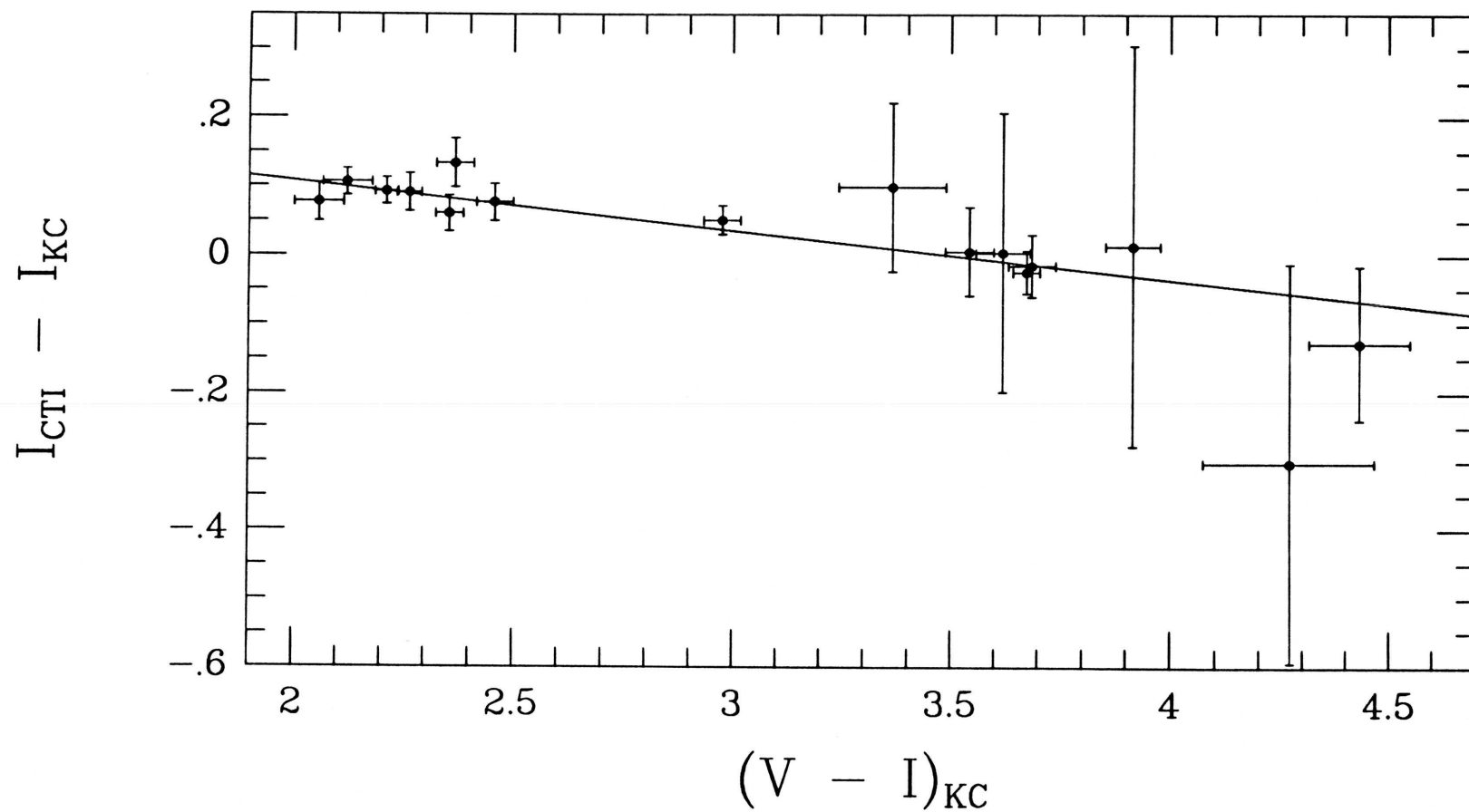
FIG. 4.6. — The $\Delta I$ vs. $(V - I)_{KC}$ diagram for CTI objects observed at the U.S. Naval Observatory. The solid line represents a weighted linear least-squares fit to the data.
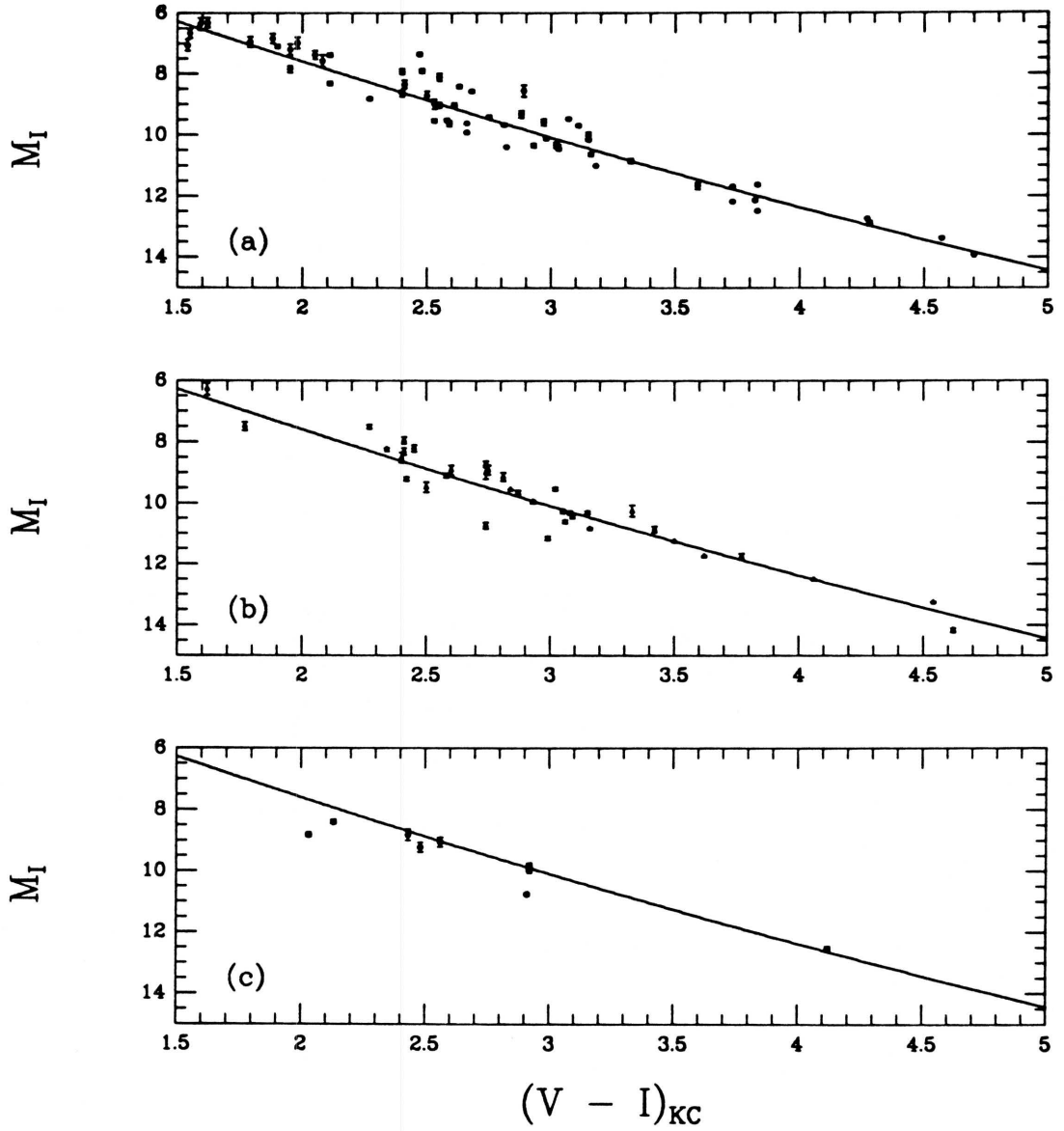
FIG. 4.7. — The fitted relation from Figure 4.5 shown for (a) low-velocity stars only, (b) intermediate-velocity stars only, and (c) high-velocity stars only. Note that the low-velocity sample tends to fall above the relation at the brighter magnitudes.
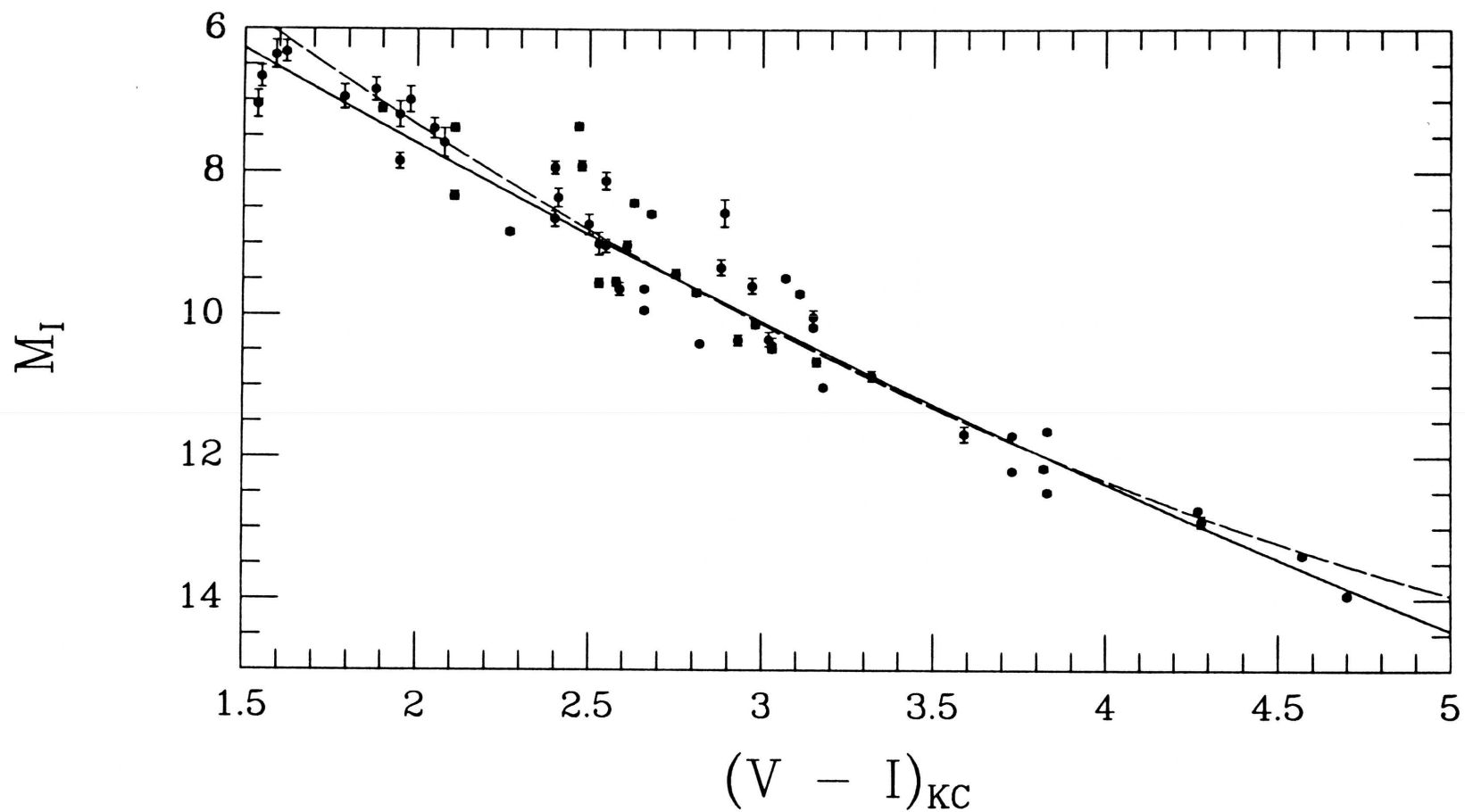
FIG. 4.8. — Figure 4.7(a) plotted with the previous relation from Figure 4.5 (solid line) and with a new second-order least-squares solution (dashed line) based on the low-velocity data only.
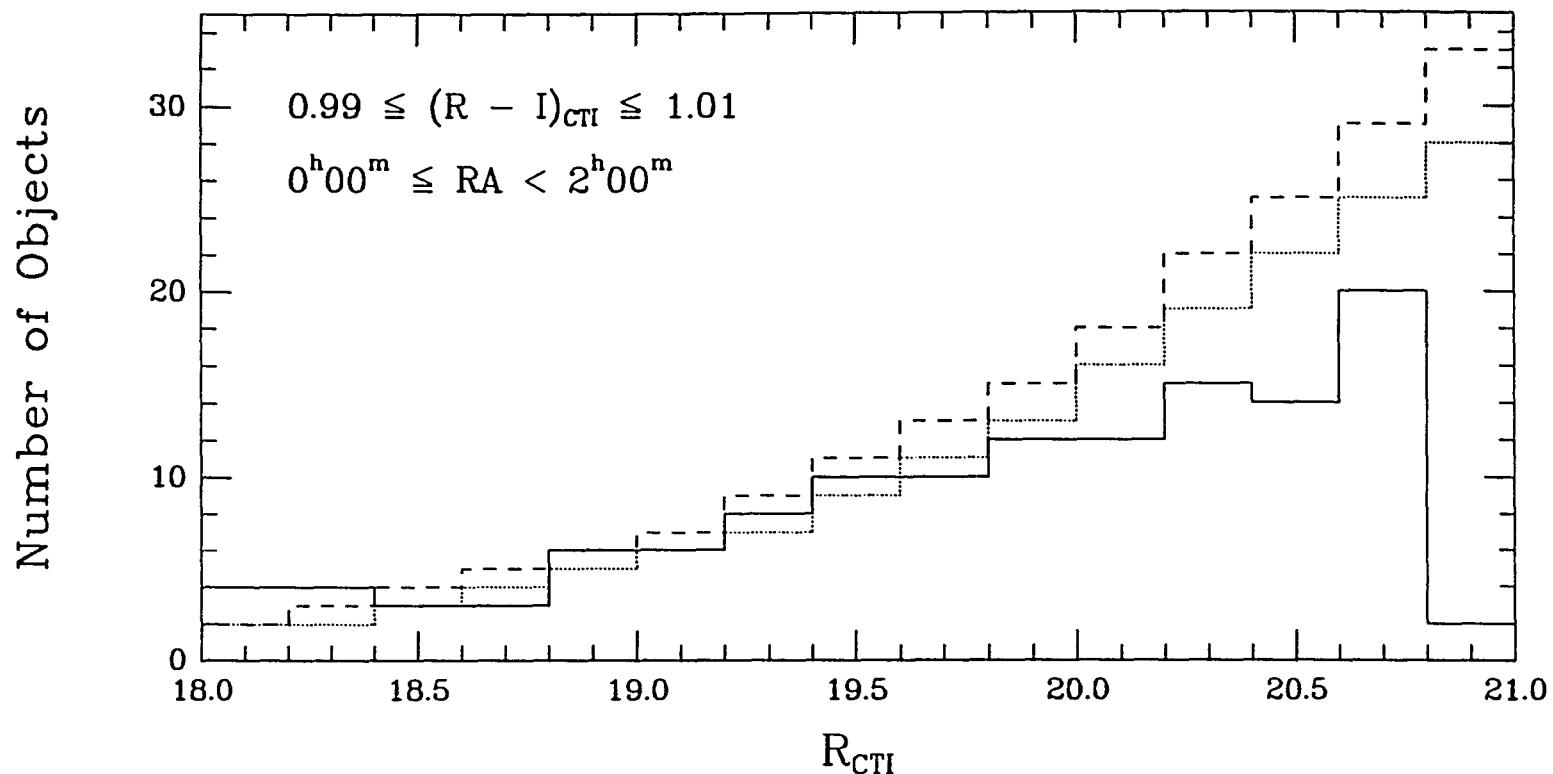
FIG. 4.9. — Observed counts of objects detected in the CTI strip with colors of $0.99 \leq (R-I)_{CTI} \leq 1.01$ and with $0^h00^m \leq \mathrm{RA} < 2^h00^m$ (representing an almost constant galactic latitude of $b \sim 35°$). Two predictions of the expected counts are shown, both of which represent the number expected per bin assuming that objects of this type have an exponential scale height of $\beta = 350$ pc: the dotted line shows the prediction normalized to the observed counts in the 19.1 magnitude bin and the dashed line shows the prediction normalized to the 18.9 magnitude bin.
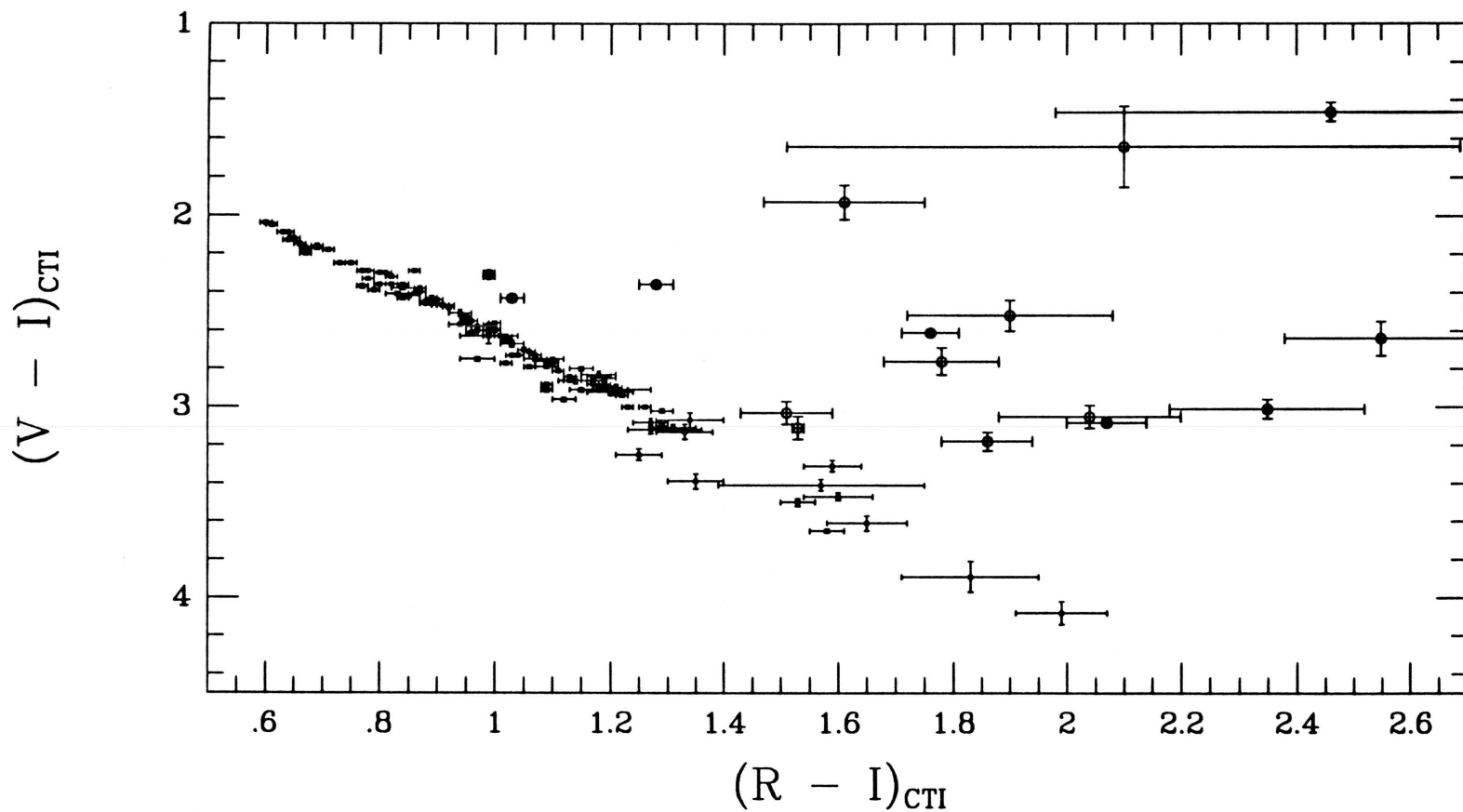
FIG. 4.10. — The $(V - I)_{CTI}$ vs. $(R - I)_{CTI}$ diagram for the final selection of objects to be used in construction of the luminosity function. The solid circles represent objects that were retained, and the open circles indicate objects that have been removed.
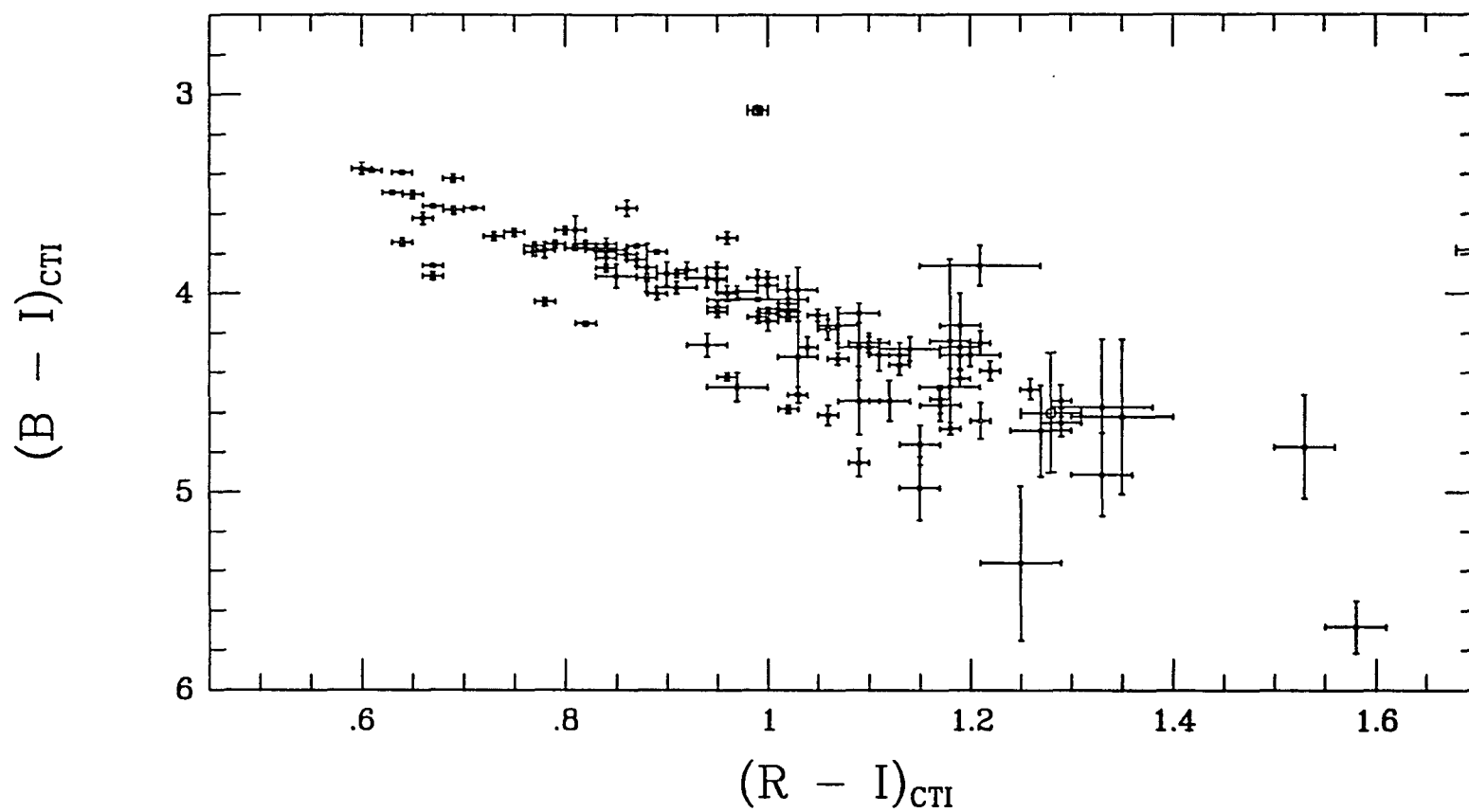
FIG. 4.11. — The $(B - I)_{CTI}$ vs. $(R - I)_{CTI}$ diagram for those objects shown in Figure 4.10.
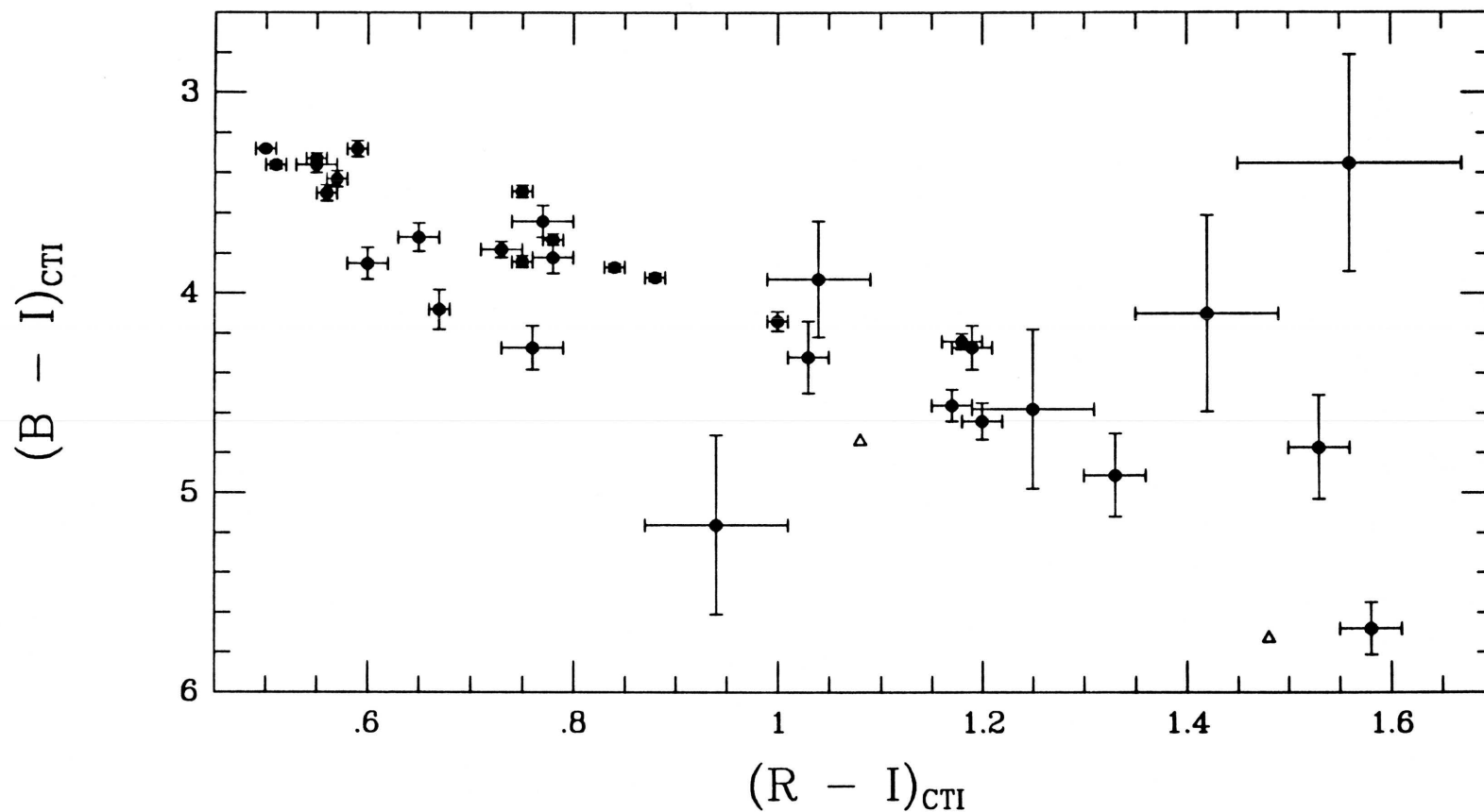
FIG. 4.12. — The $(B - I)_{CTI}$ vs. $(R - I)_{CTI}$ diagram for those spectroscopically observed objects having $B_{CTI}$ measurements. Dwarfs are shown as filled circles, and giants are shown as open triangles. Compare this plot to Figure 4.11.
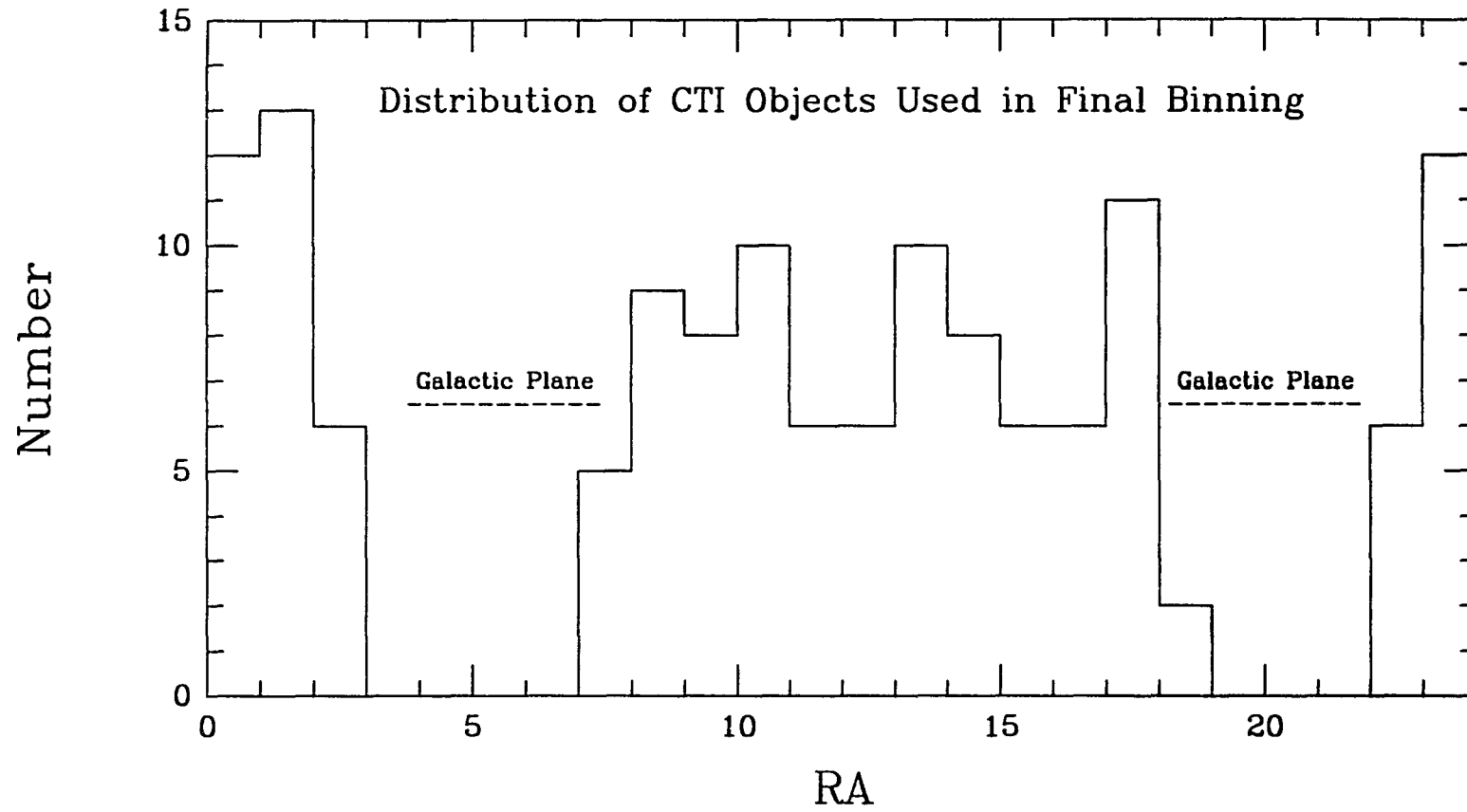
FIG. 4.13. — Histogram in right ascension of the final (136) objects to be used in construction of the luminosity function.
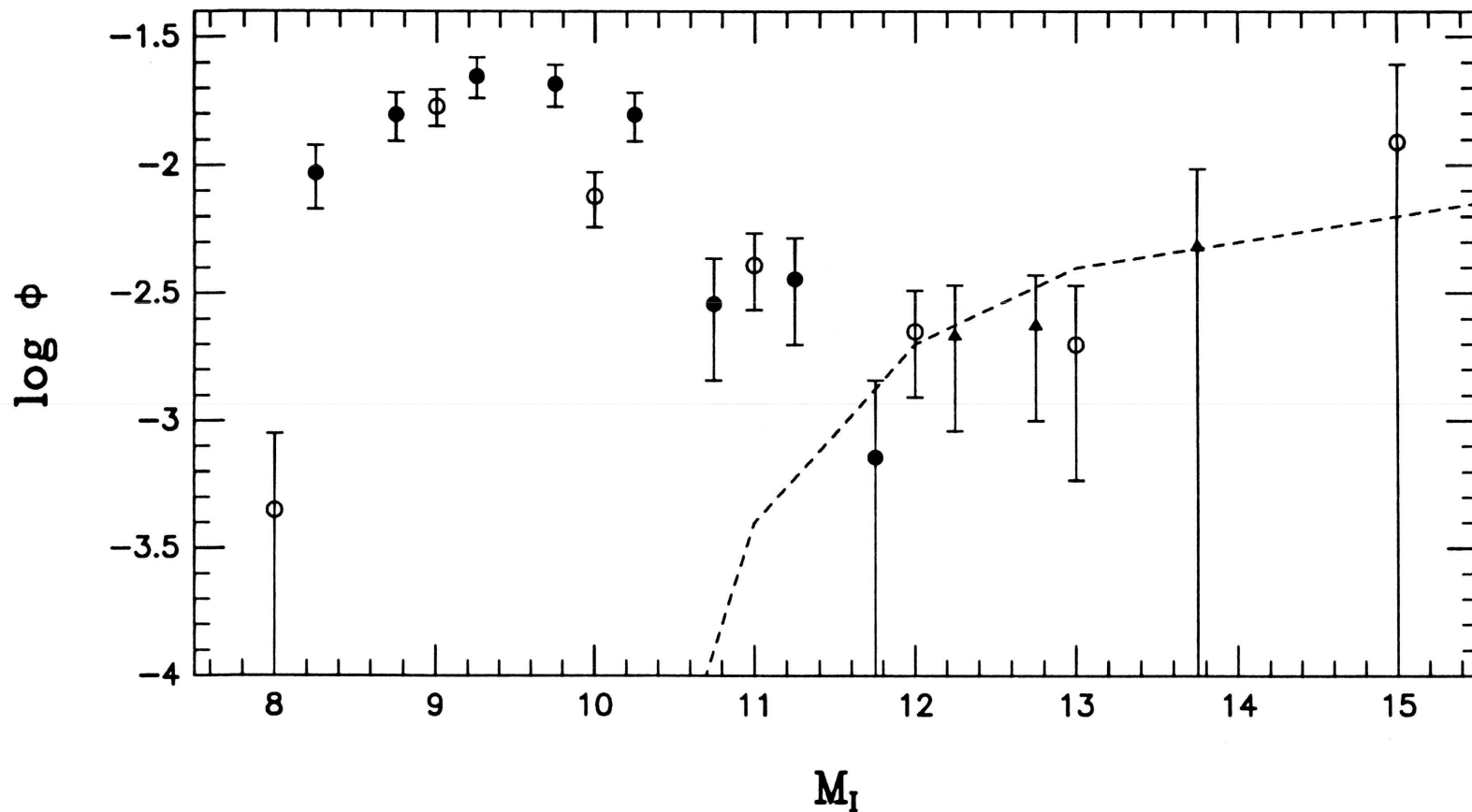
FIG. 4.14. — The (uncorrected) CTI luminosity function $\Phi$ of M dwarfs at $I$, given as filled circles. Filled triangles represent lower-limit points. The error bars represent the Poisson errors in each bin. The open circles show the Leggett & Hawkins (1988) luminosity function at the South Galactic Pole. Note the apparent increase in $\Phi$ at the lowest absolute magnitudes. The dashed line shows the contribution of brown dwarfs to the luminosity function as predicted by the theoretical models of Nelson, Rappaport, & Joss (1986).
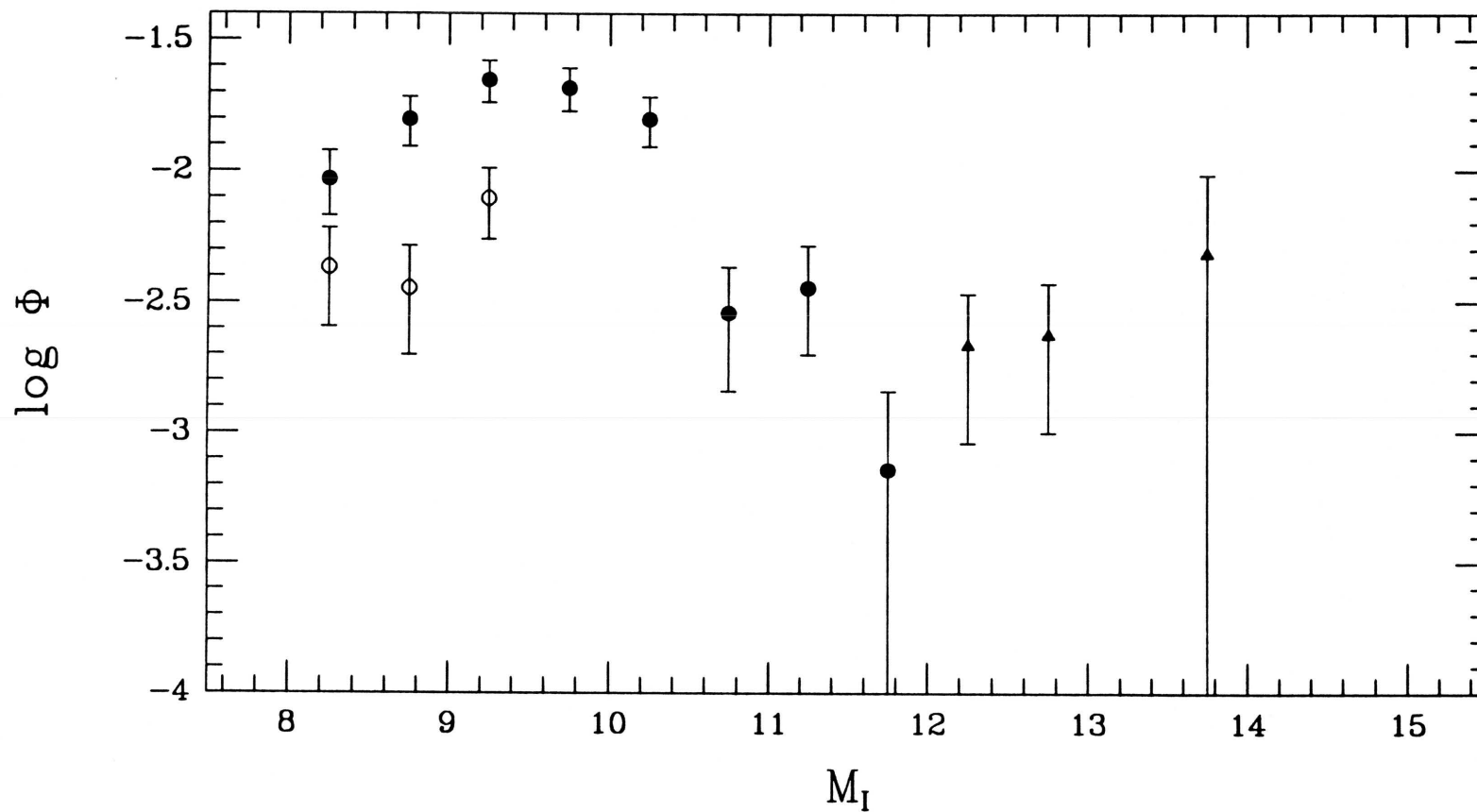
FIG. 4.15. — The CTI luminosity function from Figure 4.14. Open circles represent a recalculation of the first three luminosity bins when calibration equation 4.4 is used instead of equation 4.2. The true luminosity function for these first three bins falls somewhere *between* the open and filled circles.
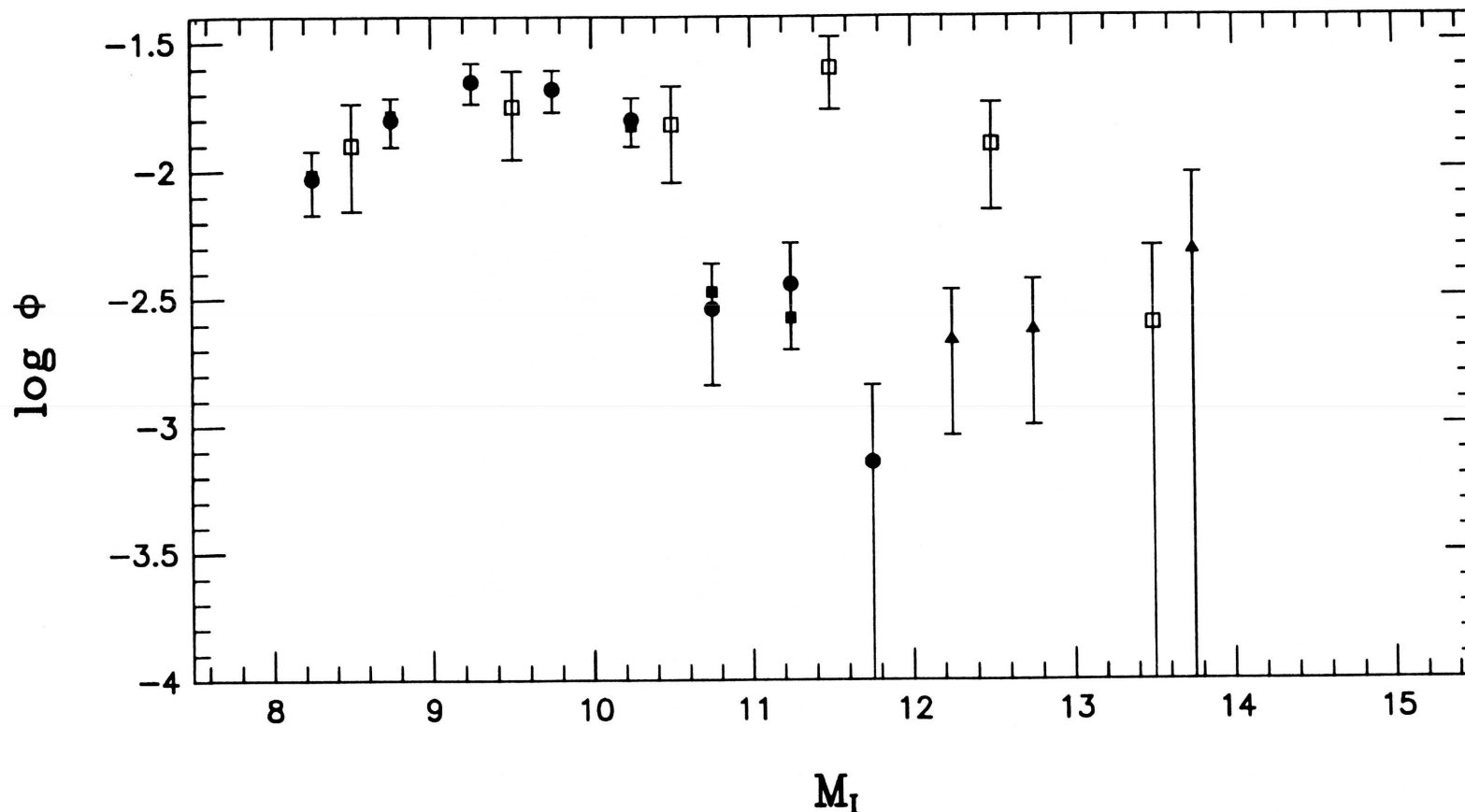
FIG. 4.16. — The CTI luminosity function at $I$ without the Malmquist correction (filled circles and triangles) and with the correction (filled squares). For the first four points, the correction is so small that the two symbols are superposed. For the data points at $M_{I_{KC}} \geq 11.75$, large errors in the absolute magnitude give an aphysical result for the Malmquist correction, so no correction was implemented. The open squares show the luminosity function for objects within 5.2 parsecs, modified from Dahn, Liebert, and Harrington (1985) using $I$ photometry from Leggett (1992) and updated trigonometric parallaxes from Gliese & Jahreiss (1991).
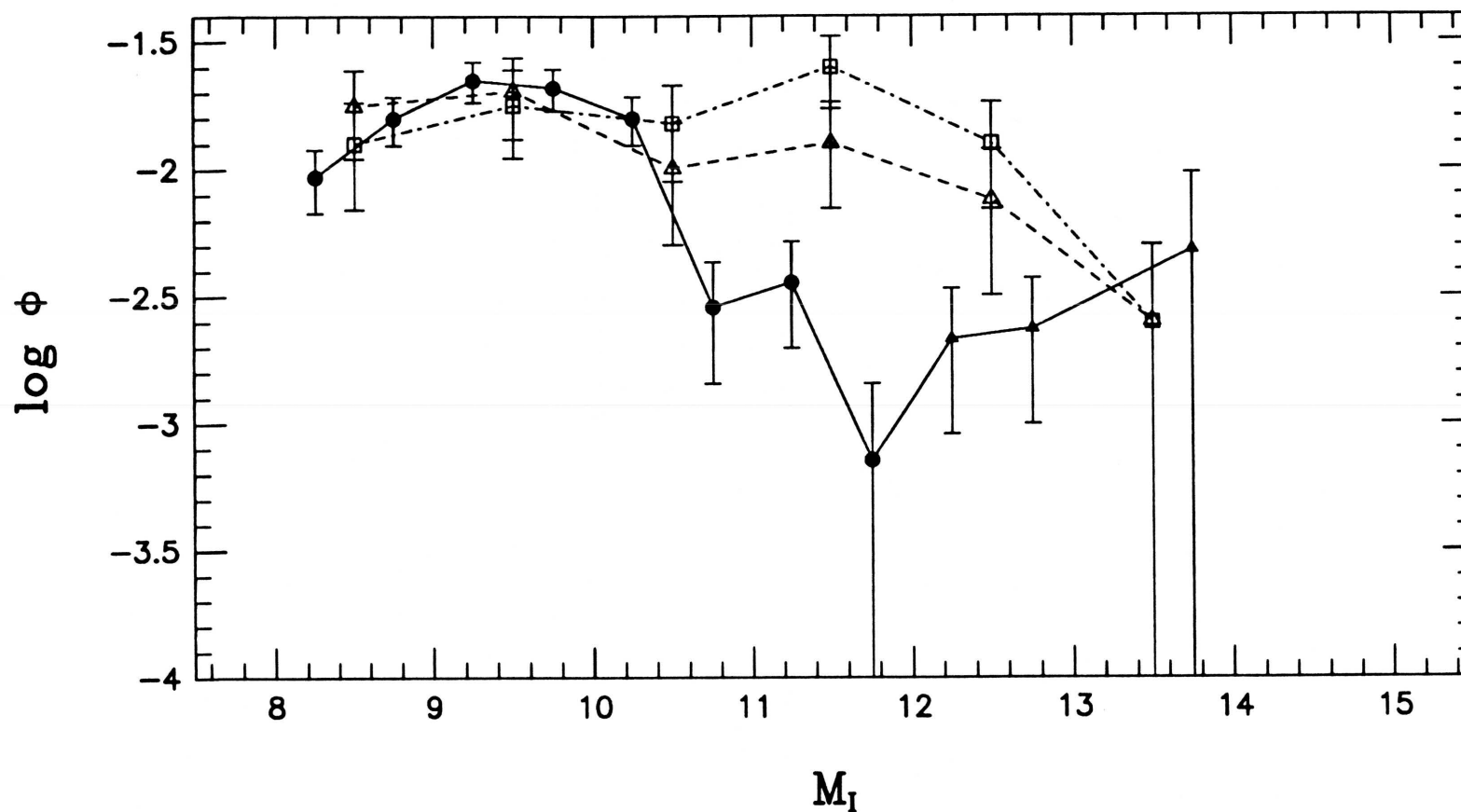
FIG. 4.17. — Comparison of the CTI luminosity function (solid symbols and solid line), the nearby luminosity function of Figure 4.16 (open squares and dot-dash line), and the nearby luminosity function when recomputed as a more distant sample derived photometrically (open triangles and dashed line). See text for discussion.
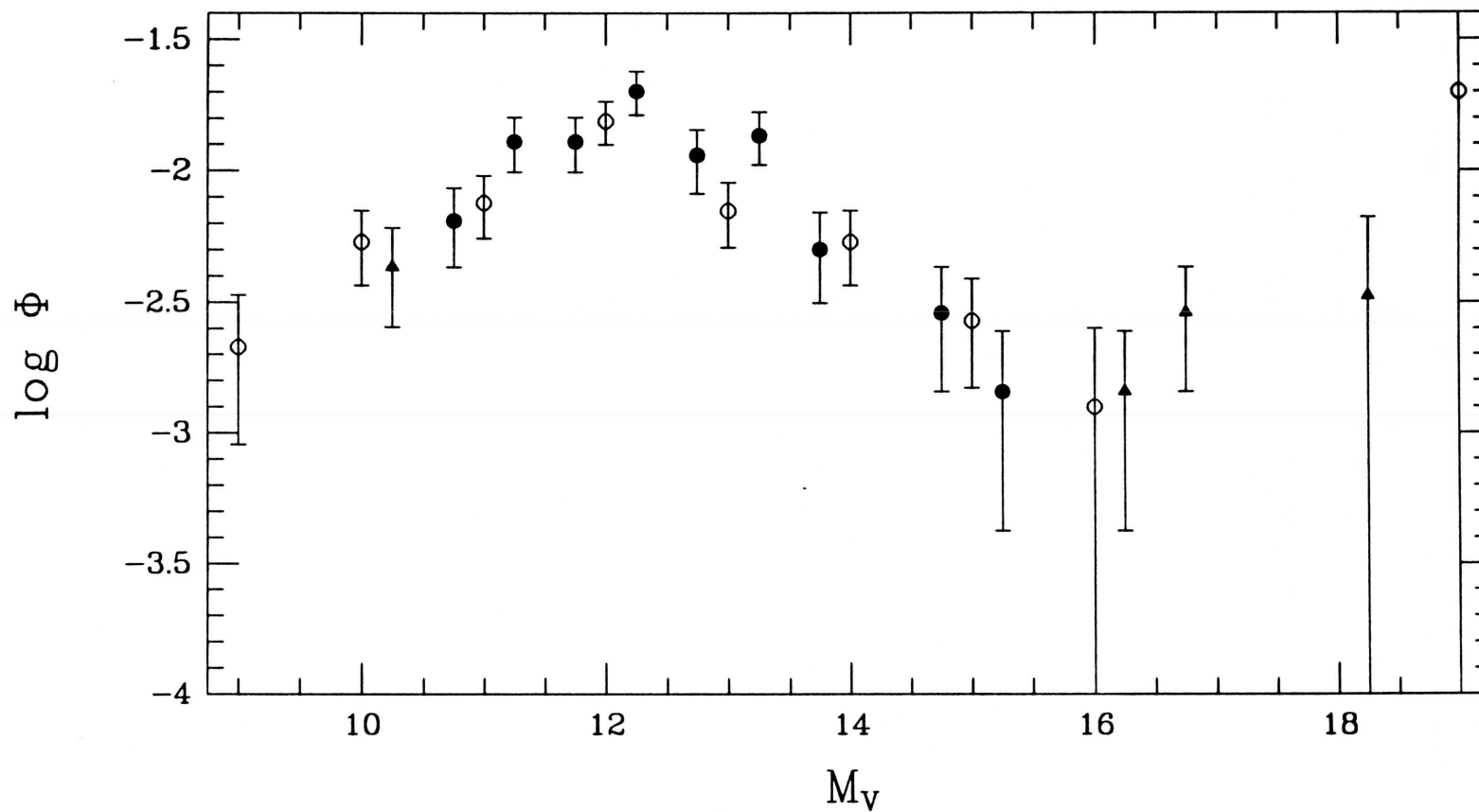
FIG. 4.18. — The (uncorrected) CTI luminosity function $\Phi$ of M dwarfs at $V$, given as filled circles and triangles. The open circles show the Reid & Gilmore (1982) luminosity function at the South Galactic Pole. Again, notice for both determinations the apparent increase in $\Phi$ for $M_V > 16$.
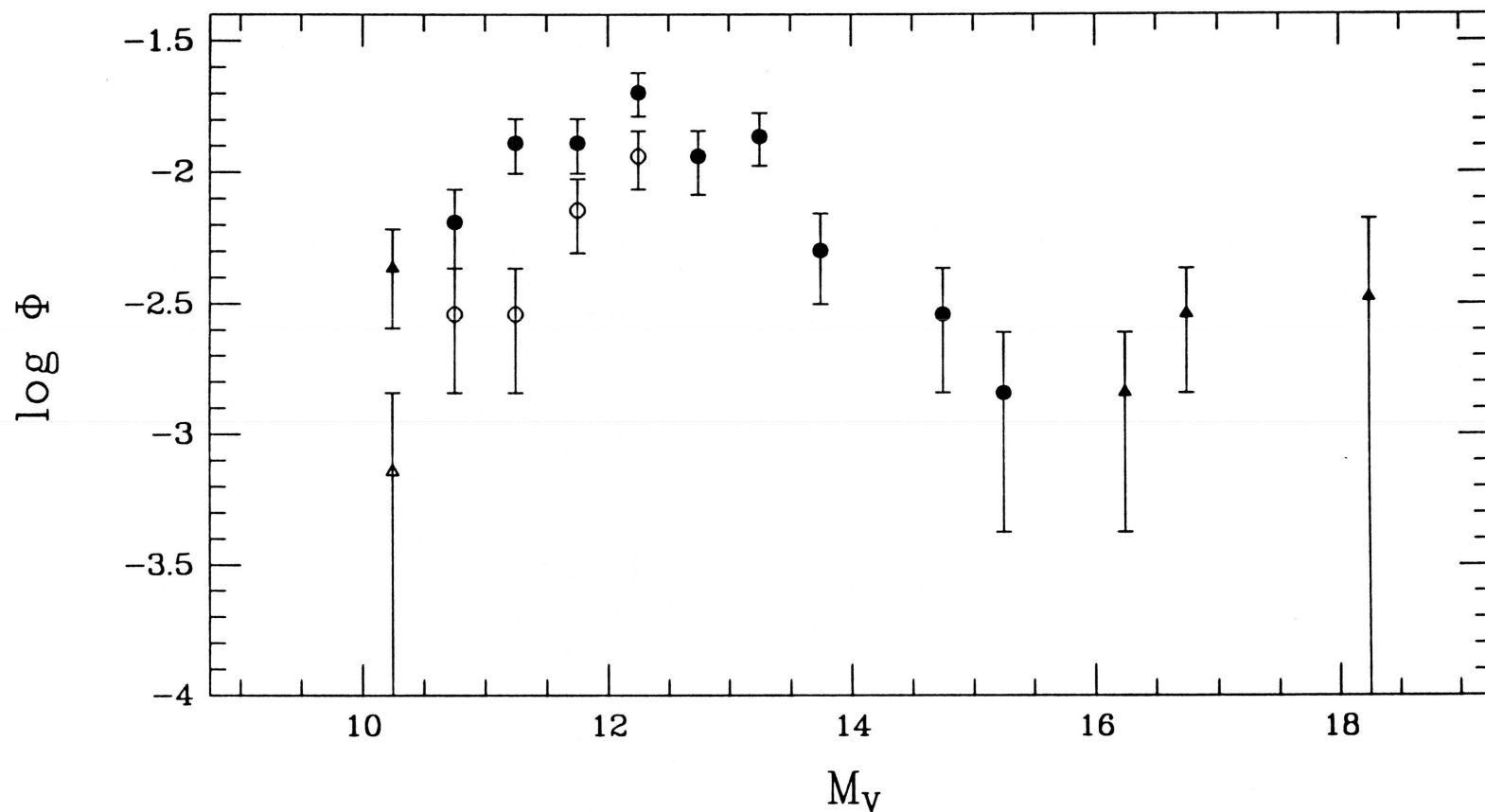
FIG. 4.19. — The CTI luminosity function from Figure 4.18 (solid circles and triangles). Open circles (and triangles for lower limits) represent a recalculation of the first five luminosity bins when calibration equation 4.4 is used instead of equation 4.2. The best estimate of the luminosity function for the first few bins falls somewhere *between* the open and solid symbols.
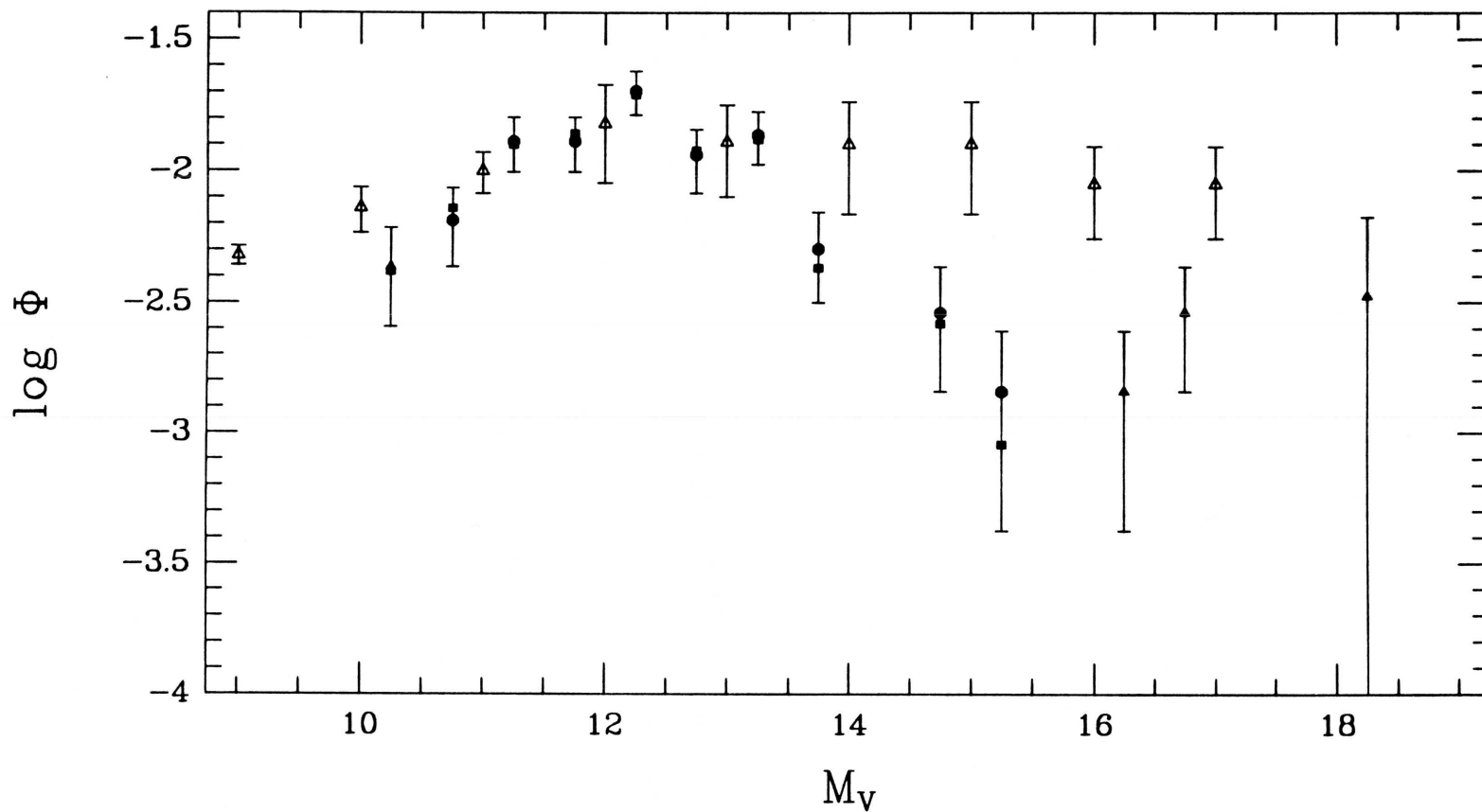
FIG. 4.20. — The CTI luminosity function shown without the Malmquist correction (solid circles and triangles) and with the correction (solid squares). For the data with $M_V \geq 16.25$, no Malmquist correction can be applied. Also shown is the Wielen, Jahreiss, & Kruger (1983) luminosity function for objects within 20 parsecs (open triangles).
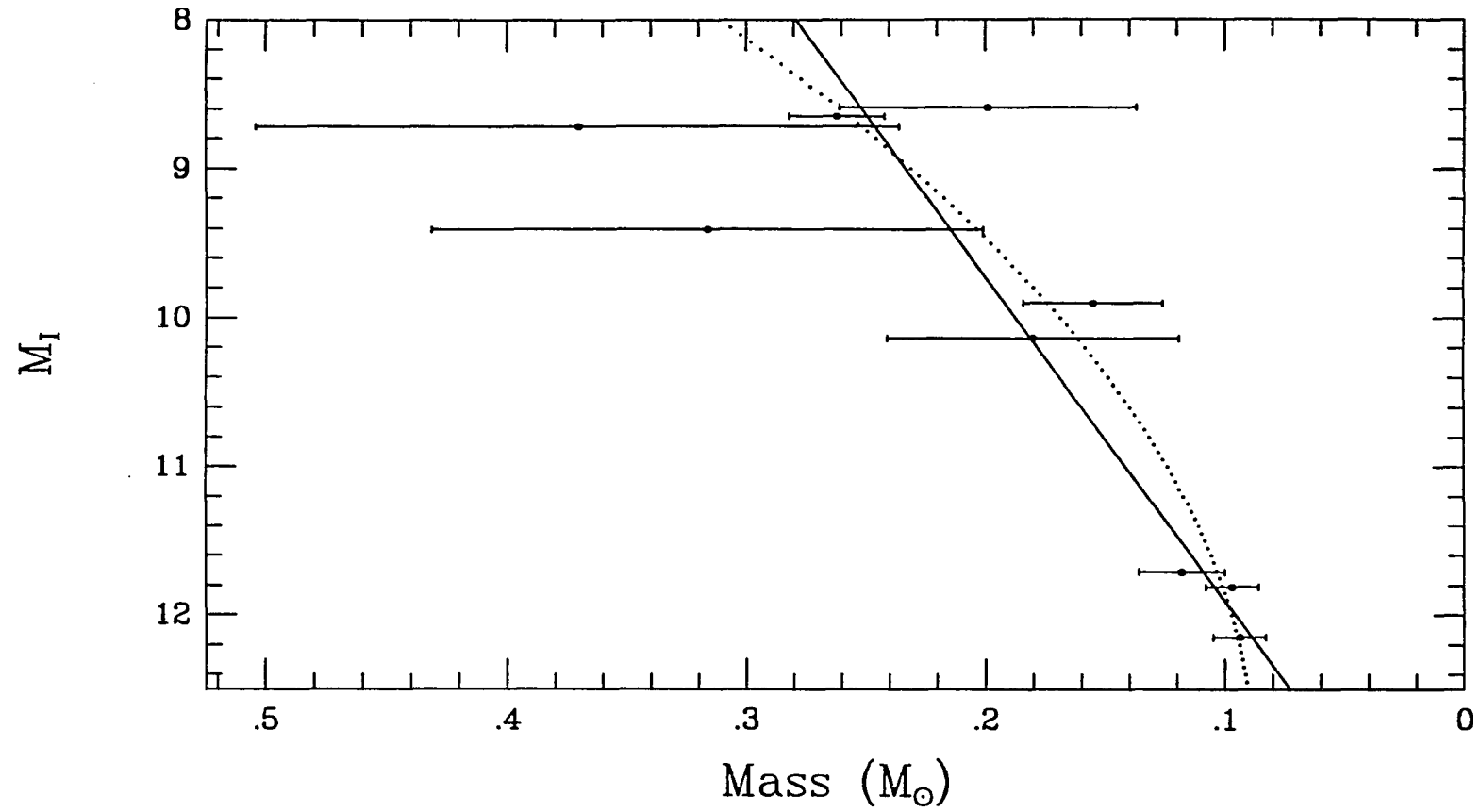
FIG. 4.21. — Plot of absolute $I$ magnitude vs. dynamically determined mass for M dwarfs. The solid line represents a weighted linear least-squares fit to the data, and the dotted line represents a weighted second-order least-squares fit to the data.
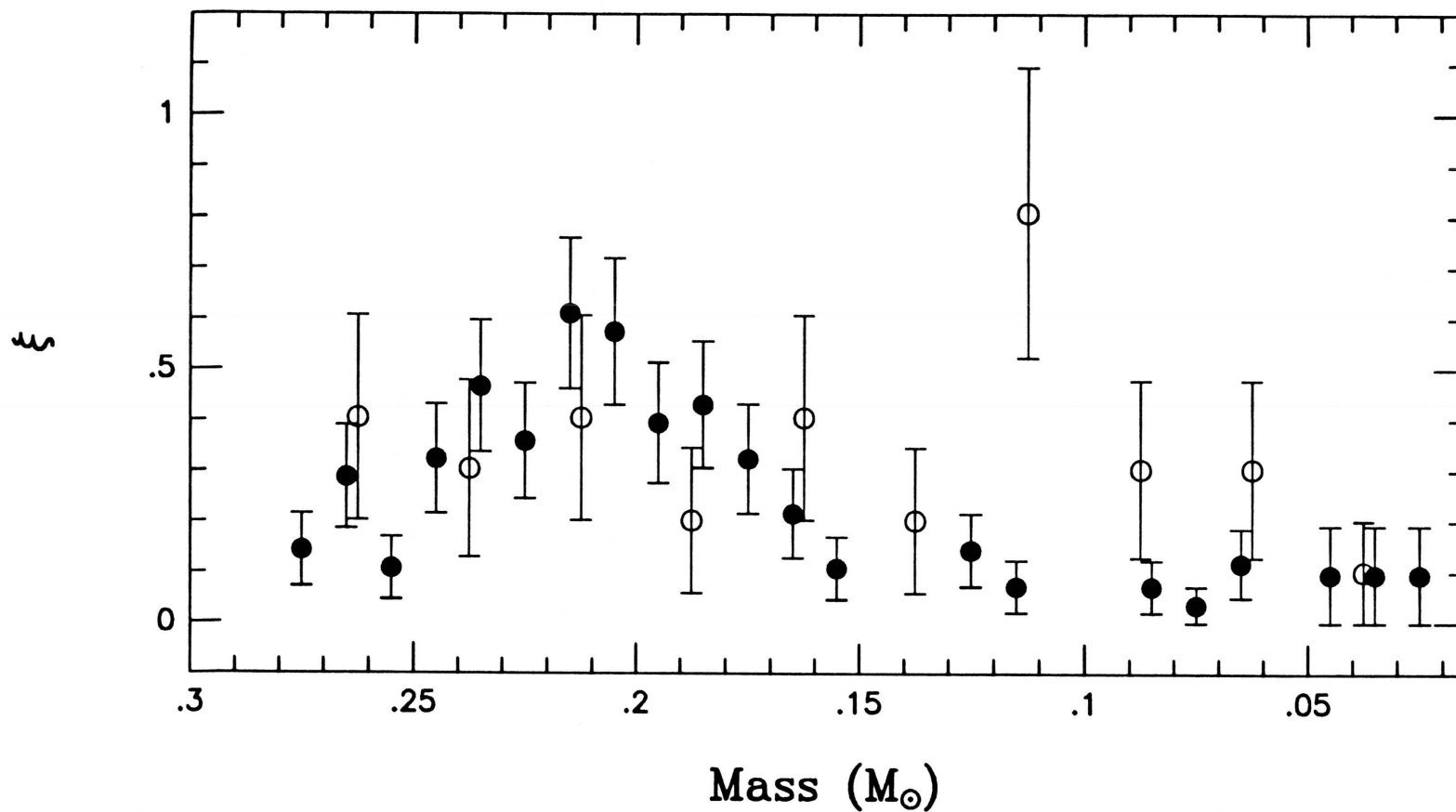
FIG. 4.22. — The derived mass function $\xi$ (filled circles) obtained by using the CTI luminosity function of Figure 4.14 with the *linear* relation of Figure 4.21. Open circles show the mass function when the nearby luminosity function of Figure 4.16 is used. The Poisson errors in each mass bin are shown.
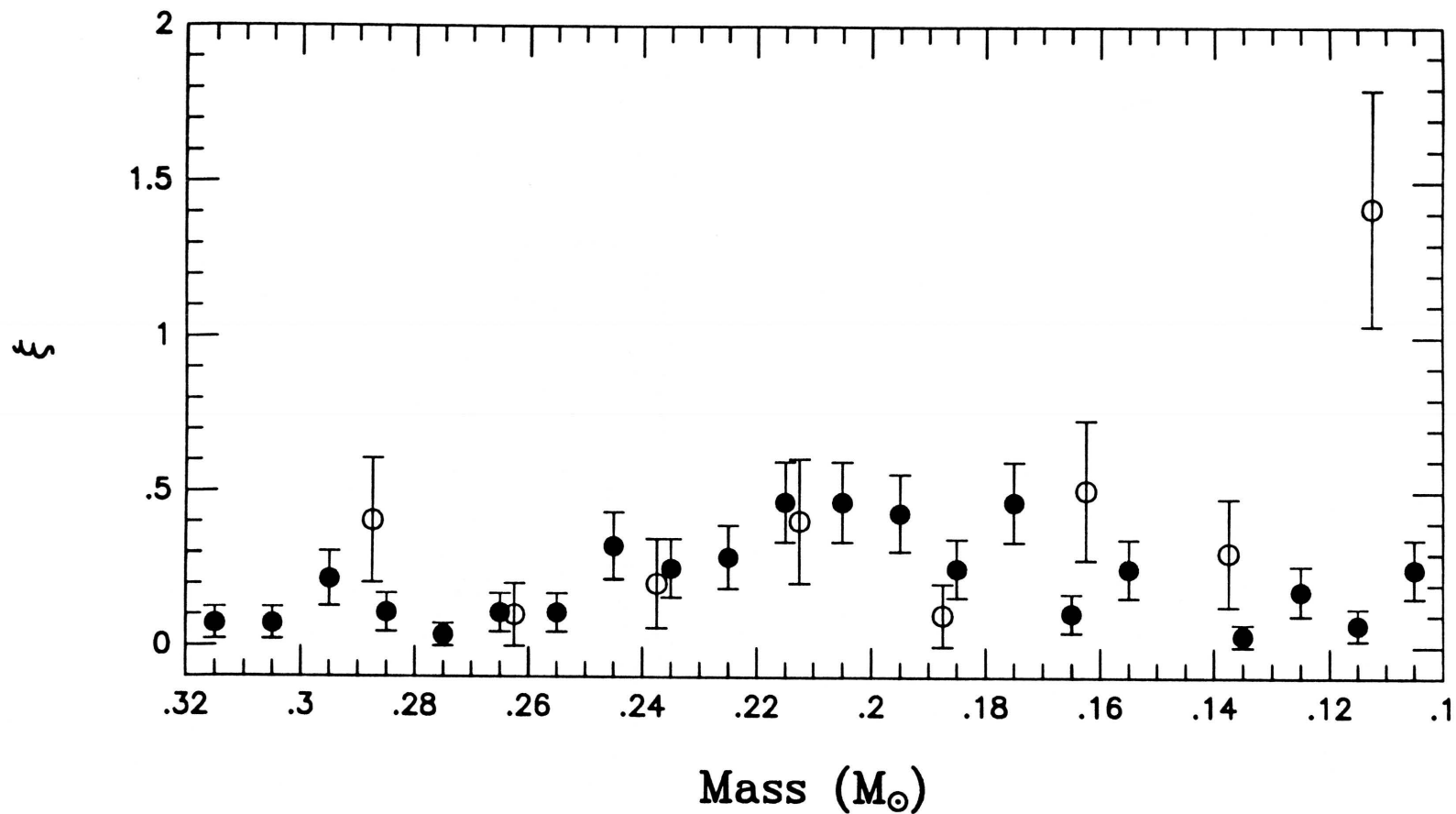
FIG. 4.23. — The derived mass function $\xi$ (filled circles) obtained by using the CTI luminosity function of Figure 4.14 with the *second-order* relation of Figure 4.21. Open circles show the mass function resulting from this second-order relation when the nearby luminosity function of Figure 4.16 is used. The Poisson errors in each mass bin are shown.

# CHAPTER 5

## GOALS FOR FUTURE STUDIES

Time is the warp of the tapestry which is life... Fate...weaves the design that is never finished. A thread from here, a thread from there, another from out of the past that has waited years for the companion thread without which the picture must be incomplete. But Fate is patient. She waits a hundred or a thousand years to bring together two strands of thread whose union is essential to the fabrication of her tapestry, to the composition of the design that was without beginning and is without end.

— Edgar Rice Burroughs, <u>Tarzan Triumphant</u>, beginning of Chapter 1 (1932)

As the last chapter has shown, there is still much to be learned about the faint end of the stellar luminosity function. The number of extremely low luminosity objects currently known is very small, although intuition might lead one to believe that these objects are actually quite plentiful. Because of their intrinsic faintness, they can only be detected photometrically in the immediate solar vicinity. Discovering large numbers of objects like vB 8, vB 10, and LHS 2924 would require laborious, all-sky surveys. In some cases, however, the companion thread — that is, the painstaking, preliminary research — *can already be found*, and only a little effort is needed to uncover many more of these objects. This chapter thus introduces several scientific projects beneficial to the study of M dwarfs and brown dwarfs and also outlines the research interests that the author plans to pursue at the termination of this thesis.

# 5.1: FOLLOW-UP TO LUYTEN'S WORK

The study of the solar neighborhood is vital to our understanding of the Milky Way and of stellar systems in general. Our knowledge of the *faintest* local consituents of the Galaxy remains, however, very limited. Of all stars known within 5.2 parsecs of the sun (Batten 1992), M dwarfs comprise 68%, or 46 out of 68, of the total. This space density implies that another 281 M dwarfs should be found between 5.2 and 10 parsecs, yet only 142 are known (Gliese 1969; Gliese & Jahreiss 1979). Furthermore, this 50% incompleteness rate serves only as a lower limit because it assumes that all M dwarfs within 5.2 parsecs have been discovered — since 1986 alone, three new M dwarfs have been added to the 5.2-parsec census (Henry & McCarthy 1990). Two of these (G 208-44 B and GL 866 B) were newly identified companions to stars already known, but the other (LHS 292) was a single object whose identity as a nearby, late-M dwarf had just been recognized (Dahn, Liebert, & Harringtion 1986). This shows that unresolved binarity is not the only reason that some objects have been missed.

LHS 292 is just one of more than 3500 objects listed in the LHS Catalogue (Luyten 1979), which lists all objects determined by Lutyen to have proper motions exceeding 0.5 arcsecond per year. The catalog is divided into four sections:

(1) Stars numbered LHS 1 through 73 have proper motions larger than 2 arcseconds per year and include such famous stars as Barnard's Star, 61 Cygni A and B, Arcturus, and the Alpha Centauri system. In general, these stars are relatively bright and had been studied long before 1979.

(2) Stars numbered LHS 101 through 552 have proper motions between 1 and 2 arcseconds per year. In general, this list contains lesser-known and fainter

objects, but also includes such noteworthy stars as Sirius A and B, Procyon A and B, vB 8, and vB 10.

(3) Stars numbered LHS 1001 through 4058 have proper motions between 0.5 and 1 arcsecond per year. These stars are generally rather faint and include LHS 2924 and LHS 2065.

(4) Stars numbered LHS 5001 through 5413, which Luyten places in his Appendix I, have motions between 0.480 and 0.499 arcsecond per year. These were included because remeasurements of their proper motions might give values of $\mu \geq 0.500$ arcsecond per year, earning them true membership in the catalog.

The number of unclassified objects remaining in the catalog should be determined. Are there late-type, very nearby dwarfs which are, as had been LHS 292, lying unrecognized in this list?

To answer this question, Table 5.1 has been produced. Column 1 gives the LHS number of the object as listed in Luyten (1979). Column 2 gives the GL name (Gliese 1969, numbers from 1 to 915) or the GJ name (Gliese & Jahreiss 1979, numbers from 1001 to 2159). Column 3 gives the G number (Giclas, Burnham, & Thomas 1971; Giclas, Burnham, & Thomas 1978). (The matching of names for columns 1, 2, and 3 was accomplished by comparing the coordinates, the magnitudes, and the sizes and directions of the proper motion listed in the LHS, Gliese, and Giclas catalogs; previous cross-listings were in general not used in an attempt to avoid earlier, incorrect matches.) Column 4 gives other names; preference is given to Bayer designations, then Flamsteed designations, BD (Bonner Durchmusterung, $-22° \leq \delta \leq +89°$) numbers, CD (Cordoba Durchmusterung, $-89° \leq \delta \leq -22°$) numbers, CP (Cape Photographic, $-89° \leq \delta \leq -18°$) numbers,

Wolf or Ross number, other name (such as vB number), and finally variable star designation. In a few cases, this hierarchy has been ignored if a designation further down the list has become the more popular name of the object. For example, LHS 57 is listed as Barnard's Star, not as BD +4° 3561a. For coordinates and magnitudes of all LHS objects, refer to Luyten (1979); for finder charts, refer to Luyten & Albers (1979).

In the LHS Catalogue, both a photographic and a red magnitude are given, and these can be used to generate an $m_{pg} - m_R$ color. These colors are listed in column 5 of Table 5.1. In column 6 are given the spectroscopic classifications and their references, the key for which is found in the notes following the table; when found, classifications from multiple sources are given. This column of the table has relied heavily on the use of the SIMBAD data base, operated at CDS, Strasbourg, France. To aid in the compilation of column 6, a number of additional tables were produced. These complementary tables are given to facilitate cross-referencing between LHS numbers and other names when the LHS number is not known: LHS numbers are cross-listed with GL and GJ numbers in Table 5.2; with G numbers in Table 5.3; with common star names in Table 5.4; with Bayer designations in Table 5.5; with Flamsteed designations in Table 5.6; with HR numbers in Table 5.7; with BD numbers in Table 5.8; with CD numbers in Table 5.9; with CP numbers in Table 5.10; with Wolf numbers in Table 5.11; with Ross numbers in Table 5.12; with variable star designations in Table 5.13; and with other, miscellaneous names (like vB or Lalande numbers) in Table 5.14.

## 5.1.1: Spectroscopic Identifications of LHS Objects

For LHS 1 to 73, published spectral types were found for 97%. For two entries (LHS 17 and 40) types have not been found; two systems (LHS 8 AB and 68 AB) have composite spectra only; and two others have poor types (LHS 18 and 22). Six objects between LHS 1 and 73 have $m_{pg} - m_R \geq 2.0$, and all are classified as mid-M dwarfs. The reddest of these is LHS 2 with $m_{pg} - m_R = 2.5$ and spectral type M5-5.5 V.

For LHS 101 to 552, published spectral types were found for 79%. Twenty-seven systems have composite spectra only and another twenty have poor types. Of the 95 objects without spectroscopic identification, two (LHS 106 and 211) have $m_{pg} - m_R \geq 2.5$ and would be considered good candidates for late-type dwarfs. Figure 5.1 plots the $m_{pg} - m_R$ color against spectral type for LHS 1 through 552. There is a general trend, though the scatter is large, of increasing $m_{pg} - m_R$ color with later spectral type.

The incompleteness of the spectroscopic classifications in Table 5.1 is glaringly evident for the objects numbered LHS 1001 and higher. In this group, a total of 119 objects have $m_{pg} - m_R \geq 2.5$. These are listed in Table 5.15. To get a better census of nearby, late-type dwarfs, follow-up spectroscopy should be done on all of these which have not been classified previously. Only 46 of the objects in Table 5.15 have known spectral classifications, and 12 of these are first-time identifications by this author. Spectroscopic observations of these 12 objects were obtained with the MMT Red Channel using the previously described set-up and are summarized in Table 5.16. The spectra are presented in Figures 5.2 and 5.3.

As would be expected from a proper-motion selected sample, and as the data in Tables 5.15 and 5.16 confirm, these objects of late color class comprise two distinct groups: nearby ($d \leq 30$ pc) mid- to late-M dwarfs and more distant ($d \sim 100$ pc) subdwarfs of extreme type. The results of the observations on 1992 Feb 25 prove that objects near the end of the main sequence lie unrecognized in the LHS Catalogue — two objects comparable in type to vB 8 and one object comparable to vB 10 were identified. Furthermore, one of the subdwarfs discovered, LHS 2352, is as red as LHS 1742a (Liebert et al. 1993), the latest subdwarf known, but has even weaker bands of $TiO$.

Neither vB 8 ($m_{pg} - m_R = 2.2$) nor vB 10 ($m_{pg} - m_R = 1.5$), however, would have earned inclusion into Table 5.15. This indicates that other late dwarf candidates, not distinguishable by their $m_{pg} - m_R$ colors, are probably included in Table 5.1. For some of the unclassified objects, clues can be found in follow-up photometry. Specifically, additional photometry of LHS objects is presented in the following sources:

UBV: Sandage (1964); Sandage (1969); Augensen & Buscombe (1978); Carney (1978); Harrington & Dahn (1980); Sandage (1981); Dahn et al. (1982); Harrington et al. (1985); Sandage & Kowal (1986); Fouts & Sandage (1986); Sandage & Fouts (1987); Carney & Latham (1987); Dahn et al. (1988); Ryan & Norris (1991).

UBVRI: Eggen (1979); Eggen (1980); Ryan (1989).

UBVRIJHK: Carney (1983a); Carney (1983b).

BVRI: Eggen (1987).

VRI: Weis (1991).

VI: Monet et al. (1992).

Table 5.1 is, of course, also useful for uncovering objects other than M dwarfs and subdwarfs:

(1) There are 71 objects having $m_{pg} - m_R \leq 0.0$. Of the 54 with spectroscopic identifications, 52 are white dwarfs. The 17 unclassified objects are all prime white dwarf candidates.

(2) Between the extremely blue and the extremely red entries of Table 5.1 lies the majority of objects, from which will doubtless come other interesting discoveries and perhaps even new classes of stars. An example is the discovery of a rare object known as a dwarf carbon star — LHS 1555, also known as G 77-61 (Dahn et al. 1977). Within the past year, four more dwarf carbon stars have been recognized (Green, Margon, & MacConnell 1991; Green et al. 1992), and among these is LHS 1075. Spectra of LHS 1555 and LHS 1075 are shown in Figure 5.4

### 5.1.2: Late-type Stars in Binary and Multiple Systems

A census of nearby stars would be incomplete without an accurate knowledge of each system's multiplicity. Binary stars are necessary for mass determinations, and the recognition of low-mass companions will help to answer questions concerning the frequency and nature of late-M dwarfs, brown dwarfs, and planets. Some of the entries in Table 5.1 have been checked for binarity through astrometric, spectroscopic, photometric, imaging, and interferometric techniques. An asterisk next to the object name in column 1 of Table 5.1 indicates an object which, although listed as a single LHS entry, has been suspected or confirmed as a binary or multiple object. Each of the asterisks refers to a note given in Table 5.17, which lists, in increasing order, the LHS number (and designations

of A, B, and C given for confirmed components) with a parenthetical note giving the status of the system followed by notes and references to the suspected or confirmed multiplicity. The codes for the system status are —

Conf. = binarity or multiplicity confirmed.

As = astrometric perturbations suggest a companion.

As? = unverified astrometric perturbations suggest a companion.

As?? = dubious astrometric perturbations suggest a companion.

CPM? = nearby object may share common proper motion.

Ecl? = photometric measures suggest eclipse by unseen companion.

Flare? = possible flaring events suggest an unseen companion.

Opt = nearby companion is optical only.

Opt? = suspected companion may be optical only.

Phot? = photometry suggests excess flux due to unseen companion.

Radio? = radio emission detected from possible unseen companion.

SB = single-lined spectroscopic binary or radial velocity variable.

SB? = unverified single-lined spectroscopic binary or velocity variable.

Speck? = speckle interferometry may suggest a companion is present.

Vis? = companion was, perhaps, visually resolved but is now unseen.

As this legend suggests, the multiplicity is considered definite (Conf.) if distinct and recurrent eclipses are detected, if the object is a double-lined spectroscopic binary, or if the companion is resolved through, for example, visual, photographic, or speckle techniques and is found to be physically associated with the primary.

Among the entries in Table 5.17 are found several confirmed secondaries which lie near the stellar/substellar break: LHS 154 B ($\delta$ Tri B), LHS 417 B (GL 623 B), LHS 472 B (Wolf 1062 B), LHS 1047 B (GJ 1005 B), and LHS 3494

B (G 208-44 B). Other entries which have suspected companions in the late-M dwarf/brown dwarf/planetary regime include LHS 26 (Stein 2051 A), LHS 33 (Luyten's Star), LHS 57 (Barnard's Star), LHS 2042 (GL 319 AB), LHS 2665 (GL 494), LHS 2693 (HD 114762), LHS 3076 (G 152-31), LHS 3277 (GJ 1215), LHS 3509 (GL 777 B), LHS 3556 (GL 791.2), LHS 3853 (EV Lacertae), and LHS 5405 (G 29-38). Follow-up observations of these objects are continuing as other entries in Table 5.1 are slowly being added to these observing programs.

Newly recognized late-type stars from Table 5.16 and from susbsequent observing runs can be imaged in the infrared to detect companions of even later type. With current infrared arrays, typical separations studied are on the order of 20 to 1000 AU for nearby stars. First-epoch images are taken to obtain colors of all field stars in an attempt to photometrically select red, possible low-mass secondaries. Second-epoch images are taken to check for common proper motion. Henry & Simons (Henry 1992) have begun such a systematic survey around all known, northern M dwarfs within 8 parsecs. This author plans to do a similar survey for all known, northern dwarfs of type M6.5 and later. These surveys are the infrared analogues to the photographic survey completed by van Biesbroeck (1961), who imaged fields around ~650 stars with proper motions of $\geq 0.75$ arcsecond per year. It was this survey which provided the original discoveries of vB 8 and vB 10.

## 5.1.3: Spectroscopic Identifications for "The Stars of Low Luminosity"

The LHS Catalogue contains only those Luyten discoveries with $\mu \geq 0.5$ arcsecond per year, though he catalogued many more objects with proper mo-

tions down to ~0.2 arcsecond per year. In a monograph entitled "The Stars of Low Luminosity" (Luyten 1977), all of his discoveries with large reduced proper motions ($H = m + 5 + 5\log\mu$, which is analogous to the absolute magnitude if one believes that the size of the proper motion gives some indication of the distance) are tabulated. In total, Luyten lists 2907 objects, and the 443 having $m_{pg} - m_R \geq 3.0$ are given in Table 5.18. Amazingly, only 18 of these have been spectroscopically identified, all of which are cross-listed as LHS objects. This author plans to produce finder charts for these objects and to obtain spectra of a subset of these. The number of presently unknown, nearby M dwarfs and brown dwarf candidates contained in this list could be staggering and would have profound ramifications on our knowledge of the stellar luminosity function.

## 5.2: A New Proper Motion Survey

A means of discovering neaby stars is to search for objects having extremely large proper motions. Table 5.19 lists all known objects with motions exceeding ~3 arcseconds per year. Columns 1 and 2 give the LHS number and other names for each star, column 3 gives the proper motion, column 4 gives the $V$ magnitude, and column 5 gives the spectral type. Note the complete absence of faint ($m_V \geq 15$) stars. When this list is compared to a similar list from a 1927 textbook by Russell, Dugan, & Stewart (see column 6 of Table 5.19), it is found that there are very few differences. Of the 35 stars listed in Table 5.19, 24 were already known in 1927. Of the 11 additions, two were discovered as companions to stars already on the list, three were discovered by Ross between 1925 and 1939, one was discovered by Luyten and Ebbighausen in 1935 (Luyten & Ebbighausen

1935), four were discovered by Luyten during the Bruce Proper Motion Survey (before 1957), and the last was discovered on Palomar plates by Luyten in 1968, before measuring machines were used (Liebert 1991). In fact, Russell, Dugan, & Stewart (1927) state emphatically that their table " is undoubtedly incomplete... there is a fair chance that photographic observations may detect some faint star with a proper motion greater than Barnard's star, and a practical certainty that they will in future add a good many stars to the list." Clearly, however, the intervening years have seen few additions.

The reason for this discrepancy can be understood by reviewing the two major proper motion surveys undertaken in the last 50 years — those by Giclas and co-workers at Lowell Observatory and by Luyten at the University of Minnesota. The Lowell Survey (Giclas, Burnham, & Thomas 1971; Giclas, Burnham, & Thomas 1978) covered declinations north of $\delta \sim -5°$, with spotty coverage between $\delta = -5°$ and $-40°$. The Bruce Proper Motion Survey (Luyten 1955) covered almost the entire southern hemisphere and about 30% of the northern hemisphere (Luyten 1963). Both of these surveys quote a limiting magnitude of $m_{pg} \sim 16.0$ to 16.5, though the onset of incompleteness is $m_{pg} \sim 14.5$ to 15.0 (Liebert & Probst 1987). The Luyten Palomar survey (Luyten 1963) covered declinations north of $-33°$ (with spotty coverage for galactic latitudes $\pm 20°$ from the plane) down to a limiting magnitude of $m_R \sim 20.8$; however, an algorithm for matching plates was limited to proper motions of less that 2.5 arcseconds per year (Luyten 1987; Liebert & Probst 1987). These surveys, therefore, would have completely missed the fainter, highest proper motion objects — those still unrecognized, nearby, low-luminosity, low-mass members of the solar neighborhood.

If Wolf 359 were moved out to 3.4 parsecs, its apparent magnitude would be fainter than the detection limit for the Lowell or Bruce surveys, and its proper motion of 3.25 arcseconds per year would be larger than the detection limit of the Luyten Palomar survey. Furthermore, if vB 10 and LHS 2924 were moved close enough so that their proper motions measured greater than 2.5 arcseconds per annum, they would shine dimly at $m_{pg} \sim 18.2$ and 18.7, respectively — too faint to have been detected by the Lowell or Bruce surveys — yet would lie at distances of 3.5 and 3.4 parsecs, respectively!

Table 5.20 lists objects with $\mu \geq 0.57$ arcsecond per year which are not included in the LHS Catalogue. Several of these objects are southern stars missed by the Bruce survey because of their faint apparent magnitudes. Several others were added by Luyten after fields near the galactic plane were measured. Interestingly, the first star in Table 5.20, GJ 2045, is an object which Luyten may have missed because its motion was larger that the Luyten Palomar detection limit. (However, there is a possibility that this object is actually a rediscovery of LHS 1777, whose proper motion Luyten gives as 0.971 arcsecond per year. This proper motion, together with Luyten's 1950 position of the object, coincides with the position given for GJ 2045 in Ohtani & Ichikawa (1977), where it is denoted as star #50. In this case the motion cited by Ohtani & Ichikawa must have been overestimated, which is likely since their caclculation was based on comparing the object's position on a 1976 plate with the object's position on the Palomar Observatory Sky Survey *prints*.)

Ruiz, Maza, & Wischnjewsky (1988) have begun a proper motion search in the southern hemisphere by blinking ESO plates taken 3 to 7 years apart. The blinking process combined with the ESO plate limit of $m_R = 21$ means that any

faint, high-$\mu$ objects missed by Luyten can be uncovered. This new search began in 1986, and to date results on only two $5° \times 5°$ fields have been reported (Ruiz, Maza, & Wischnjewsky 1988; Ruiz & Maza 1990).

In the northern hemisphere, no such follow-up to Luyten's survey is underway. Evans' (1992) search for "high proper motion" stars is limited to motions of less than 0.5 arcsecond per year. The parallax survey of Perlmutter et al. (1986), whose aim is to identify a faint stellar companion (Nemesis?) to the sun, is limited to known M dwarfs listed in the Dearborn Catalogue of Faint Red Stars, which is complete to only 13th magnitude.

Again, the preliminary observations for such a project are already being taken — by, in this case, the second-generation Palomar Observatory Sky Survey (POSS II). High proper motion objects will be best detected if the time baseline between plates is relatively short. For the Luyten Palomar survey, this baseline was typically 11 to 13 years, meaning that a star at the upper detection limit of $\mu = 2.5$ arcseconds per annum would have moved 450 $\mu m$ on the plate. Luyten was easily able to detect stars with $\mu \sim 0.1$ arcsecond per annum, corresponding to 18 $\mu m$ on the plate. (For the APM proper motion project, Evans (1992) quotes upper and lower detection limits of 160 and 16 $\mu m$ , respectively.) To allow for some overlap between Luyten's candidates and newly discovered ones, the lower limit on $\mu$ for this new search should be no larger that $\sim 1.5$ arcseconds per annum. This would correspond to a time baseline of $\geq 1$ year. Adopting Luyten's upper detection limit of 450 $\mu m$ means that a star like Barnard's could be detected in $\leq 3$ years.

Rejected POSS II plates, which have been discarded because of too many airplane trails or various other flaws but which are still useful for science, can

be used as epoch 1, and retakes of the same regions can be used as epoch 2. The typical amount of time between the discards and the retakes is 3 or 4 years, which satisfies the criteria stated above. Presently, there are already over 100 fields which have 2 useable, rejected plates (Reid 1991). These plates cover over 2900 square degrees to a limiting magnitude of $R = 20.8$ (Reid et al. 1991), and a subset will be used by this author for the preliminary stages of this investigation.

### 5.3: A New Photometric Search for Late Dwarfs

The new proper motion seach mentioned above will, of course, miss those nearby objects having small tangential velocities. To discover faint, nearby M dwarfs and brown dwarf candidates with small values of $\mu$, a photometric search is required. As Chapter 4 has shown, this search should be conducted over a large area of sky to combat the poor sampling statistics which have plagued most previous photometric surveys. Tinney and collaborators have begun such a survey by using POSS II plates covering an area of 320 square degrees. Preliminary results over 60% of this region are presented in Tinney, Mould, & Reid (1992) along with the derived luminosity and mass functions. The POSS II has an advantage over the POSS I in that for the new survey, plates are being taken in the blue (IIIa-J), the red (IIIa-F), *and* the near infrared (IVN) (Reid et al. 1991) — so a search for red stars is limited by the $R$ magnitude of 20.8 rather than by the blue magnitude of the POSS I. An extension of the Tinney survey to even larger areas can be accomplished in tandem with the new proper motion survey outlined above. After positions and magnitudes are measured for all images on the subset of IIIa-F plates, subsequent measures can be made on the IVN plates

of the same field to generate an $R - I$ color for each matched object. The reddest of these will likewise be spectroscopically observed and then imaged in the infrared to search for companions.
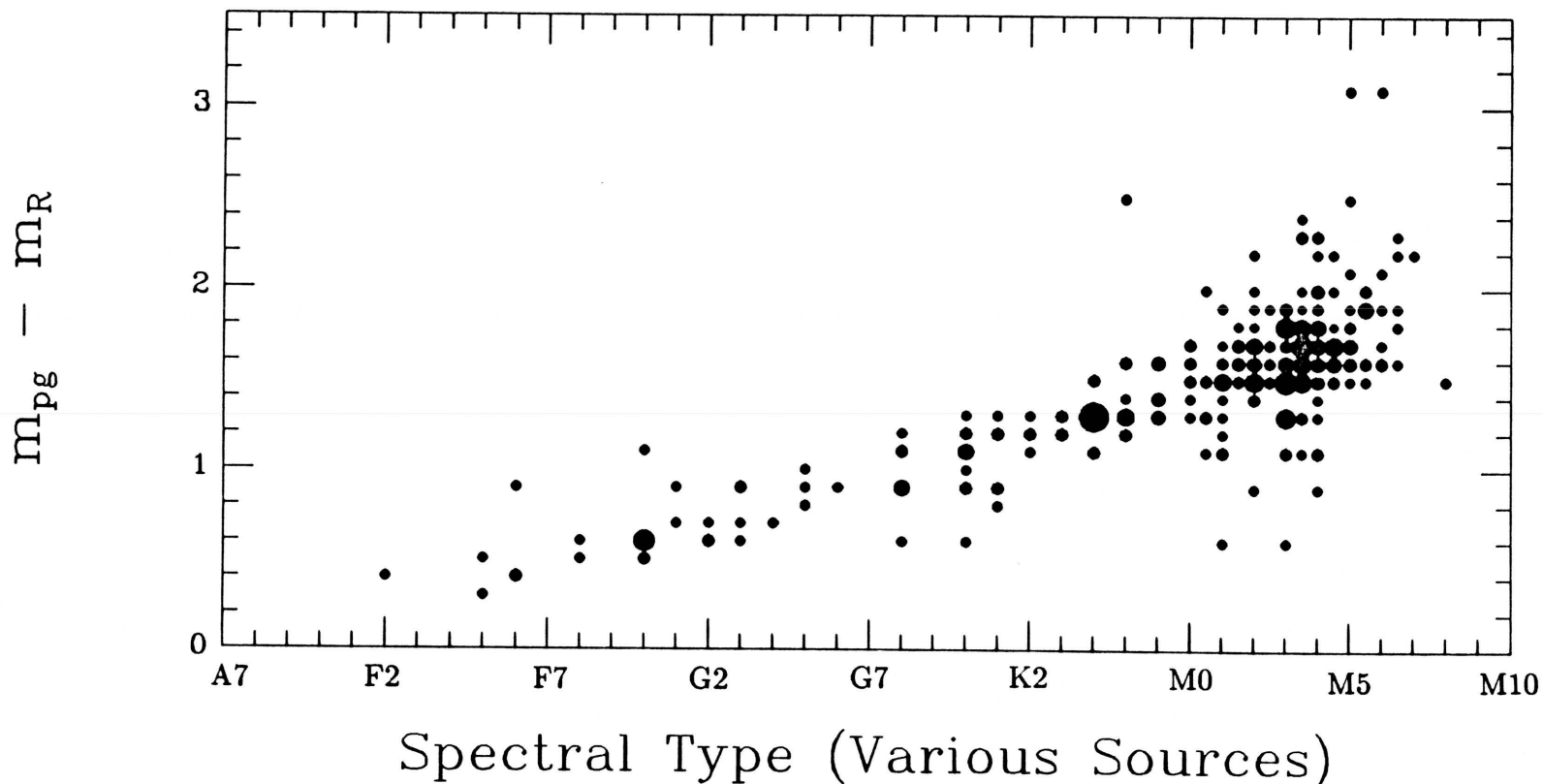
FIG. 5.1. — $m_{pg} - m_R$ color versus spectral type for those LHS stars (1 through 552) with spectral types in the literature. White dwarfs, subdwarfs, and higher luminosity stars like Arcturus are not included here. The smallest circles represent one data point each; where two data points fall together, a slightly larger circle is drawn, etc. The largest circle, at type K4, represents the superposition of eleven different points. Along the horizontal axis, tick marks are shown for every unit subclass. There are no subclasses labelled K6, K8, or K9 in accordance with Kirkpatrick, Henry, & McCarthy (1991). The scatter is large due to large color errors and to heterogeneous classifications, but nonetheless it is clear that very red candidates (later than M6) can be selected from the LHS Catalogue by using the $m_{pg} - m_R$ color as a preliminary criterion for selection.
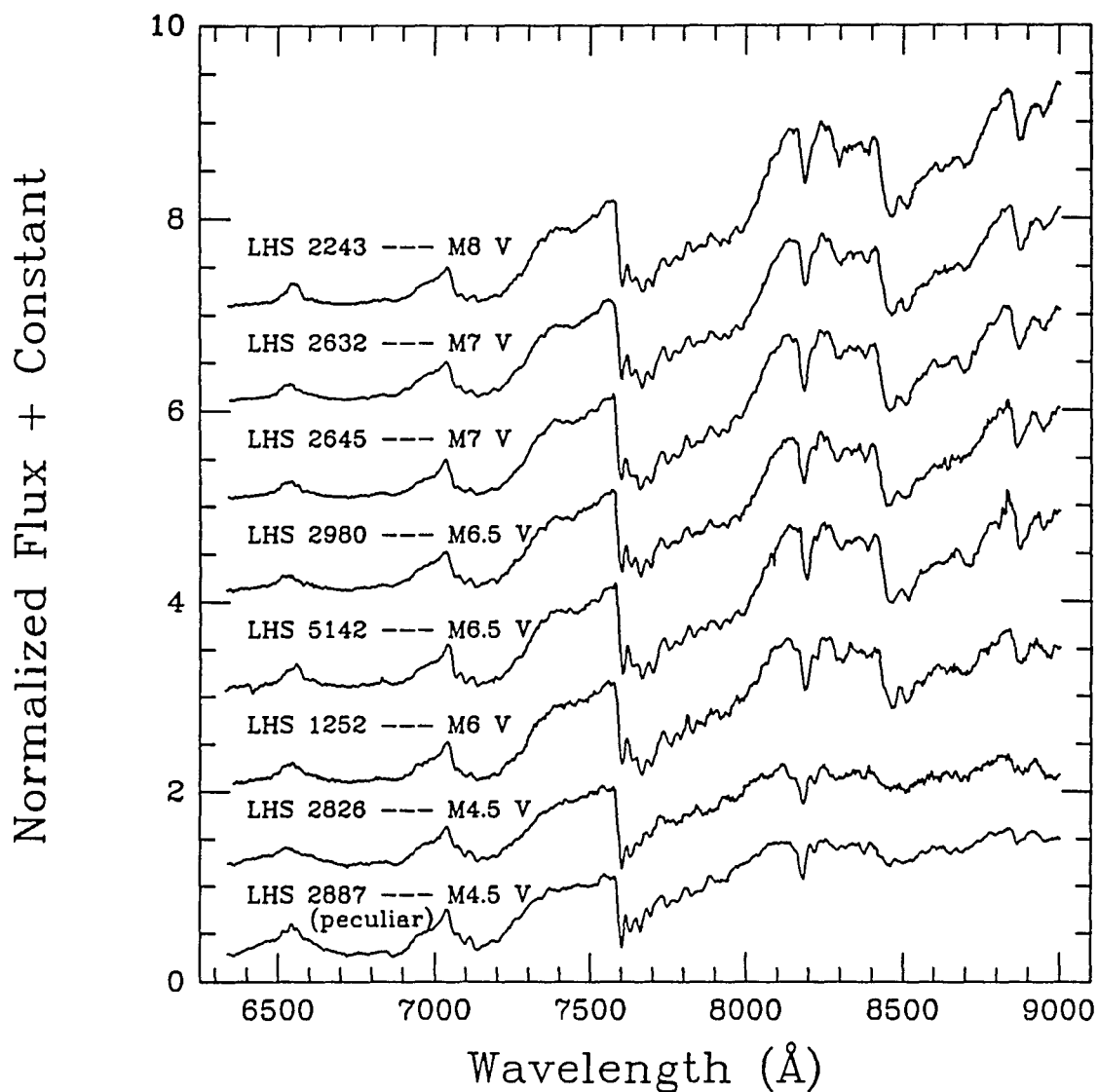
FIG. 5.2. — MMT spectra of newly identified M dwarfs from Table 5.15. Most of these have proven to be of late type, with the latest being the M8 dwarf LHS 2243. The spectrum of LHS 2887 is peculiar, relative to other M4.5 dwarfs, in that the flux between 7300 and 7600 Å is supressed. Data for each of the spectra can be found in Table 5.16. Telluric absorption has not been removed. The flux is in units of $F_\lambda$, normalized to one at 7500 Å, with integral offsets added to separate the spectra along the veritcal axis.

FIG. 5.3. — MMT spectra of newly identified M subdwarfs from Table 5.15. All of these are extreme metallic hydride subdwarfs, as indicated by the unmistakable $CaH$ absorption between 6700 and 7000 Å. Data for each of the spectra can be found in Table 5.16. As before, telluric absorption has not been removed and the flux is in units of $F_\lambda$, normalized to one at 7500 Å, with integral offsets added to separate the spectra along the vertical axis.
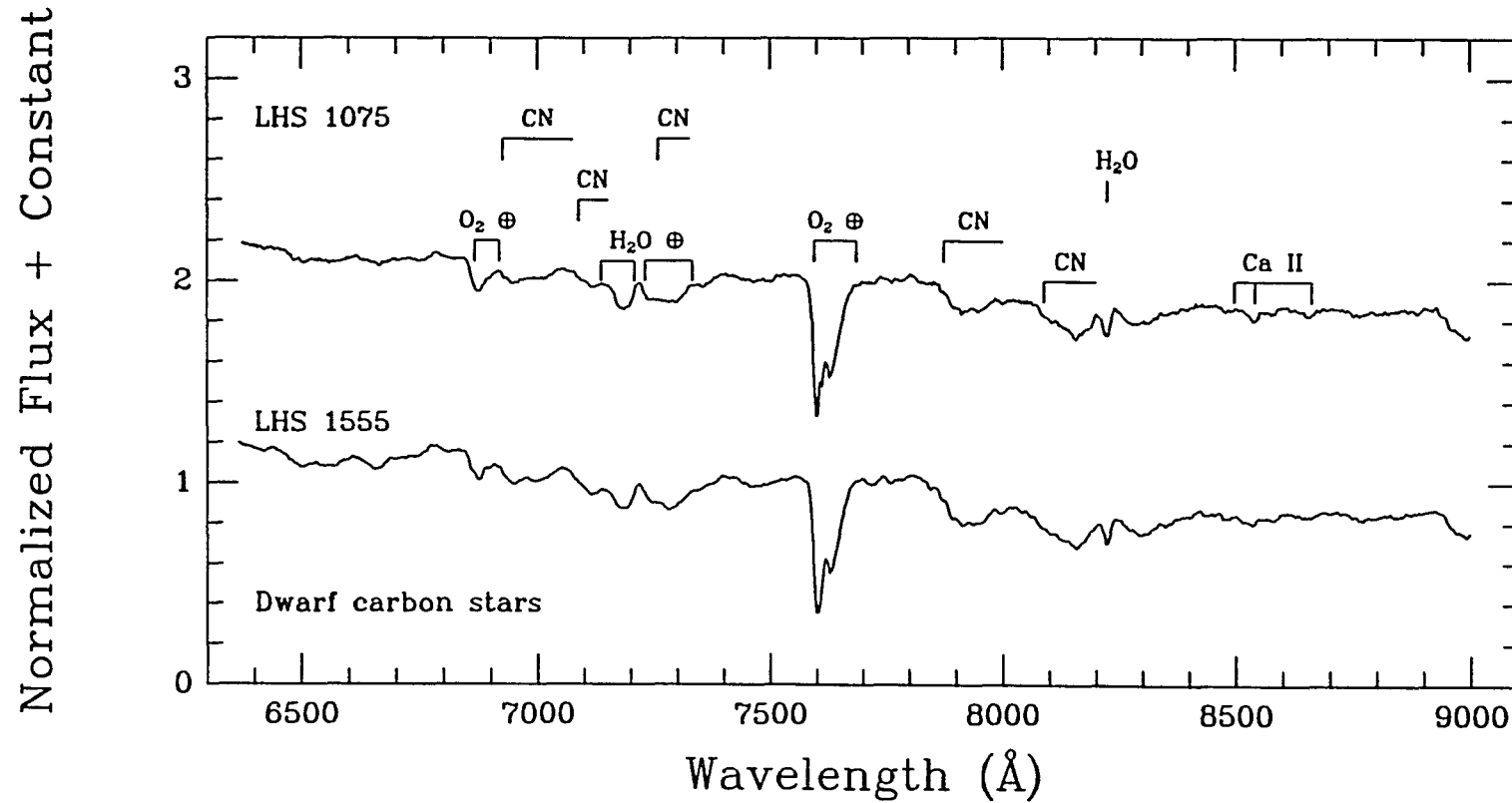
FIG. 5.4. — MMT spectra of the two LHS objects known to be dwarf carbon stars. As before, telluric lines have not been removed, but are marked in the spectra. Several stellar bands of $CN$ are noticeable in this spectral region; the $CaII$ triplet may even serve as a luminosity indicator to distinguish carbon dwarfs from carbon giants. Both spectra were obtained on (UT) 1991 Oct 17 with the MMT Red Channel Spectrograph. The integration time was 1200 seconds for LHS 1075 and 600 seconds for LHS 1555. The flux ($F_\lambda$) is normalized to one at 7500 Å, and an integral offset of 1 has been added to the spectrum of LHS 1075 to separate it from LHS 1555.

TABLE 5.1

## THE SPECTROSCOPIC LHS CATALOG

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1 | 1 | 267-25 | CD -37°15492 | 1.7 | M2 V (bf), M3.5 V (bh), M3 (af), M4 V(au) |
| 2 | 1002 | 158-27 | — | 2.5 | M5-5.5 V (ah), M5-5.5 V (ax) |
| 3* | 15 A | 171-47 | BD +43°44 A | 1.7 | M1.5 V (ah), M2.5 V (bh), M3 V (am) |
| 4 | 15 B | 171-48 | BD +43°44 B | 2.3 | M4 V (ah), M4.5 V (bh), M4 (af) |
| 5 | 17 | — | ς Tuc | 0.5 | G0 V (bf), F9 V (be), G2 V (au) |
| 6 | 19 | — | β Hyi | 0.7 | G1 IV (bf), G2 IV (be), G2 IV (au) |
| 7 | 35 | 1-27 | van Maanen's Star | 0.5 | DZ8 (br), DZ7 (bn), DZ7+ (ba) |
| 8 A* | 53 A | — | μ Cas A | 0.9 | G5 V (be), G5 (af), sdG5 (au) |
| 8 B* | 53 B | — | μ Cas B | — | composite with LHS 8 A |
| 9 | 65 A | 272-61 A | — | 1.9 | M5.5 V (bi), M5.5 V (bh) |
| 10 | 65 B | 272-61 B | UV Cet | 1.9 | M6 V (bi), M6 V (bh) |
| 11 | 83.1 | 3-33 | TZ Ari | 1.7 | M4.5 V (bi), M4.5 V (ah), M5- V (ca) |
| 12 | — | 3-36 | Wolf 110 | 0.9 | M4 (af), K4 (au), sdM (bm) |
| 13 | 86 | — | CD -51°532 | 0.9 | K1 V (bf), K0 V (au), K1 V (be) |
| 14 | 87 | 73-35 | BD +2°348 | 1.7 | M1.5 V (ah), M2.5 V (bh), M3 V (au) |
| 15* | 105 A | 73-70 | BD +6°398 A | 1.2 | K3 V (be), K3 (af), K5V (au) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 16 | 105 B | 73-71 | BD +6°398 B | 1.8 | M4: V (ah), M4.5 V (bh), M4 (af), M4 (au) |
| 17 | — | — | — | 1.9 | — |
| 18 | 1053 | 221-5 | — | 1.2 | dM (bl), dM (bo), dM (ai) |
| 19 | 139 | — | CD -43°1028 | 0.9 | G8 III (bf), G5 (af), G5 V (au), G8 III (be) |
| 20 | 1062 | 160-5 | Ross 578 | 1.4 | M2 (af), sdM (bm) |
| 21 | 158 | — | BD +34°796 | 1.1 | K0 (af), K1 V (bx), K1 V (au) |
| 22 | 1068 | — | — | 1.5 | "peculiar" (af) |
| 23 | 166 A | — | $o^2$ Eri A | 0.8 | K1 V (be), K1 (af), K1 V (au) |
| 24 | 166 B | 160-60 A | $o^2$ Eri B | 0.0 | DA4 (br), DA (af) |
| 25 | 166 C | 160-60 B | $o^2$ Eri C | 1.7 | M4.5 V (bi), M4.5 V (ah), M5 V (bw) |
| 26* | 169.1 A | 175-34 A | Stein 2051 A | 1.7 | M4 V (bi), M4 V (au) |
| 27 | 169.1 B | 175-34 B | Stein 2051 B | 0.2 | DC5 (br), DC5 (bn), DC (au), DQ?7 (ba) |
| 28 | 184 | 191-19 | BD +52°911 | 1.6 | M0 V (cb), M0.5 V (bh), M1 (af) |
| 29 | 191 | — | Kapteyn's Star | 1.4 | M1 V (ah), M0 V (bf), sd (bw), M0 (af) |
| 30* | 205 | 99-15 | BD -3°1123 | 1.5 | M1.5 V (bi), M1.5 V (ah), M1.5 V (ca) |
| 31 | 213 | 102-22 | Ross 47 | 1.7 | M4 V (bi), M4+ V (ah), sdM4.5 (bh) |
| 32 | 223.2 | 99-44 | — | 0.9 | DZ9 (br), DZ9 (bn), DC11+(ba) |
| 33* | 273 | 89-19 | Luyten's Star | 1.8 | M3.5 V (bi), M4 V (ah), M3.5 (af) |
| 34 | 293 | — | — | 0.6 | DQ9 (br) |
| 35 | 299 | 50-22 | Ross 619 | 1.6 | M4-4.5 V (ah), M5 V (bh), sdM5 (ab) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 36 | 406 | 45-20 | Wolf 359 | 2.1 | M6 V (bi), M6 V (ah), M6 V (ca), M6 V(ax) |
| 37* | 411 | 119-52 | BD +36°2147 | 1.7 | M2 V (bi), M2 V (ah), M2+ V (ca) |
| 38 | 412 A | 176-11 | BD +44°2051 A | 1.6 | M1 V (ah), M2 V (bh), M0.5 (af) |
| 39 | 412 B | 176-12 | BD +44°2051 B | 2.0 | M5.5 V (bg), M5.5 (ai), M5 V (ad) |
| 40 | 422 | — | — | 1.5 | M (au), M3 (bp) |
| | | | | | |
| 41 | 424 | 236-65 | BD +66°717 | 1.5 | M1 V (ah), M1.5 V (bh), M1 (af), M1 V(au) |
| 42 | — | 236-80 | Ross 451 | 1.3 | sdM0 (ap), sdK (ao), sdM0.5 (bh), sdM0(au) |
| 43 | 440 | — | — | -0.2 | DQ6 (br) |
| 44* | 451 | 122-51 | BD +38°2285 | 0.9 | G8 V (be), G8 (af), G8 V (au) |
| 45 | 465 | — | Ross 695 | 1.7 | M3.5 V (bq), M4.5 V (bh), M3.5 (af) |
| | | | | | |
| 46 | 518 | 62-53 | Wolf 489 | 0.8 | DZ9 (br), DZ9 (bn) |
| 47 | 526 | 63-53 | BD +15°2620 | 1.6 | M1.5 V (ah), M3 V (bh), M3 V (am) |
| 48 | 541 | — | $\alpha$ Boo | 1.1 | K1 IIIb (be), K1 III (af), K2 III (au) |
| 49 | 551 | — | Proxima Cen | 1.6 | M5.5 V (ah), M6 V (bq), M5 V (au) |
| 50 | 559 A | — | $\alpha$ Cen A | 0.6 | G2 V (bf), G2 V (be), G2 V (au) |
| | | | | | |
| 51 | 559 B | — | $\alpha$ Cen B | 1.3 | K1 V (bf), K1 V (be), K0 V (au) |
| 52 | 579.2 B | — | BD -15°4041 | 0.9 | G8-K1 V: (bf), sdK (ao), K0 (af), sdK2 (au) |
| 53 | 579.2 A | — | BD -15°4042 | 0.6 | K0-1 V (bf), sdK (ao), K0 V (am), sdK0(au) |
| 54 | 595 | — | — | 1.8 | M4 V (bq), M5 V (cb), M3.5 (af) |
| 55 | 1200 | — | — | 2.4 | M3.5 V (al) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 56 | 699.1 | 259-21 | — | 0.6 | DA7 (br), DA7 (bn), DA (au) |
| 57* | 699 | 140-24 | Barnard's Star | 2.0 | M4 V (bi), M5 V (al), sdM4.5 (bh) |
| 58* | 725 A | 227-46 | BD +59°1915 A | 1.7 | M3 V (bi), M3 V (ca), M4 V (bh), M4 V(au) |
| 59* | 725 B | 227-47 | BD +59°1915 B | 1.8 | M3.5 V (bi), M3.5 V (ca), M4.5 V (bh) |
| 60 | 754 | — | — | 1.6 | M4.5 (af), M7 (au) |
| 61 | 817 | — | Ross 769 | 1.7 | M2 (af), M3 (au), sdM3 (ab) |
| 62* | 820 A | — | 61 Cyg A | 1.3 | K5 V (bi), K5 V (ca), K5 V (be) |
| 63* | 820 B | — | 61 Cyg B | 1.4 | K7 V (bi), K7 V (ca), K7 V (be) |
| 64 | — | 231-27 | Wolf 1106 | 1.5 | sdM1.5 (bh), sdM1 (cb), sd: (bb), sdM1 (au) |
| 65 | 821 | — | Wolf 918 | 1.7 | M2 V (al), M1 (af) |
| 66 | 825 | — | CD -39°14192 | 1.5 | M1-2 (bf), M1 V (bh), M0 (af), M0 V (be) |
| 67 | 845 | — | ε Ind | 1.3 | K4-5 V (bf), K4-5 V (be), K5 V (au) |
| 68 A* | 866 A | 156-31 A | EZ Aqr A | 1.6 | M5 V (bi), M5.5 V (ah), M5 V (bw) |
| 68 B* | 866 B | 156-31 B | EZ Aqr B | — | composite with LHS 68 A |
| 69 | 1276 | — | — | 1.8 | DZ9 (br), DZ9 (bn), DZ13 (ba) |
| 70 | 887 | — | CD -36°15693 | 1.6 | M2-3 V (bf), M2.5 V (bh), M0.5 (af) |
| 71 | 892 | — | BD +56°2966 | 1.3 | K3 V (be), K3 (af), K3 V (am), K3 V (au) |
| 72 | — | 275-90 | CD -24°17814 | 1.5 | sd (bw), K4 (af), sdM (au) |
| 73 | — | 275-92 | — | 1.5 | sd (bw), K5 (af), sdM (au) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 101 A* | 914 A | — | 85 Peg A | 0.6 | G2 V (be), G5 (af), G3 V (au) |
| 101 B* | 914 B | — | 85 Peg B | — | composite with LHS 101 A |
| 102 | 1001 | — | — | 1.5 | M3.5 (af) |
| 103 | 1003 | 130-43 | — | 1.9 | — |
| 104 | — | 30-48 | — | 1.5 | K4 (af), K4 (au) |
| 105 | — | — | — | 1.6 | — |
| 106 | — | — | — | > 3.1 | — |
| 107 | 1006 A | 32-6 | — | 1.9 | M4 (af) |
| 108 | 1006 B | 32-7 | — | 2.0 | M4.5 (af) |
| 109 | — | 158-53 | — | 1.4 | sd (bw), K5 (af), sdM (au) |
| 110 | — | 266-88 | — | 1.5 | M4 (af) |
| 111 | — | 266-89 | — | 1.5 | M3.5 (af) |
| 112 | — | — | — | 2.0 | M5.5 V (ai), M6 V (ax) |
| 113 | 1013 | 158-95 | — | 1.6 | — |
| 114 A* | 22 A | 243-30 A | BD +66°34 A | 1.9 | M2 V (bi), M2.5 V (bh), M2.5 (af) |
| 114 B* | 22 C | 243-30 C | BD +66°34 C | — | composite with LHS 114 A |
| 115 | 22 B | 243-30 B | BD +66°34 B | 1.9 | M3 V (bi), M3.5 (af) |
| 116 | — | — | CD -64°12 | 0.9 | F6 V (bf), K3 V (au) |
| 117 | 1014 | 32-35 | — | 1.8 | — |
| 118 A* | 25 A | — | CD -25°225 A | 1.1 | K1 V + G (bf), G5 (af), G8 V (be) |
| 118 B* | 25 B | — | CD -25°225 B | — | composite with LHS 118 A |
| 119 | 26 | 69-10 | Wolf 1056 | 1.9 | M4 V (ap), M3.5 V (bh), M3 (af), M4 V(au) |
| 120 | 1019 | 69-16 | — | 1.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 121 | 33 | — | BD +4°123 | 1.1 | K2 V (be), K2 (af), K2 V (am), K2 V (au) |
| 122 | 34 B | — | η Cas B | 1.4 | K7 V (ah), M0 V (be), M0 V (bh) |
| 123* | 34 A | — | η Cas A | 0.5 | G0 V (be), G0 (af), G0 V (au) |
| 124 | 1022 | — | — | 1.5 | — |
| 125 | — | — | — | — | — |
| | | | | | |
| 126 | 38 | 218-17 | Wolf 33 | 1.6 | M2 V (ap), M1 V (bh), K5 (af), M2 V (au) |
| 127 | — | 268-77 | — | 1.4 | — |
| 128 | 45 | — | CD -62°39 | 1.3 | M0 V (bf), K7 V (au) |
| 129 | 46 | 269-63 | CD -28°302 | 1.6 | M4 (af) |
| 130 | 1025 | 70-28 | — | 1.3 | M3.5 (af) |
| | | | | | |
| 131 | 48 | 242-76 | BD +70°68 b | 1.7 | M3.5 V (cb), M3.5 V (bh), M3 (af) |
| 132 | — | — | — | — | — |
| 133 | — | — | CD -46°293 | 1.1 | sd (bw), K3 (af), sdK (au) |
| 134 | 1028 | 268-110 | — | 1.7 | — |
| 135 | 1029 | 69-47 | — | 2.0 | — |
| | | | | | |
| 136 | 52 | 243-60 | BD +63°137 | 1.2 | M1 V (bh), K5 (af), K7 V (au) |
| 137 | 52.2 | 132-57 | Ross 322 | 1.7 | M3 (af), M4 (ag), M4 (au) |
| 138 | 54.1 | 268-135 | YZ Cet | 1.6 | M5.5 V (bh), M4.5 (af), M5 V (au) |
| 139 | 1034 | 34-15 | — | 1.5 | — |
| 140 | 1035 | 265-8 | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 141 | 57 | — | CD -42°469 | 1.3 | M0.5 (af), M0 V (au) |
| 142 | — | 272-36 | CD -22°526 | 1.5 | M1.5 (af) |
| 144 | — | — | — | 1.6 | sdM1-2 (ai) |
| 145 | — | — | — | 0.9 | — |
| | | | | | |
| 146 | 71 | — | τ Cet | 1.1 | G8 V (bf), G8 V (be), G6 (af), G8 V (au) |
| 147 | — | — | — | 0.4 | DC7 (br), DC7 (bn) |
| 148 | — | — | — | — | — |
| 149 | 84 | 272-148 | BD -18°359 | 1.6 | M3 (af), M0 V (au) |
| 150 | 85 | — | — | 1.5 | — |
| | | | | | |
| 151 | 1042 | 74-7 | — | 0.0 | DAZ7 (br), DAZ7 (bn) |
| 152 | — | 3-44 | Wolf 125 | 1.1 | dK (bo), K3 (af), dK (au) |
| 153 | 91.3 | 134-22 | — | 0.0 | DA9/DC (br), DC9 (bn), DA9+ (ba) |
| 154 A* | 92 A | — | δ Tri A | 0.6 | G0 V (be), G0 (af), G0 V (au) |
| 154 B* | 92 B | — | δ Tri B | — | composite with LHS 154 A |
| 154a | 1046 | — | — | 1.9 | M3 (af) |
| 155 | 101 | 174-1 | Ross 21 | 1.6 | M3.5 (af), M5 (au) |
| | | | | | |
| 156 | — | 4-29 | — | 1.6 | — |
| 157 | 1050 | — | — | 1.5 | M3 (af) |
| 158 | — | — | — | 1.5 | — |
| 159 | 116 | 37-8 | BD +33°529 | 1.4 | K4 (af), sdK6 (au) |
| 160 | 118 | — | — | 1.4 | M (au) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 161 | — | 75-47 | — | 1.7 | — |
| 162 | — | — | — | — | — |
| 163 | 120 | 5-7 | Ross 791 | 1.6 | M3.5 V (bh), M3.5 (af), M3 V (au) |
| 164 | — | — | — | — | — |
| 165 | — | — | — | 1.1 | sdK (bl) |
| | | | | | |
| 166 | 124 | — | $\iota$ Per | 0.6 | G0 V (be), G1 (af), G4 V (au) |
| 167 | 130 | — | CD -38°1058 | 1.6 | M3 (af) |
| 168 | 1057 | 77-31 | — | 1.9 | M5 V (bi), M5 V (ah) |
| 169 | 129 | 5-22 | Wolf 134 | 2.0 | sdM0 (bh), K3 (af), sdM0 (au) |
| 170 | — | 78-26 | Wolf 1324 | 1.4 | sdK5 (ap), K4 (af), sdK5 (au) |
| | | | | | |
| 171 | 136 | — | $\varsigma^1$ Ret | 0.6 | G3-5 V (bf), G3-5 V (be), G2 V (au) |
| 172 | 138 | — | $\varsigma^2$ Ret | 0.6 | G2 (bf), G2 V (be), G1 V (au) |
| 173 | — | 38-1 | Ross 34 | 1.3 | sdK5 (ap), K4 (af), sdK5 (au) |
| 174 | — | 37-40 | Ross 585 | 1.4 | K5 (af) |
| 175 | — | 246-38 | BD +66°268 | 0.9 | G4 (af), sdG8 (au) |
| | | | | | |
| 176 | — | — | — | 1.9 | M5.5 V (ai) |
| 177 | — | 78-42 | Wolf 194 | 1.7 | M2 (af) |
| 178 | — | 79-59 | Wolf 1057 | 2.0 | M0.5 (af) |
| 179 | 151 | 6-30 | Wolf 219 | 0.2 | DQ8 (br), DQ8 (bn) |
| 180 | 1064 A | 95-57 A | BD +41°750 | 1.2 | K1 (af), K1 V (au) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 181* | 1064 B | 95-57 B | BD +41°750 a | 1.3 | K2 (af), K2 V (au) |
| 182 | 1064- | 95-59 | — | 1.7 | M0: V (ah), Mp (cb), sdMp (ag) |
| 183 | 1065 | 160-28 | — | 1.6 | — |
| 184 | 155.3 | — | CD -37°1501 | 1.1 | M3 (af) |
| 185 | 157.2 | 7-17 | — | 1.3 | sdM (ap), sdM (ai) |
| 186 | — | 160-42 | — | 1.5 | — |
| 187 | — | 38-25 | BD +32°719 | 1.3 | K4 (af), K4 V (au) |
| 188 | 163 | — | — | 1.5 | M4.5 V (bq), M (au) |
| 189 | — | — | — | 1.6 | sdM4 (ai) |
| 190 | — | — | — | 1.7 | — |
| 191 | — | — | — | 2.3 | M6.5 V (bi) |
| 192 | — | — | — | 1.6 | sdM (bl), sd (bb), sdK7-M0 (ai) |
| 193 | — | — | — | 1.5 | — |
| 194 | — | — | — | 0.5 | DQ7 (br), DQ7 (bn) |
| 195 | — | — | CD -65°253 | 0.6 | sdG2 (au) |
| 196 | 176 | 8-55 | BD +18°683 | 1.5 | M2.5 V (cb), M2.5 V (bh), M3 (af) |
| 197 | — | — | — | 1.8 | sdM (bl), M1 V (ai) |
| 198 | 1073 | 81-39 | — | 1.1 | sdM1 (ai) |
| 199 | 181.1 | — | — | 1.5 | — |
| 200* | 183 | — | BD -5°1123 | 1.1 | K4 (af), K3 V (am), K3 V (au), K3 V (be) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 201 | ***** the same object as LHS 28 ***** | | | | |
| 202 | — | — | — | 1.6 | — |
| 203 | 190 | — | — | 1.8 | M5 V (bq), M4 (af) |
| 204 | — | — | CD -59°1024 | 0.8 | sd (bw), sdF6 (au) |
| 205 | 1077 | — | — | 1.5 | — |
| 205a | — | — | — | 2.9 | sdM (bl), sdM (ac), sdK7-M1 (ai) |
| 206 | 1080 | 99-10 | — | 1.9 | M3 V (bk) |
| 207 | — | — | — | 1.8 | M6.5: V (ai), sdM (bl) |
| 208 | — | — | π Men | 0.9 | G1 V (be), G3 IV (au) |
| 209 | — | 96-50 | — | 1.5 | sdK (aq), sd (ao), K5-M0 V (ai) |
| 210 | 217.2 | — | CD -70°340 | 0.6 | G8 V (bf), K0 V (au) |
| 211 | — | 99-33 | — | 2.5 | — |
| 212 | 1087 | 99-47 | V1201 Ori | 0.6 | DAP9 (br), DAP9 (bn), DC (au), DAP9(ba) |
| 213 | — | 249-27 | — | 1.5 | — |
| 214 | — | 249-28 | — | 1.3 | — |
| 215 | 226 | 222-11 | — | 1.6 | M2.5 V (bi), M2.5 (af), M3 V (au) |
| 216 | — | 105-23 | — | 1.6 | — |
| 217 | — | 249-46 | — | 1.3 | — |
| 218 | — | 103-46 | — | 2.0 | — |
| 219 A* | 244 A | — | α CMa A | -0.3 | A0 V (bf), A1 V (be), A1 V (am), A1 V(au) |
| 219 B* | 244 B | — | α CMa B | — | DA2 (br), DA (au) |
| 220 | 1092 | 87-8 | vB 16 | 1.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 221 A* | — | 250-29 A | — | 1.5 | M2.5 V (bi), M3.5 (af) |
| 221 B* | — | 250-29 B | — | — | composite with LHS 221 A |
| 222 A* | 257 A | — | CD -44°3045 A | 1.8 | M3.5 V (bq), M4 (au) |
| 222 B* | 257 B | — | CD -44°3045 B | — | M3 (af), M4 (au) |
| 223 | 1093 | 109-35 | — | 1.8 | M2 V (ai) |
| 224 | — | 193-27 | — | 1.8 | M4.5 (af) |
| 225* | — | — | — | 1.1 | M3 (af) |
| 226 A* | 268 A | 87-26 A | Ross 986 A | 1.7 | M4.5 V (bi), M4.5 V (ah), M4.5 V (ca) |
| 226 B* | 268 B | 87-26 B | Ross 986 B | — | composite with LHS 226 A |
| 227 | — | — | — | 1.3 | < M2 (bp) |
| 228 | — | — | — | 1.7 | M2.5-3 V (ai) |
| 229* | 275.2 A | 107-69 | — | 2.2 | M4 V (bi), M4+: V (ai), M5 V (au) |
| 230 A* | 275.2 B | 107-70 A | — | 0.9 | DC9 (bn), DC (br) |
| 230 B* | 275.2 C | 107-70 B | — | — | DC9 (bn) |
| 231 | — | — | — | 2.2 | M4.5 V (ai) |
| 232 | — | 112-28 | — | 1.1 | — |
| 233 A* | 280 A | — | α CMi A | 0.3 | F5 IV-V (be), F4 (af), F5 IV-V (au) |
| 233 B* | 280 B | — | α CMi B | — | DA (br) |
| 234 | 283 B | — | — | 1.7 | M6 V (bi), M6 V (ai) |
| 235 | 283 A | — | — | 0.1 | DZQ6 (br), DZ6 (bn) |
| 236 | — | 251-44 | — | 1.5 | K4 (af) |
| 237 | 288 A | — | CD -33°4113 | 0.6 | G0 V (bf), G0 (af), G0 V (au), G0 V (be) |
| 237a | 288 B | — | vB 3 | 2. | — |
| 238 | 289 | 91-11 | Wolf 1421 | 2.2 | M2 (af), M2 (au), M2 V (as) |
| 239 | 1102 B | — | — | 1.1 | DC9 (br), DC9 (bn) |
| 240 | 1102 A | — | — | 0.9 | DC9 (br), DC9 (bn) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|---------------|----------------------------|
| 241* | 1104 | 90-25 | BD +31°1684 | 0.7 | G2 (af), G2 V (am), sdG2 (au) |
| 242* | 295 | — | BD +29°1664 | 0.7 | G4 (af), G8 V (bx), G8 V (au), G8 V (be) |
| 243 | – | — | — | 2.2 | M4.5 V (ai) |
| 244 | — | — | — | 1.8 | — |
| 245 | 302 | — | BD -12°2449 | 0.9 | K0 V (bf), G7.5 V (be), G9 (af), G8 V (au) |
| | | | | | |
| 246 | — | — | — | 1.5 | M5.5: V (ai) |
| 247 A* | 308 A | 51-13 A | — | 1.6 | — |
| 247 B* | 308 B | 51-13 B | — | — | — |
| 248 | 1111 | 51-15 | DZ Cnc | 1.6 | M6.5 V (bi), M6.5 V (ah), M6.5 V (ca) |
| 249 | 309 | — | CD -31°6229 | 1.0 | K0 V (bf), K0 V (be), G9 (af), K0 V (au) |
| 250 | — | 234-37 | — | 1.3 | M3 (af) |
| | | | | | |
| 251 A* | 310 A | 234-38 A | BD +67°552 A | 1.5 | M1 V (bh), K7 (af), M1 V (au) |
| 251 B* | 310 B | 234-38 B | BD +67°552 B | — | composite with LHS 251 A |
| 252 | — | 234-45 | — | 2.2 | — |
| 253 | 318 | — | CD -32°5613 | -0.3 | DA6 (br), DA (au) |
| 254 | — | — | — | 1.5 | M5.5 V (ai) |
| 255 | 328 | 46-9 | BD +2°2098 | 1.5 | M0 V (bi), M0.5 V (ah), M1 V (bh), K7 (af) |
| | | | | | |
| 256 | 325 A | 252-24 A | BD +71°482 | 1.5 | M1 V (bh), K7 (af), K5 V (au) |
| 257 | 325 B | 252-24 B | BD +71°482 a | 1.5 | M1 V (bh), K7 (af), M1 V (au) |
| 258* | 1118 | — | — | 1.3 | M4: (af) |
| 259 | — | 194-50 | — | 1.3 | — |
| 260* | 338 A | 195-17 | BD +53°1320 | 1.4 | M0 V (bi), M0 V (be), M0.5 V (bh) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 261* | 338 B | 195-18 | BD +53°1321 | 1.4 | K7 V (bi), M0 V (be), M0.5 V (bh) |
| 262 | 339.1 | 195-19 | — | 0.1 | DXP7/DCP7 (br), DXP7 (bn), DC (au) |
| 263 | 1123 | — | — | 1.5 | — |
| 264 A* | 338.1 A | 252-30 A | BD +77°361 A | 1.3 | K7 V (bi), K5 (af), dK (au) |
| 264 B* | 338.1 B | 252-30 B | BD +77°361 B | — | composite with LHS 264A |
| 265 | — | 195-22 | — | 1.6 | — |
| | | | | | |
| 266 | — | — | — | 2.9 | sdM3.5: (ai) |
| 267 | — | 46-34 | — | 1.5 | — |
| 268 | 345 | — | CD -80°328 | 0.4 | sd (bw), white dwarf (bv), sdG (au) |
| 269 | — | — | — | 1.5 | M5: V (ai) |
| 270 A* | 354 A | — | θ UMa A | 0.4 | F6 IV (be), F7 (af), F6 IV (au) |
| 270 B* | 354 B | — | θ UMa B | — | composite with LHS 270 A |
| | | | | | |
| 271 | 1128 | — | — | 1.7 | — |
| 272 | — | — | — | 2.3 | M3.5 (as), M2 (af) |
| 273 | 1129 | — | — | 2.0 | M3.5 (af) |
| 274 | 369 | 161-80 | BD -11°2741 | 2.0 | M2 V (cb), M2 V (bh), M0.5 (af), sdM2(ab) |
| | | | | | |
| 276 | — | 117-61 | Wolf 335 | 1.8 | G2 V (be), M1.5 (af) |
| 277 | 377 | — | CD -29°8019 | 1.5 | M3 (af), M4 (au) |
| 278 | 378 | 146-6 | BD +48°1829 | 1.6 | M2 (af), M2 V (au) |
| 279 | — | — | — | 1.6 | M4.5 V (ai) |
| 280 | 380 | 196-9 | BD +50°1725 | 1.3 | K7 V (bi), K7 V (ah), K2 V (be), M0 V (bh) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 281 | 1132 | — | — | 1.1 | M4 (af) |
| 282 | — | — | — | 0.5 | DC9 (br), DC8 (bn) |
| 283 | — | 236-34 | — | 1.3 | — |
| 284 | — | — | — | 1.3 | M4.5 V (ai) |
| 285 | — | — | — | 0.9 | DC9 (br), DC9 (bn) |
| | | | | | |
| 286 | — | — | — | 1.6 | M6 V (ai) |
| 287 | 1134 | 146-58 | — | 2.0 | M5 V (al) |
| 288 | — | — | — | 1.5 | M4 (bp), sd (bg) |
| 289 | 401 A | — | BD -18°3019 A | 1.6 | M0 V (bc), M3 V (bq), M0.5 (af), M (au) |
| 290 | 401 B | — | BD -18°3019 B | 0.3 | DQ9 (br), DQ9 (bn), DQ9 (bc) |
| | | | | | |
| 291 | — | — | — | 0.4 | DQ8 (br), DQ8 (bn) |
| 292 | — | — | — | 1.9 | M6.5 V (bi), M6.5 V (ai), M6.5-7 V (ax) |
| 293 | 1138 | 119-36 | — | 2.1 | — |
| 294* | 402 | 44-40 | Wolf 358 | 1.7 | M4 V (bi), M4 V (ah), M4.5 V (bq) |
| 295 | 403 | 44-42 | Hubble 3 | 1.8 | M3 (af), M4 (au) |
| | | | | | |
| 296 | — | 45-27 | — | 1.6 | — |
| 297 | — | 119-57 | — | 1.7 | M3.5 V (al), M3.5 (af) |
| 298 | 415 | — | BD -10°3216 | 1.3 | K4 (af), M0 V (au) |
| 299 | — | 163-59 | — | 1.9 | — |
| 300 | — | — | — | 1.1 | K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 301 | 1146 | 10-17 | — | 1.3 | — |
| 302 | — | — | — | 2.2 | — |
| 303 | 2085 | 10-19 | Wolf 386 | 1.9 | M1 V (bh), M1 (af), M1 V (au) |
| 304 | 427 | 120-45 | Ross 627 | 0.4 | DA7 (br), DA7 (bn) |
| 305 | — | 10-25 | Wolf 397 | 1.5 | M0 V (bh), K5 (af), M0 V (au) |
| | | | | | |
| 306 | — | — | — | 1.7 | M5.5 (bq) |
| 307 | — | 176-40 | — | 1.7 | — |
| 308 | 432 A | — | CD -32°8179 | 1.1 | K0 V (bf), K0 V (be), K0 (af), K0 V (au) |
| 309 | 432 B | — | vB 4 | 2. | — |
| 310 | 436 | 120-68 | BD +27°28217 | 1.8 | M3 V (bi), M3 V (ah), M3.5 V (bh), M3 (af) |
| | | | | | |
| 311 | 442 A | — | CD -39°7301 | 0.9 | G3-5 V (bf), G5 V (be), G6 (af), G5 V (au) |
| 312 | — | 176-53 | BD +51°1696 | 0.6 | G0 (af) |
| 313 | 442 B | — | vB 5 | — | — |
| 314 | 443 | — | — | 1.6 | M3.5 V (bq), M3 (af), M (au) |
| 315 | 447 | 10-50 | Ross 128 | 1.7 | M4+ V (ah), M4.5 V (bq), M5 V (au) |
| | | | | | |
| 316 | 1151 | 122-49 | — | 1.6 | M5 V (al) |
| 317 | — | — | — | 2.0 | M4 (af) |
| 318 | — | — | — | 1.3 | sdM0-2 (ai) |
| 319 | 453 | — | CD -26°8883 | 1.3 | K4 V (bf), K5 V (be), K4 (af), K5 V (au) |
| 320 | — | 11-35 | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 321 | — | 122-67 | Ross 943 | 1.1 | M0.5 (af) |
| 322 | — | — | BD -9°3468 | 0.5 | F5 (af), F6 V (bx), F6 V (au), F5 V (be) |
| 323 | — | — | — | 1.5 | — |
| 324 | 1156 | 12-30 | GL Vir | 2.5 | dM (bt) |
| 325 | — | — | — | 1.6 | sd (bb), sdM0-2 (ai) |
| | | | | | |
| 325a | — | — | — | 3.1 | M6 V (ad (but mis-ID'd as LHS 325)) |
| 326 | — | — | — | 1.6 | — |
| 327 | — | — | — | 1.1 | K0: (af), sd (bw), sdK (au) |
| 328 | 467 A | — | — | 1.3 | — |
| 329 | 467 B | — | — | 1.6 | — |
| 330 | 1159 B | 199-17 B | — | 2.5 | dM (ai) |
| | | | | | |
| 331 | 1159 A | 199-17 A | — | 1.5 | dM (bl), dM (ai) |
| 332 | 1158 | — | — | 1.3 | M3 (bp) |
| 333 A* | 473 A | 12-43 A | Wolf 424 A | 1.7 | M5.5 V (bi), M5.5 V (ah), M5.5 V (bq) |
| 333 B* | 473 B | 12-43 B | Wolf 424 B | — | composite with LHS 333A |
| 334 | 2093 | — | — | 2.8 | sdM4 peculiar (ai) |
| 335 | — | — | — | 1.5 | sdM (bl), sdM (ai) |
| | | | | | |
| 336 | 479 | — | CD -51°6859 | 0.6 | M3 V (bq), white dwarf (bv), M3 (af) |
| 337 | — | — | — | 1.5 | M4 (af) |
| 338 | 480 | 60-24 | Wolf 433 | 1.6 | M4 V (bh), M3.5 (af), M4 V (au) |
| 339 | — | — | — | -0.2 | DA (br) |
| 340 | 480.1 | — | — | 1.1 | M3.5 (af), M4 (au) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|-----------|----------------|----------------------------|
| 341 | 486 | 60-32 | Wolf 437 | 1.6 | M4 V (ah), M4.5 V (bh), M3 (af), M4 V(au) |
| 342 | — | — | — | 1.5 | DC9 (br), DC9 (bn) |
| 343 | — | 61-21 | — | 1.3 | sd (bb), $\leq$ K5 V (al), K4: (af) |
| 344 | 496.1 | — | CD -51°7244 | 1.3 | K5-M0 V (bf), K9 V (au) |
| 345 | — | 62-15 | — | 1.9 | — |
| 346 | — | — | — | 1.5 | M3.5 (af) |
| 347 | — | 61-35 | — | 1.3 | K0 (af) |
| 348 | 502 | — | $\beta$ Com | 0.6 | G0 V (be), G0 (af), G0 V (au) |
| 349 | 506 | — | BD -17°3813 | 0.8 | G5 V (bf), G6 V (be), G6 V (au) |
| 350 | — | 149-81 | Ross 1020 | 1.6 | M3.5 (af) |
| 351 | 513 | 63-32 | — | 1.7 | M5 V (cb), M3.5 (af), M5 (au) |
| 352* | 514 | 63-34 | BD +11°2576 | 1.1 | M1 V (ah), M1 V (cb), M0.5 V (bh) |
| 353 | 514.1 | 14-57 | Ross 476 | 1.6 | M6 V (bq), M6 V (cb), M4: (af), M6 V (au) |
| 354 | 515 | 14-58 | BD -7°3632 | -0.5 | DA5/DA4 (br), DA (au) |
| 355 | 1171 | 149-94 | — | 1.7 | — |
| 356 | — | — | — | 1.5 | sdM0-1 (ai) |
| 357 | 1174 | 177-51 | Ross 1026 | 1.1 | dM (bo), M4 V (al), M3 (af), dM (au) |
| 358 | — | — | — | 1.8 | dM (bl), dM (ai) |
| 359* | 525 | 63-52 | BD +18°2776 | 1.7 | M0 (af), M1 V (au), sdK9 (ab) |
| 360 | — | — | — | 1.8 | sdK7-M0 (ai) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 361 | 1179 B | — | — | 1.6 | DC9 (br), DC9 (bn) |
| 362 | 1179 A | — | — | 2.0 | M4: V (bo) |
| 363 | 529 | — | BD -21°3781 | 1.3 | K4-5 V (bf), M0 V (bh), K6 V (am) |
| 364 | — | 165-47 | — | 1.6 | sdM (bl) |
| 365 | — | — | — | 1.2 | sdM (bl), sdM (ai) |
| | | | | | |
| 366 | 1182 | 65-39 | — | 2.1 | — |
| 367 | — | — | — | 0.6 | sd (bw), sdK (au) |
| 368 | 543 | 124-23 | Wolf 534 | 1.8 | M3 (af), M4 V (as) |
| 369 | 545 | 124-25 | Ross 848 | 1.8 | M4 V (bh), M5 (au) |
| 370 | — | — | — | 1.9 | M5.5 V (ai) |
| | | | | | |
| 371 | 548 A | 166-27 | BD +24°2733 A | 1.6 | M1 V (bh), M0 (af), M1 V (au) |
| 372 | 548 B | 166-28 | BD +24°2733 B | 1.6 | M1.5 V (bh), M0.5 (af), M1 V (au) |
| 373 | 552 | 135-56 | BD +16°2658 | 1.8 | M2 V (bq), M2.5 V (bh), M3 (af), M3 V(au) |
| 374* | 553 | 124-47 | BD -7°3856 | 1.5 | M2.5 V (bq), M1.5 V (bh), M0 (af) |
| 375 | — | — | — | 2.0 | — |
| | | | | | |
| 376 | — | 135-67 | — | 1.5 | M3 V (ai) |
| 377 | — | — | — | 3.1 | sdM5 (ai), sdM5 (ax) |
| 378 | — | — | — | 0.6 | DC (br), DC9 (bn) |
| 379 | 563.2 B | — | CD -25°10553 B | 1.3 | M3 (af) |
| 380 | 563.2 A | — | CD -25°10553 A | 1.3 | M3 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 381 | — | — | — | 1.5 | — |
| 382 | — | — | — | 1.3 | — |
| 383 | 565 | — | CD -23°11940 | 1.3 | K3 V (bf), K3 (af), K5 V (au) |
| 384 | 569.1 | 200-62 | BD +54°1716 | 0.9 | K1 (af), K1 V (au), K1 V (am), K1 V (au) |
| 385 | — | — | — | 1.5 | — |
| | | | | | |
| 386 A* | 570 B | — | BD -20°4123 A | 1.6 | K5 V (bf), M1 V (cb), M2 V (bh), M0 V(au) |
| 386 B* | 570 C | — | BD -20°4123 B | — | composite with LHS 386 A |
| 387 | 570 A | — | BD -20°4125 | 1.3 | K4 V (bf), K4 V (be), K4 V (am), K5 V(au) |
| 388 | 570.2 | 166-57 | Ross 53 | 1.4 | M2 V (bh), K5 (af), M2 V (au) |
| 389 | 1188 | 15-4 | Ross 1044 | 1.6 | K7 (af) |
| 390 | — | — | — | 1.2 | K5 (af) |
| | | | | | |
| 391 | 579 | 167-19 | BD +25°2874 | 1.5 | M0.5 V (bh), K7 (af), K7 V (au) |
| 392 | — | 151-34 | — | 1.6 | — |
| 393 A* | 580 A | — | BD -0°2944 A | 1.1 | G9 V (be), K0 (af), K0 V (am) |
| 393 B* | 580 B | — | BD -0°2944 B | — | composite with LHS 393 A |
| 394 | 581 | 151-46 | BD -7°4003 | 1.7 | M5 V (cb), M4 V (bh), M3 (af), M5 V (au) |
| 395 | 582 | — | $\nu^2$ Lup | 0.7 | G3-5 V (bf), G3-5 V (be), G2 V (au) |
| | | | | | |
| 396 | 585 | 136-103 | Ross 508 | 1.9 | M5.5 V (bq), M6 V (cb), M4 V (al), M6 (au) |
| 397 | 588 | — | CD -40°9712 | 1.7 | M3.5 V (bq), M3 (af), M4 (au) |
| 398 | — | — | — | 1.6 | sdM (bl), sdM0+: (ai) |
| 399 | 589 A | 137-26 | Ross 513 | 1.9 | M2.5 V (bq), M4 V (al), M4 (au) |
| 400 | 589 B | 137-25 | — | 1.7 | M4.5: (af), M6 (au) |

## TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 401 | — | — | — | 1.3 | sd (bw), sdM (au) |
| 402 | 1194 A | 179-43 A | vB 24 a | 1.6 | M3 V (al), M2 V (bk) |
| 403 | 1194 B | 179-43 B | vB 24 b | 1.5 | composite with LHS 402 |
| 404 | 597 | 257-20 | Ross 1057 | 1.8 | M3 (af) |
| 405 | 1195 | — | BD -10°4149 | 0.4 | F2 (af), sdF5 (bx), sdG2 (au) |
| 406 | 2116 | — | — | 1.3 | M1 (af) |
| 407 | — | — | — | 2.2 | sd (bb) |
| 408 | 603 | — | γ Ser | 0.4 | F6 V (be), F5 (af), F6 IV (au) |
| 409 | — | 16-17 | Wolf 611 | 1.7 | sd (bw), M3.5 (af), sdM (au) |
| 410 | — | 16-18 | Wolf 612 | 2.4 | sd (bw), M0: (af), sdM (au) |
| 411 | 609 | 137-78 | — | 1.7 | M4 V (al), M3 (af) |
| 412 | 1198 | 153-27 | Plaut 1 | 2.1 | — |
| 413 | 615 | — | CD -57°6303 | 0.9 | G8-K0 V (bf), K0 V (au) |
| 414 | — | — | — | 1.7 | — |
| 415 | 618 A | — | CD -37°10765 A | 1.6 | M3 (af), M4 (au) |
| 416 | 618 B | — | CD -37°10765 B | 1.7 | M5: (af), M7 (au) |
| 417 A* | 623 A | 202-45 A | — | 1.7 | M2.5 V (bi), M3 V (bh), M3 (af), M3 V (au) |
| 417 B* | 623 B | 202-45 B | — | — | composite with LHS 417A |
| 418 | — | 138-25 | — | 2.5 | K5 V: (al) |
| 419* | 628 | 153-58 | BD -12°4523 | 2.3 | M4 V (bq), M5 V (cb), M4.5 V (bh) |
| 420 | — | 17-21 | BD+4°3195 | 0.5 | F8 (af), F9 V (au), F9 V (am) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 421 A* | 630.1 A | 225-67 A | CM Dra A | 1.5 | M5 V (au) |
| 421 B* | 630.1 C | 225-67 B | CM Dra B | — | composite with LHS 421 |
| 422 | 630.1 B | 225-68 | — | 0.4 | DQ8 (br), DQ8 (bn), DC (au), DQ8+ (ba) |
| 423 | — | — | — | 1.3 | M3: (bp), M3.5 (af) |
| 424 | — | 17-28 | — | 1.1 | — |
| 425 | — | 138-59 | — | 1.5 | M2-2.5 V (ai) |
| | | | | | |
| 426 | 641 | 19-4 | BD +0°3593 | 1.0 | G7 V (be), G5 (af), G6 V (au), G8 V (am) |
| 427* | 643 | — | BD -8°4352 C | 1.7 | M3.5 V (bi), M4.5 V (bq), sdM4 (cb) |
| 428 A* | 644 A | — | BD -8°4352 A | 1.8 | M3.5 V (bq), M4.5 V (cb), M3.5 V (bh) |
| 428 B* | 644 B | — | BD -8°4352 B | — | composite with LHS 428 A |
| 429* | 644 C | — | vB 8 | 2.2 | M7 V (bi), M7 V (ax), M7 V (ai) |
| 430 | 1209 | 170-12 | — | 1.5 | M2-3: (al), M3 (af) |
| | | | | | |
| 431 | 653 | 19-13 | BD -4°4225 | 1.6 | K5 V: (al), K5 (af), K5 V (am), K5 V (au) |
| 432 | 654 | 19-14 | BD -4°4226 | 1.5 | M3.5 V (cb), M3.5 V: (al), M3 V (bh) |
| 433 | 661 A | 203-51 A | BD +45°2505 A | 1.6 | M3 V (bi), M3 V (cb), M4 V (bh) |
| 434 | 661 B | 203-51 B | BD +45°2505 B | 1.6 | composite with LHS 433 |
| 435 | 1213 | 203-52 | BD +42°2810 | 1.6 | K8 V (al), M1 V (bh), K5 (af), M1 V (au) |
| | | | | | |
| 436 | — | — | — | 1.7 | M5.5 V (ai) |
| 437 | 663 A | — | CD -26°12026 A | 1.2 | K2: III: (bf), K0 V (be), K2 (af) |
| 438 | 663 B | — | CD -26°12026 B | 1.2 | K2: III: (bf), K1 V (be), K1 (af) |
| 439 | 664 | — | CD -26°12036 | 1.3 | K5 V (bf), K7 (af), K5 V (au), K5 V (be) |
| 440 | — | — | — | 0.6 | M1 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|-----------|------------|------------------------------|
| 441 | 672 | — | BD +32°2896 | 0.6 | G0 V (be), G3 (af), G1 V (am), G2 V (au) |
| 442 A* | 667 A | — | CD -34°11626 A | 1.3 | K4 V (bf), K3 V (be), K3 (af), K3 V (au) |
| 442 B* | 667 B | — | CD -34°11626 B | — | K5 V (be), K4 (af), K5 V (au) |
| 443 | 667 C | — | CD -34°11626 C | 1.6 | M2 (bp), M2.5 (af), M2 V (au) |
| 444 | 666 A | — | CD -46°11370 A | 1.1 | G8-K0 V (bf), K0 (af), G8-K0 V (be) |
| 445 | 666 B | — | CD -46°11370 B | 1.5 | M0.5 (af), M0 V (au) |
| | | | | | |
| 446 | 1216 | 203-63 | — | 1.6 | — |
| 447 | 673 | 19-24 | BD +2°3312 | 1.3 | K7 (af), K7 V (au), K7 V (am) |
| 448 | 1219 | 139-39 | — | 1.6 | — |
| 449 | 674 | — | CD -46°11540 | 1.8 | M3 (af), M4 (au) |
| 450* | 687 | 240-63 | BD +68°946 | 1.6 | M3.5 V (cb), M4 V (bh), M3 (af), M4 V(au) |
| | | | | | |
| 451 | 682 | — | CD -44°11909 | 1.5 | M3 (bp), M3.5 (af), M5 (au) |
| 452* | 686 | 170-55 | BD +18°3421 | 1.7 | M1 V (bh), M0.5 (af), M1 V (au) |
| 453 | — | — | — | 2.3 | sdM (aa), sdM (bl), sdM (ap), sdK5-M1 (ai) |
| 454 | 693 | — | — | 1.5 | M4.5 (bp), M (au) |
| 455 | 1221 | 240-72 | — | 1.1 | DXP9 (br), DXP9 (bn), DXP11 (ba) |
| | | | | | |
| 456 | — | — | — | 1.5 | M3: (bp) |
| 457 | 1223 | 182-36 | — | 1.7 | — |
| 458* | 702 A | — | 70 Oph A | 1.2 | K0 V (be), K0 V (am), K0 V (au) |
| 459* | 702 B | — | 70 Oph B | 1.3 | K5 (af), K4 V (am), K5 V (au) |
| 460 | 1225 | 260-1 | — | 1.6 | M4.5: V (ai) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 461 | — | 204-57 | — | 1.5 | — |
| 462 | — | 204-58 | — | 1.5 | — |
| 463 A* | 1226 A | 21-10 A | — | 1.3 | M3.5 (af) |
| 463 B* | 1226 B | 21-10 B | — | — | composite with LHS 463 A |
| 464 | 712 | 141-4 | Ross 136 | 1.7 | M3.5 V (al), M3 (af), M4 (au) |
| 465 | 1227 | 227-29 | — | 1.6 | — |
| 466 | — | 155-27 | Wolf 1465 | — | K5 (af), sdM (au) |
| 467 | — | 21-23 | Wolf 851 | 1.3 | < M0 (bp), K4 (af) |
| 468 | — | 22-1 | — | 1.1 | M3: (bp), M1 (af) |
| 469 A* | 732 A | — | — | 1.1 | G0: (af) |
| 469 B* | 732 B | — | — | — | composite with LHS 469 A |
| 470 | 740 | 22-10 | BD +5°3993 | 1.5 | M2 V (cb), M1 V (bh), M0 (af), M2 V (au) |
| 471 A* | 747 A | 207-16 A | — | 1.7 | M5 V (cb), M2 V (al), M4 V (bh), M4 V(au) |
| 471 B* | 747 B | 207-16 B | — | — | composite with LHS 471 A |
| 472 A* | 748 A | 22-18 A | Wolf 1062 A | 1.5 | M3.5 V (bi), M4 V (cb), M4 V (bh) |
| 472 B* | 748 B | 22-18 B | Wolf 1062 B | — | composite with LHS 472A |
| 473 | 752 A | 22-22 A | BD +4°4048 A | 1.5 | M3 V (bi), M3.5 V (al), M3 V (ah) |
| 474* | 752 B | 22-22 B | vB 10 | 1.5 | M8 V (bi), M8 V (ca), M8 V (ai) |
| 475 | — | — | — | 1.5 | — |
| 476 | 1235 | 185-18 | — | 1.3 | dM (bl), M8:: V (al) |
| 477 | 764 | — | σ Dra | 0.9 | K0 V (be), G9 (af), K0 V (au) |
| 478 A* | 766 A | 185-37 A | Ross 165 A | 1.7 | M4.5 V (cb), M4.5 V (bh), M4 (af) |
| 478 B* | 766 B | 185-37 B | Ross 165 B | — | composite with LHS 478 A |
| 479 | — | 142-52 | — | 1.1 | dK-dM (bl), dK-dM (ai) |
| 480 | 769 | — | — | 1.8 | M3 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 481 | 778 | 186-11 | BD +22°3908 | 1.2 | K2 (af), K1 V (au) |
| 482* | 781 | 230-26 | Wolf 1130 | 1.5 | M3 V (cb), M3 V (bh), K7 (af), M3 V (au) |
| 483 | — | — | — | 1.3 | DC9 (br), DC9 (bn), DC13 (ba) |
| 484 | 776 | — | CD -67°2385 | 0.9 | G3 V (bf), G3 V (be), G2 V (au) |
| 485 | 780 | — | $\delta$ Pav | 0.9 | G6-8 V (bf), G6-8 IV (be), G5 IV (au) |
| | | | | | |
| 486 | 783 A | — | CD -36°13940 A | 1.2 | K2 V (bf), K3 V (be), K2 (af), K3 V (au) |
| 487 | 783 B | — | CD -36°13940 B | 1.8 | M3.5 (af) |
| 488* | 785 | — | CD -27°14659 | 1.2 | K3 V (bf), K0 V (be), K1 (af), K0 V (au) |
| 489 | — | — | — | 2.0 | sdM0 (ax), sdM (aa), K5-M0 V (ai) |
| 490 | — | — | BD -21°5703 | 0.6 | F8 (af), F8 V (am), sdG0 (au) |
| | | | | | |
| 491 | — | 210-19 | — | 1.3 | dK-dM (bl), K3: V (ai) |
| 492 | 1252 | — | — | 1.5 | — |
| 493 | 1251 | — | — | 1.5 | — |
| 494 | 1254 | 230-42 | — | 2.3 | M3.5 V (al) |
| 495 | 1256 | 144-25 | — | 2.1 | M5 V: (al), M4 V (au) |
| | | | | | |
| 496 | 798 | — | CD -53°8617 | 1.2 | K5 V (bf), K7 V (au) |
| 497 A* | 800 A | — | BD -19°5899 A | 1.5 | M2 V (bh), M1 (af), M2 V (au) |
| 497 B* | 800 B | — | BD -19°5899 B | — | composite with LHS 497 A |
| 498 | 802 | 231-13 | Wolf 1084 | 1.6 | M5 V (bh), M5.5 (af), M5 V (ai) |
| 499 | 808 | — | — | 1.5 | M (au) |
| 500 | 810 B | — | — | 1.9 | composite with LHS 501 |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 501* | 810 A | — | — | 1.9 | M3.5 (af), M5 (au) |
| 502 | 811.1 | — | Wolf 896 | 1.8 | M4 V (cb), M3 V (bh), M3 (af), M4 V (au) |
| 503 | 812.1 | — | CD -44°14214 | 0.6 | G0 V (bf), G0 (af), G0 V (au), G0 V (be) |
| 504 | — | — | — | 1.7 | — |
| 505 | — | — | — | 1.3 | — |
| 506 | — | — | Ross 770 | 1.3 | K4 (af) |
| 507 | — | — | — | 1.9 | sdK (bl), sdM (ac), K3-5 V (ai) |
| 508 | 829 | 126-4 | Ross 775 | 1.8 | M3.5 V (bi), M4 V (cb), M3.5 V (bh) |
| 509 | 830 | — | BD -13°5945 | 1.3 | K4-5 V (bf), M0 V (cb), M0 V (bh) |
| 510 | — | — | — | 1.5 | M3 (af) |
| 511 A* | 831 A | 26-7 A | Wolf 922 A | 1.6 | M4.5 V (bi), M5 V (bh), M4 (af), M4 V (au) |
| 511 B* | 831 B | 26-7 B | Wolf 922 B | — | composite with LHS 511A |
| 512 | — | — | — | 1.5 | M2 (af) |
| 513 | 836 | — | — | 1.7 | M3.5 (af), M5 (au) |
| 514 | — | 261-46 | — | 1.1 | dM (bo) |
| 515 | — | — | — | 2.5 | sdM2.5 (bi), sdM0-2 (ax), sdM0-2 (ai) |
| 516 | — | — | — | 1.3 | — |
| 517 | 849 | 27-16 | BD -5°5715 | 1.6 | M3.5 V (bh), M3 (af), M3 V (au) |
| 518 | — | — | — | 1.3 | K5: (af) |
| 519 | — | — | CD -51°13248 | 0.9 | K0 V (au) |
| 520* | 855.1 | — | $\nu$ Ind | 0.6 | A3 V:+F9 V (be), G0-2 V (bf), G0 V (au) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 521 | — | — | — | 1.8 | — |
| 522* | 861 | 18-51 | Wolf 1037 | 1.3 | K4 (af), sdK6 (au) |
| 523 | — | — | — | 2.2 | M6.5 V (bi), M6.5 V (ai), M6.5 V (ax) |
| 524 | 1270 | 215-50 | — | 1.9 | — |
| 525 A* | 863.1 A | 233-17 A | BD +53°2911 A | 1.6 | K7 V (bi), M1 V (bh), K5 (af), M1 V (au) |
| 525 B* | 863.1 B | 233-17 B | BD +53°2911 B | — | composite with LHS 525 A and C |
| 525 C* | 863.1 C | 233-17 C | BD +53°2911 C | — | composite with LHS 525 A and B |
| | | | | | |
| 526 | — | — | — | 1.7 | M4.5 V (ai) |
| 527 | — | — | — | — | — |
| 528 | 1271 | 67-15 | — | 1.7 | M3 (af), M3 V (bk) |
| 529 | 1275 | 128-7 | — | 0.5 | DA9 (br), DA9 (bn) |
| 530 | 876 | 156-57 | BD -15°6290 | — | M5 V (cb), M4.5 V (bh), M3.5 (af) |
| | | | | | |
| 531 | 877 | — | — | 1.1 | — |
| 532 | 1277 | — | — | 1.5 | — |
| 533* | 880 | 67-37 | BD +15°4733 | 1.7 | M1.5 V (bi), M2 V (cb), M2.5 V (bh) |
| 534 | — | 241-44 | — | 1.5 | M2 V (bk) |
| 535 | — | 241-45 | — | 1.5 | — |
| | | | | | |
| 536 | — | 128-34 | — | 1.3 | — |
| 537 | — | 28-43 | BD -0°4470 | 0.8 | sdG2 (au) |
| 538 | 1281 | — | — | 1.8 | M3 (af) |
| 539 | — | — | — | — | — |
| 540 A* | — | 273-1 A | BD -14°6437 A | 0.4 | sdG2: (ar), F8 (af), sdF7 (am), sdG2 (au) |
| 540 B* | — | 273-1 B | BD -14°6437 B | — | composite with LHS 540 A |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 541 | — | — | BD -14°6437 C | 2.0 | sdM (ac), sd (ai) |
| 542 | — | — | — | 1.3 | DC9 (br), DC9 (bn) |
| 543 | — | 68-8 | — | 1.7 | — |
| 543a | — | — | — | 1.7 | — |
| 544 | 895.4 | 217-11 | BD +58°2605 | 1.2 | G8 (af), K2 V (am), K0 V (au), K1 IV (be) |
| 545 | 899 | 29-43 | Wolf 1039 | 1.6 | M2.5 (af) |
| 546 | 1286 | 157-77 | — | 1.6 | — |
| 547 | — | — | — | 1.8 | M4 (af) |
| 548 | 901 | 29-53 | Wolf 1040 | 1.7 | M3.5: (af) |
| 549 | 905 | 171-10 | Ross 248 | 1.8 | M5 V (ah), M5.5 V (bh), M4.5 (af) |
| 550 | 908 | 29-68 | BD +1°4774 | 1.6 | M1.5 V (ah), M2 V (bb), M2.5 V (bh) |
| 551 | 1292 | 129-47 | — | 1.3 | M3 V (bk) |
| 552 | — | 266-20 | BD -17°6856 | 0.9 | K2 (af), K0 V (au), K0 V (am) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1001 | — | — | — | — | — |
| 1002a | — | 217-27 | — | 1.5 | — |
| 1003 | — | 267-16 | — | 1.7 | M3.5 (af) |
| 1004 | — | 130-36 | Ross 679 | 1.3 | K3 (af) |
| 1005 | 915 | — | — | -0.1 | DAs (af) |
| 1006 | — | 158-22 | — | 1.6 | — |
| 1007 | — | — | — | 1.5 | — |
| 1008 | — | 267-18 | — | 0.4 | DC9 (br), DC (af) |
| 1009 | — | 30-38 | — | 2.1 | — |
| 1010 | — | — | — | 1.5 | — |
| 1011 | — | 266-36 | — | 1.6 | — |
| 1012 | — | 267-23 | — | 1.6 | — |
| 1013 | — | — | BD +33°4828 | 0.5 | G2 V (be), G2 V (am), G3 (af) |
| 1014 | 2 | 171-39 | BD +44°4548 | 1.5 | M2 V (bh), M1 (af) |
| 1015 | 3 | — | CD -68°2378 | 1.1 | — |
| 1016* | 4 A | 171-40 A | BD +45°4408 A | 1.2 | K7 (af) |
| 1017 | 4 B | 171-40 B | BD +45°4408 B | 1.2 | M0 V (ai), K7 (af), M0.5 V (bh) |
| 1018 | — | — | — | 1.5 | — |
| 1019 | — | — | — | 1.5 | — |
| 1020 | 4.2 A | — | CD -49°14337 A | 0.6 | G1 IV (be), F7 V (bf), F8 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1021 | 4.2 B | — | CD -49°14337 B | — | — |
| 1022 | — | 30-45 | — | 1.7 | M3.5 (af) |
| 1023 | — | 158-31 | — | 1.6 | — |
| 1024 | — | — | — | 2.2 | — |
| 1025 | — | 266-55 | — | 2.1 | — |
| | | | | | |
| 1026 | 7 | 266-57 | CD -27°16 | 1.5 | M0 (af) |
| 1027* | 8 | — | $\beta$ Cas | 0.3 | F2 III-IV (be), F2 IV (am), F1 (af) |
| 1028 | — | 130-49 | — | -0.2 | DC6 (br), DC6+ (ba) |
| 1029 | — | 130-50 | — | 1.9 | — |
| 1030 | — | — | — | — | — |
| | | | | | |
| 1031 | — | — | — | 1.5 | — |
| 1032 | — | — | — | 2.0 | — |
| 1033 | — | 31-31 | — | 1.8 | — |
| 1034 | — | — | — | 1.5 | — |
| 1035 | — | — | — | 2.8 | — |
| | | | | | |
| 1036 | — | 267-45 | CD -39°31 | 1.5 | K4 (af) |
| 1037 | — | 130-53 | — | 1.3 | — |
| 1038 | 1004 | 217-37 | — | 0.1 | DA8 (br) |
| 1039 | — | 217-38 | — | 1.5 | — |
| 1040 A* | 11 A | 241-76 A | — | 1.7 | M6 V (cb), M4 comp (af) |
| 1040 B* | 11 B | 241-76 B | — | — | composite with LHS 1040 A |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1041 | — | 130-56 | — | 1.1 | — |
| 1042 | — | — | — | 1.7 | — |
| 1043 | — | 130-57 | — | 2.0 | — |
| 1044 | — | 158-45 | — | 0.3 | DC8 (br), DC8 (bn) |
| 1045 | — | 266-72 | — | 1.3 | — |
| | | | | | |
| 1046 | — | 266-73 | — | 1.5 | — |
| 1047 A* | 1005 A | 158-50 A | — | 2.2 | M4 V (bi), M4 (af) |
| 1047 B* | 1005 B | 158-50 B | — | — | composite with LHS 1047 A |
| 1048 | — | 267-58 | — | 1.5 | M4: (af) |
| 1049 | — | — | — | 1.5 | — |
| 1050 | 12 | 30-55 | — | 1.7 | M3.5 (af) |
| | | | | | |
| 1051 | — | — | — | 1.5 | — |
| 1052 | 1007 | 31-39 | — | 1.9 | — |
| 1053 | 14 | 171-44 | BD +40°45 | 1.5 | M0.5 (bh), K7 (af) |
| 1054 | — | 130-61 | Ross 680 | 2.4 | M2 (af), M0 (bk) |
| 1055 | — | — | — | 1.5 | — |
| | | | | | |
| 1056 | — | — | — | 1.5 | — |
| 1057 | — | 266-87 | — | 1.3 | K7 (af) |
| 1058 | — | — | — | 2.2 | — |
| 1059 | — | — | — | 1.5 | — |
| 1060 | — | — | — | 2.0 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1061 | 17.1 | — | CD -46°76 | 1.6 | M1 (af) |
| 1062 | — | 171-51 | — | 1.3 | — |
| 1063 | — | — | CD -53°70 | 1.1 | K3 V (at) |
| 1064 | — | — | CD -51°89 | 1.5 | — |
| 1065 | 1010 A | 242-51 | — | 1.3 | dK (bj) |
| 1066 | 1010 B | 242-52 | — | 1.5 | M4 V (ai), dK (bj) |
| 1067 | 18 | 226-107 | CD -27°108 | 1.1 | K3 (af), K2 V (bf) |
| 1068 | — | 130-68 | — | 1.7 | — |
| 1069 | — | — | — | 2.3 | — |
| 1070 | 2005 | — | McCarthy 45 | 1.6 | M6 V (ad), M6 V (bg) |
| 1071 | — | — | CD -51°95 | 0.6 | G0 V (bf), G3-4 IV-V (be) |
| 1072 | — | — | — | — | — |
| 1073 | — | 131-66 | — | 1.7 | — |
| 1074 | — | — | — | 2.4 | — |
| 1075 | — | — | — | 1.8 | dwarf carbon star (ay) |
| 1076 | — | — | — | -0.2 | DA5 (br) |
| 1077 | — | 267-106 | — | 1.1 | — |
| 1078 | — | 167-107 | CD -33°143 | 1.1 | K3: (af) |
| 1079 | — | 1-2 | — | 1.8 | — |
| 1080 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1081 | — | — | — | 1.6 | — |
| 1082 | — | 31-52 | — | 1.9 | K5 (af) |
| 1083 | — | — | — | 1.7 | — |
| 1084 | 1012 | 31-53 | — | 1.7 | M4 (af) |
| 1085 | — | — | — | 1.6 | — |
| 1086 | — | 158-86 | — | 1.5 | — |
| 1087 | — | 158-87 | — | 1.5 | — |
| 1088 | — | 217-55 | — | 1.5 | M3.5 V (ai) |
| 1089 | — | — | — | 1.3 | sdM (bm) |
| 1090 | — | — | — | 1.5 | — |
| 1091 | — | 158-94 | — | 2.0 | — |
| 1092 | — | 267-121 | — | 1.6 | — |
| 1093 | — | — | — | 0.9 | — |
| 1094 | — | — | CD -63°9 | 1.5 | — |
| 1095 | — | — | — | 1.5 | — |
| 1095a | — | — | — | 1.6 | — |
| 1096 | — | — | — | 1.5 | M2 (bz) |
| 1097 | — | 267-128 A | CD -35°170 A | 0.9 | G0 (af), G3 IV (be), F8/G0 V (bf) |
| 1098 | — | 267-128 B | CD -35°170 B | 1.2 | K1 (af) |
| 1099 | — | 266-132 | — | 1.5 | M3 (af) |
| 1100 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1101 | — | 242-60 | — | 1.3 | — |
| 1102 | — | 266-135 | — | -0.1 | DA5+ (ba) |
| 1103 | — | — | — | 1.6 | — |
| 1104 | — | 172-11 | — | 1.5 | — |
| 1105 | — | 217-59 | — | 1.8 | — |
| 1106 | — | 158-103 | BD -10°109 | 1.8 | K7 (af) |
| 1107 | — | — | — | — | — |
| 1108 | — | 267-138 | — | 1.6 | MS (bz) |
| 1109 | — | — | — | 2.5 | — |
| 1110 A* | — | 267-141 A | CD -37°205 A | 0.6 | G5 V (be), G8 V (bf), G8 (af) |
| 1110 B* | — | 267-141 B | CD -37°205 B | — | composite with LHS 1110 A |
| 1111 | — | 172-14 | — | 1.1 | — |
| 1112 | — | 270-23 | BD -9°122 | 0.4 | F5 V (bx), G0 V-VI (bu) |
| 1113 | — | 270-26 | — | 1.3 | sd? (ae) |
| 1114 | — | 1-9 | BD +2°84 | 0.6 | M2.5 (af), G2 V (am) |
| 1115 | — | 270-28 | — | 1.6 | — |
| 1116 | 27 | — | 54 Psc | 1.1 | K0 V (be), K1 (af), K0 V (am) |
| 1117 | — | — | — | 1.6 | — |
| 1118 | — | 1-10 | BD +9°73 | 1.3 | K5 (af) |
| 1119 | — | 267-149 | — | 1.5 | M3 (bz) |
| 1120 | — | 132-14 | — | 1.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1121 | — | — | — | — | — |
| 1122 | 27.1 | — | CD -44°170 | 1.5 | M0.5 (af) |
| 1123 | 29 | — | CD -60°118 | 0.6 | G1 V (be), F6/8 (bf) |
| 1124 | 27.2 | 266-152 | CD -24°263 | 0.9 | G3-5 V (bf), G3 V (be), G6 (af) |
| 1125 | 28 | 132-15 | BD +39°154 | 1.2 | K3 (af), K2 V (am) |
| 1126 | 2012 | 266-157 | — | 0.5 | DC9 (br), DX-DQ10 (ba), DC (af) |
| 1127 | — | 267-157 | — | 1.3 | K3 (af) |
| 1128 | — | 270-39 | — | 1.1 | — |
| 1129 | 1017 | — | — | 1.5 | — |
| 1130 | — | — | — | 1.5 | — |
| 1131 | — | — | — | 1.0 | DA3 (br) |
| 1132 | — | — | — | 1.1 | — |
| 1133 | — | 1-17 | — | 1.5 | M1 (af) |
| 1134 | — | — | — | 1.6 | M4 (af) |
| 1135 | — | — | — | 2.5 | — |
| 1136 | — | — | — | 1.5 | — |
| 1137 | — | 1-18 | — | 1.6 | — |
| 1138 | — | 69-18 | Wolf 1504 | 0.9 | G2 (af), G5 (ag) |
| 1139 | 31.5 | — | CD -66°38 | 0.9 | G3-5 V (be), G5 V (bf) |
| 1140 | — | 268-38 | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|------------|----------------|------------------------------|
| 1141 | 31.4 | 1-20 | BD +1°131 | 1.3 | K2 V (am), K2 (af) |
| 1142 | — | — | — | 1.5 | — |
| 1143 | — | — | — | — | — |
| 1144 | — | 267-168 | — | 1.5 | M2.5: (af) |
| 1145 | — | — | — | 1.5 | sdK7-M5 (ai) |
| 1146 | — | — | — | 2.8 | — |
| 1147 | — | — | — | 1.7 | — |
| 1148 | — | — | — | — | — |
| 1149 | — | — | — | 1.5 | M4 V (ai) |
| 1150 | — | — | — | 1.9 | — |
| 1151 | — | — | — | 2.7 | M4 V (ai) |
| 1152 | — | — | — | 1.3 | — |
| 1153 | — | 132-32 | — | 1.5 | — |
| 1154 | 36 | 268-53 | CD -23°315 | 0.9 | G8/K0 V (bf), G9 (af) |
| 1155 | — | — | — | 1.5 | — |
| 1156 | — | 69-26 | — | 1.1 | — |
| 1157 | — | — | — | 2.0 | M3 V (ai) |
| 1158 | — | — | — | 0.6 | DC9 (br), DC9 (bc) |
| 1159 | 40 A | 268-60 | CD - 23°332 | 1.2 | K5 V (bf), K5 (af) |
| 1160 | 40 B | — | — | 1.4 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1161 | — | 132-35 | — | 1.3 | — |
| 1162 | — | 132-36 | — | 1.3 | — |
| 1163* | 42 | 269-49 | CD -31°325 | 1.0 | K2 V (bf), K3 (af) |
| 1164 | — | — | — | 1.5 | — |
| 1165 | — | 268-76 | — | 1.5 | M3 (af) |
| 1166 | — | — | — | 2.9 | mid-M V-VI (bm) |
| 1167 | — | 242-73 | BD +68°60 | 1.3 | K3 (af) |
| 1168 | 1024 | 32-59 | — | 1.7 | — |
| 1169 | — | 172-30 | — | 1.3 | — |
| 1170 | — | 243-48 | Wolf 40 | 1.1 | — |
| 1171 | — | 269-67 | — | 1.5 | M3.5: (af) |
| 1172 | — | 69-38 | — | 1.7 | — |
| 1173 | — | — | — | 1.5 | M3.5 V (ai) |
| 1174 | — | — | — | 1.5 | sdK7-M1 (ai) |
| 1175 | — | 69-40 | Wolf 1506 | 1.6 | M3 (af) |
| 1176 | 47 | 243-50 | Wolf 44 | 1.7 | M2.5 V (bh), M3 (af) |
| 1177 | — | — | — | 1.6 | — |
| 1178 | — | — | — | 1.5 | sd (bw) |
| 1179* | 49 | 243-52 | BD +61°195 | 1.6 | M1.5 V (ah), M2 V (bh), M2 V (cb), M1(af) |
| 1180 | 1026 A | 33-35A | — | 1.5 | M1.5 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1181 | 1026 B | 33-35 B | — | 1.6 | M3.5 (af) |
| 1182 | — | 242-77 | — | 1.6 | — |
| 1183 | 51 | 243-55 | Wolf 47 | 2.1 | M5 V (bi), M5 V (ah), M5 V (bh), M5 (af) |
| 1184 | — | — | — | 1.5 | — |
| 1185 | — | 132-52 | — | 1.9 | — |
| | | | | | |
| 1186 | — | 269-87 | CD -35°360 | 0.6 | G8 (af) |
| 1187 | — | — | — | 1.6 | M5.5 V (ai) |
| 1188 | — | — | CD -40°239 | 0.6 | G2/3 V (bf), G2 (af) |
| 1189 | — | — | — | 1.3 | — |
| 1190 | — | — | — | 1.5 | — |
| | | | | | |
| 1191 | — | — | — | 1.8 | M3.5 (af) |
| 1192 | — | — | — | — | — |
| 1193 | 52.1 | — | CD -51°273 | 1.1 | K2 V (bf) |
| 1194 | — | — | — | — | — |
| 1195 | — | 33-39 | — | 1.5 | — |
| | | | | | |
| 1196 | — | — | — | — | — |
| 1197 | 1031 | 269-106 | — | 1.5 | M3.5 (af) |
| 1198 | — | 243-62 | Wolf 56 | 1.1 | K2 (af) |
| 1199 | 53.2 | 33-40 | BD +16°120 | 1.5 | M0 V (bh), K4 (af) |
| 1200 | — | 33-41 | — | 0.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1201 | — | — | — | — | — |
| 1202 | — | — | — | 1.5 | — |
| 1203 | — | 270-154 | — | 1.5 | M3.5 V (ai) |
| 1204 | — | 33-43 | — | 1.6 | — |
| 1205 | — | 270-155 | — | 1.6 | M4 V (ai) |
| 1206* | — | 243-63 | BD +60°170 | 0.6 | G5 (af), F9 V (am) |
| 1207 | — | 269-112 | — | 1.3 | — |
| 1208 | 54 | — | CD -68°47 | 1.1 | — |
| 1209 | — | — | — | 1.6 | — |
| 1210 | — | — | — | 1.3 | — |
| 1211 | — | 132-61 | — | 1.5 | — |
| 1212 | — | 2-27 | — | 1.7 | — |
| 1213 | — | 70-44 | — | 1.9 | — |
| 1214 | — | — | — | 1.6 | — |
| 1215 | — | — | — | — | — |
| 1216 | — | — | — | 1.5 | — |
| 1217 | — | 269-125 | — | 1.6 | — |
| 1218 | — | — | — | 1.8 | M5 V (ai) |
| 1219 | — | — | — | 0.6 | DC9 (br), DC9 (bc) |
| 1220 | 55 | — | $\nu$ Phe | 0.6 | G0 V (bf), F8 V (be), G0 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1221 | — | 34-12 | — | 1.3 | — |
| 1222 | — | — | — | 1.5 | — |
| 1223 | — | — | — | 1.3 | — |
| 1224 | — | 268-145 | — | 1.3 | K0 (af) |
| 1225 | 56 | 268-146 | BD -16°214 | 1.6 | K3 V (bf), K3 (af) |
| 1226 | — | 2-33 | — | 1.5 | M1 (bk) |
| 1227 | 1037 | 33-49 | Wolf 1516 | 0.1 | DQ6/DC6 (br), DC (af), DQ5+ (ba) |
| 1228 | 56.1 | 270-188 | — | 1.3 | M3 (af) |
| 1229 | 56.3 B | 70-50 | BD -1°167 B | 1.1 | M0 (af) |
| 1230 | 56.3 B | 70-51 | BD -1°167 A | 1.1 | K2 (af), K1 V (am) |
| 1231 | — | 271-34 | BD -9°256 | 0.6 | G2 (af), G2 V (am) |
| 1232 | — | 269-138 | — | 1.7 | — |
| 1233 | — | — | — | 0.3 | — |
| 1234 | — | 219-5 | Ross 9 | 1.5 | K5 (af), K6 V (ag) |
| 1235 | — | — | — | 1.5 | — |
| 1236 | — | 69-65 B | BD +30°206 B | 1.5 | M1: (af) |
| 1237 | — | 69-65 A | BD +30°206 A | 1.1 | K1 (af) |
| 1238 | — | 272-4 | — | 1.1 | — |
| 1239 | — | — | BD +17°197 | 0.6 | G3 V (be), G4 (af), G3 V (am) |
| 1240 | — | 70-55 A | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1241 | — | 70-55 B | — | 1.5 | — |
| 1242 | — | 133-7 | — | 1.3 | — |
| 1243 | — | — | — | — | — |
| 1244 | — | 133-8 | — | 0.2 | DC9 (az) |
| 1245 | — | — | CD -44°397 | — | — |
| 1246 | — | 33-56 | BD +17°202 | 1.2 | K2 (af) |
| 1247 | 1039 | 269-160 | — | 0.2 | DC7 (br) |
| 1248 | — | — | — | 1.1 | — |
| 1249 | — | 269-161 | — | 1.8 | M4.5 (af) |
| 1250 | — | — | — | 1.5 | — |
| 1251 | — | 269-166 | — | 2.1 | — |
| 1252 | — | — | — | >3.2 | M6 V (bi) |
| 1253 | — | 269-171 | — | 1.5 | — |
| 1254 | — | 245-25 | — | 1.5 | — |
| 1255 | — | — | — | 1.5 | — |
| 1255a | — | 274-53 | — | 1.5 | — |
| 1256 | — | 271-84 | — | 1.1 | — |
| 1257 | — | — | — | 1.5 | M4 V (ai) |
| 1258 | — | — | — | 1.5 | — |
| 1259 | — | — | — | 1.5 | — |
| 1260 | — | — | — | — | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1261 | — | — | — | 1.5 | — |
| 1262 | — | — | — | 1.5 | — |
| 1263 | — | — | — | — | — |
| 1264 | — | — | — | 1.5 | — |
| 1265 | — | — | — | 3.1 | — |
| | | | | | |
| 1266 | — | 133-21 | — | 1.8 | — |
| 1267 | — | — | CD -61°282 | 0.4 | sdF8 (ak) |
| 1268 | — | — | CD -49°451 | 1.5 | K7 (af) |
| 1269 | — | — | — | 1.5 | — |
| 1270 | 64 | 271-115 | — | 0.1 | DA7 (br), DA (af) |
| | | | | | |
| 1271 | — | 272-58 | — | 1.1 | K3 (af) |
| 1272 | — | 71-24 | — | 1.1 | — |
| 1273 | — | — | — | 1.0 | — |
| 1274 | — | — | — | — | — |
| 1275 | — | 72-21 | BD +27°262 | 0.8 | G8 V (am) |
| | | | | | |
| 1276 | — | — | — | 1.3 | — |
| 1277 | — | 173-14 | Ross 11 | 1.7 | K7 (af), K7 (ag) |
| 1278 | — | 274-83 | CD -31°682 | 1.1 | K4: (af) |
| 1279 | — | — | CP - 68°77 B | 1.5 | — |
| 1280 | — | — | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1281 | — | — | CD -68°74 | 0.5 | G0wF5: (bf) |
| 1282 | — | — | — | 1.6 | — |
| 1283 | — | 244-31 | BD +66°145 | 0.9 | G5 V (am), G6 (af) |
| 1284 A* | 67 A | — | BD +41°328 A | 0.5 | G1.5 V (be), G2 V (am), G1 (af) |
| 1284 B* | 67 B | — | BD +41°328 B | — | composite with LHS 1284 A |
| 1285 | — | 133-29 | — | 1.3 | — |
| | | | | | |
| 1286 | — | 272-81 | BD -18°287 | 0.6 | G2-3 V (bf), G1 V (am) |
| 1287 | 68 | — | 107 Psc | 0.9 | K1 V (be), K1 V (am), K0 (af) |
| 1288 | — | — | CD -42°594 | 1.6 | M0 (af) |
| 1289 | — | 35-8 | BD +27°273 | 1.1 | — |
| 1290 | 70 | 3-14 | — | 1.6 | M2.5 V (ah), M2 V (bh) |
| | | | | | |
| 1291 | 69 | 244-33 | BD +63°229 | 1.5 | K5 V (am), K4 (af), M0.5 V (bh) |
| 1292 | 73 | 3-17 | Wolf 1530 | 1.5 | M3 (af) |
| 1293 | — | 274-90 | — | 1.5 | M3.5 (af) |
| 1294 | — | — | — | 2.8 | — |
| 1295 | — | — | — | 1.6 | — |
| | | | | | |
| 1296 | — | 133-39 | — | 1.6 | — |
| 1297 | 75 | — | BD +63°238 | 1.1 | K0 V (be), K0 V (am), K0 (af) |
| 1298 | — | — | — | 1.7 | — |
| 1299 | — | — | — | 3.3 | — |
| 1300 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1301 | — | 271-163 | — | 1.6 | — |
| 1302 | — | 159-3 | — | 2.3 | — |
| 1303 | 78 | 271-168 | Ross 555 | 1.7 | M3.5 (af) |
| 1304 | — | — | — | 2.0 | — |
| 1305 | — | — | CD -42°654 | 1.3 | G8 (af) |
| 1306 | — | — | CD -44°545 B | 1.7 | M0 (af) |
| 1307 | 79 | 272-114 | CD -23°693 | 2.1 | K5-M0 V (bf), M1.5 V (bh), K7 (af) |
| 1308 | — | — | — | 1.5 | — |
| 1309 | — | 3-27 | — | 1.5 | — |
| 1310 | — | 245-34 | — | 1.3 | K4 (af), K5 (bk) |
| 1311 | — | — | — | 1.8 | — |
| 1312 | — | 244-42 | — | 1.7 | — |
| 1313 | — | 244-41 | — | 1.7 | — |
| 1314 A* | 81 A | — | χ Eri A | 0.9 | G8 IIIb (be), G8 IIIb (bf) |
| 1314 B* | 81 B | — | χ Eri B | — | composite with LHS 1314 A |
| 1315 | — | — | — | 1.5 | K3: (af) |
| 1316 | — | — | — | 1.3 | — |
| 1317 | — | — | — | 2.9 | M6.5: (ai) |
| 1318 | — | 17-45 | — | 1.3 | M4 V (ai) |
| 1319 | — | 3-29 | — | 1.1 | — |
| 1320 | — | — | — | 1.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1321 | — | 274-136 | — | 1.1 | — |
| 1322 | — | — | — | 1.1 | dK-M? (bc) |
| 1323 | — | — | CD -41°556 | 0.6 | G4 (af), G3 V (bf) |
| 1324 | — | 71-47 | — | 1.5 | — |
| 1325 | — | 272-137 | — | 1.7 | — |
| | | | | | |
| 1326 | — | — | — | 1.5 | — |
| 1327 | — | — | — | 1.6 | — |
| 1328 | — | — | — | 1.5 | — |
| 1329 | — | 274-143 | — | 1.3 | — |
| 1330 | — | 173-34 | — | 1.7 | — |
| | | | | | |
| 1331 | — | — | — | 1.3 | — |
| 1332 | — | 159-34 | — | 2.0 | — |
| 1333 | — | 3-39 | — | 1.6 | M3 (af) |
| 1334 | — | — | — | 1.5 | — |
| 1335 | — | 35-24 | BD +22°301 | 1.1 | K2 (af) |
| | | | | | |
| 1336 | — | — | — | 1.8 | — |
| 1337 | 84.1 A | 274-145 | CD -28°657 A | 1.1 | M0.5 (af) |
| 1338 | 84.1 B | 274-146 | CD -28°657 B | 1.2 | M3.5 (af) |
| 1339 | — | 274-149 | CD -30°731 | 1.4 | M3.5 (af) |
| 1340 | — | — | — | 1.5 | M2-3 V (ai) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1341 | — | — | — | 0.5 | — |
| 1342 | — | — | — | — | — |
| 1343* | 84.2 | 134-1 | — | 1.3 | K4 (af) |
| 1344 | — | 242-81 | — | 1.1 | K5 (af) |
| 1345 | — | — | — | 1.9 | — |
| | | | | | |
| 1346 | — | — | BD -17°400 | 1.3 | K7 (af) |
| 1347 | — | — | — | 2.3 | M3 (af) |
| 1348 | 85.1 | 74-4 | Ross 17 | 1.5 | M3 (af), M3 (ag) |
| 1349 | — | — | — | 2.1 | M5 V (ai) |
| 1350 | — | 245-45 | — | 1.5 | — |
| | | | | | |
| 1351 | — | — | — | 1.5 | — |
| 1352 | — | — | — | 1.6 | — |
| 1353 | — | — | — | 1.1 | — |
| 1354 | — | — | — | 1.0 | — |
| 1355 | — | — | — | — | — |
| | | | | | |
| 1356 | — | — | — | 1.5 | — |
| 1357 | 88 | — | — | 1.7 | M0 (af) |
| 1358 | — | 159-46 | — | 1.8 | — |
| 1359 | — | — | — | 1.5 | M4.5 V (ai) |
| 1360 | — | — | — | 1.5 | K2: (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1361 | 91 | — | CD -32°828 | 1.3 | M2.5 (af) |
| 1362 | — | — | — | 1.5 | — |
| 1363 | — | — | — | 1.5 | — |
| 1364 | — | — | — | 1.3 | — |
| 1365 | — | 159-50 | BD -1°306 | 0.6 | G0 (af), G1 V (am) |
| 1366 | 1045 | 35-35 | — | 1.9 | — |
| 1367 | — | — | — | 2.8 | — |
| 1368* | — | 74-10 | Ross 18 | 0.6 | G4 (af), G2 (ag) |
| 1369 | — | 73-37 | Wolf 127 | 1.1 | M1 (af) |
| 1370 | — | — | — | 1.7 | — |
| 1371 | 90 | 244-56 | BD +67°191 | 1.4 | K2 V (am), K2 V (be), K2 (af) |
| 1372 | — | 159-53 | — | 1.6 | — |
| 1373 | — | — | — | 1.9 | M3 (af) |
| 1374 | — | — | — | 1.5 | — |
| 1375 | — | — | — | 1.5 | — |
| 1376 | — | — | — | 1.7 | M4 (af) |
| 1377 | — | — | CD -31°909 | 1.9 | M4 (af) |
| 1378 | — | — | — | 2.1 | — |
| 1379 | 93 | — | CD -54°487 | 1.5 | — |
| 1380 | — | — | — | 1.3 | M1: (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1381 | — | — | — | 1.8 | M3 (af) |
| 1382 | — | — | BD +1°410 | 0.5 | G0.5 IVb (be), F9 V (am) |
| 1383 | 92.2 | 134-24 | — | 1.9 | M4 (ag), M3 (af) |
| 1384 | — | — | — | 1.5 | — |
| 1385 | — | — | — | — | — |
| 1386 | — | — | — | — | — |
| 1387 | 95 | — | CD -26°828 | 0.9 | G8 V (bf), G5 V (be), G6 (af) |
| 1388 | 94 | 74-14 | Ross 19 | 1.5 | M3.5 (af) |
| 1389 | — | — | — | 0.5 | — |
| 1390 | — | — | — | 1.6 | — |
| 1391 | — | — | CD -31°943 | 1.1 | K2-3 V (bf), K1: (af) |
| 1392 | 1047 C | 74-18 | — | 1.8 | — |
| 1393 A* | 1047 A | 74-19 A | — | 1.8 | — |
| 1393 B* | 1047 B | 74-19 B | — | — | — |
| 1394 | — | — | — | 1.6 | — |
| 1395 | — | — | — | 2.3 | — |
| 1396 | — | — | — | 2.5 | — |
| 1397 | — | 244-60 | BD +70°169 | 1.2 | K1 (af), K2 V (am) |
| 1398 | — | — | — | 1.3 | — |
| 1399 | — | — | — | 1.5 | — |
| 1400 | — | 74-21 | — | 1.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1401 | — | — | — | 1.7 | — |
| 1402 | — | — | — | -0.8 | — |
| 1403 | — | 4-21 | — | 0.9 | — |
| 1404 | — | 75-9 | — | 1.5 | M2.5: (af) |
| 1405 | — | — | — | 1.1 | — |
| | | | | | |
| 1406 | — | — | — | 1.3 | — |
| 1407 | — | — | — | 1.8 | M5.5 V (ai) |
| 1408 | 100 C | — | — | 1.3 | M3 (af) |
| 1409 A* | 100 A | — | BD -20°465 A | 1.2 | K4 V (bf), K4 V (am), K4 (af) |
| 1409 B* | 100 B | — | BD -20°465 B | — | composite with LHS 1409 A |
| 1410 | — | 36-22 | — | 1.1 | — |
| | | | | | |
| 1411 | — | — | — | 1.4 | — |
| 1412 | — | — | — | 1.5 | — |
| 1413 | — | — | — | >2.5 | — |
| 1414 | — | — | — | 1.5 | — |
| 1415 | — | — | — | 1.4 | DC/DF? (br) |
| | | | | | |
| 1416 | — | — | — | 1.5 | — |
| 1417 | 102 | 36-24 | — | 1.9 | M4+ V (ah), M4 (af), M6 V (cb) |
| 1418 | — | 221-1 | — | 1.5 | — |
| 1419 | — | 73-67 | BD +4°415 | 1.2 | K4 (af) |
| 1420 | — | — | — | 2.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1421 | — | — | — | 0.9 | — |
| 1422 | — | — | — | 2.5 | — |
| 1423 | — | — | — | 1.5 | — |
| 1424 | — | — | — | 1.6 | — |
| 1425 | — | — | — | 1.3 | — |
| 1426 | — | 75-30 | — | 1.7 | — |
| 1427 | — | — | — | 1.6 | — |
| 1428* | — | 36-28 | BD +30°421 | 0.6 | G1 V (am) |
| 1429 | — | 76-20 | — | 0.9 | — |
| 1430 | — | — | — | — | — |
| 1431 | — | — | — | 1.8 | — |
| 1432 | — | — | CD -30°990 | 0.6 | F8 V (bf) |
| 1433 | — | — | — | -0.2 | — |
| 1434 | — | — | — | 1.8 | M3.5 (af) |
| 1435 | — | 75-37 | — | 1.6 | — |
| 1436 | — | — | CD -46°790 | 1.1 | K4 V (bf), K3 (af) |
| 1437 | — | — | — | 1.5 | — |
| 1438 | 1051 | — | Wolf 1132 | 1.5 | M2.5 (af) |
| 1439 | 109 | 36-31 | Ross 556 | 1.8 | M3.5 V (ah), M3.5 V (bh), M3 (af) |
| 1440 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1441 | — | — | — | 1.1 | — |
| 1442 | 1052 | 75-39 | — | 0.3 | DA7 (br), DA7+ (ba) |
| 1443 | — | — | — | 1.6 | M5.5-6: V (ai), M5.5-6 V (ax) |
| 1444 | — | — | — | 1.5 | — |
| 1445 | — | — | — | 2.0 | — |
| | | | | | |
| 1446 | — | 174-14 | — | 0.6 | DA9/DC (br), DA11 (ba) |
| 1447 | — | — | — | -1.1 | — |
| 1448 | — | — | — | 1.5 | — |
| 1448a | — | 74-43 | — | 1.8 | — |
| 1449 | — | — | — | 1.3 | — |
| 1450 | — | — | — | 2.2 | — |
| | | | | | |
| 1451 | — | — | — | 1.6 | — |
| 1452* | 114.1 | — | CD -53°570 | 1.1 | — |
| 1453 | 114 | 4-43 | BD +15°395 | 1.3 | K5 (af) |
| 1454 | — | — | — | 1.6 | — |
| 1455 | — | 246-13 | — | 1.7 | — |
| | | | | | |
| 1456 | — | 246-14 | — | 1.6 | — |
| 1457 | — | 75-43 | — | 1.6 | — |
| 1458 A* | — | 78-7 A | BD +45°669 A | 0.9 | G1 V (am), G5 (af) |
| 1458 B* | — | 78-7 B | BD +45°669 B | — | composite with LHS 1458 A |
| 1459 | — | — | — | 1.9 | M2 (af) |
| 1460 | — | 75-45 | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 1461 | — | — | — | 1.5 | — |
| 1462 | — | — | — | 2.4 | M5-6: (ai) |
| 1463 | — | — | — | 2.2 | — |
| 1464 | — | — | — | 1.5 | — |
| 1465 | — | — | — | 1.5 | — |
| | | | | | |
| 1466* | 118.1 A | — | CD -36°1091 A | 1.3 | K1 V (bf), K1 (af) |
| 1467 | 118.1 B | — | CD -36°1091 B | 1.5 | M3: (af) |
| 1468 | — | 36-41 | — | 1.6 | — |
| 1469 | — | — | — | 1.8 | — |
| 1470 | — | — | — | 1.3 | — |
| | | | | | |
| 1471 | — | — | — | 1.5 | — |
| 1472 | — | — | — | 1.5 | — |
| 1473 | — | 174-18 | — | 1.7 | — |
| 1474 | 2028 | — | — | -0.3 | DA6 (br) |
| 1475 | 119 A | 174-19 | Ross 364 | 1.6 | M1 (af) |
| | | | | | |
| 1476 | 119 B | 174-20 | Ross 365 | 1.7 | M3 (af) |
| 1477 | — | — | — | 1.9 | — |
| 1478 | — | 245-61 | — | 1.5 | — |
| 1479 | — | — | — | 1.1 | K4 (af) |
| 1480 | — | — | — | 1.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1481 | — | — | — | 1.9 | M2.5 (af) |
| 1482 | — | — | — | 1.1 | K4 (af) |
| 1483 | — | 74-52 | Ross 331 | 1.5 | M3.5 (af) |
| 1484 | — | — | — | 1.5 | — |
| 1485 | — | 36-48 | — | 1.3 | — |
| | | | | | |
| 1486 | — | 78-11 | — | 1.3 | — |
| 1487 | — | 75-57 | BD +5°435 | 1.1 | K2 (af), K0 V (am) |
| 1488 | — | 174-27 | Ross 367 | 1.7 | M3 (af) |
| 1489 | — | — | $\epsilon$ For | 0.9 | G5 IV (be), G8-K0 V (bf) |
| 1490 | — | — | — | — | — |
| | | | | | |
| 1491 | — | — | — | 3.3 | — |
| 1492 | — | — | BD +61°513 A | 0.7 | G4 V (be), G4 V (am), G2 (af) |
| 1493 | — | — | — | — | — |
| 1494 | — | 246-22 | BD +61°513 B | — | M3 (af) |
| 1495 | — | 174-31 | Ross 341 | 1.3 | M3 (af) |
| | | | | | |
| 1496 | 123 | 76-58 | BD +1°543 | 1.5 | M1 V (bh), K5 (af) |
| 1497 | — | — | — | 1.5 | — |
| 1498 | — | 174-33 | — | 1.7 | — |
| 1499 | — | 78-18 | — | 1.5 | — |
| 1500 | — | — | — | — | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1501* | — | 37-26 | BD +25°495 | 0.4 | F5 (af), sdF7 (am) |
| 1502 | — | — | — | — | — |
| 1503 | — | — | — | 1.0 | — |
| 1504 | 1055 | 76-62 | — | 1.6 | — |
| 1505 | 122 | 245-65 | — | 1.5 | M1 V (bh) |
| 1506 | — | — | — | 2.2 | — |
| 1507 | 125 | 78-19 | — | 1.6 | M1 V(bh), M3 (af) |
| 1508 | — | 5-16 B | — | 1.3 | — |
| 1509 | — | 5-16 A | — | 1.1 | — |
| 1510 | — | — | — | 1.5 | — |
| 1511 | — | — | CD -85°33 | 1.5 | — |
| 1512 | — | 76-66 | — | 1.7 | — |
| 1513 | — | — | — | 1.6 | M3.5 (af) |
| 1514 | — | — | — | 1.3 | — |
| 1515 A* | 127 A | — | $\alpha$ For A | 0.5 | F8 V (be), F8 V (bf), F8 (af) |
| 1515 B* | 127 B | — | $\alpha$ For B | — | — |
| 1516 | — | — | — | 2.0 | M5.5 (ai) |
| 1517 | — | — | — | 1.3 | — |
| 1518 | — | 174-38 | BD +51°697 | 1.3 | M0 V (ag), M0 V (bh), K5 (af) |
| 1519 | — | — | — | 1.5 | — |
| 1520 | — | 79-18 | BD +8°482 | 1.2 | K1 (af), K1 V (am) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1521 | — | 246-30 | — | 1.7 | — |
| 1522 | 130.1 A | 174-41 A | Ross 370 A | 1.5 | M1.5 (af) |
| 1523 | 130.1 B | 174-41 B | Ross 370 B | 1.7 | M2 (af) |
| 1524 | — | — | — | 1.7 | — |
| 1525 | — | 37-32 | — | 1.1 | — |
| 1526 | — | 77-41 | — | 1.1 | — |
| 1527 | — | 5-26 | Ross 373 | 1.1 | K2 (af) |
| 1528 | 134 | 78-31 | BD +37°748 | 1.6 | M1.5 (af), M1.5 V (bh) |
| 1529 | — | — | — | 1.7 | — |
| 1530 | — | 246-32 | Ross 371 | 1.1 | M3.5 (af) |
| 1531 | — | — | — | — | — |
| 1532 | — | 77-45 | — | 1.1 | — |
| 1533 | — | 37-34 | BD +33°622 | 1.2 | K2 (af) |
| 1534 | — | — | CD -33°1180 | 0.8 | — |
| 1535 | — | — | — | — | — |
| 1536 | — | — | — | 1.5 | — |
| 1537 | — | — | — | 1.5 | — |
| 1538 | — | 79-32 | — | 1.3 | — |
| 1539 | — | 77-47 | — | 1.5 | — |
| 1540 | 1058 | 77-48 | — | 1.5 | M4.5 V (ai) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1541 | 1059 | 95-30 | — | 1.5 | — |
| 1542 | — | — | — | 1.5 | — |
| 1543 | — | — | — | 1.6 | K3 (af) |
| 1544 | — | 5-34 | — | 2.1 | — |
| 1545 | — | 5-35 | BD +11°468 | 1.4 | G0 V (ag) |
| 1546 | 141 | 77-49 | BD -5°642 | 1.2 | K5 V (am), K4 (af) |
| 1547 | — | 77-50 | — | 0.6 | DZ9/DA10 (br), DZ9 (bn), DA10+ (ba) |
| 1548 | 142 | — | BD -20°643 | 1.4 | K5 V (bf), K7 V (am), K7 (af), M0.5 V (bh) |
| 1549 | 1060 A | — | — | -0.6 | DA5 (br), DAs (af) |
| 1550 | 1060 B | — | — | 1.7 | M3 (af) |
| 1551 | 143.2 A | — | $\kappa$ Ret A | 0.4 | F3 IV-V (bf), F5 IV-V (be) |
| 1552 | 143.2 B | — | $\kappa$ Ret B | 1.6 | — |
| 1553 | — | 221-12 | — | 1.6 | — |
| 1554 | 143.3 | 5-43 | — | 1.3 | M3: V (ah), sdM3 (ag) |
| 1555* | — | 77-61 | — | 1.8 | dwarf carbon star (an) |
| 1556 | — | — | — | 1.1 | — |
| 1557* | 144 | — | — | $\epsilon$ Eri | 1.2K2 V (be), K2 V (ca), K2 V (am) |
| 1558 | — | — | — | 1.6 | — |
| 1559 | — | — | — | 1.1˙ | M3: V (bs) |
| 1560 | — | — | CD -31°1454 | 1.0 | K2: (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1561 | — | 77-64 | — | 1.3 | — |
| 1562 | — | 38-3 | — | 1.7 | — |
| 1563 | 146 | — | CD -48°1011 | 1.2 | K5-M0 V (bf), K7: (af) |
| 1564 | — | — | — | 2.7 | — |
| 1565 | 1061 | — | — | 1.6 | M4.5 (af) |
| 1566 | — | 77-65 | — | 1.3 | — |
| 1567 | — | — | — | 1.8 | M3 (af) |
| 1568 | — | 6-18 | — | 1.3 | — |
| 1569* | 147 | — | 10 Tau | 0.6 | F8 V (am), F9 V (be), G0 (af) |
| 1570 | — | — | — | 1.5 | — |
| 1571 | — | 37-45 | — | 1.8 | — |
| 1572 | — | — | — | 1.5 | — |
| 1573 | — | 6-24 | Wolf 204 | 1.5 | M3.5 (af) |
| 1574 | — | 6-25 | Wolf 205 | 1.5 | M3.5 (af) |
| 1575 | — | — | — | — | — |
| 1576 | — | — | — | 1.5 | — |
| 1577 | 147.1 | 80-15 | BD -3°592 | 0.5 | F9 V (am), F9 V (be), F9 (af) |
| 1578 | — | — | — | 1.3 | — |
| 1579 | — | 38-10 | — | 1.3 | — |
| 1580 | — | — | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|-----------|----------------|-----------------------------|
| 1581 | 150 | — | $\delta$ Eri | 1.1 | K0+ IV (be), K0 IV (am), G9 (af) |
| 1582 | — | 160-19 | — | 1.9 | — |
| 1583 | — | 246-44 | — | 1.3 | — |
| 1584 | — | — | CD -51°887 | 0.5 | G1 V (be), F6 V (bf) |
| 1585 | — | 38-11 | — | 1.3 | — |
| 1586 | — | 6-31 | — | 1.3 | — |
| 1587 | — | 38-12 | — | 1.8 | — |
| 1588 | — | 95-54 | Ross 36 | 1.7 | M3.5 (af) |
| 1589 | — | 79-69 | — | 1.8 | — |
| 1590 | — | 160-22 | — | 2.0 | M2.5 (af) |
| 1591 | 155 | — | $\tau^6$ Eri | 0.5 | F3 III (be), F3-5 V (bf), F5 (af) |
| 1592 | — | — | — | 1.7 | — |
| 1593 | — | 7-4 | — | 1.3 | — |
| 1594 | 155.1 | 80-22 | Ross 588 | 1.6 | M1 (af) |
| 1595 | — | — | — | 1.5 | — |
| 1596 | — | 221-22 | — | 1.5 | — |
| 1597 | — | 175-8 | Ross 566 | 0.6 | K0 (af), K0 (bk) |
| 1598 | — | 80-23 | — | 1.1 | — |
| 1599 | — | 80-24 | BD +0°659 | 1.1 | K1 (af) |
| 1600 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1602* | — | 246-49 | — | 0.4 | — |
| 1603 | — | — | CD -42°1269 | 1.1 | K3 V (bf), K5 (af) |
| 1604 | — | — | — | 3.3 | — |
| 1605 | — | 38-17 | — | 1.3 | — |
| 1606 | — | — | — | 0.6 | K (af) |
| 1607 | — | 79-75 | Ross 589 | 1.3 | K4 (af) |
| 1608 | — | 80-29 | — | 1.8 | — |
| 1609 | — | — | — | 2.3 | — |
| 1610 | — | 6-39 | Wolf 227 | 1.7 | M4.5 (af) |
| 1611 | — | — | — | -0.2 | DA9 (br), DA9 (bc) |
| 1612 | — | — | — | 1.8 | — |
| 1613 | 155.2 | 246-53 | BD +60°762 | 1.1 | K0 V (am), K2 (af) |
| 1614 | — | 7-12 | — | 0.9 | — |
| 1615 | — | — | — | 1.6 | — |
| 1616 | 157.1 | 6-42 | Wolf 1322 | 1.8 | M4 V (bh), M3.5 (af) |
| 1617 | — | 7-16 | — | 0.6 | DC9 (br) |
| 1618 | — | 175-13 | Ross 25 | 1.7 | M3.5 (af) |
| 1619 | 156.2 | 248-10 | BD +75°154 | 1.2 | K4 (af), K4 V (am) |
| 1620 | — | — | CD -57°806 | 0.5 | F7 V (bf) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1621 | — | 175-14 | — | 1.3 | — |
| 1622 | — | — | — | — | — |
| 1623 | — | 221-26 | — | 1.6 | — |
| 1624 | — | 160-43 | — | 1.6 | — |
| 1625 | — | — | — | >2.3 | — |
| 1625a | — | — | — | 2.3 | — |
| | | | | | |
| 1626 | — | — | — | 1.8 | — |
| 1627 | — | — | — | 1.1 | dM? (bc) |
| 1628 | 160.2 | — | BD -21°784 | 1.4 | K5 (af) |
| 1629 | — | 248-12 | — | 1.5 | — |
| 1630 | — | — | — | 2.8 | — |
| | | | | | |
| 1631 | — | 221-28 | — | 1.5 | — |
| 1632 | — | — | — | 2.3 | sd (bb) |
| 1633 | — | — | — | 1.1 | — |
| 1634 | 162 | 38-26 | Ross 587 | 1.6 | M1 (af) |
| 1635 | — | — | — | 1.7 | — |
| | | | | | |
| 1636 | — | — | — | 0.5 | DC9(br) |
| 1637 | — | 247-14 | — | 1.3 | — |
| 1638 | — | 247-15 | — | 1.7 | — |
| 1639 | — | — | — | 1.5 | — |
| 1640 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|------------|-----------|-----------------------------|
| 1641 | — | — | — | 1.3 | — |
| 1642* | 164 | 175-19 | Ross 28 | 1.8 | M3.5 (af) |
| 1643 | — | 222-2 | — | 1.5 | — |
| 1644 | — | 8-16 | BD +21°607 | 0.5 | F2 (af) |
| 1645 | — | 82-4 | — | 2.0 | — |
| | | | | | |
| 1646 | — | 82-5 | BD -6°855 | 0.9 | — |
| 1647 | — | — | — | 1.6 | — |
| 1648 | — | — | — | 1.9 | — |
| 1649 | — | 82-6 | — | 1.3 | — |
| 1650 | 167 | — | CD -53°889 | 1.1 | K5 V (bf) |
| | | | | | |
| 1651 | 167.2 | — | — | 0.9 | M0 (af) |
| 1652 | — | — | — | 1.5 | sdM0 (ax), K7-M0 V (ai) |
| 1653 | — | 8-22 | Ross 597 | 1.3 | K3 (af) |
| 1654 | — | — | — | 1.5 | M4 (af) |
| 1655 | — | 82-9 | — | 1.5 | — |
| | | | | | |
| 1656 | — | — | — | 1.5 | — |
| 1657 | — | — | — | >2.0 | — |
| 1658 | — | — | — | 1.6 | — |
| 1659 | — | 38-30 | Ross 593 | 1.1 | M3 (af) |
| 1660 | 2034 | — | RR Cae | -0.2 | DA8 (br) |
| 1660a | — | — | — | >2.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|-----------------------------|
| 1661 | — | 82-13 | — | 1.1 | — |
| 1662 | — | — | — | 1.5 | — |
| 1663 | — | 248-19 | — | 1.7 | M3 (af) |
| 1664 | — | 248-18 | — | 1.5 | — |
| 1665 | — | — | — | 1.5 | — |
| 1666 | — | — | — | 1.6 | — |
| 1667 | 1070 | 39-9 | — | 1.3 | — |
| 1668 | — | — | — | 1.5 | M3.5 (af) |
| 1669 | — | — | — | 2.1 | — |
| 1670 | — | — | — | -0.4 | DC9 (bc), DC9 (bn), DC9 (br) |
| 1671 | — | 7-39 | — | 1.1 | — |
| 1672 | — | — | — | 1.5 | M2.5 (af) |
| 1673 | — | — | — | 1.5 | K7: (af) |
| 1674 | 170 | 81-21 | Ross 594 | 1.6 | M4.5 (af), M7 V (cb) |
| 1675 | — | 82-25 | — | 2.0 | — |
| 1676 | — | — | — | 1.5 | — |
| 1677 | — | 222-4 | — | 1.3 | — |
| 1678 | — | — | — | 1.5 | M1.5 (af) |
| 1679 | — | 247-22 | — | 2.0 | — |
| 1680 | — | 247-23 | — | 2.0 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1681 | — | 8-41 | — | 1.5 | — |
| 1682 | — | 81-25 | — | 1.3 | — |
| 1683 | — | 175-37 | Ross 31 | 1.2 | K3 (af) |
| 1684 | 171 | 175-39 | BD +55°900 | 1.2 | K2 V (am), K1 (af) |
| 1685 | — | — | — | 1.4 | — |
| 1686 | — | 83-22 | — | 1.3 | — |
| 1687 | — | — | — | 1.5 | M3.5 (af) |
| 1688 | 172 | 175-42 | BD +52°857 | 1.3 | M0 V (ca), K8 V (am), M1 V (bh), K7 (af) |
| 1689 | — | 82-37 | Ross 398 | 1.1 | M0 (af) |
| 1690 | — | — | — | 1.8 | — |
| 1691 | — | — | — | 3.3 | sdM (bi), sd (bb) |
| 1692 | — | 8-49 | — | 1.5 | — |
| 1693 | — | — | — | -0.7 | DA8 (br) |
| 1694 | — | — | — | 1.1 | — |
| 1695 | — | 8-50 | Ross 600 | 1.1 | K2 (af) |
| 1696 | — | 81-30 | BD +41°931 | 0.7 | G2 V (am) |
| 1697 | — | 175-45 | — | 1.7 | M1 (bk) |
| 1698 | — | 39-32 | — | 1.7 | sdM1.5-2 (ai) |
| 1699 | — | — | — | 1.3 | — |
| 1700 | — | — | — | 2.1 | M0 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 1701 | 176.3 | — | CD - 50°1492 | 0.9 | K1 V (bf) |
| 1702 | — | 191-11 | — | 1.1 | sdK (bo) |
| 1703 | — | 8-57 | — | 1.3 | — |
| 1704 | — | — | — | 1.1 | K3: (af) |
| 1705 | — | 39-37 | — | 1.5 | — |
| 1706 | 1072 | 85-19 | — | 1.8 | — |
| 1707 | — | — | — | 1.5 | — |
| 1708 | — | 81-38 | BD +45°992 | 0.6 | G1 V-VI (be), G1 V-VI (am), G2 (af) |
| 1709 | — | — | — | 1.5 | — |
| 1710 | — | 39-40 | — | 0.9 | M0-1 V (ai) |
| 1711 | — | — | — | 1.6 | — |
| 1712 | 180 | — | — | 1.3 | M3: (af) |
| 1713 | — | — | — | 1.5 | — |
| 1714 | — | 81-42 | — | 1.1 | K3 (af) |
| 1715 | — | 39-41 | — | 1.7 | — |
| 1716 | — | 39-42 | — | 1.8 | — |
| 1717 | — | — | — | 1.1 | — |
| 1718 | — | 83-46 | Ross 382 | 1.1 | G8 (af), K0 (bk) |
| 1719 | — | 39-43 | BD +34°927 | 0.8 | G8 V (am) |
| 1720 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1721 | 1074 | 191-15 | — | 1.7 | M0 V (ag), M1 (af) |
| 1722 | — | 39-44 | — | 1.3 | — |
| 1723 | — | — | — | 1.5 | — |
| 1724 | 186.1 A | — | CD -56°1071 A | 0.7 | G5 V (be), G0 V (bf) |
| 1725 | — | — | — | 1.3 | K4 (af) |
| 1726 | — | — | — | 1.6 | K (af) |
| 1727 | 186.1 B | — | CD -56°1071 B | 1.5 | — |
| 1728 | — | 247-45 | — | 1.6 | — |
| 1729 | — | — | — | 1.0 | — |
| 1730 | — | — | — | 1.8 | sdM4 (ad) |
| 1731 | — | — | — | 1.1 | M3 (af) |
| 1732 | — | 83-53 | — | 0.9 | — |
| 1733 | — | 191-21 | – | 1.8 | — |
| 1734 | — | — | — | -0.2 | DZ9?/DC9? (br) |
| 1735 | — | — | — | 1.5 | — |
| 1736* | 188 | — | 104 Tau | 0.7 | G4 V (be), G4 V (am), G4 (af) |
| 1737 | — | — | — | -0.8 | — |
| 1738 | — | 85-42 | — | 1.4 | — |
| 1739 | — | — | — | 0.2 | — |
| 1740 | — | 85-44 | Ross 388 | 1.6 | M3 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1741 | — | 247-50 | — | 1.5 | — |
| 1742 | — | 86-27 | — | 1.9 | — |
| 1742a | — | — | — | 2.9 | sdM5: (ai) |
| 1743 | — | 85-48 | — | 2.1 | — |
| 1744 | — | — | BD -9°1094 | 1.1 | K0 (af), K1 V (am) |
| 1745 | — | 85-54 | BD +19°869 | 1.3 | K3 (af) |
| 1746* | — | 96-28 | BD +44°1142 | 1.1 | K3 (af), K3 (bk) |
| 1747 | — | — | – | 1.5 | M3: (bp) |
| 1748 | — | — | — | 1.6 | — |
| 1749 | — | — | — | 1.5 | — |
| 1750 | — | — | — | 1.6 | — |
| 1751 | 200.1 | — | — | 1.1 | — |
| 1752 | — | 249-2 | — | 1.6 | K4 (af) |
| 1753 | 197 | — | λ Aur | 0.6 | G2 IV-V (be), G0 V/G2 IV-V (am), G1 (af) |
| 1754 | 200 A | 84-45 A | BD -3°1061 A | 1.3 | K3 V (am), K4 (af) |
| 1755 | 200 B | 84-45 B | BD -3°1061 B | 1.6 | M2: (af) |
| 1756 | — | — | — | 1.7 | — |
| 1757 | — | 191-29 | — | 1.8 | — |
| 1758 | — | 191-30 | — | 2.2 | — |
| 1759 | — | 86-39 | Ross 65 | 1.1 | K2 (af) |
| 1760 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1761 | 203 | 97-42 | Ross 41 | 2.0 | M4⁻-4 V (ah), M3.5 (af) |
| 1762 | — | 99-11 | — | 1.3 | — |
| 1763 | 204 | 99-12 | BD -3°1110 | 1.2 | K5 V (am), K5 (af) |
| 1764 | — | — | — | -0.2 | DA (br) |
| 1765 | — | 86-44 | Ross 406 | 1.1 | M3 (af) |
| | | | | | |
| 1766 | 204.2 | 99-14 | Wolf 1450 | 1.3 | M4.5 V (bq), M4: (bp), M3.5 (af) |
| 1767 | — | — | — | 1.8 | — |
| 1768 | — | — | — | 1.5 | — |
| 1769 | 207.2 | — | CD - 23°2865 | 1.2 | K3 (af), K2 V (bf) |
| 1770 | — | — | CD -46°1936 A | 0.6 | G6 V (bf), G8 (af) |
| | | | | | |
| 1771 | — | — | CD -46°1936 B | 1.4 | K3 (af) |
| 1772 | — | 191-48 | BD +51°1094 | 1.2 | K2 (af) |
| 1773 | — | 191-50 | — | 1.9 | — |
| 1774 | 211 | — | BD +53°934 | 1.1 | K1 V (am), K1 V (be), K1 (af) |
| 1775 | 212 | 191-51 | BD +53°935 | 1.5 | M1 V (bh), M1 (af) |
| | | | | | |
| 1776 | — | 99-24 | Ross 48 | 1.1 | K4 (af) |
| 1777 | — | — | — | 1.7 | M5 V (ai) |
| 1778 | — | 99-27 | — | 1.5 | — |
| 1779 | — | 99-26 | BD +2°1041 | 1.2 | K3 (af), K1 V (am) |
| 1780* | — | 99-31 | BD +9°946 | 0.6 | F8f (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1781 | — | — | vB 1 | 1.3 | — |
| 1782 | 215 | 249-18 | BD +62°780 | 1.3 | K5 V (ag), K7 (af) |
| 1783 | 217 | 96-51 | BD +37°1312 | 1.0 | K0 V (am), K1 (af) |
| 1784 | — | 96-52 | Wolf 237 | 2.5 | M4 (af) |
| 1785 | — | — | — | 1.5 | M4 V (ai) |
| | | | | | |
| 1786 | — | 191-53 | — | 0.9 | — |
| 1787 | 218 | — | CD -36°2458 | 1.5 | M3.5 (bq), M3 (af) |
| 1788 | — | — | — | 1.5 | — |
| 1789 | — | 98-25 | Ross 66 | 1.1 | M0 (af) |
| 1790 | — | 102-33 | — | 0.6 | sdG (bo), sdK: (bd) |
| | | | | | |
| 1791 | — | 102-34 | — | 0.9 | K4 (af), sdK: (bd) |
| 1792 | — | — | δ Lep | 1.2 | G8 III (be), G8 III-IV (bf), G8p (am) |
| 1793 | — | — | — | 1.5 | — |
| 1794 | 220 | 100-44 | Ross 59 | 1.5 | M1.5 (af) |
| 1795 | — | — | — | 2.2 | sd (bb) |
| | | | | | |
| 1796 | 224.1 | — | CD -63°218 | 1.1 | K1 III-IV (be), K1 III-IV (bf) |
| 1797 | 223.3 | — | CD -50°1977 | 1.2 | K1 (af), G8 IV (be) |
| 1798 | 223 | 99-43 | BD +2°1085 | 1.2 | K3 (af) |
| 1799 | — | 192-8 | — | 1.3 | — |
| 1800 | — | 99-45 | — | 1.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1801 | — | — | — | 0.3 | — |
| 1802 | — | — | — | 2.5 | — |
| 1803 | 224 | — | BD +13°1036 | 1.8 | G0 V (am), G5 IV (be), G8 (af) |
| 1804 A* | 225.2 A | — | CD -31°2902 A | 1.3 | K3-4 V (bf), K4p (af) |
| 1804 B* | 225.2 B | — | CD -31°2902 B | — | composite with LHS 1804 A and C |
| 1804 C* | 225.2 C | — | CD -31°2902 C | — | composite with LHS 1804 A and B |
| 1805 | — | 192-13 | — | 1.6 | — |
| 1806 | — | 192-14 | — | 1.9 | — |
| 1807 | — | — | — | 2.8 | — |
| 1808 | — | 249-32 | — | 1.5 | — |
| 1809 | — | 192-15 | — | 1.6 | M5 V (ai) |
| 1810 | — | — | — | 1.7 | — |
| 1811 | — | 100-54 A | BD +19°1185 A | 0.6 | G1 (af), G0 V (am) |
| 1812 | — | 100-54 B | BD +19°1185 B | 1.2 | K3 (af) |
| 1813 | — | 101-16 | Wolf 261 | 2.3 | M3.5 (af) |
| 1814 | 226.1 | 98-38 | Ross 60 | 1.8 | M3.5 (af) |
| 1815 | — | — | — | 1.1 | — |
| 1816 | — | — | — | 2.3 | — |
| 1817 | — | 249-36 | — | 1.3 | — |
| 1818 | — | — | CD -59°1224 | 0.8 | K1 V (bf) |
| 1819 | — | 106-25 | Ross 413 | 1.3 | K4 (af) |
| 1820 | — | 106-26 | vB 2 | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1821 | — | — | — | 1.3 | — |
| 1822 | — | — | — | 0.9 | DA/DC (bo), DC9 (br) |
| 1823 | — | — | — | 2.0 | — |
| 1824 | — | 98-46 | Ross 62 | 1.7 | M3 (af) |
| 1825 | — | — | Ross 414 | 1.3 | M1.5 (af) |
| 1826 | — | — | — | 2.6 | sdM (ac) |
| 1827 | 229 | — | BD -21°1377 | 1.2 | M1 V (bi), M1 V (ah), M1-2 V (bf) |
| 1828 | — | 98-49 | Wolf 1058 | 1.6 | M2 (bk), M1.5 (af) |
| 1829 | — | — | — | 2.5 | — |
| 1830 A* | 228 A | 102-53 A | BD +10°1032 A | 1.7 | M2.5 V (bh), M3 V (cb), M3 (af) |
| 1830 B* | 228 B | 102-53 B | BD +10°1032 B | — | composite with LHS 1830 A |
| 1831 | 1088 | — | — | 1.1 | M3.5 (af) |
| 1832 | — | — | — | 1.1 | — |
| 1833 | — | — | — | >1.8 | — |
| 1834 | — | — | — | 1.5 | — |
| 1835 | — | 101-30 | BD +47°1276 | 1.1 | K1 (af) |
| 1836 | 231.3 | — | Ross 417 | 1.7 | M4 (af), M3.5 V (bq) |
| 1837 | — | — | — | 1.5 | — |
| 1838 | — | 105-30 | — | 0.3 | DA9 (br) |
| 1839 | — | — | — | 2.9 | M4.5 V (ad) |
| 1840 | 2049 | — | BD -22°3005 | 1.3 | M1.5 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1841 | — | — | — | 1.1 | sd (bw) |
| 1842 | — | — | — | 1.8 | — |
| 1843 | — | — | — | 1.7 | — |
| 1844 | — | — | — | 1.5 | M0.5 (af) |
| 1845 | — | — | CD -42°2503 | 0.8 | G5 V (be), G5 V (bf) |
| 1845a | — | — | — | 2.3 | — |
| | | | | | |
| 1846 | 232 | 104-37 | Ross 64 | 1.8 | M4 V (bi), M4.5 (af), M6 V (cb) |
| 1847 | — | — | — | 2.0 | M2: (af) |
| 1848 | — | 192-26 | — | 2.3 | — |
| 1849 | 234 A | 106-49 A | Ross 614 A | 1.7 | M4.5 V (bi), M4.5 V (ah), M4.5 V (bh) |
| 1850 | 234 B | 106-49 B | Ross 614 B | — | composite with LHS 1849 |
| | | | | | |
| 1851 | — | 101-42 | — | 1.2 | K4 (af) |
| 1852 | — | — | — | 1.5 | — |
| 1853 | — | 249-51 | — | 1.5 | — |
| 1854 | — | 192-30 | — | 1.5 | — |
| 1855 | 238 | — | — | 1.5 | M2 V (bq) |
| | | | | | |
| 1856 | — | 192-32 | — | 1.3 | — |
| 1857 | — | 105-46 | — | 1.3 | M4.5 V (ai) |
| 1858 | 239 | 104-49 | BD +17°1320 | 1.6 | M0 V (ah), M1 V (bh), M0 (af), M1 V (cb) |
| 1859 | — | — | — | 1.8 | — |
| 1860 | — | 104-50 | — | 1.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1861 | — | 109-16 | — | 1.9 | — |
| 1862 | — | 103-51 | — | 1.8 | — |
| 1863 | — | — | — | 1.5 | — |
| 1864 A* | — | 192-39 A | — | 2.1 | M3.5 (af) |
| 1864 B* | — | 192-39 B | — | — | composite with LHS 1864 A |
| 1865 | 2050 | 251-16 | — | 1.5 | K7 (af), M3.5 V (bh) |
| | | | | | |
| 1866 | — | 87-3 | BD +32°1398 A | 1.5 | K3 V (am), K2 (af) |
| 1867 | — | 87-4 | BD +32°1398 B | 1.6 | M0.5 (af) |
| 1868* | 240.1 | — | BD +79°212 | 0.5 | F8 V (be), F8 V (am) |
| 1869 | — | 87-5 | — | 1.5 | — |
| 1870 | 246 | 87-7 | — | -0.1 | DA2 (br) |
| | | | | | |
| 1871 | — | 110-17 | — | 1.7 | — |
| 1872 | — | — | — | 1.5 | M2 (bp) |
| 1873 | — | — | — | 1.1 | — |
| 1874 | 249 | 107-27 | BD +47°1355 | 1.4 | K5 (af) |
| 1875 | 250 A | — | BD -5°1844 A | 1.2 | K4 V (be), K4 (af) |
| | | | | | |
| 1876 | 250 B | — | BD -5°1844 B | 1.7 | M2.5 V (bi), M2.5 V (ah), M2 (af) |
| 1877 | — | — | — | 1.5 | — |
| 1878 | — | — | CD -28°3554 | 0.6 | G5 IV (be), G8: (af) |
| 1879 | 251 | 87-12 | Wolf 294 | 1.5 | M3 V (bi), M3.5 V (ah), M3.5 V (bh) |
| 1880 | — | 107-34 | — | 1.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1881 | — | — | CD -56°1692 | 0.5 | F8-G0 V (bf) |
| 1882 | — | 192-58 | — | 1.3 | — |
| 1883 | — | 107-36 | — | 1.6 | — |
| 1884 | — | 108-40 | BD +1°1600 | 0.9 | G8 V (am) |
| 1884a | — | 87-15 | — | 1.6 | — |
| 1885 | — | 250-31 | — | 1.5 | — |
| | | | | | |
| 1886 | — | 108-43 | BD -0°1520 | 0.6 | G1 (af) |
| 1887 | — | — | — | 1.5 | M2-3 (bp) |
| 1888 | — | 250-32 | — | 1.6 | — |
| 1889 | — | — | — | 0.9 | DC9 (br), DC9 (bc), DA?11 (ba) |
| 1890 | 257.1 | 107-42 | BD +48°1469 | 1.3 | K3 V (am), K3 (af) |
| | | | | | |
| 1891 | — | 108-48 | Ross 612 | 0.7 | G7 (af) |
| 1892 | 261 | — | — | -0.2 | DA8 (bn), DA (ai) |
| 1893 | 262 | — | BD +29°1441 | 0.7 | G4 V (am), G4 V (be), G1 (af) |
| 1894 | — | — | — | 1.5 | K5-M0 V (ai) |
| 1895 | 263 | — | Ross 54 | 1.7 | M3.5 (af) |
| | | | | | |
| 1896 | — | — | CD -57°1633 | 0.5 | sd (bw) |
| 1897 | — | 250-38 | — | 1.5 | — |
| 1898 | — | — | — | 0.6 | — |
| 1899 | — | 88-9 | BD +21°1528 | 0.9 | G9 V (am), G9 V (be) |
| 1900 | — | — | BD -14°1750 | 1.5 | K5 (af), M0 (bp) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1901 | — | — | — | 2.1 | — |
| 1902 | — | — | CD -49°2676 | 0.8 | G8 V (bf), G8 (af) |
| 1903 | — | 107-55 | — | 1.3 | — |
| 1904 | — | — | — | 1.6 | — |
| 1905 | — | — | — | 0.9 | — |
| 1906 | — | — | — | 1.1 | — |
| 1906a | — | 107-56 | — | 1.1 | sdK (bd) |
| 1907 | — | 193-38 | — | 1.3 | — |
| 1908 | 268.2 | — | CD -63°295 | 1.3 | — |
| 1909 | — | — | — | 1.5 | — |
| 1910 | — | — | BD -12°1871 | 0.7 | G5 V (bf), G2 V (am), G3 (af) |
| 1911 A* | 269 A | — | CD -46°3046 A | 1.1 | K1 V (be), K3 V (bf), K2 (af) |
| 1911 B* | 269 B | — | CD -46°3046 B | — | K4 V (be) |
| 1912 | 270 | 87-33 | BD +33°1505 | 2.0 | M0 V (bi), M0 V (ah), M0 (af), M1.5 V (bh) |
| 1913 | — | — | BD -15°1776 | 0.5 | G6 (af) |
| 1913a | — | 107-63 | — | 1.1 | — |
| 1914 | — | 87-36 | — | 1.3 | — |
| 1915 | — | 107-67 | — | 1.6 | sdM0-2 (ai) |
| 1916 | — | — | — | 0.2 | K5 (af) |
| 1917 | — | 87-37 | — | 1.6 | — |
| 1918 | — | — | — | 1.3 | — |
| 1919 | — | 87-38 | Ross 988 | 1.1 | G5: (af) |
| 1920 | 1097 | 112-21 | — | 1.3 | M3 (bp) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 1921 | — | — | — | 2.7 | — |
| 1922 | — | — | CD -44°3484 | 1.1 | K5: (af) |
| 1923 | — | — | — | 1.5 | M6: V (ai), M6: V (ax) |
| 1924 | — | — | — | 1.1 | M3 (af) |
| 1925 | — | — | — | 1.5 | M4.5: V (ai) |
| | | | | | |
| 1926 | — | — | vB 17 | — | — |
| 1927 | 2062 | — | — | -0.1 | DAE (br), DAe (af) |
| 1928 | 1099 | 112-27 | — | 1.9 | — |
| 1929* | — | — | CD -45°3283 | 0.5 | G0f: (af) |
| 1930 | — | — | Ross 390 | 0.9 | G6 (af), sd (bw) |
| | | | | | |
| 1931 | — | 111-18 | — | 1.8 | — |
| 1932 | — | — | — | 1.5 | M3: (bp) |
| 1933 | — | 88-43 | Ross 394 | 1.7 | M3 (af) |
| 1934 | — | 87-48 | BD +37°1748 | 1.1 | K2 (af) |
| 1935 | — | — | — | 1.9 | M3 (bp) |
| | | | | | |
| 1936 | — | — | — | 1.5 | — |
| 1937 | — | — | — | 2.8 | — |
| 1938 | — | — | — | 1.9 | — |
| 1939 | 284 | — | CD -44°3675 | 0.9 | G6 IV (bf), G6 IV (be), G8 (af) |
| 1940 | — | 193-59 | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1941 | — | 193-60 | — | 1.3 | — |
| 1942 | — | 88-48 | BD +18°1719 | 1.3 | — |
| 1943 | 285 | 50-4 | Ross 882 | 1.1 | M4.5 V (ah), M4.5 V (bq), M4 V (ax) |
| 1944 | — | — | BD +39°1998 | 0.5 | F8 V (be), F8 V (am) |
| 1945* | 286 | — | $\beta$ Gem | 1.1 | K0 IIIb (be), K0 III (am), G8 (af) |
| 1946 | — | 193-62 | — | 0.9 | — |
| 1947 | — | 193-67 | — | 0.9 | — |
| 1948 | — | 193-70 | BD +54°1175 | 1.3 | K3 (af), K4 V (am) |
| 1949 | — | 50-5 | — | 1.8 | — |
| 1950 | — | 50-6 | — | 1.7 | — |
| 1951 | 1103 A | 112-50 | — | 2.0 | dM (bt) |
| 1952 | 1103 B | — | — | 2.0 | — |
| 1953 | — | — | — | 1.5 | — |
| 1954 | — | 193-75 | — | 1.1 | — |
| 1955 A* | — | — | — | 1.3 | M4 (af) |
| 1955 B* | — | — | — | — | composite with LHS 1955 A |
| 1956 | 1101 | 253-6 | — | 1.8 | — |
| 1957 | — | — | — | 1.5 | M3 (af) |
| 1958 | — | 111-45 | — | 1.2 | K4 (af) |
| 1959 | 294 A | — | CD -59°1773 | 0.8 | G0 V (bf), G0 V (be) |
| 1960 A* | 294 B | — | CD -59°1774 A | 1.1 | — |
| 1960 B* | 294 C | — | CD -59°1774 B | — | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|----------------------------|
| 1961 | — | 90-34 | — | 1.8 | — |
| 1962 | — | 253-2 | — | 1.5 | — |
| 1963 | 1105 | 111-47 | — | 1.1 | M4 V (al) |
| 1964 | — | 193-81 | — | 1.1 | — |
| 1965 | — | — | — | 1.5 | — |
| 1966 | — | 40-2 | BD +21°1731 | 1.0 | K0 V (am), K1 (af) |
| 1967 | — | — | — | 1.1 | — |
| 1968 | 296 | — | CD -39°3869 | 1.4 | K[5] V (bf), K5 (af) |
| 1969 | — | — | — | 1.3 | — |
| 1970 | — | — | — | 1.9 | sdM0-2 (ai), sdM (bl), sdM (ac) |
| 1971 | — | — | — | 2.3 | — |
| 1972 | — | 50-16 | — | 1.1 | — |
| 1973 | — | 193-83 | — | 1.5 | — |
| 1974 | — | — | — | 1.6 | — |
| 1975 | — | 90-39 | — | 1.8 | sdM1.5-3 (ai) |
| 1976 | — | 194-7 | — | 1.9 | — |
| 1977 | — | 40-3 | — | 1.8 | — |
| 1978 | — | — | — | 1.5 | — |
| 1979 | — | — | — | 1.8 | — |
| 1980 | — | — | — | 0.6 | DC9 (br), DC9 (bc), DC9 (bn) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 1981 | — | — | — | 1.5 | — |
| 1982 | 296.1 | — | CD -29°5555 | 0.6 | G4 IV-V (be), G2 V (bf) |
| 1983 | — | 251-51 | — | 1.4 | — |
| 1984 | — | 251-52 | BD +72°395 | 0.6 | G2 V (am) |
| 1985 | 298 | — | — | 1.5 | — |
| | | | | | |
| 1986 | — | — | — | 1.1 | DC: (br) |
| 1987 | — | — | BD +32°1695 | 0.8 | G4 V (am), G4 V (be), G4 (af) |
| 1988 | — | 111-61 | — | 1.3 | — |
| 1989 | 300 | — | — | 1.6 | M4 (af) |
| 1990 | — | — | — | 1.9 | — |
| | | | | | |
| 1991 A* | 301 A | — | BD -13°2439 A | 1.3 | K7 V comp (bi), K7 comp (af) |
| 1991 B* | 301 B | — | BD -13°2439 B | — | M0 V (bh) |
| 1992 | — | — | — | 1.3 | — |
| 1993 | — | 251-58 | — | 1.7 | — |
| 1994 | — | — | — | 1.7 | — |
| 1995 | — | — | — | 1.5 | — |
| | | | | | |
| 1996 | — | 194-19 | — | 1.1 | — |
| 1997 | — | — | — | 1.5 | K7 (af), M2 (bp) |
| 1998 | 301.1 | 51-6 | BD +31°1781 | 1.4 | K4 V (am), K3 (af) |
| 1999 | — | — | — | 1.8 | — |
| 2000 | — | 194-22 | BD +54°1216 | 0.4 | F4 (af), sdF6 (am) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|------------|------------|------------------------------|
| 2001 | — | 252-10 | BD +73°407 | 0.9 | K0 (af) |
| 2002 | — | — | — | 1.5 | — |
| 2003 | — | — | — | 1.5 | — |
| 2004 | — | — | — | 1.6 | — |
| 2005 | — | — | — | 1.3 | — |
| | | | | | |
| 2006 | — | — | — | 1.6 | — |
| 2007 | — | 51-10 | BD +33°1694 | 1.2 | K3 (af) |
| 2008 | — | 234-33 | BD +66°550 | 1.3 | K2 (af) |
| 2009 | — | — | — | 1.5 | — |
| 2010 | — | — | — | 1.5 | M3 (af), M4 (bp) |
| | | | | | |
| 2011 | 1110 | 9-7 | — | 0.9 | M3 V (al) |
| 2012 | — | — | — | 1.6 | — |
| 2013 | — | — | — | 1.3 | — |
| 2014 | — | 115-5 | — | 1.1 | — |
| 2015 | — | — | — | 0.6 | — |
| | | | | | |
| 2016 | — | 115-4 | BD +46°1405 | 1.3 | K4 (af) |
| 2017 | 308.2 | 113-40 | — | 1.3 | K3 (af), sd (bw) |
| 2018 | 308.1 | 234-35 | — | 1.5 | M0 V (ag) |
| 2019 | — | 52-15 | — | 1.3 | — |
| 2020 | — | — | — | 2.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|------------|------------|------------------------------|
| 2021 | — | — | — | 1.5 | — |
| 2022 | 1112 | 51-16 | — | -0.2 | DA7 (br), DAs (ag) |
| 2023 | — | — | — | 2.1 | — |
| 2024 | — | — | — | 1.5 | — |
| 2025 | — | 252-13 | — | 1.5 | — |
| | | | | | |
| 2026 | — | — | — | 2.7 | M6 V (ad) |
| 2027 | — | 9-9 | — | 1.5 | — |
| 2028 | — | 115-10 | BD +42°1899 | 1.2 | K3 (af), K2 V (am) |
| 2029 | — | 9-11 | — | 1.1 | — |
| 2030 | — | 252-17 | — | 1.3 | — |
| | | | | | |
| 2031 | — | 252-19 | — | 1.6 | — |
| 2032 | — | 234-42 | — | 1.3 | — |
| 2033 | 315 | 9-13 | BD +12°1888 | 1.1 | K1 V (am), K1 (af) |
| 2034 | 316.1 | — | AZ Cnc | 1.5 | M6 V (bi), M6.5 V (ai), M6 V (ad) |
| 2035 | — | — | — | 2.3 | — |
| | | | | | |
| 2036 | — | — | BD -15°2546 | 0.5 | F2 (af), sdF6 (am), Fw (bf) |
| 2037 | 317 | — | — | 1.5 | M3.5 (af) |
| 2038 | — | 234-43 | — | 1.6 | — |
| 2039 | — | — | — | 2.9 | — |
| 2040 | — | 114-13 | — | 1.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2041 | — | 115-18 | Wolf 320 | 1.9 | M3 (af) |
| 2042 A* | 319 A | 46-1 A | BD +10°1857 A | 1.4 | M0 (af), M1 V (bh) |
| 2042 B* | 319 B | 46-1 B | BD +10°1857 B | — | — |
| 2043 | 319 C | 46-2 | BD +10°1857 C | 1.5 | M3.5 (af) |
| 2044 | — | — | — | 1.5 | — |
| 2045 | — | — | — | 3.3 | sdM (bi) |
| | | | | | |
| 2046 | — | — | — | 1.8 | — |
| 2047 | 321 | 115-23 | BD +42°1922 | 1.2 | K3 V (am), K3 (af) |
| 2048 | — | 47-5 | — | 1.7 | — |
| 2049 | — | — | — | 2.8 | M6 V (ad) |
| 2050 | — | 46-4 | BD +7°2031 | 1.3 | K4 (af), M0 V (bh) |
| | | | | | |
| 2051 | — | 234-47 | — | 1.8 | — |
| 2052 | — | — | — | 2.2 | — |
| 2053 | — | 115-27 | BD +37°1912 | 1.5 | K5 (af), M1 V (bh) |
| 2054 | — | 194-41 | — | 1.3 | — |
| 2055 | — | 114-19 | BD -4°2468 | 1.0 | G6 (af), G8 V (am) |
| | | | | | |
| 2056 | — | 46-5 | Ross 683 | 0.6 | G6 (af) |
| 2057 | — | 51-27 | — | 1.7 | M3 V (ai) |
| 2058 | — | — | — | 1.7 | — |
| 2059 | — | 9-25 | — | 0.9 | sdK (bo) |
| 2060 | 1114 | 9-28 | Ross 622 | 1.6 | M2 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2061 | — | — | — | 1.5 | — |
| 2062 | 324 A | — | $\rho^1$ Cnc A | 1.1 | G8 V (am), G8 V (be), K0 (af) |
| 2063 | 324 B | 47-9 | $\rho^1$ Cnc B | 1.8 | M3.5 (af), M5 V (cb) |
| 2064 | — | — | — | 1.6 | — |
| 2065 | — | — | — | 2.9 | M9 V (bi) |
| 2066 | — | 234-48 | — | 1.1 | K5: (af) |
| 2067 | — | — | — | 2.7 | sdM5 (bi), sdM (ac), erroneous M10 III (ad) |
| 2068 | — | — | — | 0.9 | <K5 V (bi) |
| 2069 | 326 A | — | — | 1.8 | M4 V (bq), M4 (af), M3.5 V (bh) |
| 2070 | 326 B | — | — | 1.8 | composite with LHS 2069 |
| 2071 | — | — | — | 1.8 | — |
| 2072 | — | — | — | 1.5 | — |
| 2073 | — | — | — | 1.5 | — |
| 2074 | — | — | — | 1.9 | — |
| 2075 | — | — | — | 1.5 | dM? (bc) |
| 2076 | 1116 A | 9-38 | EI Cnc | 1.8 | M5.5 V (bi), ~M5? V (al) |
| 2077 | 1116 B | — | — | 1.3 | composite with LHS 2076 |
| 2078 | 330.1 | 9-39 | BD +21°1949 | 1.2 | K4 (af) |
| 2079 | — | — | — | 2.1 | — |
| 2080 | — | 114-25 | BD -5°2678 | 0.5 | G0f (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2081 | — | 115-39 | — | 0.9 | — |
| 2082 A* | — | 114-26 A | BD -3°2525 | 0.5 | F3 (af) |
| 2082 B* | — | 114-26 B | BD -3°2525 | — | composite with LHS 2082 A |
| 2083 A* | 331 B | — | ι UMa B | 1.3 | M1.5 (af), M1 V (bh) |
| 2083 B* | 331 C | — | ι UMa C | — | composite with LHS 2083 A |
| 2084* | 331 A | — | ι UMa A | 0.3 | A7 IV (be), A7 V (am), A6 (af) |
| 2085 | 333 | — | — | 1.5 | M2 V (bq), M2-3 (bp), M3 (af) |
| | | | | | |
| 2086 | — | 234-51 | — | -0.6 | DCE? (br) |
| 2087 | — | 234-52 | — | 1.6 | DBQ (br) |
| 2088 | — | 252-25 | — | 1.6 | M4.5 V (ai) |
| 2089 | — | — | — | 1.6 | — |
| 2090 | — | — | — | 1.9 | — |
| | | | | | |
| 2091 | — | 252-26 | — | 1.2 | K3 (af) |
| 2092 | 1119 | 115-42 | — | 2.2 | M4 (af) |
| 2093 A* | 332 A | — | 10 UMa A | 0.4 | F5 V (be), F5 V (am) |
| 2093 B* | 332 B | — | 10 UMa B | — | G5 V (be) |
| 2094 | — | 41-18 | — | 1.1 | — |
| 2095 | — | 253-18 | — | 1.0 | K0 (af) |
| 2096 | — | — | — | 2.0 | — |
| 2097 | — | 115-47 | — | 2.0 | — |
| 2098 | — | — | — | 2.2 | — |
| 2099 | — | — | — | 1.6 | sdM (ac) |
| 2100 | — | — | — | 2.2 | sdM (ac) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2101 | — | 252-27 | — | 0.3 | DC9 (br) |
| 2102 | — | 234-54 | — | 1.3 | M0-1 V (ai) |
| 2103 | — | 115-50 | — | 1.3 | — |
| 2104 | — | — | — | 1.1 | — |
| 2105 | — | 234-55 | — | 1.3 | M1 (af) |
| 2106 | — | — | — | 1.3 | — |
| 2107 | — | — | — | 1.6 | — |
| 2108 | — | — | BD -14°2757 | 0.7 | G2 V (am), G3 V (bf) |
| 2109 | — | 194-57 | — | 1.7 | — |
| 2110 | — | — | — | 1.5 | — |
| 2111 | 1121 | 115-57 | — | 1.7 | — |
| 2112 | — | — | — | 2.9 | M4: V (ai) |
| 2113 | 336 | 47-26 | BD +33°1814 | 0.9 | M2 V (ag) |
| 2114 A* | 337 A | — | $\pi^1$ Cnc A | 0.9 | G9 V (be), G9 V (am), G8 (af) |
| 2114 B* | 337 B | — | $\pi^1$ Cnc B | — | — |
| 2115 | — | — | — | 1.1 | — |
| 2116 | — | — | — | 2.3 | — |
| 2117 | — | 115-63 A | — | 2.1 | — |
| 2118 | — | 115-63 B | — | 2.2 | — |
| 2119 | — | 46-30 | — | 1.3 | — |
| 2120 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2121 | — | 47-31 | — | 1.1 | — |
| 2122 | — | — | — | 1.5 | — |
| 2123 | — | 253-21 | — | 1.6 | — |
| 2124 | — | 252-31 | — | 1.5 | — |
| 2125 A* | 340 A | — | BD +29°1883 A | 1.1 | K3 (af), K3 V (am) |
| 2125 B* | 340 B | — | BD +29°1883 B | — | — |
| 2126 | — | 252-33 | — | 1.6 | M4.5 V (ai) |
| 2127 | — | — | — | 1.5 | M2: (bp) |
| 2128 | 341 | — | CD -51°2351 | 1.4 | — |
| 2129 | — | 46-35 | — | 1.5 | — |
| 2130 | — | — | CD -31°7195 | 1.1 | K2 (af), K1 V (bf) |
| 2131 | 1124 | 116-23 | BD +40°2197 | 1.2 | K2 V (am), K3 (af) |
| 2132 | — | — | — | 1.8 | — |
| 2133 | — | 41-35 | — | 1.8 | — |
| 2133a | — | — | — | 1.3 | — |
| 2134 | — | — | — | 1.5 | K5 (af) |
| 2135 | — | — | — | 1.6 | — |
| 2136 | — | — | — | 1.6 | M4: V (ai) |
| 2137 | — | 161-24 | BD -12°2889 | 1.1 | K3 (af), K1-2 V (bf) |
| 2138 | — | 161-25 | Ross 436 | 1.4 | K5 (af) |
| 2139 | — | — | — | 1.7 | — |
| 2140 | — | 46-40 | — | 1.4 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2141 | 343 | 41-37 | Ross 83 | 1.7 | M2 (af) |
| 2142 | — | 161-30 | Ross 438 | 1.1 | K5 (af) |
| 2143 | — | — | — | 2.1 | — |
| 2144 | — | — | — | 1.5 | — |
| 2145 | 347 A | 161-33 | Ross 439 | 1.6 | M3.5 (af), M5 V (cb) |
| | | | | | |
| 2146 | 347 B | 161-34 | — | 1.5 | — |
| 2147 | 349 | — | BD +6°2182 | 1.2 | K3 V (am), K3 (af) |
| 2148 | — | — | — | 1.5 | — |
| 2149 | 1125 | 48-20 | — | 1.3 | M3.5 (af), M4 (bk) |
| 2150 | — | — | CD -46°5238 | 1.1 | K3 (af), K2 V (bf) |
| | | | | | |
| 2151 A* | 352 A | — | Bd -12°2918 A | 1.7 | M3 V (bi), M3+ V (ah), M3 (af), M4 V (cb) |
| 2152 | — | — | — | 1.3 | — |
| 2153 | — | — | — | 1.5 | — |
| 2154 | 351.1 | 41-43 | Ross 84 | 1.1 | M3 (af) |
| 2155 | 353 | 116-36 | BD +36°1970 | 1.6 | M0.5 (af), M0.5 (af) |
| | | | | | |
| 2156 A* | 356 A | — | 11 LMi A | 1.1 | G8 III (be), G8 IV-V (am), G8 (af) |
| 2156 B* | 356 B | — | 11 LMi B | — | composite with LHS 2156 A |
| 2157 | 357 | — | — | 2.0 | M3 (af), M4 (bp) |
| 2158 | — | 161-51 | — | 1.8 | — |
| 2159 | — | 161-52 | — | 1.1 | M3.5 (af), "peculiar" (bw) |
| 2160 | — | — | — | 1.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2161 | — | 48-21 | Ross 887 | 0.6 | K4 (af), K5 (bk) |
| 2162 | — | — | — | 1.3 | — |
| 2163 | — | 49-18 | Ross 90 | 1.5 | M0.5 (af) |
| 2164 | — | 48-25 | Ross 888 | 1.7 | M0 (af), M1 (bk) |
| 2165* | — | — | CD -38°5760 | 1.1 | K4 (af), <M0 (bp) |
| 2166 | 358 | — | CD -40°5404 | 1.5 | M3 V (bq), M3 (af), M3 (bp) |
| 2167 | — | — | — | 2.1 | — |
| 2168 | — | 48-27 | — | 1.5 | — |
| 2169* | — | 48-29 | BD +1°2341p | 0.1 | A4 (af) |
| 2170 | — | 48-30 | — | 1.5 | — |
| 2171 | 359 | 49-20 | Ross 92 | 1.6 | M4 (af) |
| 2172 | — | — | — | 2.4 | — |
| 2173 | 361 | 42-17 | Ross 85 | 1.7 | M1.5 (af), M2.5 V (bh) |
| 2174 | — | — | — | 1.9 | — |
| 2175 | 363 | 195-36 | — | 1.5 | M3.5 (af) |
| 2176 | 360 | 235-35 | — | 1.7 | M3 (af) |
| 2177 | — | — | — | 1.8 | M3 (af) |
| 2178 | 362 | 235-36 | — | 1.7 | M3 (af) |
| 2179 | — | — | — | 2.9 | M5 V (ad) |
| 2180 | 365 | 116-42 | BD +43°1953 | 1.2 | K5 V (am), <K5 V (ah), K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2181 | — | 49-23 | Ross 93 | 1.6 | M4 (ag), M3 (af) |
| 2182 | 367 | — | CD -45°5378 | 1.6 | M3 (af) |
| 2183 | — | 116-46 | — | 1.5 | — |
| 2184 | — | 42-19 | — | 1.6 | — |
| 2185 | — | 116-48 | — | 1.3 | — |
| 2186 | — | 161-74 | — | 2.3 | — |
| 2187 | — | — | — | 1.8 | — |
| 2188* | 366 | 252-44 | Ross 434 | 1.6 | M1.5 (af), M1.5 V (bh), M2 (au) |
| 2189 | — | — | — | 1.6 | — |
| 2190 | — | — | — | 1.7 | — |
| 2191 | — | 235-40 | — | 2.2 | — |
| 2192 | — | — | — | 1.3 | — |
| 2193 | — | — | — | 1.1 | — |
| 2194* | — | 43-3 | BD +14°2151 | 0.4 | sdF5 (am), sdF2 (ag), F0 (af) |
| 2195 | — | — | — | >1.8 | — |
| 2196 | — | 253-31 | — | 1.5 | — |
| 2197 | — | 235-46 | — | 1.7 | — |
| 2198 | — | 48-42 | — | 1.3 | — |
| 2199 | — | — | — | 1.6 | — |
| 2200 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 2201 | 370 | — | CD -42°5678 | 1.4 | M0 V (bf), K5 (af) |
| 2202 | — | 235-48 | — | 1.1 | — |
| 2203 | — | 116-61 | — | 1.5 | — |
| 2204 | — | — | — | 1.3 | — |
| 2205 | — | 195-47 | — | 1.6 | — |
| 2206 | — | 42-24 | — | 1.8 | — |
| 2207 | — | 42-25 | — | 1.6 | — |
| 2208 | — | — | CD -58°2884 | 1.1 | K3-4 V (bf) |
| 2209 | — | — | — | 1.5 | — |
| 2210 | — | — | — | 1.2 | — |
| 2211 | 373 | 235-49 | BD +63°869 | 1.5 | M0 (af), M1.5 V (bh) |
| 2212 | — | 49-32 | — | 1.8 | — |
| 2213 | 375 | — | CD -45°5627 | 1.8 | M3.5 (af), M3.5 V (bq) |
| 2214 | — | — | — | 3.0 | — |
| 2215 | — | — | — | 2.6 | M6 V (ad) |
| 2216 | 376 | — | 20 LMi | 0.9 | G2 Va (be), G8 (af), G1 V (am) |
| 2217 | — | 43-24 | — | 1.7 | — |
| 2218 | — | — | — | 1.7 | — |
| 2219 | — | — | — | 0.5 | — |
| 2220 | — | 116-77 | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2221 | — | — | CD -84°102 | 0.9 | F8-G0 (bf) |
| 2222 | 1131 | 235-55 | — | 1.5 | M4 V (ai) |
| 2223 | — | — | — | 1.6 | — |
| 2224 | — | 195-57 | — | 1.3 | — |
| 2225 | — | 146-11 | — | 1.3 | — |
| 2226 | — | — | — | 1.1 | — |
| 2227 | — | — | — | 1.5 | — |
| 2228 | — | — | — | 1.1 | — |
| 2229 | — | — | — | 0.9 | — |
| 2230 | 381 | 53-28 | — | 1.5 | M2.5 V (bi), M3 V (ah), M2.5 V (bq) |
| 2231 | 383 | — | BD -17°3088 | 2.0 | M1.5 V (bq), M0 (af) |
| 2232 | — | 195-59 | — | 1.3 | — |
| 2233 | — | — | — | 1.5 | M3.5 (af) |
| 2234 | — | 43-34 | BD +10°2122 | 1.2 | K2 (af) |
| 2235 | — | 43-36 | — | 1.6 | — |
| 2236 | — | — | — | 3.1 | M5 V (ad) |
| 2237 | 383.1 | 196-13 | BD +53°1395 | 1.3 | M0 V (bh), K3 (af) |
| 2238 | — | 146-15 | — | 2.5 | sdM (bi) |
| 2239 | — | 235-62 | — | 1.5 | — |
| 2240 | — | 162-32 | Ross 445 | 1.1 | K3 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2241 | — | — | — | 1.5 | — |
| 2242 | — | 53-38 | — | -0.1 | — |
| 2243 | — | — | — | 3.4 | M8 V (bi) |
| 2244 | 386 | 162-38 | — | 1.3 | M3 (af) |
| 2245 | — | 118-48 | — | 1.3 | — |
| 2246 | — | — | — | 1.6 | — |
| 2247 | — | — | — | 1.1 | — |
| 2248 | — | 118-50 | — | 1.3 | — |
| 2249 | — | 146-23 | — | 1.5 | — |
| 2250 | — | 236-22 | — | 1.3 | — |
| 2251 | — | 53-40 | BD -0°2326 | 1.1 | K4 (af) |
| 2252 | — | — | — | 1.8 | — |
| 2253 | 389 A | — | — | 1.5 | M3 (bp) |
| 2254 | 389 B | — | — | 1.5 | — |
| 2255 | — | — | — | 1.5 | — |
| 2256 | — | — | — | 1.5 | — |
| 2257 | — | — | — | 1.5 | M4 V (ai) |
| 2258 | — | — | — | 1.9 | — |
| 2259 | 390 | 162-52 | BD - 9°3070 | 2.3 | M1.5 (af), M0 V (cb) |
| 2260 | — | 54-26 | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2261 | — | — | — | 1.3 | — |
| 2262 | — | 196-22 | — | 1.3 | — |
| 2263 | — | 196-23 | — | 1.5 | — |
| 2264 | — | — | — | 1.1 | K5 (af) |
| 2265 | — | 55-16 | BD -5°3063 | 1.1 | K3 (af) |
| | | | | | |
| 2266 | 392 B | — | BD +49°1961 B | — | — |
| 2267 | 392 B | — | BD +49°1961 B | 0.5 | F9 V (be), G1 V (am), G2 (af) |
| 2268 | — | 146-35 | — | 1.8 | — |
| 2269 | — | — | — | 1.6 | — |
| 2270 | – | 118-61 | — | 1.6 | — |
| | | | | | |
| 2271 | — | 54-29 | Ross 893 | 1.5 | — |
| 2272 | 393 | 55-24 | BD +1°2447 | 1.7 | M2 V (ah), M2 (af), M2.5 V (bh) |
| 2273 | 2080 | 43-54 | — | 0.2 | DC8 (br), DC (ag) |
| 2274 | — | 118-66 | — | 1.3 | |
| 2275 | — | 196-28 | BD +60°1266 | 1.3 | K4 (af) |
| | | | | | |
| 2276 | — | — | — | 0.9 | — |
| 2277 | — | 196-29 | — | 1.5 | — |
| 2278 | — | 119-11 | — | 1.1 | — |
| 2279 | 397 | 146-39 | BD +46°1635 | 1.5 | K7 (af), M0.5 V (bh) |
| 2280 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2281 | — | 54-30 | — | 1.5 | — |
| 2282 | — | — | — | 1.7 | — |
| 2283 | – | 44-24 | — | 1.8 | — |
| 2284 | — | 44-25 | Ross 99 | 0.6 | K2 (af) |
| 2285 | 398 | 44-27 | RY Sex | 1.8 | M4 (af), M4 V (bh) |
| 2286* | 398.1 | — | BD -11°2918 | 0.5 | F7 V (be), F8 V (am), F9 (af) |
| 2287 | — | — | — | 1.7 | — |
| 2288 | — | — | — | 2.1 | — |
| 2289 | — | — | — | 1.6 | — |
| 2290 | — | 119-22 | — | 1.1 | — |
| 2291 | — | 253-37 | — | 1.3 | K5 (af) |
| 2292 | — | 119-25 | — | 1.3 | — |
| 2293 | — | — | — | -0.3 | DQP9/DX (br) |
| 2294 | — | — | — | 1.5 | — |
| 2295 | 399 | 55-35 | — | 2.4 | M3 (af) |
| 2296 | — | — | — | 1.1 | M1 (af) |
| 2297 | — | — | — | 1.8 | M3 (af) |
| 2298 | — | 55-37 | — | 1.5 | — |
| 2299 | — | — | — | 1.6 | sd (bb) |
| 2300 | — | — | — | 2.2 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2301 | — | — | — | 1.5 | — |
| 2302 | — | — | — | 1.6 | — |
| 2303 | — | — | — | 1.6 | — |
| 2304 | — | 58-14 | — | 1.1 | — |
| | | | | | |
| 2306 | — | — | — | 1.5 | M1 (af) |
| 2307 | — | 119-29 | — | 2.1 | M3.5 V (al) |
| 2308 | — | 119-32 | BD +2°2091 | 0.5 | F8f (af) |
| 2309 | — | — | — | 1.8 | — |
| 2310 | — | — | — | 1.5 | — |
| | | | | | |
| 2311 | — | — | — | 2.0 | M0 (af) |
| 2312 | — | 196-45 | — | 1.1 | — |
| 2313 | — | — | — | 1.6 | — |
| 2314 | — | — | — | 3.1 | M6 V (ad) |
| 2315 | — | — | — | 2.2 | — |
| | | | | | |
| 2317 | — | 119-37 | — | 1.9 | — |
| 2318 | — | 58-25 | BD +21°2247 | 0.4 | sdF7 (am), F8 (af) |
| 2319 | — | — | — | 1.7 | — |
| 2320 | — | 44-43 | — | 1.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2321 | — | 55-44 | BD -1°2457 | 1.1 | K4 (af), M0.5 V (bh) |
| 2322 | — | — | — | 1.5 | — |
| 2323 | — | — | — | 1.5 | — |
| 2324 | — | — | — | 2.3 | — |
| 2325 | — | 44-46 | Hubble 4 | 1.8 | M4 (af) |
| 2326 | — | — | — | 1.4 | — |
| 2327* | — | 146-72 | — | 1.8 | M2 V (al) |
| 2328 | — | 163-23 | — | 2.1 | M4 (af) |
| 2329 | — | — | — | 1.5 | M2: (bp) |
| 2330 | — | — | — | 2.9 | — |
| 2331 | 405 | 196-51 | Ross 107 | 1.5 | M1.5 (af) |
| 2332 | — | 146-75 | BD +42°2163 | 1.2 | K2 (af) |
| 2333 | 1140 | 163-27 | — | 0.0 | DA6 (br), DA7 (bn), DA (af) |
| 2334 | 406.1 | 236-46 | BD +70°639 | 1.3 | M0 (af), M0.5 V (bh) |
| 2335 | — | — | — | 2.8 | — |
| 2336 | — | 176-3 | — | 1.6 | — |
| 2337 | — | 147-11 | — | 1.9 | — |
| 2338 | — | — | — | 1.5 | M3: (af) |
| 2339 | — | — | — | 2.7 | — |
| 2340 | — | 147-13 | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2341 | — | — | — | 1.7 | — |
| 2342 | — | — | — | 2.4 | — |
| 2343 | — | — | — | 1.8 | — |
| 2344 | — | 58-40 | — | 1.3 | — |
| 2345 | — | — | — | 1.5 | — |
| | | | | | |
| 2346 | — | — | — | 1.6 | — |
| 2347 | — | — | — | 2.7 | M5 V (ad) |
| 2348 | — | 45-33 | — | 1.1 | M3.5 (af), M2 (bk) |
| 2349 | — | 196-58 | Ross 108 | 1.3 | K7 (af) |
| 2350 | — | — | — | 1.9 | — |
| | | | | | |
| 2351 | — | — | — | 3.2 | M6.5 V (ad) |
| 2352 | — | — | — | 3.0 | sdM (bi) |
| 2353 | — | 10-2 | Wolf 362 | 1.3 | M3.5 (af) |
| 2354 | 412.2 | — | CD -29°8875 | 0.6 | G1-2 V (bf), G2 V (be) |
| 2355 | — | — | — | 1.7 | — |
| | | | | | |
| 2356 | — | 163-52 | — | 1.7 | — |
| 2357 | — | — | — | 1.1 | — |
| 2358 | 413.1 | — | CD -23°9765 | 1.5 | M3 (af) |
| 2359 | — | 254-16 | — | 1.5 | — |
| 2360 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2361 | — | 10-3 | Wolf 364 | 1.0 | K2 (af) |
| 2362 | — | — | — | 1.7 | — |
| 2363 | — | 176-15 | — | 1.9 | — |
| 2364 | — | — | — | 0.9 | DC:9 (br), DC?9 (bc), DC9: (bn) |
| 2365 | — | 10-4 | Wolf 365 | 0.6 | G2f (af) |
| | | | | | |
| 2366 | 414 B | 119-59 | BD +31°2240 B | 1.8 | M2 (af), M2.5 V (bh) |
| 2367 | 414 A | 119-60 | BD +31°2240 A | 1.5 | K7 (af), K9 V (am), M1 V (bh) |
| 2368 | 414.1 A | 122-2 A | — | 1.6 | M3 (af), M2 V (bh) |
| 2369 | 414.1 B | 122-2 B | — | 1.7 | M3 (af), M2 V (bh) |
| 2370 | 416 | — | BD -14°3277 | 1.2 | K4 V (bf), K4 (af), M0.5 V (bh) |
| | | | | | |
| 2371 | — | — | — | 1.7 | — |
| 2372 | — | — | — | 1.6 | — |
| 2373 | — | 119-64 | BD +36°2165 | 0.4 | F2 (af) |
| 2374 | — | 45-39 | Wolf 368 | 1.6 | M3.5 (af) |
| 2375 | — | — | — | 1.6 | — |
| | | | | | |
| 2376 | — | — | — | 1.3 | — |
| 2377 | — | — | — | 2.8 | — |
| 2378 | 421 C | — | — | 1.6 | M3.5 (af), M5 V (bq) |
| 2379 | 421 A | — | BD -17°3336 | 1.4 | K7 (af), M0.5 V (bh), M1 V (bq) |
| 2380* | 421 B | — | BD -17°3337 | 1.4 | K7 (af), M0.5 V (bh), M1 V (bq) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2381 | — | 10-8 | – | 1.9 | — |
| 2382 | — | 119-65 | — | 1.3 | M0 V (al) |
| 2383 | — | 10-9 | Wolf 373 | 1.3 | M3 (af) |
| 2384 | — | — | — | 1.3 | M2: (af) |
| 2385 | — | — | — | 1.5 | M4 (af) |
| | | | | | |
| 2386 | — | — | — | 1.1 | M3: (af) |
| 2387 | — | 120-30 | BD +22°2340 | 0.9 | G5 (af) |
| 2388 | — | 10-10 | BD -1°2505 | 1.7 | K5 (af) |
| 2389 | — | 56-29 | — | 1.8 | M3 (af), G5 (ag) |
| 2390* | 423 A | — | $\xi$ UMa A | 0.7 | G0 V (aj), G0 V (be), G0 V (am), G0 (af) |
| | | | | | |
| 2391* | 423 B | — | $\xi$ UMa B | 0.7 | G5 V (aj), G0 V (be), G0 V (am) |
| 2392 | — | 10-11 | — | -0.3 | DC5 (br), DC? (af) |
| 2393 | 423.1 | 163-74 | BD -4°3049 | 0.9 | G8 V (am), K0 (af) |
| 2394 | — | 120-32 | — | 1.5 | M3.5 (af) |
| 2395 | — | — | — | 2.7 | — |
| | | | | | |
| 2396 | — | — | — | 2.2 | — |
| 2397 | — | — | — | 3.3 | M5 V (ad) |
| 2397a | — | — | — | 2.8 | M8 V (bi), M8 V (ax) |
| 2398 | — | — | — | 1.5 | — |
| 2399 | — | — | — | 1.9 | — |
| 2400 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2401 | — | — | — | 1.8 | M3 (af) |
| 2402 A* | 428 A | — | CD -60°3532 A | 1.3 | K7 V (av), K5-M0 V (bf) |
| 2402 B* | 428 B | — | CD -60°3532 B | — | M0 V (aw) |
| 2403 | — | 176-34 | — | 1.7 | — |
| 2404 | — | 253-49 | — | 1.9 | M3 (af) |
| 2405 | — | 253-50 | — | 1.8 | M2.5 (af) |
| | | | | | |
| 2406 | — | 10-22 | Wolf 391 | 1.1 | M2 (af) |
| 2407 | 429 A | — | BD +3°2502 | 1.1 | K0 IV (be), K) IV (am), K0 (af) |
| 2408 | 429 B | 10-23 | BD +3°2503 | 1.3 | K2 V (am), K3 (af) |
| 2409 | — | 56-41 | Wolf 395 | 1.3 | M0 (af) |
| 2410 | — | 197-14 | Ross 109 | 1.1 | K0 (af) |
| | | | | | |
| 2411 | — | 120-51 | — | 1.3 | — |
| 2412 | 429.2 | — | — | 1.1 | M2 (af) |
| 2413 | — | 197-15 | Ross 110 A | 1.5 | M3.5 (af) |
| 2414 | — | 197-16 | Ross 110 B | 1.5 | M3.5 (af) |
| 2415 | — | 56-44 | Wolf 398 | 1.1 | M3 (af), M2.5 (bk) |
| | | | | | |
| 2416 | — | — | — | 1.9 | — |
| 2417 | 429.4 | — | CD -56°3980 | 1.1 | <M0 (bp) |
| 2418 | — | 120-56 | — | 2.2 | — |
| 2419 | — | — | — | 3.0 | sdM4.5 (ad) |
| 2420 | — | 10-29 | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2421 | — | — | — | 1.3 | — |
| 2422 | 430.1 | 120-57 | BD +23°2359 | 1.5 | M0.5 (af), M1 V (bh) |
| 2423 | 431 | — | — | 1.5 | M3.5 (af), M4.5 (bq), M3 V (bw) |
| 2424* | — | 254-24 | — | 0.6 | G0f (af) |
| 2425 | — | — | — | 1.5 | M5.5 V (ad), sdM (ac) |
| | | | | | |
| 2426 | — | 122-30 | — | 1.1 | K0 (af), K0 (bk) |
| 2427 | — | — | CD -23°10062 | 1.8 | M1 (af) |
| 2428 | — | — | — | 2.4 | M4 V (ai) |
| 2429 | 433 | — | CD -31°9113 | 2.5 | M2.5 V (bq), M2 (af) |
| 2430 | — | 122-34 | — | 1.8 | — |
| | | | | | |
| 2431 | — | 120-61 | — | 1.5 | K7 V (al), K3: (af) |
| 2432 | — | 122-36 | BD +40°2442 | 1.3 | K5 (af) |
| 2433 | — | — | CD -47°7000 | 1.1 | K4 (af), M1 (bp) |
| 2434 | — | 10-39 | Ross 910 | 1.1 | K7 (af), K7: (bk) |
| 2435 | 1147 | — | — | 1.1 | M3.5 (af) |
| | | | | | |
| 2436* | 433.2 B | — | BB +45°1947 B | 1.2 | K2 V (am), K3 (af) |
| 2437* | 433.2 A | — | BD +45°1947 A | 0.6 | G0 V (be), G0 V (am), G0 (af) |
| 2438 | — | — | — | 2.0 | — |
| 2439 | — | 254-27 | — | 1.3 | — |
| 2440 | — | 10-42 | — | 0.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2441 | 435 | — | CD -43°7228 | 1.2 | K4-5 V (bf), K4 (af) |
| 2442 | — | 56-50 | — | 1.8 | — |
| 2443 | 1148 | 122-40 | Ross 1003 | 1.7 | M3.5 (af), M5 (ag) |
| 2444 | — | — | — | 1.6 | sdK5-M1 (ai) |
| 2445 | — | — | — | 1.5 | sdM0 (ai) |
| 2446 | — | — | — | 1.5 | — |
| 2447 | 438 | — | CD -51°5974 | 1.1 | — |
| 2448 | — | 10-45 | Ross 912 | 1.6 | M3 (af) |
| 2449 | — | 122-42 | — | 1.1 | — |
| 2450 | — | 121-12 | BD +26°2251 | 0.5 | F6 (af) |
| 2451 | — | 121-14 | Ross 907 | 1.3 | K5 (af), K8 V (al) |
| 2452 | — | — | — | 1.5 | M3.5 V (ai) |
| 2453 | — | 122-45 | BD +48°1964 | 0.6 | G2 (af), G2 V (am) |
| 2454 | — | — | — | 1.5 | — |
| 2455 | — | 11-20 | — | 0.3 | — |
| 2456 | — | — | CD -65°1143 A | 1.5 | <M0 (bp) |
| 2457 | — | — | CD -65°1143 B | 1.5 | <M0 (bp) |
| 2458 | — | 122-46 | — | 1.7 | — |
| 2459 | 445 | 254-29 | — | 1.8 | M3 (af), M4 V (bh), sdM4 (cb) |
| 2460 | — | — | — | 1.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2461 | — | 197-32 | — | 1.3 | — |
| 2462 A* | 448 A | — | $\beta$ Leo A | -0.1 | A3 V (be), A3 V (am), A2 (af) |
| 2462 B* | 448 B | — | $\beta$ Leo B | — | composite with LHS 2462 A |
| 2463 | — | 10-53 | — | 0.9 | — |
| 2464 | — | — | – | 1.5 | — |
| 2465* | 449 | — | $\beta$ Vir | 0.5 | F9 V (be), F8 V (am), F8 (af) |
| 2466 | — | — | — | 1.8 | — |
| 2467 | — | 121-27 | Ross 908 | 0.6 | G7 (af) |
| 2468 | — | — | — | 1.6 | — |
| 2469 | — | — | — | 1.5 | — |
| 2470 | 452 A | — | — | 1.1 | M4 V (bq), M3 (af) |
| 2470a | 452 B | — | — | 0.4 | — |
| 2471 | — | — | — | 2.4 | M6 V (ai), M6: V (ax), M6.5 V (ad) |
| 2472 | 452.1 | 12-4 | Ross 119 | 1.6 | M3.5 (af) |
| 2473 | — | — | — | 1.6 | M3 (af) |
| 2474 | — | — | — | 1.5 | K3:: (af) |
| 2475 | — | 11-31 | Ross 129 | 1.7 | M1.5 (af) |
| 2476 | – | — | — | 1.6 | — |
| 2477 | 2086 | — | – | 1.3 | M0 (af) |
| 2478 | — | — | — | 0.2 | DC9 (br), DC9 (bc) |
| 2479 | — | — | — | 2.9 | — |
| 2480 | — | — | — | 1.6 | M6 V (ai) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2481 | — | 148-23 | — | 1.5 | — |
| 2482 | — | 12-12 | Ross 122 | 1.6 | M2.5 (af) |
| 2483 | — | — | — | 2.5 | — |
| 2484 | — | — | vB 6 | — | — |
| 2485 | — | — | CD -41°6879 | 0.9 | K1 V (bf), K2 (af) |
| 2486 | — | 197-38 | — | 1.5 | — |
| 2487 | — | — | — | 3.5 | — |
| 2488 | — | 237-38 | — | 1.5 | — |
| 2489 | — | — | — | 2.2 | — |
| 2490 | — | — | — | 1.9 | — |
| 2491 | — | 122-62 | — | 1.5 | – |
| 2492 | — | — | — | 1.6 | — |
| 2493 | — | — | — | 1.5 | — |
| 2494 | 454.1 | 11-34 | Ross 920 | 1.1 | K4 (af) |
| 2495 | — | 121-43 | Wolf 1426 | 1.7 | K7 (af) |
| 2496 | — | — | — | 1.6 | sd (bb) |
| 2497 | 455 | 121-45 | — | 1.8 | M3 (af) |
| 2498 | — | 122-66 | BD +43°2182 | 1.1 | G8 V (be), G9 IV-V (am) |
| 2499 | — | — | — | 1.8 | — |
| 2500 | — | — | — | 3.3 | sdM0.5-1: (ai), sd (bb) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2501 | — | 122-68 | — | 1.1 | — |
| 2502 | — | — | — | 3.8 | M6+ V (ad) |
| 2503 | — | 198-19 | — | 1.6 | — |
| 2504 | — | — | — | 1.6 | — |
| 2505* | — | — | — | 1.1 | K5 (af) |
| | | | | | |
| 2506 | — | — | — | 1.8 | M4.5 (af) |
| 2507 | — | 11-36 | BD +4°2568 | 0.7 | G4 (af), G0 V (am) |
| 2508 | — | — | — | 1.6 | — |
| 2509 | 2090 | — | — | 1.1 | M0 (af) |
| 2510 | — | 11-37 | BD -0°2532 | 0.9 | F8 IV-V (am) |
| | | | | | |
| 2511 | — | — | — | 1.1 | K1: (af) |
| 2512 | — | — | — | 1.7 | — |
| 2513 | — | 254-35 | — | 1.5 | — |
| 2514 | — | — | — | 2.2 | — |
| 2515 | 456 | 11-40 | Wolf 406 | 1.6 | M2 V (bq), M0.5 (af), M2 V (bh) |
| | | | | | |
| 2516 | — | — | — | 1.7 | — |
| 2517 | — | — | — | 1.6 | — |
| 2518 | — | 11.42 | Wolf 1435 | 1.6 | M3 (af) |
| 2519 | — | — | — | 1.1 | — |
| 2520 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 2521 | — | — | — | 1.5 | — |
| 2522 | — | 197-47 | — | 0.4 | DA9 (br) |
| 2523 | — | — | — | 1.8 | — |
| 2524* | 458.1 | 11-45 | BD -2°3481 | 0.9 | G4 V (am) |
| 2525 | — | — | — | 1.5 | — |
| | | | | | |
| 2526 | — | 12-24 | BD +11°2439 | 0.9 | G3 V (am) |
| 2527 | — | 12-25 | Wolf 1438 | 1.1 | M1.5 (af) |
| 2528 | — | — | — | 1.1 | K7: (af) |
| 2529 | — | 121-68 | — | 1.5 | — |
| 2530 | — | — | — | 1.3 | M3 (bp) |
| | | | | | |
| 2531* | 1154 | 13-22 | — | 1.7 | — |
| 2532 | — | — | — | 0.4 | — |
| 2533 | — | — | — | 2.2 | — |
| 2534 | — | — | — | -0.2 | — |
| 2535 | — | — | — | 1.3 | — |
| | | | | | |
| 2536 | — | 237-54 | — | 1.5 | — |
| 2537 | — | 12-26 | — | 1.8 | M3: (af) |
| 2538 | — | 59-9 | Wolf 1439 | 1.3 | M2.5 (af) |
| 2539 | — | — | — | 1.6 | — |
| 2540 | — | — | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2541 | 1155 A | 13-26 A | — | 1.7 | sdM3 (ag) |
| 2542 | 1155 B | 13-26 B | — | 0.2 | DAs (ag) |
| 2543 | — | — | — | 1.5 | — |
| 2544 | 459.3 | 121-77 | BD +29°2279 | 1.6 | M0.5 (af), M2 V (bh) |
| 2545 | — | — | — | >2.3 | M6 V (ad) |
| 2546 | — | 199-7 | — | 2.3 | — |
| 2547 | — | 12-35 | — | 1.6 | — |
| 2548 | 462 | 123-26 | BD +42°2296 | 1.5 | K5 (af), M3 (bk), M0.5 V (bh) |
| 2549 | — | 59-14 | Wolf 409 | 1.6 | M0 (bk), M0 (af) |
| 2550 | — | — | — | 1.1 | K3:: (af) |
| 2551 | 463 | 237-63 | Ross 690 | 1.7 | M3 (af), M4 V (cb) |
| 2552 | 1157 | — | — | 1.1 | M3.5 : (af) |
| 2553 | — | — | CD -66°1212 | 1.3 | G8-K0 IV (be), G8-K0 IV (bf) |
| 2554 | — | — | — | 1.6 | — |
| 2555 | — | — | — | 1.5 | K7 (af) |
| 2555a | — | — | — | 2.7 | — |
| 2556 | — | 123-29 | BD +39°2519 | 0.5 | G0 V (am) |
| 2557 | — | — | — | 2.1 | M5 V (ai) |
| 2558 | — | — | CD -48°7414 | 0.6 | K4: (af) |
| 2559 | — | — | — | 0.9 | DC9 (br), DC9 (bc) |
| 2560 | — | — | CD -48°7426 | 0.6 | G3-5 V (bf), G3-5 V (be), G6 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2561 | — | — | — | 1.3 | — |
| 2562 | — | 12-37 | — | 1.3 | — |
| 2563 | — | — | — | 1.5 | — |
| 2564 | — | — | BD -16°3469 | 0.9 | K3 (af), K2 V (bf) |
| 2565 | 469 | 12-38 | Wolf 414 | 1.5 | M3.5 (af), M4 V (bh) |
| 2566* | 469.1 | 13-43 | BD -2°3528 | 0.9 | G7 V (am) |
| 2567 | — | 13-44 A | — | 1.5 | M3.5 (af) |
| 2568 | — | 13-44 B | — | 1.5 | M3.5: (af) |
| 2569 | — | — | — | 1.5 | — |
| 2570 | 471 | 12-39 | BD +9°2636 | 1.5 | K7 (af), M1 V (bh) |
| 2571 | — | 198-58 | — | 1.8 | — |
| 2572 | — | — | — | 1.5 | — |
| 2573 | — | — | — | 2.0 | — |
| 2574 | — | 199-24 | — | 1.6 | — |
| 2575 | — | 12-42 | Wolf 422 | 1.5 | M2 (af) |
| 2576 | — | 237-68 | — | 1.3 | — |
| 2577 | 472 | — | CD -68°1095 | 0.9 | K1 V (bf) |
| 2578 | — | — | — | 1.6 | — |
| 2579 | 475 | — | $\beta$ CVn | 0.6 | G0 V (ca), G0 V (be), G0 V (am), G0 (af) |
| 2580 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 2581 | — | — | — | 1.5 | — |
| 2582 | 476 | 12-44 | Wolf 427 | 1.7 | M3 (af) |
| 2583 | — | — | — | 1.7 | M6 V (ad) |
| 2584 | — | 199-31 | — | 1.3 | — |
| 2585 | 477 | — | CD -45°7872 | 1.6 | M1 (af) |
| | | | | | |
| 2586 | — | 13-47 | — | 1.6 | M3 (af) |
| 2587 | 478 | — | — | 1.5 | M1 V (bq) |
| 2588 | — | 199-33 | — | 1.9 | — |
| 2589 | — | — | — | 1.5 | M5.5 V (ai), M4 V (ad) |
| 2590 | — | — | — | 1.3 | — |
| | | | | | |
| 2591 | — | — | — | 1.5 | — |
| 2592 | — | — | — | 1.5 | — |
| 2593 | — | 60-23 | — | 1.3 | — |
| 2594 | 2095 | — | — | -0.2 | DA6 (br) |
| 2595 | 1162 | 13-51 | — | 1.8 | M3 V: (al) |
| | | | | | |
| 2596 | — | — | — | 0.1 | DC8 (br), sdM0: (ai), DC8 (bn) |
| 2597 | — | — | — | 1.9 | — |
| 2598 | — | — | — | 1.9 | — |
| 2599 | — | — | — | 1.6 | — |
| 2600 | 2096 | — | CD -77°568 | 1.3 | K5 V (bf) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2601 | — | — | — | 0.9 | — |
| 2602 | — | — | — | 1.5 | M5.5 V (ai) |
| 2603 | — | — | — | 1.3 | — |
| 2604 | 482 A | — | $\gamma$ Vir A | 0.6 | F0 V (be), F0s (af) |
| 2605 | 482 B | — | $\gamma$ Vir B | 0.6 | F0 V (be), F0s (af) |
| 2606 | — | — | — | 1.5 | — |
| 2607 | — | — | — | 1.1 | — |
| 2608 | — | — | — | 1.3 | — |
| 2609 | — | — | — | 1.3 | sdM (ac) |
| 2610 | — | 255-17 | — | 1.7 | M4.5 V (ai) |
| 2611 | — | — | — | 2.0 | — |
| 2612 | — | 164-12 | — | 1.3 | — |
| 2613 | — | 123-55 | — | 1.8 | — |
| 2614 | — | 164-13 | — | 1.5 | — |
| 2615 | — | — | CD -37°8082 | 0.8 | G5 V (bf) |
| 2616 | — | 60-27 | — | 1.8 | — |
| 2617 | — | 199-35 | — | 1.3 | M2.5 V (ai) |
| 2618 | — | — | — | 1.9 | — |
| 2619 | — | — | — | 1.6 | — |
| 2620 | — | — | Ross 704 | 1.1 | K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|-----------------------------|
| 2621 | — | — | — | 0.1 | — |
| 2622 | — | — | — | 1.5 | — |
| 2623 | — | — | — | 2.2 | — |
| 2624 | — | 164-17 | — | 1.3 | — |
| 2625 | — | — | — | 1.3 | — |
| 2626 | — | — | — | 1.3 | — |
| 2627 | — | — | — | 1.3 | — |
| 2628 | — | — | — | 1.1 | — |
| 2629 | — | — | — | 2.8 | — |
| 2630 | — | — | — | 2.0 | M5 V (ai) |
| 2631 | — | — | 33 Vir | 1.1 | K1 III-IV (be), K1 IV (am), G9 (af) |
| 2632 | — | — | — | 3.1 | M7 V (bi) |
| 2633 | — | 123-60 | Ross 991 | 1.3 | M2.5 (af) |
| 2634 | — | 14-1 | — | 1.6 | M3 (af) |
| 2635 | — | — | — | 1.5 | — |
| 2636 | — | 60-33 | Wolf 438 | 1.5 | M3 (af) |
| 2637 | — | 123-61 | — | 2.2 | — |
| 2638 | — | 14-4 | — | 1.7 | — |
| 2639 | — | 199-41 | BD +62°1257 | 1.3 | G1 (af), G1 V (am) |
| 2640 | — | 199-42 | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2641 | — | 14-5 | BD +2°2585 | 0.9 | G8 V (am) |
| 2641a | — | — | — | 1.1 | — |
| 2642 | — | — | BD -16°3543 | 1.3 | K5 (af) |
| 2643 | — | — | — | 2.5 | M4.5 V (ad) |
| 2644 | — | — | CD -55°4825 | 0.6 | — |
| 2645 | — | — | — | 3.2 | M7 V (bi) |
| 2646 | — | 199-45 | — | 1.5 | — |
| 2647 A* | — | — | BD -17°3723 A | 0.5 | K7 V (bf), sdF7 (am), F9 (af) |
| 2647 B* | — | — | BD -17°3723 B | — | composite with LHS 2647 A |
| 2648 | — | — | — | 1.5 | — |
| 2649 | — | 237-81 | — | 1.2 | — |
| 2650 | — | — | — | 1.6 | — |
| 2651 | — | 177-4 | — | 1.7 | — |
| 2652 | — | — | — | 1.3 | — |
| 2653 | — | — | — | 1.5 | K (af) |
| 2654 | — | 123-74 | — | 1.1 | — |
| 2655 | — | — | — | 1.3 | — |
| 2656 A* | 491 A | — | BD -9°3595 A | 1.1 | K0 V (am), K0 (af) |
| 2656 B* | 491 B | — | BD -9°3595 B | — | composite with LHS 2656 A |
| 2657 | — | — | — | 2.5 | — |
| 2658 | — | — | — | 1.8 | — |
| 2659 | — | 199-51 | — | 1.5 | — |
| 2660 | — | 61-26 | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2661 | 492 | 60-54 | Wolf 457 | 0.5 | DC9 (br), DC9 (bn), DC (af) |
| 2662 | — | — | — | 1.6 | — |
| 2663 | 493 | 14-19 | BD -1°2754 | 1.3 | K8 V (am), K5 (af), M0.5 V (bh) |
| 2664* | 493.1 | 60-55 | Wolf 461 | 2.2 | M4.5 (af), M5 V (bh) |
| 2665* | 494 | 60-57 | BD +13°2618 | 1.8 | M1.5 V (ag), M1 (af), M1.5 V (bh) |
| 2666 | — | 123-82 | — | 0.9 | — |
| 2667 | — | — | — | 1.9 | — |
| 2668 | — | — | — | 1.5 | M2 (bp) |
| 2669 | — | — | CD -26°9470 | 0.5 | G1 V (bf), F9f (af) |
| 2670 | — | 177-13 | — | 1.3 | — |
| 2671 | — | — | — | 2.1 | — |
| 2672 | — | 123-84 | — | 1.3 | — |
| 2673 | — | — | — | 1.1 | DC:/DC9 (br), DC9 (bn) |
| 2674 | — | 149-33 | — | 1.7 | — |
| 2674a | — | — | — | 1.5 | — |
| 2675 | — | — | — | 2.2 | — |
| 2676 | — | — | — | 1.8 | — |
| 2677 | — | 237-88 | — | 1.3 | — |
| 2678 | — | — | CD -40°7705 | 0.9 | K0 V (bf), G9 (af) |
| 2679 | — | 149-44 | — | 1.3 | — |
| 2680 | — | 61-33 | — | 2.2 | M3 (af), G5 (ag) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2681 | — | 60-67 | BD +6°2697 | 0.9 | G5 IV (be), G5 IV (am) |
| 2682 | — | 14-35 | — | 1.3 | — |
| 2683 | — | — | — | 1.1 | M0 (af) |
| 2684 | — | 199-60 | — | 1.3 | — |
| 2685 | — | — | — | 1.5 | K3: (af) |
| 2686 | — | 177-25 | — | 1.8 | — |
| 2687 | — | 238-26 | BD +68°714 | 1.1 | K2 V (am), K2 (af) |
| 2688 | — | — | — | 1.5 | — |
| 2689 | — | 63-5 | BD +10°2519 A | 0.6 | G1 V (am), G4 (af) |
| 2690 | — | 63-6 | BD +10°2519 B | 1.6 | M0 (af) |
| 2691 | — | — | — | 1.5 | — |
| 2691a | — | — | — | 1.9 | — |
| 2692 | — | — | — | 1.1 | M1 (af) |
| 2692a | — | — | — | 1.3 | — |
| 2693* | — | 63-9 | BD +18°2700 | 0.6 | F9 V (am) |
| 2694 | — | — | — | 1.1 | — |
| 2695 | 1168 | 61-41 | — | 1.8 | — |
| 2696 | — | — | — | 0.9 | — |
| 2697 | — | — | — | 1.6 | — |
| 2698 | — | — | — | 1.6 | M3.5 (af) |
| 2699 | — | 62-18 | — | 1.6 | — |
| 2700 | — | 199-64 | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2701 | — | 14-39 | — | 0.9 | K3 (af) |
| 2702 | — | 177-27 | — | 1.8 | — |
| 2703 | — | 164-53 | — | 1.8 | — |
| 2704 | — | — | — | 1.5 | — |
| 2705 | — | 61-44 | — | 1.7 | — |
| 2706 | — | — | — | 1.5 | — |
| 2707 | — | — | — | 1.5 | — |
| 2708* | — | 164-55 | — | 0.9 | K3 (bk) |
| 2709 | — | 14-42 | — | 1.6 | — |
| 2710 | — | — | — | 0.6 | DC9 (br), DC9 (bc) |
| 2711 | 1169 | 149-70 | — | 1.5 | M3.5 V (al) |
| 2712 | — | — | — | 0.4 | — |
| 2713 | 505 A | 63-18 A | BD +17°2611 A | 1.2 | K1 V (be), K2 V (am), K3 (af) |
| 2714 | 505 B | 63-18 B | BD +17°2611 B | 1.5 | M1 V (be), M1.5 V (bh), M0 (af) |
| 2715 | 506.1 | 14-45 | Ross 484 | 1.3 | K3 (af), K8.5 V (bq) |
| 2716 | 507 A | 164-64 | BD +35°2436 A | 1.8 | M0 (af), M1.5 V (bh) |
| 2717 | 507 B | 164-65 | BD +35°2436 B | 1.9 | M3 (af), M3.5 V (bh) |
| 2718 | — | — | — | 1.5 | M3.5 (af) |
| 2719 | — | – | — | 1.7 | M6: V (ai) |
| 2720 | — | — | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2721 | — | — | — | 1.5 | — |
| 2722 | — | 62-33 | BD +4°2729 | 1.3 | K2 V (am), K2 (af) |
| 2723 | — | — | — | 2.4 | — |
| 2724 | 508.2 | 164-68 | BD +35°2439 | 1.7 | M1 V (ag), M1 V (bh), M2 (af) |
| 2725 | — | 62-34 | — | 1.7 | — |
| 2726 | — | — | CD -38°8457 | 0.4 | F/Gw[A] (bf), F4 (af) |
| 2727 | — | 238-35 | — | 1.5 | — |
| 2728 A* | 509 A | 164-71 A | BD +29°2405 A | 1.5 | K7 (af), M0 V (bh) |
| 2728 B* | 509 B | 164-71 B | BD +29°2405 B | — | M0.5 V (bh) |
| 2729 | — | — | — | 2.5 | — |
| 2730 | — | — | — | 1.5 | — |
| 2731 | 508.3 | — | Wolf 482 | 1.3 | K7 (af) |
| 2732 | — | — | — | 2.3 | — |
| 2733 | — | 149-88 | — | 1.3 | — |
| 2734 | — | — | — | 1.9 | — |
| 2735 | — | 164-73 | Ross 1011 | 1.1 | K5 (af), K7 (bk) |
| 2736 | — | — | — | 1.8 | — |
| 2737 | — | — | — | -0.2 | DA4 (br) |
| 2738 | — | — | — | 1.6 | — |
| 2739 | — | — | — | 1.8 | M4 (af) |
| 2740 | 521.1 | — | 70 Vir | 0.9 | G2.5 Va (be), G3 (af), G5 V (am) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 2741 | — | 14-56 | — | 1.9 | — |
| 2742 | — | — | — | 2.3 | M6 V (ad) |
| 2743 | — | — | — | 1.5 | — |
| 2744 | — | — | — | 1.3 | — |
| 2745 | — | 165-7 | — | 0.2 | DZ7 (br) |
| | | | | | |
| 2746 | — | — | — | 2.1 | — |
| 2747* | — | 62-44 | BD -1°2832 | 1.0 | G9 V (am) |
| 2748 | — | 238-39 | — | 1.5 | — |
| 2749 | — | 150-9 | Ross 1020b | 1.5 | K3 (af) |
| 2750 | — | — | CD -42°8521 | 1.1 | G0: (af) |
| | | | | | |
| 2751 | — | 199-72 | — | 1.5 | — |
| 2752 | — | 238-42 | — | 1.5 | — |
| 2753 | — | — | — | 1.3 | — |
| 2754 | 2102 | 62-49 | BD +9°2776 | 1.1 | — |
| 2755 | — | — | — | 3.0 | — |
| | | | | | |
| 2756 | — | — | — | 1.3 | — |
| 2757 | — | — | — | 1.5 | M2-3 (bp) |
| 2758 | — | — | — | 2.8 | — |
| 2759 | — | — | CD -26°9804 | 1.1 | K2 V (bf), K3 (af) |
| 2760 | — | — | CD -38°8635 | 0.6 | G3 V (bf) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2761 | — | 150-15 | — | 1.3 | — |
| 2762 | — | 177-44 | BD +47°2072 | 1.2 | K3 (af) |
| 2763 | — | 165-17 | — | 1.5 | — |
| 2764 | — | — | — | 2.3 | — |
| 2765 | — | 63-40 | — | 0.9 | — |
| | | | | | |
| 2766 | 518.1 | 62-54 | BD +8°2735 | 0.9 | M0 (ag), K4 (af) |
| 2767 | — | 63-43 | — | 1.7 | — |
| 2768 | — | — | — | 1.7 | — |
| 2769 | — | — | — | -0.2 | DA6 (br) |
| 2770 | — | 64-7 | — | 1.7 | — |
| | | | | | |
| 2771 | — | 150-25 | Ross 1022 | 1.1 | M3 (af) |
| 2772 | — | 177-48 | — | 1.8 | — |
| 2773 | 521.1 | 62-60 | BD -3°3508 | 1.4 | K7 (af), M1 V (bh) |
| 2774 | — | 63-45 | — | 1.8 | — |
| 2775 | — | — | — | 1.8 | — |
| | | | | | |
| 2776 | — | — | — | 2.1 | M5 V (ai) |
| 2777 | — | 177-52 | — | 1.6 | — |
| 2778 | — | 177-53 | — | 1.3 | — |
| 2779 | — | — | — | 1.5 | — |
| 2780 | — | — | — | 0.9 | K0 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|-----------------------------|
| 2781 | — | — | — | -0.1 | — |
| 2782 | — | — | — | 1.3 | — |
| 2783 | — | — | — | 1.7 | — |
| 2784 | — | 165-25 | Ross 1015 | 1.7 | M3 (af) |
| 2785 | — | 177-57 | — | 1.3 | — |
| | | | | | |
| 2787 | — | 62-66 | BD +5°2791 | 1.3 | K7 (af), M2 (bk) |
| 2788 | — | 223-22 | — | 1.5 | — |
| 2789 | — | 177-58 | Ross 492 | 1.5 | — |
| 2790 | — | — | — | 2.2 | — |
| | | | | | |
| 2791 | — | 165-29 | Ross 1018 | 1.3 | — |
| 2792 | — | 150-34 | — | 1.1 | $\geq$M3: (al) |
| 2793 | — | — | — | 1.5 | sdM1: (ai) |
| 2794 | — | — | — | 1.5 | M3.5 (af) |
| 2795 | — | 150-36 | — | 1.5 | — |
| | | | | | |
| 2796 | — | — | — | 1.7 | — |
| 2797 | — | — | — | 2.2 | — |
| 2798 | — | — | BD +7°2690 | 0.6 | G0-1 IV-V (be), G0 V (am), G2 (af) |
| 2799 | — | 64-24 | BD -5°3763 | 1.4 | K4 (af) |
| 2800 | 1178 | 63-54 | — | 0.2 | DA7/DA6 (br), DA7 (bn), DA/F (ag) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2801 | — | 65-2 | BD +7°2692 | 1.5 | K4 (af), M0 V (bh) |
| 2802 | — | — | — | 1.3 | — |
| 2803 | — | — | — | 1.7 | M4.5: V (ai) |
| 2804 | — | 64-26 | — | 1.6 | — |
| 2805 | — | — | — | 1.5 | — |
| | | | | | |
| 2806 | — | — | CD -35°9019 B | 1.5 | K4: (af) |
| 2807 | — | — | CD -35°9019 A | 0.7 | G3 IV-V (be), G0 V (bf), F9 (af) |
| 2808 | — | — | — | 0.5 | DC9 (br), DC9 (bc) |
| 2809 | — | 63-60 | — | 1.8 | — |
| 2810 | — | — | — | 2.7 | — |
| | | | | | |
| 2811 | — | — | — | 1.7 | M3.5-4: V (ai) |
| 2812 | — | — | — | 1.5 | — |
| 2813 | — | — | — | 1.5 | — |
| 2814 | 530 | — | CD -23°11329 | 0.9 | G5 V (bf), G5 V (be) |
| 2815 | — | — | CD -56°5169 | 0.6 | G5wF8 V (bf) |
| | | | | | |
| 2816 | — | — | — | 1.5 | — |
| 2817 | 531 | — | CD -50°8092 | 0.9 | K3 V (bf) |
| 2818 | — | — | — | 1.5 | — |
| 2819 | — | 238-55 | — | 1.5 | — |
| 2820 | 533.1 | 238-54 | — | 1.6 | M1.5 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2821 | 533 | 65-12 | BD +13°2721 | 1.5 | M0 (af), M0 V (bh) |
| 2822 | — | — | — | 1.8 | M1 (af) |
| 2823 | — | — | — | 1.5 | — |
| 2824 | — | 223-35 | — | 1.1 | — |
| 2825 | — | — | — | 2.6 | — |
| 2826 | — | — | — | 2.7 | M4.5 V (bi) |
| 2827 | — | 223-38 | — | 1.5 | — |
| 2828 | — | — | — | 2.3 | M5.5 V (ai), M5.5 V (ax) |
| 2829 | — | — | — | 1.1 | — |
| 2830 | — | 65-19 | Ross 837 | 1.1 | M3 (af) |
| 2831 | — | — | — | 1.1 | — |
| 2832 | — | 64-29 | — | 1.3 | — |
| 2833 | — | 165-38 | — | 1.5 | — |
| 2834 | 534.3 | — | CD -33°9467 | 0.9 | G5 V (bf) |
| 2835 | — | 64-31 | — | 1.3 | — |
| 2836 | — | — | — | 2.3 | K2: (af) |
| 2837 | — | 150-54 | Ross 494 | 1.1 | K5 (af) |
| 2838 | — | — | — | 1.5 | — |
| 2839 | — | 200-14 | vB 7 | 2.0 | — |
| 2840 | — | 200-15 | Ross 1027 | 1.6 | K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2841 | — | — | BD -31°10833 | 2.7 | K7 (af) |
| 2842 | 536 | 64-35 | BD -1°2892 | 1.3 | M1 (af) |
| 2843 | — | — | — | 1.6 | sdK5-M0 (ai) |
| 2844 | — | 135-10 | — | 1.7 | — |
| 2845* | — | 165-40 | — | 1.1 | M1: (bk) |
| | | | | | |
| 2846 | — | 65-22 | Ross 838 | 0.6 | G5 (af) |
| 2847 | — | — | — | 2.6 | M5.5: V (ai), M5 V (ad) |
| 2848 | — | — | — | 1.5 | M3.5 (af) |
| 2849 | 537 A | 200-16 A | BD +47°2112 A | 1.6 | M1 (af), M2 V (bh), M3 V (cb) |
| 2850 | 537 B | 200-16 B | BD +47°2112 B | 1.6 | M1 (af), M2.5 V (bh) |
| | | | | | |
| 2851 | — | — | — | 0.9 | — |
| 2852 | — | — | — | 2.7 | M0.5 (af) |
| 2853 | — | 135-13 | Wolf 530 | 1.3 | M3.5 : (af) |
| 2854 | — | — | — | 1.3 | — |
| 2855 | — | — | — | 2.6 | M6 V (ad) |
| | | | | | |
| 2856 | — | — | — | 0.9 | DC (br) |
| 2857 | — | 64-42 | — | 1.3 | — |
| 2858 | 539 | — | θ Cen | 1.2 | K0 IIIb (bf), K0 IIIb (be), G9 III (af) |
| 2859 | — | — | — | 3.1 | — |
| 2860 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|-----------------|------------------------------|
| 2861 | — | 165-48 | — | 1.3 | — |
| 2862 | — | — | — | 1.6 | — |
| 2863 | — | 64-47 | — | 2.4 | — |
| 2864 | — | 223-43 | — | 1.5 | — |
| 2865 | 540 | 255-51 | BD +81°465 | 1.5 | M1 (af), M0.5 V (bh) |
| 2866 | — | 255-49 | — | 1.6 | M1 (af) |
| 2867 | — | — | — | 2.2 | — |
| 2868 | — | 255-50 | — | 1.5 | — |
| 2869 | — | 64-48 | Ross 800 | 1.6 | K5 (af), K5: (bk) |
| 2870 | 539.2 | — | CD -30°11195 | 2.1 | M0 (af) |
| 2871 | — | — | CD -60°5077 | 0.9 | G8 [V] (bf) |
| 2872 | — | — | BD -13°3834 | 1.6 | G0: (af) |
| 2873 | — | 65-33 | — | 1.1 | — |
| 2874 | — | — | — | 1.1 | — |
| 2875 | — | 64-52 | — | 1.8 | M2-3: (al), M3.5 (af) |
| 2876 | — | — | — | >1.6 | M6.5 V (ad) |
| 2877 | — | — | — | 1.3 | — |
| 2878 | — | 65-35 | — | 1.8 | — |
| 2879 | — | — | — | 1.6 | M3.5 (af) |
| 2880 | 540.2 | — | Ross 845 | 1.5 | M4: (af), M5 V (bh) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2881 | — | — | — | 1.5 | M1: (bp) |
| 2882 | — | 200-24 | — | 1.8 | — |
| 2883* | — | 64-60 | — | 1.3 | K4: (af), sd (ab) |
| 2884 | — | 178-10 | Ross 992 | 1.5 | M2.5 (af) |
| 2885 | — | — | — | 1.6 | — |
| 2886 | — | 165-60 | — | 1.3 | — |
| 2887 | — | 165-61 | — | 2.5 | M4.5 V (bi), M (by) |
| 2888 | — | 135-35 | — | 1.3 | — |
| 2889 | — | 200-29 | — | 2.4 | — |
| 2890 | — | 165-62 | — | 1.6 | — |
| 2891 A* | 542.1 A | — | CD -25°10271 A | 0.5 | F5 V (be), F7wF3 V (bf) |
| 2891 B* | 542.1 B | — | CD -25°10271 B | — | composite with LHS 2891 A |
| 2892 | 542 | — | CD -58°5564 | 1.1 | K3 V (be), K3 V (bf) |
| 2893 | — | — | — | 3.3 | M1.5 (ai), sd (bb) |
| 2894 | 544 A | 124-24 A | BD -4°3665 A | 1.1 | K1 V (am), K1 (af) |
| 2895 | 544 B | 124-24 B | BD -4°3665 B | 1.5 | M4 (af), M6 V (cb) |
| 2896 | — | — | — | 1.7 | — |
| 2897 | — | 200-31 | — | 1.9 | — |
| 2898 | — | 200-32 | — | 2.1 | — |
| 2899 | — | 124-27 | — | 1.9 | M3 (af) |
| 2900 | 545.1 | — | CD -39°8857 | 1.1 | K3-4 V (bf), K3 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2901 | — | 178-18 | — | 1.2 | — |
| 2902 | — | 178-19 | — | 1.2 | M1: V (ai) |
| 2903 | 546 | 166-22 | BD +30°2512 | 1.7 | K8 V (am), K7 (af), M0.5 V (bh) |
| 2904 | — | 124-29 | Ross 849 | 1.1 | K5 (af) |
| 2905 | — | 135-44 | — | 1.3 | K4 (af), K4 (ag) |
| 2906 | — | — | — | 2.3 | — |
| 2907 | 547 | 65-47 | BD +1°2920 | 0.8 | G1 V (be), G1 V (am), G5 (af) |
| 2908 | — | 135-47 | — | 1.3 | M3 V (al), M1.5 (af) |
| 2909 | — | — | — | 2.0 | — |
| 2910 | — | — | — | 1.5 | — |
| 2911 | — | — | — | 1.7 | — |
| 2912 | — | — | — | 1.6 | — |
| 2913 | — | 65-49 | — | 1.6 | — |
| 2914 | 549 C | 200-38 | Hubble 10 | 1.1 | K1 (af) |
| 2915 | — | 166-25 | BD +21°2649 | 0.6 | G0 (af), F9 V (am) |
| 2916 | — | — | — | 2.1 | — |
| 2917 | — | — | — | >2.0 | — |
| 2918 | 550.1 | 166-29 | BD +24°2735 | 1.5 | K4 (af), M0 V (cb), M0 V (bh) |
| 2919 | — | — | — | 2.1 | — |
| 2920 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2921 | — | — | — | 1.6 | M5.5: V (ai), M5.5: V (ax) |
| 2922 | — | 255-52 | — | 1.5 | — |
| 2923 | — | — | — | 1.6 | — |
| 2924 | — | — | — | 3.0 | M9 V (bi), M9 V (ax), M9 V (ai) |
| 2925 | — | 166-33 | — | 1.7 | — |
| 2926 | — | — | CD -46°9361 | 1.1 | K5-M0 V (bf), K5 (af), <M0 (bp) |
| 2927 | — | — | — | 1.5 | — |
| 2928 | — | — | — | 2.1 | — |
| 2929 | — | 224-9 | — | 1.5 | — |
| 2930 | — | — | — | 1.7 | M6.5 V (bi), M6.5 V (ai), M6.5 V (ax) |
| 2931 | 554 | 178-31 | BD +36°2500 | 1.1 | K4 (af) |
| 2932 | 553.1 | — | Wolf 1478 | 1.7 | M4 V (bq), M3 (af), M4 V (cb) |
| 2933 | — | — | CD -26°10340 | 0.8 | G6-8 V (bf), G9 (af) |
| 2934 | — | — | — | 1.6 | — |
| 2935 | — | — | — | 1.5 | — |
| 2936 | — | 200-46 | — | 2.2 | — |
| 2937 | — | 135-61 | — | 2.0 | — |
| 2938 | — | — | CD -27°9894 | 0.9 | K7 (af) |
| 2939 | — | — | — | 2.1 | — |
| 2940 | — | 124-51 | BD -9°3964 | 1.3 | K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 2941 | — | 66-5 | BD +10°2703 A | 1.1 | K3 (af), K2 V (am) |
| 2942 | — | 66-6 | BD +10°2703 B | 1.5 | M3: (af) |
| 2943 | — | 178-37 | — | 1.5 | — |
| 2944 | — | 66-7 | — | 1.3 | K5 (bk) |
| 2945 | 555 | — | BD -11°3759 | 2.0 | M4.5 V (bq), M3 (af), M4 V (cb) |
| 2946 | — | 239-21 | — | 1.3 | — |
| 2947 | — | 166-36 | — | 2.0 | — |
| 2948 | 558 | 166-38 | BD +34°2541 | 1.5 | K4 (af), M0.5 V (bh) |
| 2949 | — | 66-10 | — | 1.6 | — |
| 2950 | — | — | — | 2.6 | sd (bb) |
| 2951 | — | — | — | 0.9 | DC9 (br), DC9 (bc) |
| 2952 | — | 223-74 | — | 1.5 | — |
| 2953 | — | — | BD -11°3770 | 0.6 | F5 V (be), F6 IV-V (am) |
| 2954 | — | — | — | 1.3 | — |
| 2955 | — | — | — | 1.5 | — |
| 2956 | — | 66-18 | Wolf 536 | 1.1 | K3: (af) |
| 2957 | — | 124-57 | — | 1.8 | M1 (af) |
| 2958 | — | — | — | 1.5 | — |
| 2959 | — | 201-7 | — | 2.1 | — |
| 2960 | — | — | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2961 | — | — | CD -56°5542 | 0.9 | G5-6 V (bf) |
| 2962 | — | 166-40 | Ross 51 | 1.2 | K5 (af) |
| 2963 | — | 178-44 | Ross 993 | 1.2 | K3 (af) |
| 2964 | — | — | — | 1.5 | sdM0 (ai) |
| 2965 | — | 66-21 | Wolf 537 | 1.3 | M3: (af) |
| | | | | | |
| 2966 | — | — | — | 0.9 | — |
| 2967 | — | — | — | 1.3 | K5-M0 V (ai) |
| 2968 | — | 66-22 | BD +6°2932 | 0.6 | G3: (af) |
| 2969 | — | — | — | 0.6 | G5 (af), dK (bo) |
| 2970 | — | — | CD -49°9033 | 1.1 | K3 (af), K3 V (bf) |
| | | | | | |
| 2971 | — | — | — | 1.5 | — |
| 2972 | — | — | — | 1.5 | — |
| 2973 | — | 200-58 | — | 1.8 | — |
| 2974 | 562 | 136-13 | BD +17°2785 | 1.4 | K7 (af), M0 V (bh) |
| 2975 | — | — | — | 0.6 | sdK (ab) |
| | | | | | |
| 2976 | — | 239-29 | — | 1.5 | — |
| 2977 | — | 136-14 | Ross 994 | 1.5 | M0.5 (af) |
| 2978 | 563 | — | Ross 499 | 1.5 | M0 (af), M2 V (bq) |
| 2979 | 1185 | 124-72 | — | 1.9 | M3 (af) |
| 2980 | — | — | — | 3.3 | M6.5 V (bi) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 2981 | — | — | — | 2.1 | — |
| 2982 | — | 124-76 | — | 1.1 | — |
| 2983 | 563.3 | 66-31 | BD +7°2850 | 1.3 | K3 (af) |
| 2984 | — | 66-32 | — | -0.3 | DA4 (br), DA (af) |
| 2985 | — | 124-81 | Wolf 553 | 1.9 | M3.5 (af) |
| 2986 | — | — | — | 1.5 | — |
| 2987 | — | — | — | 1.5 | — |
| 2988 | — | — | — | 1.1 | M3 (af) |
| 2989* | — | — | — | 2.4 | — |
| 2990 | — | 200-59 | — | 1.7 | — |
| 2991 | — | 239-32 | BD +72°659 | 1.3 | K4 (af) |
| 2992 | — | — | — | 1.5 | — |
| 2993 | — | 151-6 | — | 1.5 | K2 (af) |
| 2994 | — | — | Ross 501 | 1.6 | M0: (af) |
| 2995 | 1186 | 136-27 | — | 1.5 | — |
| 2996 | — | 166-52 | BD +23°2751 | 1.2 | K3 (af), K3 V (am) |
| 2997 A* | 568 A | 166-53 A | Ross 52 A | 1.8 | M3.5 (af), M5 V (cb) |
| 2997 B* | 568 B | 166-53 B | Ross 52 B | — | composite with LHS 2997 A |
| 2998 | — | 178-55 | Ross 1041 | 1.6 | M3.5 (af) |
| 2999 | — | 66-41 | Ross 1028b | 1.1 | M0.5 (af), M1 (bk) |
| 3000 | — | — | — | 2.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3001 | — | — | — | 1.9 | M5 V (ai), M5 V (ax), M5 V (ad) |
| 3002 | — | — | — | 3.5 | M7 V (ai), M7: V (ax), M7 V (ad) |
| 3003 | — | — | — | 3.4 | M6.5 V (ad) |
| 3004 | — | — | — | 1.5 | — |
| 3005 | — | 136-39 | — | 1.8 | — |
| 3006 | 1187 | 201-27 | — | 1.7 | — |
| 3007 | — | 166-58 | — | -0.1 | DA6 (br) |
| 3008* | — | — | BD -21°4009 | 0.3 | sdF7 (am), F5-6 V (bf) |
| 3009 | — | 224-39 | — | 1.5 | — |
| 3010 | — | — | — | 1.8 | — |
| 3011 | — | 136-47 | — | 1.4 | — |
| 3012 | — | 15-1 | Ross 1030a | 1.3 | M3.5 (af) |
| 3013 | — | — | — | 1.6 | — |
| 3014 | — | — | — | 1.5 | — |
| 3015 | — | 167-12 | — | 1.1 | — |
| 3015a | — | 151-20 | — | 1.8 | — |
| 3016 | — | 179-9 | — | 1.8 | — |
| 3017 | — | 256-20 | — | 1.5 | — |
| 3018 | — | 224-44 | Ross 1051 | 1.5 | M2 (af), M0 (bk) |
| 3019 | — | — | — | 1.5 | — |
| 3020* | 576 | 15-5 | BD +16°2986 | 1.3 | K5 (af), M0 V (bh) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3021 | — | — | — | 0.9 | M5 V (bc) |
| 3022 | — | — | — | 2.1 | — |
| 3023 | — | — | — | 1.3 | — |
| 3024 | — | 66-65 | BD +9°3001 | 0.6 | F9 V (am), F9 (af) |
| 3025 | — | — | — | 1.3 | — |
| | | | | | |
| 3026 | 1189 | 167-22 | BD +24°2824 | 1.5 | — |
| 3027 | — | 136-69 | — | 1.9 | — |
| 3028 | — | — | — | 1.4 | — |
| 3029 | — | — | — | 1.3 | K5 (af) |
| 3030 | — | 15-9 | Ross 1047 | 1.7 | M3 (af) |
| | | | | | |
| 3031 | — | 201-37 | — | 1.7 | — |
| 3032 | — | — | — | 1.9 | — |
| 3033 | — | 136-76 | — | 2.2 | >M5 V (al) |
| 3034 | 2111 | 15-13 | Ross 1038 | 0.6 | G3 (af), G2: (ag) |
| 3035 | — | 179-20 | — | 2.1 | — |
| | | | | | |
| 3036 | — | 136-77 | BD +19°2939 A | 0.9 | G5 V (be), G5 V (am) |
| 3037 | — | 136-78 | BD +19°2939 B | 0.9 | G7 V (am) |
| 3038 | — | — | CP -21°5912 | 0.6 | K3 (af) |
| 3039 | 1190 | 15-15 | BD -3°3746 | 1.5 | K4 (af), M0 V (bh) |
| 3040 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|---------|------------|-----------|------------------------------|
| 3041 | — | — | — | 1.1 | M5 V (bc) |
| 3042 | — | — | — | 2.6 | — |
| 3043 | — | — | — | 2.0 | — |
| 3044 | — | 224-57 | — | 1.7 | — |
| 3045 | — | — | — | 1.4 | K5 (af) |
| 3046 | — | 136-85 | — | 1.9 | — |
| 3047 | — | — | — | 1.5 | — |
| 3048 | — | — | — | 1.3 | — |
| 3049 | — | 151-41 | — | 2.2 | — |
| 3050 | — | — | — | 1.5 | — |
| 3051 | — | 179-25 | — | 1.8 | — |
| 3052 | — | 167-32 | — | 1.3 | — |
| 3053 | — | — | BD -18°4031 | 1.6 | K5p (af) |
| 3054 | — | 167-33 A | BD +26°2677 A | 0.7 | G9 (af), G8 V (am) |
| 3055 | — | 167-33 B | BD +26°2677 B | — | composite with LHS 3054 |
| 3056 | — | 151-45 | — | 1.3 | M3 (af) |
| 3057 | — | 239-48 | — | 1.5 | — |
| 3058 | — | 167-34 | — | 1.6 | — |
| 3059 | — | — | 5 Ser A | 0.5 | F8 III-IV (be), F8 IV-V (am), F8 (af) |
| 3060 | — | — | 5 Ser B | 1.3 | K4 (af), M0.5 V (bh) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3061 | — | — | — | >2.2 | — |
| 3062 | — | 151-49 | Wolf 563 | 1.3 | K5 (af) |
| 3063 | — | — | — | 1.5 | — |
| 3064* | 2112 | — | — | 1.8 | M3: (af) |
| 3065 | — | — | — | 1.5 | — |
| | | | | | |
| 3066 | — | — | — | 1.7 | — |
| 3067 | 1192 | 15-20 | BD +1°3071 | 1.3 | K3 V (am), K3 (af) |
| 3068 | — | 136-102 | — | 1.9 | — |
| 3069 | — | 201-48 | — | 1.3 | — |
| 3070 | — | 15-21 | — | 1.3 | — |
| | | | | | |
| 3071 | — | — | CD -26°10870 | 1.1 | K3-4 V (bf), K3 (af) |
| 3072 | — | — | — | 1.5 | — |
| 3073 | — | 137-8 | Ross 510 | 1.4 | K5 (af) |
| 3074 | — | — | — | 1.5 | M2-3 (bp) |
| 3075 | — | 179-33 | — | 1.6 | — |
| | | | | | |
| 3076* | — | 152-31 | — | 1.8 | — |
| 3077 | — | 152-32 | — | 2.0 | — |
| 3078 | — | 15-25 | — | 1.1 | — |
| 3079 | — | — | — | 1.3 | M3.5 (af) |
| 3080 | — | 167-47 | — | 1.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3081 | — | — | — | 1.3 | — |
| 3082 | — | 201-55 | — | 1.3 | — |
| 3083 | 1193 | 137-22 | Ross 512 | 1.7 | M3.5 (af) |
| 3084 | — | 15-26 | — | 1.6 | — |
| 3085 | — | — | — | 1.5 | — |
| 3086 | — | 152-37 | — | 2.3 | — |
| 3087 | — | — | — | 1.5 | M5 V (bc) |
| 3088 | — | — | — | 0.9 | DC?9 (br), DC?9 (bc) |
| 3089 | — | 224-74 | — | 1.5 | — |
| 3090 | — | — | — | 1.5 | — |
| 3091 | — | 167-51 | — | 1.3 | — |
| 3092 | 590 | — | — | 1.1 | M4 (af) |
| 3093 | 592 | 152-40 | Ross 802 | 1.5 | M4 (af) |
| 3094 | — | — | — | 1.1 | — |
| 3095 | — | — | — | 1.6 | — |
| 3096 | — | — | — | 2.3 | — |
| 3097 | — | — | — | 1.3 | K4 (af) |
| 3098 | — | — | — | 1.3 | — |
| 3099 | — | — | — | 2.5 | sd (bb) |
| 3100 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3101 | — | 137-35 | — | 1.1 | — |
| 3102 | — | — | — | 1.4 | — |
| 3103 | — | 239-58 | — | 1.5 | M2.5 V (ai) |
| 3104 | — | — | — | 2.7 | — |
| 3105 | — | 224-79 | — | 1.5 | — |
| 3106 | — | — | — | 3.4 | M6 V (ad) |
| 3107 | — | — | — | 1.7 | — |
| 3108 | — | — | — | 1.5 | — |
| 3109 | — | — | — | 1.5 | — |
| 3110 | — | 152-46 | Ross 804 | 1.1 | K5 (af) |
| 3111 | — | — | — | 2.9 | — |
| 3112 | — | — | — | 1.3 | — |
| 3113 | — | — | — | 1.1 | — |
| 3114 | — | — | CD -46°10351 | 1.5 | M0 (af) |
| 3115 | — | 152-49 | BD -13°4246 | 1.4 | K1 (af) |
| 3116 | — | — | — | 2.2 | — |
| 3117 | — | 152-50 | — | 1.3 | — |
| 3118 | — | — | — | 1.7 | — |
| 3119 | — | — | — | 1.5 | M2-3 (bp) |
| 3120 | — | — | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|------------|------------|-----------------------------|
| 3121 | — | — | — | 2.8 | — |
| 3122 | — | 179-57 | — | 2.0 | — |
| 3123 | — | 16-11 | — | 1.6 | — |
| 3124 | — | 168-14 | — | 1.3 | — |
| 3125 | — | — | — | 1.7 | — |
| | | | | | |
| 3126 | — | — | — | 2.5 | — |
| 3127 | 602 | — | $\chi$ Her | 0.5 | F8 V (be), F9 V (am), G0 (af) |
| 3128 | — | 137-60 | — | 1.5 | — |
| 3129 | — | 180-8 | Ross 806 | 1.5 | M3 (af), M2 (bk) |
| 3130 | — | 180-9 | — | 2.3 | — |
| | | | | | |
| 3131 | — | — | 39 Ser | 0.6 | G0 IV (be), G2 V (am) |
| 3132 | — | — | — | 2.3 | — |
| 3133 | — | — | — | 1.6 | sdM0-1 (ai), sdM (ac) |
| 3134 | — | — | — | 1.7 | M2-3 V (ai) |
| 3135 | — | — | — | 1.5 | — |
| | | | | | |
| 3136 | — | 137-71 | — | 1.8 | — |
| 3137 | — | 180-17 | — | 1.8 | — |
| 3138 | — | 168-20 | BD +28°2503 | 1.1 | K0 V (am) |
| 3139 | — | 225-40 | — | 1.5 | M1.5-2 V (ai) |
| 3140 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3141 | — | — | — | 1.9 | — |
| 3142 | — | 137-74 | — | 1.6 | — |
| 3143 | — | — | 49 Lib | 0.6 | F7 V (bf), F8 V (be), F8 V (am) |
| 3144 | — | — | — | 1.5 | M3: (af) |
| 3145 | 606.2 | — | $\rho$ CrB | 0.6 | G2 V (be), G2 V (am), G1 (af) |
| | | | | | |
| 3146 | — | 180-23 | Ross 808 | 0.1 | DAV5/DA4 (br), vDA (af) |
| 3147 | — | — | — | 1.5 | — |
| 3148* | 609.2 | — | BD +25°3020 | 0.8 | G8 V (be), G8 V (am), G8 (af) |
| 3149 | — | — | — | 1.9 | M4.5: V (ai) |
| 3150 | 611 B | 180-27 | BD +39°2947 B | 2.1 | — |
| | | | | | |
| 3151 | — | — | — | 0.6 | DC9 (br) |
| 3152 | 611 A | — | BD +39°2947 A | 0.9 | G8 V (be), G8 V (am), K0: (af) |
| 3153 | 612 | 180-31 | BD +39°2950 | 1.2 | K3 V (am), K3 (af) |
| 3154 | — | — | — | 2.1 | — |
| 3155 | 612.1 | 180-33 | BD +35°2774 | 1.3 | K5 (af), M0 V (bh) |
| | | | | | |
| 3156 A* | 611.3 A | 16-29 A | — | 2.0 | M3 V (ag), M3 V (bh) |
| 3156 B* | 611.3 B | 16-29 B | — | — | composite with LHS 3156 A |
| 3157 | — | — | — | 1.1 | — |
| 3158 | 1197 | 168-32 | — | 1.7 | — |
| 3159 | — | — | — | 1.5 | — |
| 3160 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3161 | — | 16-32 | BD +6°3169 | 1.1 | K0 IV (be), K0 IV (am), G8 (af) |
| 3162 | — | — | — | 1.5 | — |
| 3163 | 1199 | 138-8 | — | -0.3 | DA6 (br) |
| 3164 | — | 16-34 | — | 1.3 | K3 (af) |
| 3165 | — | — | — | — | — |
| 3166 | — | 202-32 | Ross 522 | 1.6 | M0.5 (af) |
| 3167 | — | — | — | 1.3 | — |
| 3168 | — | — | — | 2.7 | — |
| 3169 | — | — | — | 0.6 | M3.5 (af) |
| 3170 | — | — | — | 3.1 | — |
| 3171 | 616 | — | 18 Sco | 0.6 | G2 Va (be), G1 V (am), G3 (af) |
| 3172 A* | — | 17-8 A | BD +7°3125 A | 1.4 | K4 (af), K4 V (am) |
| 3172 B* | — | 17-8 B | BD +7°3125 B | — | K4 (af) |
| 3173 | — | — | — | 1.8 | — |
| 3174 | — | — | — | 1.1 | dM (ba) |
| 3175 | 617 A | 225-57 | BD +67°935 A | 1.3 | M0 V (am), K7 (af), M0 V (bh) |
| 3176 | 617 B | 225-58 | BD +67°935 B | 1.6 | M2.5 (af) |
| 3177 | — | — | — | 1.1 | — |
| 3178 | — | — | — | 2.7 | — |
| 3179 | — | — | — | 1.8 | — |
| 3180 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3181 | — | — | — | 2.0 | — |
| 3182 | — | — | CD -47°10664 | 0.6 | K2 V (bf), K2 (af) |
| 3183 | — | — | Ross 528 | 1.4 | K4 (af) |
| 3184 | — | — | CD -70°1402 | 0.6 | — |
| 3185 | 618.4 | — | — | 1.7 | M3 (af) |
| 3186 | 620 | — | CD -24°12677 | 1.6 | M2 V (bq), M2 (bp), M1 (af) |
| 3187 | — | — | — | 1.5 | — |
| 3188 | 620.2 | — | — | 1.5 | M1-2 (bp), K5 (af) |
| 3189 | — | — | — | 1.7 | M5.5 V (ad) |
| 3190 | — | — | — | 2.1 | — |
| 3191 | 622 | — | BD -21°4352 | 1.3 | M1.5 (bp), K5 (af) |
| 3192 | — | 169-6 | — | 2.1 | — |
| 3193 | — | 169-7 | — | 1.3 | — |
| 3194 | — | 17-14 | BD +2°3101 | 1.1 | K2 (af) |
| 3195 | — | — | — | 1.5 | — |
| 3196 | — | — | — | 1.9 | M4.5 V (ai) |
| 3197 | — | — | — | 2.6 | — |
| 3198 | — | — | — | 1.5 | — |
| 3199* | — | 180-58 | — | 0.9 | G5 (af) |
| 3200 | 626.2 | 180-57 | Ross 640 | 0.3 | DZA6 (br), DF (af), DZA5+ (ba) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3201 | — | 180-56 | — | 1.3 | — |
| 3202 | — | 17-19 | BD +3°3203 | 1.1 | — |
| 3203 | 627 A | 138-34 A | BD +18°3182 A | 1.2 | K3 V (be), K2 V (am), K1 (af) |
| 3204 | 627 B | 138-34 B | BD +18°3182 B | 1.2 | K3 V (be) |
| 3205 | 2121 | 153-57 | — | 1.1 | M3 (af) |
| 3206 | — | — | — | 1.3 | K0:: (af) |
| 3207 | — | 153-59 | — | 1.3 | sdM1: (ai) |
| 3208 | — | 226-9 | — | 1.3 | — |
| 3209 | 629 | — | CD -38°11019 | 1.0 | K0 V (bf), K1 (af) |
| 3210 | 1202 | 138-37 | — | 1.3 | — |
| 3211 | — | — | — | 1.7 | — |
| 3212 | — | 225-65 | — | 1.5 | — |
| 3213 | 1203 | 138-39 | — | 1.1 | — |
| 3214 | — | 202-61 | — | 1.1 | — |
| 3215* | 629.2 A | 17-25 | BD -3°3968 A | 0.9 | G5 V (am), K1 (af) |
| 3216 | — | — | — | 1.5 | M2 (bp) |
| 3217 | — | — | — | 1.5 | — |
| 3218 | — | — | — | 1.7 | — |
| 3219 | 629.2 B | 17-27 | BD -3°3968 B | 1.1 | — |
| 3220 | — | — | — | 0.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3221 | 1204 | 138-43 | — | 1.5 | — |
| 3222 | — | — | BD -14°4454 | 1.1 | K3 (af) |
| 3223 | 629.3 | — | — | 1.1 | M1: (af), M1-2 (bp) |
| 3224 | 631 | — | 12 Oph | 1.1 | K2 V (be), K2 V (am), K0 (af) |
| 3225 | — | 138-44 | — | 1.1 | — |
| 3226 | 632.1 | 169-20 | BD +31°2875 | 1.3 | K4 (af) |
| 3227 | — | — | — | 1.8 | — |
| 3228 | — | — | CD -40°10550 | 1.1 | K3 V (bf), K1 (af) |
| 3229 | — | — | — | 1.9 | — |
| 3230 | — | 138-49 | — | 0.2 | DA6 (br) |
| 3231 | — | — | — | -0.4 | DC9 (br) |
| 3232 | — | — | — | 1.5 | — |
| 3233 | 633 | — | — | 0.6 | M3 (af) |
| 3234 A* | 635 A | — | ς Her A | 0.6 | G0 IV (be), G0 IV (am), G0 (af) |
| 3234 B* | 635 B | — | ς Her B | — | — |
| 3235 | 634 | — | CD -43°11010 | 1.8 | M3 (af) |
| 3236 | — | 138-56 | — | -0.1 | — |
| 3237 | — | — | — | 1.6 | — |
| 3238 | 637.1 | 240-25 | BD +68°883 | 0.9 | K1 V (am), K1 (af) |
| 3239 | — | — | — | 1.6 | — |
| 3240 | — | 138-64 | — | 2.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 3241 | — | — | — | 1.9 | — |
| 3242 | 637 | — | — | 1.5 | — |
| 3243 | — | — | — | 1.3 | — |
| 3244 | 639.1 | — | ε Sco | 1.1 | K2.5 III (be), K2 IIIb (bf), G9 III (af) |
| 3245 | — | — | — | -0.1 | — |
| 3246 | — | 17-38 | — | 1.1 | — |
| 3247 | — | — | — | 1.7 | — |
| 3248 | 639.2 | — | — | 0.6 | — |
| 3249 | — | — | — | 2.1 | — |
| 3250 | — | — | — | -0.2 | DC9 (br), DC9 (bc) |
| 3251 | 642 | 138-67 | Ross 644 | 1.3 | K7 (af), M1.5 V (bh), M1.5 V (cb) |
| 3252 | — | — | — | 1.1 | — |
| 3253 | — | — | vB 26 | 1.1 | — |
| 3254 | 1208 | 169-34 | V749 Her | -0.2 | DA5 (br) |
| 3255 | 1207 | 19-7 | — | 1.3 | M3.5 (af) |
| 3256 | — | — | — | 1.5 | — |
| 3257 | 649 | 169-38 | BD +25°3173 | 1.6 | M0.5 V (bi), M0.5 (af), M2 V (bh) |
| 3258 | — | 240-38 | — | 1.5 | — |
| 3259 | — | — | — | 2.3 | sd (bb) |
| 3260 | 651 | — | BD +47°2420 | 1.1 | G8 V (be), G8 V (am), G9 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3261 | — | 181-24 | — | 1.5 | — |
| 3262 | — | 203-42 | — | 1.3 | — |
| 3263 | — | — | — | 1.5 | — |
| 3264 | — | 226-45 | — | 1.5 | — |
| 3265 | 1210 | 139-12 | — | 2.2 | — |
| 3266 | — | 170-19 | Ross 864 | 1.5 | K4 (af) |
| 3267 | — | 181-30 | Wolf 648 | 1.8 | M3.5 (af) |
| 3268 | 656 | — | CD -60°6576 | 0.9 | K2 V (bf) |
| 3269 A* | 660 A | 19-15 A | — | 0.9 | M3.5 (af) |
| 3269 B* | 660 B | 19-15 B | — | — | composite with LHS 3269 A |
| 3270 | — | — | CD -46°11288 | 0.9 | K0 V (bf), K3 (af) |
| 3271 | 660.1 | 19-16 | — | 1.1 | M0 (af) |
| 3272 | 1212 | — | — | 1.5 | M3 (af) |
| 3273 | — | — | — | 1.1 | — |
| 3274 | — | — | — | 1.5 | — |
| 3275 | 1214 | 139-21 | — | 2.7 | — |
| 3276 | — | 181-33 | — | 1.3 | — |
| 3277* | 1215 | 139-29 | — | 1.8 | — |
| 3278 | — | 19-20 | Wolf 672 A | -0.3 | DA6 (br), DA4 (ba), DA (af) |
| 3279 | — | 19-21 | Wolf 672 B | 2.2 | M3.5 (af) |
| 3280 | — | — | — | 1.5 | — |

## TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3281 | 671 | 181-39 | — | 0.9 | M1 V: (al), M3 (af) |
| 3282 | — | 181-37 A | Wolf 692 A | 1.6 | M3 (af) |
| 3283 | — | 181-37 B | Wolf 692 B | 1.7 | — |
| 3284 | — | — | — | 1.1 | M0: (af) |
| 3285 | 667.1 | — | CD -75°967 | 0.6 | G2 V (be), G2 V (bf) |
| | | | | | |
| 3286 | 672.1 | — | — | 1.5 | M2 (af), M2 (bp) |
| 3287* | 675 | — | BD +67°1014 | 1.1 | K0 V (be), K0 V (am), K0 (af) |
| 3288 | — | 170-37 | — | 1.5 | — |
| 3289 | — | 20-1 | — | 1.1 | — |
| 3290 | — | — | — | 0.6 | M3 (af) |
| | | | | | |
| 3291 | — | — | — | 1.1 | M3.5 (af) |
| 3292 | 1218 | — | — | 1.5 | — |
| 3293 | — | 226-62 | — | 1.7 | — |
| 3294 | — | — | — | 1.5 | — |
| 3295 | — | — | — | 1.5 | — |
| | | | | | |
| 3296 | — | — | — | 1.5 | — |
| 3297 | 1220 | 259-15 | — | 1.5 | — |
| 3298 | — | 203-71 | — | 2.1 | — |
| 3299 | — | 226-64 | — | 0.9 | — |
| 3300 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3301 | — | — | Ross 858 | 1.1 | K4 (af), sd (bw) |
| 3302 | — | 170-50 | — | 1.1 | — |
| 3303 | — | — | — | 1.5 | — |
| 3304 | — | 139-48 | BD +6°3455 | 0.6 | G0 V (am) |
| 3305 A* | 684 A | — | 26 Dra A | 0.5 | G0 Ve (be), G0 V (am), G0 (af) |
| 3305 B* | 684 B | — | 26 Dra B | — | — |
| | | | | | |
| 3306 | 685 | 226-66 | BD +61°1678 C | 1.5 | M0.5 (af), M1.5 V (bh) |
| 3307 | — | — | — | 2.2 | M6- V (ad) |
| 3308 | — | — | — | 0.6 | M4 (af) |
| 3309 | — | 259-12 | — | 1.5 | — |
| 3310 | — | — | CD -27°11772 | 1.1 | K5 (af) |
| | | | | | |
| 3311 | — | — | — | 1.3 | — |
| 3312 | — | 182-19 | BD +37°2926 | 0.6 | G0 V (am), G0 (af) |
| 3313 | — | 204-24 | — | 2.0 | — |
| 3314 | — | — | — | 1.5 | — |
| 3315 | — | 20-9 | Wolf 1471 | 1.5 | M3 (af) |
| | | | | | |
| 3316 | 690.1 | 154-8 | — | 1.1 | M2.5 (af) |
| 3317 | — | — | — | 1.1 | M3 (af), M3-4 (bp) |
| 3318 | — | 259-17 | — | 1.5 | — |
| 3319 | 692.1 | 170-61 | BD +21°3198 | 1.1 | K0 V (am) |
| 3320 | — | 154-9 | Ross 133 | 1.6 | M2 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3321 | 694 | 204-27 | BD +43°2796 | 1.8 | M2 (af). M3.5 V (bh) |
| 3322 | — | — | — | 1.7 | — |
| 3323 | — | 20-12 | — | 1.5 | — |
| 3324 | — | 170-62 | — | 2.1 | — |
| 3325 A* | 695 B | — | μ Her B | 0.8 | M3 (af), M3.5 V (bh), M4 V (cb) |
| 3325 B* | 695 C | — | μ Her C | — | — |
| 3326* | 695 A | — | μ Her A | 0.9 | G5 IV (ca), G5 IV (be), G5 IV (am) |
| 3327 | — | 154-19 | — | 0.6 | — |
| 3328 | — | 240-70 | — | 1.5 | — |
| 3329 | — | 140-11 | BD +4°3509 | 1.1 | K1 (af) |
| 3330 | 695.1 | — | CD -33°12476 | 0.9 | G6-8 V (bf), K0 (af) |
| 3331 | — | — | — | 2.0 | — |
| 3332 | — | — | — | 2.3 | M6.5 V (ai) |
| 3333 | — | 183-5 | — | 2.1 | M4.5-5 V (ax) |
| 3334 | — | 204-32 | — | 1.3 | M2 V (ai) |
| 3335 | 2132 | — | — | 1.1 | K4:: (af), M1-2: (bp) |
| 3336 | — | 140-16 | — | 1.1 | — |
| 3337 | — | — | CP -38°7124 | 0.5 | G0: (af) |
| 3338 | 1222 | 140-19 | — | 1.8 | M3 V (al) |
| 3339 | — | — | — | 1.6 | M5.5 V (bi), M5.5 V (ai) |
| 3340 | — | 154-34 | — | 0.6 | G4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3341 | — | 228-12 | — | 1.1 | — |
| 3342 | — | — | — | 2.2 | — |
| 3343 | — | 204-39 | — | 1.7 | M1 (bk) |
| 3344 | — | 259-22 | — | 1.5 | — |
| 3345 A* | — | 154-36 A | BD -13°4807 A | 0.6 | G3 V (bf), G2 (af) |
| 3345 B* | — | 154-36 B | BD -13°4807 B | — | — |
| 3346 | — | — | — | 1.5 | — |
| 3347 | — | — | CD -30°15026 | 0.6 | G8 (af) |
| 3348 | — | — | — | 1.5 | — |
| 3349 | — | 140-29 | BD +14°3384 | 0.9 | K0 (ag) |
| 3350 | — | 182-34 | — | 1.3 | — |
| 3351 | — | 258-28 | — | 1.3 | — |
| 3352 | — | 154-41 | — | 1.9 | — |
| 3353 | 700.2 | 182-35 | BD +26°3151 | 1.1 | G8-K0 V (be), K0 V (am), K0 (af) |
| 3354 | — | — | — | 1.6 | — |
| 3355 | — | 183-23 | — | 1.3 | — |
| 3356 | 701 | 20-22 | BD -3°4233 | 1.4 | M0.5 (af), M1.5 V (al), M2 V (bh) |
| 3357 | — | 140-39 | — | 0.6 | K2 (af) |
| 3358 | — | — | — | 1.8 | — |
| 3359 | 1224 | 154-44 | — | 1.3 | — |
| 3360 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3361 | — | 183-26 | Wolf 816 | 1.1 | K1 (af) |
| 3362 | — | — | — | 2.0 | — |
| 3363 | 706 | 205-5 | BD +38°3095 | 1.1 | K2 V (be), K2 V (am), K2 (af) |
| 3364 | — | 183-28 | — | 0.6 | G0 (bk) |
| 3365 | — | 204-48 | — | 1.1 | K (ai) |
| 3366 | — | 140-46 | BD +5°3640 | 0.6 | G8 (af), G5 (bk), sd (bw) |
| 3367 | — | — | — | 1.5 | — |
| 3368 | — | 183-31 | Wolf 830 | 2.0 | M3.5: (af) |
| 3369 | — | 140-47 | — | 0.6 | sdK (ba) |
| 3370 | — | — | — | 1.6 | — |
| 3371 | — | 183-32 | Wolf 834 | 1.4 | M0.5 V (al), K5 (af) |
| 3372 | — | — | — | 1.5 | M3.5 (af) |
| 3373 | 708.2 | 140-49 | BD +13°3578 | 1.3 | M0 V (ag), K5 (af), M0 V (bh) |
| 3374 | 708.3 | 21.7 | — | 1.8 | M3: (af), M3.5 V (bh) |
| 3375 | — | 140-52 | — | 0.6 | M3 (af) |
| 3376 | — | 258-33 | — | 1.5 | — |
| 3377 | — | 21-9 | — | 1.4 | M2.5 (af) |
| 3378 | — | — | — | 1.5 | — |
| 3379 A* | 713 A | — | χ Dra A | 0.5 | F7 V (am), F8 (af) |
| 3379 B* | 713 B | — | χ Dra B | — | composite with LHS 3379 A |
| 3380 | — | 227-28 | — | 1.3 | DC:9 (br) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3381 | 711 | — | $\eta$ Ser | 1.1 | K2 IIIab (be), K0 III-IV (am), G8 (af) |
| 3382 | — | — | — | 1.7 | sdM (aa), sdM (bm), sdM (ap) |
| 3383 | — | — | — | 1.1 | M3: (af) |
| 3384 | 2135 | 155-15 | — | 0.2 | DA7 (br) |
| 3385 | — | 205-20 | — | 1.7 | M1 (bk) |
| 3386 | — | 227-30 | — | 1.6 | — |
| 3387 | — | 141-8 | BD +8°3689 | 0.9 | G7 V (am), G6 (af) |
| 3388 | — | 141-9 | BD +8°3692 | 0.9 | G9 V (am), K0 (af) |
| 3389 | — | — | — | 1.6 | — |
| 3390 | — | — | — | 2.1 | sdM (bm) |
| 3391 | — | 259-31 | — | 1.5 | — |
| 3392 | 718 | 183-44 | BD +22°3406 | 1.3 | K4 V (am), K5 (af) |
| 3393 | — | 21-28 | Wolf 1463 | 1.3 | K7 (af) |
| 3394 | 720 A | 205-30 | BD +45°2743 | 1.3 | M0.5 V (bi), M0 (af), M2 V (bh) |
| 3395 | 720 B | 205-32 | vB 9 | 1.6 | — |
| 3396 | — | 155-26 | — | 1.3 | — |
| 3397 | — | — | — | 0.6 | K3 (af) |
| 3398 | 2138 | 155-29 | — | 1.5 | — |
| 3399 | — | 141-24 | — | 0.6 | sdM (ba) |
| 3400 | 723 | 155-30 | Wolf 1466 | 1.5 | M0.5 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3401 | — | 206-38 A | BD +31°3330 A | 1.2 | K0 (af) |
| 3402 | — | 206-38 B | BD +31°3330 B | 1.6 | M0 (af) |
| 3403 | 724 | 155-33 | BD -13°5069 | 1.5 | M0 (af), M2 (bp) |
| 3404 | 1230 B | — | — | 1.5 | — |
| 3405 | 1230 A | 184-19 | — | 1.3 | — |
| 3406 | — | — | — | 2.2 | — |
| 3407 | — | — | CD -40°12743 | 1.3 | K4 (af) |
| 3408 | — | — | — | 0.6 | G9 (af) |
| 3409 | — | — | — | 2.0 | sdM4 (ai) |
| 3410 | — | 229-16 | — | 1.1 | — |
| 3411 | — | — | — | 1.5 | — |
| 3412 | 728 | 184-29 | BD +17°3729 | 1.6 | K7 (af), M1.5 V (bh) |
| 3413 | — | — | — | 1.5 | — |
| 3414 | 729 | — | Ross 154 | 1.7 | M4 (af), M4.5 V (bh), M4.5 V (cb) |
| 3415 | — | 141-41 | — | 1.1 | — |
| 3416 | — | 141-42 | — | 1.1 | M4 V (ai) |
| 3417 | 731 | 184-35 | Ross 160 | 1.5 | M0 (af), M1.5 V (bh) |
| 3418 | — | — | — | 1.5 | — |
| 3419 | — | 22.5 | — | 0.6 | — |
| 3420 | — | 205-40 | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3421 | — | — | — | 1.3 | — |
| 3422 | — | — | — | 1.3 | — |
| 3423 | 739 | — | CD -48°12818 | 1.7 | M3 (af) |
| 3424 | 742 | 260-15 | — | -0.1 | DXP5 (br), DAP4+ (ba) |
| 3425 | — | 184-42 | BD +18°3911 | 0.6 | G8 (af) |
| 3426 | — | 22-12 | BD +5°4011 | 0.9 | K3 (bk) |
| 3427 | — | — | BD -20°5385 | 0.7 | G6 V (bf) |
| 3428 | 741 | — | — | 1.7 | M4: (af) |
| 3429 | — | 205-55 | — | 1.7 | — |
| 3430 | — | 22-14 | — | 0.9 | — |
| 3431 | — | 22-15 | BD +7°3967 | 1.3 | K5 (af) |
| 3432 | 745 A | 184-48 | Ross 730 | 1.6 | M1 (af), M2 V (bh), sdM2 (cb) |
| 3433 | 745 B | 184-49 | Ross 731 | 1.6 | M1.5 (af), M2 V (bh), sdM2 (cb) |
| 3434 | 1231 | 207-18 | — | 1.8 | — |
| 3435 | — | 185-8 | — | 1.5 | — |
| 3436 | — | 261-1 | — | 1.5 | — |
| 3437 | 747.1 | — | Ross 727 | 1.3 | M3 (af) |
| 3438 | 1232 | 142-11 | — | 1.3 | M4 V: (al) |
| 3439 | 747.3 | — | CD -47°12773 | 1.3 | K5-M0 V (bf), K7 (af) |
| 3440 | — | — | BD +49°2959 a | 0.9 | G4 V (be), G4 V (am), G4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3441 | — | — | BD +49°2959 | 0.7 | G4 V (be), G4 V (am), G2 (af) |
| 3442 | — | 142-12 | — | 1.3 | — |
| 3443 | — | — | — | 1.5 | M3 (af), M3 (bp) |
| 3444 | — | 22-20 | BD -0°3676 | 0.4 | sdF7 (am) |
| 3445 | — | 185-12 | Ross 733 | 1.5 | M3 (af) |
| | | | | | |
| 3446 | — | 185-13 | Ross 734 | 1.5 | M3.5 (af) |
| 3447 | 748.2 A | 22-21 A | BD +1°3942 A | 1.1 | K7 V (bi), K4 (af), K7 (bk) |
| 3448 | 748.2 B | 22-21 B | Bd +1°3942 B | 1.3 | M0 V (bi) |
| 3449 | — | — | — | 1.1 | M2: (af) |
| 3450 | — | 125-4 | BD +41°3306 | 1.2 | K1 (af), K0 V (am) |
| | | | | | |
| 3451 | — | — | — | 1.8 | — |
| 3452 | — | — | — | 1.7 | — |
| 3453 | — | — | — | 0.6 | M3 (af) |
| 3454 | — | — | — | 1.5 | — |
| 3455 | — | — | — | 1.7 | — |
| | | | | | |
| 3456 | 756 | 185-19 | Ross 163 | 1.6 | M1 (af) |
| 3457 | 1236 | 22-26 | — | 1.6 | M4 V (al), M2-3 (bp) |
| 3458 | — | 125-6 | BD +33°3433 | 1.4 | K5 (af) |
| 3459 | — | 207-30 | — | 1.6 | — |
| 3460 | – | — | CD -45°13178 | 0.5 | F3-5w (bf), sd (bw) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3461 | 1238 | 261-6 | — | 1.7 | — |
| 3462 | — | — | — | 1.9 | — |
| 3463* | 759 | — | 31 Aql | 0.9 | G8 IV (be), G8 IV (am), G6 (af) |
| 3464 | — | — | BD +24°3737 | 0.6 | F7 V (be), F6 V (am), F8 (af) |
| 3465 | 1237 | 208-22 | BD +49°3009 | 1.1 | K3 (af) |
| 3466 | 762.1 | 229-33 | BD +58°1929 | 1.2 | K1 V (be), K1 V (am), K2 (af) |
| 3467 | — | 125-13 | BD +35°3659 sf | 0.4 | F6 (af) |
| 3468 | — | – | CD -28°15936 | 0.6 | K0+F/G (bf) |
| 3469 | — | — | BD +32°3474 | 0.6 | G0 V (be), G0 V (am) |
| 3470 | 763 | 23-5 | BD +4°4157 | 1.3 | M0 V (bi), K7 (af), M0.5 V (bh) |
| 3471 | 762 | — | — | 1.7 | — |
| 3472 | — | 229-35 | Wolf 1108 | 1.8 | M3 (af) |
| 3473 | — | 125-24 A | — | 1.5 | — |
| 3474 | — | 125-24 B | — | 1.5 | — |
| 3475 | — | — | — | 1.5 | — |
| 3476 | — | — | — | 1.6 | M2.5: (af) |
| 3477 | — | — | — | 2.0 | — |
| 3478 | — | 125-27 | — | 1.3 | — |
| 3479 | 1242 | 23-8 | — | 1.6 | — |
| 3480 | — | — | — | 2.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3481 | — | — | — | 2.5 | — |
| 3482 | 767 A | 125-31 A | BD +31°3767 A | 1.6 | M0.5 V (bi), M0.5 (af), K5 V (al) |
| 3483 | 767 B | 125-31 B | BD +31°3767 B | 1.7 | M2.5 V (bi), M1 V (al), M2:: (af) |
| 3484 | — | — | — | 1.5 | <M0 (bp) |
| 3485 | — | 208-39 | — | 1.5 | — |
| 3486 | — | — | — | 1.7 | M0 (af) |
| 3487 | — | — | — | 1.6 | — |
| 3488 | — | — | — | 1.9 | — |
| 3489 | — | 125-35 | — | 1.5 | M3 (af) |
| 3490 | 768 | — | α Aql | 0.1 | A7 V (be), A7 IV-V (am), A5 (af) |
| 3491 | — | — | CD -59°7305 | 0.6 | G8 V (bf) |
| 3492 | — | — | — | 1.6 | — |
| 3493 | — | 92-34 | — | 1.3 | — |
| 3494 A* | 1245 A | 208-44 A | V1581 Cyg A | 1.5 | M5.5 V (bi), M5+ V (ah) |
| 3494 B* | 1245 C | 208-44 B | V1581 Cyg B | — | composite with LHS 3494 A |
| 3495 | 1245 B | 208-45 | — | 1.6 | M6 V (bi) |
| 3496 | — | — | — | 1.5 | — |
| 3497 | — | 125-45 | — | 1.3 | — |
| 3498 | — | — | — | 1.6 | — |
| 3499 | — | 230-18 | Wolf 1122 | 1.6 | M2 (af) |
| 3500 | — | — | — | 1.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3501 | 772 | 92-40 | — | -0.1 | DA6 (br), DAs (af) |
| 3502 | 773 A | — | BD -12°5594 A | 1.8 | K4 V (bf), K7 (af), M1.5 V (bh) |
| 3503 | 773 B | — | BD -12°5594 B | 1.5 | — |
| 3504 | — | — | — | 1.6 | M3: (af) |
| 3505 | — | 23-19 | — | 1.1 | — |
| 3506 | — | 186-7 | — | 1.3 | — |
| 3507 | 775.1 | — | BD +15°4026 | 0.9 | G7 V (am), G8 (af) |
| 3508 | 773.6 | — | CD -50°12780 | 1.2 | K4 V (bf) |
| 3509* | 777 B | 125-55 | BD +29°3872 B | 1.8 | M4 V (ai), M4: (af), M6 V (be) |
| 3510 | 777 A | — | BD +29°3872 A | 1.1 | G8 IV-V (am), G6 IV (be), G8 (af) |
| 3511 | 1248 | 23-24 | — | 1.3 | — |
| 3512 | 774 B | — | — | 1.5 | — |
| 3513 | 774 A | — | — | 1.5 | — |
| 3514 | — | — | — | 1.3 | — |
| 3515 | 779 | — | 15 Sge | 0.6 | G1 V (be), G1 V (am), F9 (af) |
| 3516 | — | — | — | 1.8 | — |
| 3517 | 776.1 | — | — | 1.5 | K4: (af) |
| 3518 | — | 230-25 | Wolf 1129 | 1.8 | M3.5 (af) |
| 3519 | — | 143-26 | — | 1.1 | — |
| 3520 | — | — | — | 1.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3521 | — | — | — | 1.6 | K3 (af) |
| 3522 | — | — | — | 1.5 | — |
| 3523 | 781.1 B | — | — | 1.6 | M3.5 (af) |
| 3524 | 781.1 A | — | — | 2.0 | M3 (af) |
| 3525 | — | — | — | 1.5 | — |
| 3526 | 782 | — | BD -20°5833 | 1.5 | K4 Vp (bf), K5 (af), M0 V (bh) |
| 3527 | 786 | 261-19 | BD +76°785 | 1.3 | K7 V (bi), K7 (af), M0.5 V (bh) |
| 3528 | — | — | — | 2.0 | — |
| 3529 | 783.2 A | 143-34 | BD +15°4074 A | 1.1 | K1 V (am), K1 (af) |
| 3530 | 783.2 B | 143-35 | BD +15°4074 B | 1.5 | — |
| 3531 | 784 | — | CD -45°13677 | 1.3 | M1-2 V (bf), M0 (af) |
| 3532 | 784.2 B | 24-9 | V1412 Aql | 0.2 | DQ7 (br), DC? (ag), DQ7+ (ba) |
| 3533 | 784.2 A | 24-10 | — | 1.6 | M5 V (ag) |
| 3534 | — | — | — | 1.5 | — |
| 3535 | — | — | — | 1.6 | — |
| 3536 | — | 143-41 | — | 1.3 | K2 (bk) |
| 3537 | 788 | — | BD +66°1281 | 0.6 | G3 V (be), G3 V (am), G1 (af) |
| 3538 | — | — | — | 1.5 | — |
| 3539 | — | — | — | 2.3 | — |
| 3540 | 788.2 | — | — | 1.3 | K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|------------|-------------|------------------------------|
| 3541 | — | — | — | 0.1 | — |
| 3542 | 788.1 | — | CD -58°7734 | 1.5 | — |
| 3543 | — | 230-37 | — | 1.1 | — |
| 3544 | — | 143-48 | — | 1.3 | — |
| 3545 | — | 261-22 | — | 1.6 | — |
| | | | | | |
| 3546 | — | — | — | 1.5 | — |
| 3547 | — | 261-23 | — | 1.5 | — |
| 3548 | — | — | — | 1.7 | sdM0 (ai), sd (bb) |
| 3549 | 1253 | 230-40 | Wolf 1069 | 1.6 | M5 (af) |
| 3550 | — | 24-15 | BD +9°4529 | 0.6 | sdF7 (am), F8 (af) |
| | | | | | |
| 3551 | — | — | — | 1.1 | — |
| 3552 | — | — | — | 1.5 | — |
| 3553 | 791 | — | CD -28°16676 | 1.9 | M3 (af) |
| 3554 | 790 | — | CD -31°17597 | 0.9 | G5-8 V (be), G6-8 V (bf), G8 (af) |
| 3555 | — | — | — | 2.2 | — |
| | | | | | |
| 3556* | 791.2 | 24-16 | HU Del | 2.2 | M4.5 V (bi), M4 V (ag), M6 V (cb) |
| 3557* | — | 24-17 | — | 0.9 | K2 (bk) |
| 3558* | 793 | 262-15 | — | 1.6 | M3 (af), M3 V (bh) |
| 3559 | 792 | 209-33 | Ross 188 | 1.8 | M4 (af) |
| 3560 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3561 | — | 24-19 | — | 1.1 | M1 (bk) |
| 3562 | 794 | 186-31 | Wolf 1346 | -0.2 | DA3 (br) |
| 3563 | — | — | — | 1.1 | — |
| 3564 | — | 24-20 | — | 1.8 | — |
| 3565 A* | 1255 A | 261-28 A | BD +75°752 A | 0.9 | K0-1 V + G5-6 (be), K0 V (am), K0 V (ag) |
| 3565 B* | 1255 B | 261-28 B | BD +75°752 B | — | composite with LHS 3565 A and C |
| 3565 C* | 1255 C | 261-28 C | BD +75°752 C | — | composite with LHS 3565 A and B |
| | | | | | |
| 3566 | — | — | — | 2.3 | M6 V (ad) |
| 3567 | — | 186-35 | — | 1.5 | — |
| 3568 A* | 795 A | 24-23 A | BD +4°4510 A | 1.2 | K5 V (am), K5 V (al), K4 (af) |
| 3568 B* | 795 B | 24-23 B | BD +4°4510 B | — | — |
| 3569 | 794.2 | — | $\phi^2$ Pav | 0.4 | F8 V (be) |
| 3570 | 796 | — | CD -24°16193 | 0.9 | G8-K0 V (bf), G8 V (be), G8 (af) |
| | | | | | |
| 3571 | — | — | — | 1.5 | — |
| 3572 | 1257 | — | BD -22°5504 | 1.1 | K5 V (bf), K5 (af) |
| 3573 | — | 144-29 | — | 1.3 | — |
| 3574 | 1258 | 210-31 | Ross 766 | 1.2 | K7 (af), M3 V (bh) |
| 3575 | — | — | — | 2.1 | — |
| | | | | | |
| 3576 | 804 | 144-34 | BD +19°4499 | 1.3 | K7 (af), M1.5 V (bh) |
| 3577* | 806 | 209-41 | — | 1.5 | M2 V (bi), M3 V (bh), M3 V (cb) |
| 3578 | 807 | — | $\eta$ Cep | 1.0 | K0 IV (be), K0 IV (am), G8 (af) |
| 3579 | 2150 | 25-1 | — | 1.1 | — |
| 3580 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3581 | — | — | — | 1.5 | — |
| 3582 | — | — | CD -47°13548 | 1.3 | M0.5 (af) |
| 3583 | — | — | — | 1.5 | — |
| 3584 | — | 25-3 | BD +10°4379 | 1.3 | K2 (ag) |
| 3585 | — | — | — | 1.5 | — |
| | | | | | |
| 3586 | — | 262-27 | — | 0.9 | K7 (af) |
| 3587 | — | 144-40 | Ross 258 | 1.6 | M3 (af) |
| 3588 | — | — | — | 1.1 | — |
| 3589 | — | 187-8 | — | 1.1 | DC9 (br) |
| 3590 | — | 231-17 | BD +52°2815 | 1.3 | K5 (af) |
| | | | | | |
| 3591 | — | 210-38 | — | 1.7 | — |
| 3592 | 1255- | 261-29 | BD +74°889 | 0.8 | G8 V (am), G8 (af) |
| 3593 | — | 25-8 | — | 2.2 | — |
| 3594 | — | — | — | 1.8 | — |
| 3595* | 809 | 231-19 | BD +61°2068 | 1.6 | M0 V (bi), M1 (af), M2 V (bh) |
| | | | | | |
| 3596 | — | — | BD -3°5059 | 1.2 | K5 (af), sd (bw) |
| 3597 | — | — | — | 1.5 | — |
| 3598 | 1259 | 144-44 | BD +12°4499 | 1.3 | K5 (af), K5 V (ag) |
| 3599 | — | 25-9 | — | 0.9 | M3 V (ai) |
| 3600 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3601 | 812 B | — | vB 11 | 1.1 | DC9 (br), DC9 (bn), DC13 (ba) |
| 3602 | 812 A | — | Ross 193 | 1.7 | M3 (af) |
| 3603 | — | — | — | 1.3 | — |
| 3604 | — | 25-10 | — | 0.9 | — |
| 3605 | 813 | 187-9 | Wolf 1373 | 1.6 | M3 (af) |
| | | | | | |
| 3606 | — | — | — | 1.8 | sdK5-M0 (ai) |
| 3607 | — | 25-11 | Wolf 901 | 1.2 | K5 (af) |
| 3608 | — | — | CD -70°1800 | 0.9 | G1 IV-V (bf), G1 IV-V (be) |
| 3609 A* | 815 A | 210-48 A | — | 1.5 | M2 (af), M3 V (bh), M3 V (cb) |
| 3609 B* | 815 B | 210-48 B | — | — | composite with LHS 3609 A and C |
| 3609 C* | 815 C | 210-48 C | — | — | composite with LHS 3609 A and B |
| 3610 | — | 144-50 | — | 1.9 | — |
| | | | | | |
| 3611 | — | — | — | 1.5 | — |
| 3612 | 816 | — | Wolf 906 | 1.5 | M2.5 (af) |
| 3613 | — | — | CD -47°13670 | 1.4 | — |
| 3614 | — | — | — | 1.5 | M3: (af) |
| 3615 | — | — | — | 1.5 | — |
| | | | | | |
| 3616 | — | — | — | 1.7 | — |
| 3617 | — | — | — | 1.8 | — |
| 3619 | — | 144-58 | — | 1.5 | — |
| 3620 | — | — | — | 1.3 | sdM (ac) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3621 | — | 144-60 | — | 1.3 | — |
| 3622 | — | 144-61 | — | 1.3 | — |
| 3623 | — | — | — | 1.3 | M1.5 (af) |
| 3624 | 818 | 25-16 | BD +6°4741 | 1.2 | K4 (af) |
| 3625 | — | 144-62 | BD +1°4614 | 1.1 | K5 (af), K5 (bk) |
| 3626 | — | — | — | 1.5 | — |
| 3627 | — | — | — | 1.5 | — |
| 3628 | — | — | — | 1.8 | sdM (bm) |
| 3629 | — | — | CD -47°13695 | 0.9 | G8 (bf), K1 (af) |
| 3630 | — | — | — | 1.7 | — |
| 3631 | — | 261-38 | BD +73°925 | 1.2 | K1 V (am), K2 (af) |
| 3632 | — | — | — | 1.5 | — |
| 3633 | — | — | — | 1.7 | — |
| 3634 | — | — | — | 1.6 | — |
| 3635* | 818.1 | — | CD -73°1547 | 1.3 | F8-G0 V (be), F8-G0 V (bf) |
| 3636 | — | — | — | -0.3 | DA9 (br), DA9 (ba) |
| 3637 A* | — | 187-30 A | Ross 825 A | 1.3 | K3 (af), K3+ (ag) |
| 3637 B* | — | 187-30 B | Ross 825 B | — | composite with LHS 3637 A |
| 3638 | — | 212-29 | — | 1.1 | — |
| 3639 | — | — | CD -44°14334 | 1.6 | M1 (af) |
| 3640 | — | — | BD +17°4519 | 1.4 | sdF8 (am), F9 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3641 | — | 145-23 | vMa 72 | 1.6 | M3.5 (af) |
| 3642 | — | 261-39 | — | 1.5 | — |
| 3643 | — | — | — | 1.5 | — |
| 3644 | — | — | — | 1.5 | — |
| 3645 | — | — | — | 1.7 | — |
| 3646 | — | 211-15 | — | 1.1 | — |
| 3647 | — | — | — | 1.5 | — |
| 3648 | — | — | — | 2.0 | — |
| 3649 | — | 231-39 | Ross 197 | 0.9 | K3 (af) |
| 3650 | — | — | — | 1.3 | K3 (af) |
| 3651 | — | 145-35 | — | 1.1 | — |
| 3652 | 825.1 | — | CD -61°6571 | -0.6 | G5 V (be) |
| 3653 | — | 187-39 | — | 1.8 | — |
| 3654 | — | — | — | 1.6 | G5 (af) |
| 3655* | 825.4 A | — | CD -26°15541 A | 0.9 | G5 V (bf), G5 V (be), K5 (af) |
| 3656 | 825.4 B | — | CD -26°15541 B | 1.2 | — |
| 3657 | 826.1 | — | BD -20°6185 | 1.2 | K5 V (bf), K7 (af), M0 V (bh) |
| 3658 | — | — | — | 1.5 | — |
| 3659 | — | — | — | 1.5 | — |
| 3660 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|-----------------------------|
| 3661 | — | — | — | 1.9 | — |
| 3662 | — | — | — | 1.7 | — |
| 3663 | — | — | — | 1.5 | — |
| 3664 | — | — | — | 1.5 | — |
| 3665 | — | — | — | 1.8 | — |
| 3666 | 826.2 | — | — | 1.5 | M2 (af) |
| 3667 | — | 145-37 | — | 1.3 | K7 (af) |
| 3668 | — | — | — | 1.5 | — |
| 3669 | — | — | — | 1.3 | — |
| 3670 | — | 231-42 | — | 1.3 | — |
| 3671 | — | — | — | 1.5 | — |
| 3672 | — | — | — | 1.3 | — |
| 3673 | — | 187-43 | — | 2.1 | — |
| 3674 | 827 | — | $\gamma$ Pav | 0.4 | F7 V (bf), F6 V (be) |
| 3675 | 827.1 | — | CD -56°8316 | 0.9 | K3 V (bf) |
| 3676 | — | 231-44 | vB 29 | 1.6 | — |
| 3677 | — | 25-32 | Ross 778 | 1.8 | M0.5 (af), M2 (bk) |
| 3678 | — | 212-39 | BD +45°3561 | 0.9 | G8 V (am) |
| 3679 | — | — | — | 1.6 | M1.5: (af) |
| 3680 | — | 126-5 | — | 1.8 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3681 | — | — | — | 3.1 | — |
| 3682 A* | — | 26-5 A | Wolf 921 A | 1.5 | K4: (af) |
| 3682 B* | — | 26-5 B | Wolf 921 B | — | composite with LHS 3682 A |
| 3683 | — | — | — | 2.3 | — |
| 3684 | — | — | — | 1.7 | M3: V (ai) |
| 3685 | 832 | — | CD -49°13515 | 1.5 | M2-3 V (bf), M3 (af) |
| | | | | | |
| 3686 | — | 26-14 A | — | 1.5 | — |
| 3687 | 836.2 | 261-45 | — | 0.0 | — |
| 3688 | — | 26-14 B | — | 1.5 | — |
| 3689 | — | 26-13 | Wolf 923 | 1.3 | M3.5 (af) |
| 3690 | — | — | — | 1.5 | M4.5 V (ai) |
| | | | | | |
| 3691 | — | — | — | 1.5 | — |
| 3692 | — | — | CD -50°13411 | 0.9 | G3 V (bf) |
| 3693 | — | 215-2 | Wolf 926 | 1.8 | M3.5 (af) |
| 3694 | — | — | — | 1.1 | — |
| 3695 | — | 93-25 | — | 2.2 | — |
| | | | | | |
| 3696 | — | 26-21 | BD -2°5588 | 1.1 | K0 (af) |
| 3697 | — | — | — | 1.7 | — |
| 3698 | — | 188-15 | — | 1.5 | — |
| 3699 A* | — | 231-53 A | Ross 200 A | 1.7 | M3 (af) |
| 3699 B* | — | 231-53 B | Ross 200 B | — | composite with LHS 3699 A |
| 3700 | — | 213-9 | — | 1.6 | M3 (bk) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3701 | — | — | — | 1.5 | — |
| 3702 | 836.4 | — | Ross 206 | 1.7 | M1.5: (af) |
| 3703 | 836.5 | 126-27 | — | -0.2 | DQ6 (br), DQ6 (ba) |
| 3704 | — | 188-24 | BD +24°4460 | 1.1 | — |
| 3705 | — | 212-56 | BD +43°4035 | 1.1 | M1.5 (af), M2 (bk) |
| | | | | | |
| 3706 | — | 26-29 | — | 1.3 | K3 (af) |
| 3707 A* | 836.9 A | — | CD -58°8156 A | 1.5 | — |
| 3707 B* | 836.9 B | — | CD -58°8156 B | — | — |
| 3708 | 1263 | 26-30 | Wolf 940 | 2.1 | M3.5 (af) |
| 3709 | — | — | — | 1.3 | — |
| 3710 | — | — | — | 1.5 | — |
| | | | | | |
| 3711 | — | 212-59 | Wolf 945 | 1.5 | M4 (af) |
| 3712 | — | — | — | 1.9 | — |
| 3713 | — | 188-26 | — | 1.6 | — |
| 3714 | — | — | — | — | — |
| 3715 | — | — | — | 1.5 | M3.5 (af) |
| | | | | | |
| 3716 | — | — | — | — | composite with LHS 3715 |
| 3717 | 838.1 A | 93-40 | BD +5°4874 | 1.2 | K3 V (am), K3 (af) |
| 3718 | — | — | — | 1.5 | — |
| 3719 | — | — | — | 1.6 | — |
| 3720 | 838.1 B | 93-41 | — | 2.0 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 3721 | — | — | — | 1.5 | — |
| 3722 | — | 18-1 | — | 1.7 | — |
| 3723 | — | — | — | 1.3 | M4.5 V (ai) |
| 3724 | — | — | — | 2.1 | — |
| 3725 | — | 188-28 | — | 1.6 | — |
| | | | | | |
| 3726 | — | — | — | — | — |
| 3727 | 839 | 215-20 | — | 1.3 | M0.5 V (bi), M1 V (bh), K7 (af) |
| 3728 | — | — | — | — | — |
| 3729 | — | 215-21 | — | 1.5 | — |
| 3730 | — | 215-22 | Wolf 1567 | 1.3 | K5 (af) |
| | | | | | |
| 3731* | — | 188-30 | Wolf 1143 | 0.6 | G2 (af) |
| 3732 | — | — | — | 1.5 | K3:: (af), sd (bw) |
| 3733 | — | — | — | 1.1 | — |
| 3734 | — | — | — | 1.1 | sdM (ba) |
| 3735 | — | — | — | 1.5 | — |
| | | | | | |
| 3736 | — | — | — | 1.5 | — |
| 3737 | — | — | BD +29°4550 | 0.4 | F8 V-VI (be), sdF8 (am) |
| 3738 | — | — | — | 1.7 | — |
| 3739 | — | — | — | 1.8 | — |
| 3740 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3741 | 842 | — | CD -60°7821 | 1.1 | — |
| 3742 | — | 18-14 | BD +9°4955 | 1.1 | K4 (af) |
| 3743 | — | 188-37 | — | 1.5 | — |
| 3744 | 843 | — | — | 1.6 | M3 (af) |
| 3745 | 846 | 18-16 | BD +0°4810 | 1.3 | M0.5 V (bi), M0.5 V (ah), M0.5 V (al) |
| 3746 | — | — | — | 1.5 | M3.5 (af) |
| 3747 | — | — | — | 1.5 | — |
| 3748 | — | — | — | 1.5 | — |
| 3749 | — | 264-17 | — | 1.5 | — |
| 3750 | 847 A | — | — | 1.5 | — |
| 3751 | 847 B | — | — | 1.5 | — |
| 3752 | — | — | — | -0.1 | DA5 (br) |
| 3753 | — | — | — | 0.6 | — |
| 3754 | — | — | — | 1.5 | — |
| 3755 | — | — | — | 1.5 | — |
| 3756 | — | — | — | 2.1 | M3.5 (af) |
| 3757 | — | — | — | 1.5 | — |
| 3758 | — | 232-54 | BD +52°3112 | 1.1 | G8 V (am) |
| 3759 | — | — | — | 1.8 | — |
| 3760 | — | 18-31 | Wolf 990 | 1.6 | M4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3761 | — | — | — | — | — |
| 3762 | — | — | — | 2.8 | — |
| 3763 | — | — | — | 1.1 | — |
| 3764 | 848.3 A | 27-14 A | Wolf 1328 A | 1.5 | M0 (af) |
| 3765 | 848.3 B | 27-14 B | Wolf 1328 B | 1.6 | — |
| 3766 | — | — | CD -79°878 | 1.5 | — |
| 3767 | — | 126-60 | BD +22°4567 | 1.3 | K3 (af) |
| 3768 | — | — | — | 3.6 | sd (bb) |
| 3769 | — | — | — | — | — |
| 3770 A* | — | 126-62 A | BD +17°4708 A | 0.6 | sdF8 (am), F2 (af) |
| 3770 B* | — | 126-62 B | BD +17°4708 B | — | composite with LHS 3770 A |
| 3771 | 851.1 | 188-46 | BD +30°4633 | 1.3 | K4 (af), M0 V (ag), M0 V (bh) |
| 3772 | — | — | — | 1.7 | — |
| 3773 | — | 18-36 | Wolf 1014 | 1.6 | M3 (af) |
| 3774 | — | — | — | 1.3 | — |
| 3775 | — | — | — | 1.5 | — |
| 3776 | 1265 | — | — | 1.8 | M4 (af) |
| 3777 | — | — | — | 1.1 | — |
| 3778 | — | — | — | 1.0 | — |
| 3779 | — | — | — | -0.2 | DC?8 (br), DC?8+ (ba) |
| 3780 | — | — | Wolf 1332 | 0.9 | K2 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3781 | 851.1 | 127-11 | — | 1.5 | M0.5 V (ag), M0.5 V (bh) |
| 3782 | 851.2 | — | CD -41°14804 | 0.6 | G5 V (bf), G5 V (be) |
| 3783 | 1266 | 241-1 | — | 1.1 | dK (bo) |
| 3784 | — | 188-51 | — | 2.1 | — |
| 3785 | — | — | — | 2.5 | — |
| | | | | | |
| 3786 | — | — | BD +12°4797 | 0.6 | G2 V (be), G2 V (am), G2 (af) |
| 3787 | 852 A | — | Wolf 1561 | 1.7 | M4: (af), M4.5 V (bh) |
| 3788 | 852 B | — | — | 1.6 | M5 (af), M5 V (bh) |
| 3789 | — | — | — | — | — |
| 3790 A* | 853 A | — | CD -54°9222 A | 0.6 | G3 V (bf), G3 V (be) |
| 3790 B* | 853 B | — | CD -54°9222 B | — | composite with LHS 3790 A |
| | | | | | |
| 3791 | — | — | — | 1.3 | K2: (af) |
| 3792 | — | — | CD -42°15867 | 1.5 | K3 (af) |
| 3793 | — | — | — | 1.6 | — |
| 3794 | — | — | — | -0.1 | DZ5 (br) |
| 3795 | — | 18-42 | — | 1.3 | — |
| | | | | | |
| 3796 | — | 189-11 | — | 2.3 | — |
| 3797 | — | 189-12 | Wolf 1216 | 2.2 | K3 (af) |
| 3798 | — | — | — | 1.5 | K4 (af) |
| 3799 | — | — | — | 1.7 | M4 (af) |
| 3800 | — | — | — | — | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3801 | — | 18-45 | — | 1.1 | — |
| 3802 | 855 | — | CD -57°8454 | 1.5 | — |
| 3803 | — | — | — | 1.5 | — |
| 3804 | — | — | — | 1.5 | M3.5 (af) |
| 3805 | — | — | — | — | — |
| | | | | | |
| 3806 | — | — | — | 1.5 | — |
| 3807 | 858 | — | — | 1.3 | K1 (af) |
| 3808 | — | 18-48 A | Wolf 1201 A | 1.8 | — |
| 3809 | — | 18-48 B | Wolf 1201 B | 1.9 | — |
| 3810 | — | 215-46 | — | 1.3 | — |
| | | | | | |
| 3811 | — | — | — | 1.3 | — |
| 3812 | — | 232-71 | Ross 666 | 1.1 | A2 (ag) |
| 3813 | — | — | — | 1.5 | K3: (af) |
| 3814* | 860 A | 232-75 A | BD +56°2783 A | 1.7 | M3 V (bi), M3.5 V (ah), M3 (af) |
| 3815 | 860 B | 232-75 B | BD +56°2783 B | 1.8 | M4 V (bi), M4: (af), M4.5 V (bh) |
| | | | | | |
| 3816 | — | — | — | 2.2 | — |
| 3817 | 862 | — | CD -30°19175 | 1.2 | K4 (af) |
| 3818 | — | 215-49 | — | 1.5 | — |
| 3819 | — | — | — | 1.6 | — |
| 3820 | — | — | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|------|--------|--------|------------|----------------|------------------------------|
| 3821 | — | — | — | -0.1 | — |
| 3822 | — | 263-21 | — | 1.3 | — |
| 3823 | — | 189-23 | — | 1.7 | — |
| 3824 | — | — | — | 1.1 | — |
| 3825 | — | 27-32 | — | 1.3 | — |
| 3826 | — | — | — | 1.5 | — |
| 3827 | — | — | — | 1.5 | — |
| 3828 | 863 | 18-56 | BD +8°4887 | 1.6 | M2 V (bh) |
| 3829 | — | 241-12 | — | 1.3 | — |
| 3830 | — | 241-13 | — | 1.3 | — |
| 3831 | — | — | — | 1.5 | — |
| 3832 | — | — | — | — | — |
| 3833* | 864 | 27-36 | BD -1°4323 | 1.6 | M0 (af), M1.5 V (bh) |
| 3834 | — | — | — | 2.1 | — |
| 3835 | — | 189-28 | — | 1.6 | — |
| 3836 | — | — | — | 1.6 | — |
| 3837 | — | — | — | >3.1 | — |
| 3838 | — | 67-8 | BD +9°5076 | 1.1 | K2 (af), K0 V (ag) |
| 3839* | 865 | — | — | 1.3 | M3 V (bw) |
| 3840 | — | 27-38 | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 3841 | — | — | — | — | — |
| 3842 | — | — | — | 1.5 | — |
| 3843 | — | — | — | 1.8 | — |
| 3844 | — | — | — | 1.6 | — |
| 3845 | — | — | — | 1.1 | M5: V (bc) |
| | | | | | |
| 3846 | — | 156-43 | — | 1.9 | — |
| 3847 | — | 27-45 | Ross 288 | 0.9 | K0 (af) |
| 3848 | — | — | — | 1.5 | — |
| 3849 | — | — | — | 1.5 | — |
| 3850 | — | — | — | 1.6 | M5 V (ai) |
| | | | | | |
| 3851 | 872 A | — | $\xi$ Peg A | 0.5 | F6 III-IV (be), F7 V (am), F8 (af) |
| 3852 | 872 B | — | $\xi$ Peg B | 1.5 | M1 (af) |
| 3853* | 873 | 216-16 | BD +43°4305 | 1.8 | M3.5 V (bi), M4- V (ah), M3.5 (af) |
| 3854 | — | 128-3 | — | 1.7 | — |
| 3855 | 874 | — | — | 1.5 | M3 (af) |
| | | | | | |
| 3856 | — | — | — | 1.6 | — |
| 3857 | 1273 | 67-23 | — | 0.1 | DA5 (br), DA (ag) |
| 3858 | — | 241-24 | — | 1.5 | — |
| 3859 | 1274 | 189-38 | — | 1.8 | — |
| 3860 | — | 28-20 | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3861 | 875.1 | 128-8 | — | 1.7 | M3.5 V (bh) |
| 3862 | — | 128-10 | BD +30°4824 | 1.5 | K5 (af) |
| 3863 | — | — | — | 1.8 | M4.5 V (ai) |
| 3864 | — | — | $\sigma$ Peg A | 0.5 | F7 IV (be), F6 V or F7 IV (am), F7 (af) |
| 3865 | — | 28-21 | $\sigma$ Peg B | 1.7 | M3: (af) |
| 3866 | — | — | — | 2.8 | — |
| 3867 | — | 67-30 | — | 0.9 | — |
| 3868 | — | — | — | 1.3 | sdM (bm) |
| 3869* | — | 128-11 | Ross 237 | 1.1 | G8 (af) |
| 3870 | — | — | — | -0.2 | — |
| 3871 | 878 | 233-31 | Ross 226 | 1.9 | M3 (af) |
| 3872 | — | 156-63 | — | 2.1 | — |
| 3873 | — | — | — | 2.6 | — |
| 3874 | 878.1 A | 156-65 | BD -8°5980 A | 0.9 | G6 (af), G6 V (am) |
| 3875 | 878.1 B | 156-64 | BD -8°5980 B | 0.1 | — |
| 3876 | — | — | — | 1.5 | — |
| 3877 | — | 241-31 | — | 1.7 | — |
| 3878 | — | — | — | 1.5 | — |
| 3879 | — | 189-53 | — | 1.3 | — |
| 3880 | — | — | — | 1.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|--------------|------------------------------|
| 3881 | — | 241-32 | BD +68°1345 B | 1.5 | — |
| 3882 | — | 241-33 | BD +68°1345 A | 1.1 | K0 V (am), K0 (af) |
| 3883 | — | — | — | 2.1 | — |
| 3884 | — | — | — | 1.5 | — |
| 3885 | 884 | — | CD -23°17699 | 1.5 | K5-M0 V (bf), K7 (af) M0.5 V (bh) |
| 3886 | — | — | — | 1.8 | — |
| 3887 | — | — | — | 1.5 | — |
| 3888 | — | — | Ross 781 | 1.3 | K3 (af) |
| 3889 | — | — | CD -55°9220 | 1.5 | sd (bw) |
| 3890 | — | — | — | — | — |
| 3891 | — | — | — | — | — |
| 3892 | — | 67-42 | — | 2.0 | K7 (af), K7 (bk) |
| 3893 | — | — | — | 1.7 | — |
| 3894 | — | 241-42 | BD +67°1498 | 0.7 | G6 V (am), G8 (af) |
| 3895 | — | — | — | 1.5 | — |
| 3896 | — | — | — | 1.5 | — |
| 3897 | — | 28-34 | — | 1.1 | K3 (af) |
| 3898 | — | 275-6 | — | 2.1 | M1 (af) |
| 3899 | 889.1 | 28-39 | — | 1.1 | M0 V (al), M0 V (ag) |
| 3900 | — | 28-41 | BD -3°5577 | 1.3 | K3 V (am), K3 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3901 | — | — | — | — | — |
| 3902 | — | — | — | 1.5 | M5 V (ai) |
| 3903 | — | 190-13 | — | 1.3 | — |
| 3904 | 891 | 275-13 | CD -26°16501 | 1.3 | M2.5 (af) |
| 3905 | — | 275-14 | — | 1.7 | — |
| 3906 | — | — | — | 1.5 | — |
| 3907 | — | — | — | 1.1 | — |
| 3908 | — | — | — | — | — |
| 3909 | — | — | — | 1.5 | — |
| 3910 | — | — | — | 1.6 | — |
| 3911 | — | — | — | 1.1 | M4.5 V (ai) |
| 3912 | — | — | CD -63°1596 | 0.6 | G8 V (be), G8 V (bf) |
| 3913 | — | 157-32 | BD -9°6149 | 0.5 | F9 V (am), F9 V (be) |
| 3914 | — | 157-33 | BD -9°6150 | 0.9 | G3 V (am), G3 V (be) |
| 3915 | — | — | — | 1.5 | — |
| 3916 | — | — | — | 1.3 | — |
| 3917 | — | 157-35 | — | 0.1 | DZ8 (br), DZ7+ (ba) |
| 3918 | — | — | — | 1.8 | M1 (af) |
| 3919 | — | — | — | 1.4 | — |
| 3920 | — | — | γ Psc | 1.0 | G8 III (am), K0 III: (be), G8 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3921 | — | — | CD -67°2593 | 1.1 | K2-4 (bf) |
| 3922 | — | — | CD -67°2594 | 1.1 | K2-3 [V] (bf) |
| 3923 | — | 190-17 | — | 2.0 | — |
| 3924 | — | — | — | 1.5 | — |
| 3925 | — | — | — | 1.5 | — |
| 3926 | — | — | — | 2.7 | — |
| 3927 | — | 275-29 | — | 1.8 | K4: (af) |
| 3928 | — | — | — | — | — |
| 3929 | — | 157-44 | — | 1.8 | K5 (af) |
| 3930 | — | 217-1 | — | 1.7 | — |
| 3931 | — | 128-48 | BD +28°4562 | 1.2 | K1 V (am), K2 (af) |
| 3932 | — | 273-15 | — | 1.8 | K4 (af) |
| 3933 | — | — | — | 3.0 | — |
| 3934 | — | — | — | 1.3 | — |
| 3935 | — | — | — | 1.9 | — |
| 3936 | 894.4 | 190-20 | BD +43°4445 | 0.8 | K1 V (am), G9 (af) |
| 3937 | — | — | — | 1.6 | sdM1-3 (ai) |
| 3938 | — | 242-32 | — | 1.5 | — |
| 3939 | 894.5 | 157-54 | BD -11°6064 | 1.1 | K2 V (am), K2 (af) |
| 3940 | — | — | — | 1.6 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3941 | — | 157-59 | — | 1.9 | — |
| 3942 | — | 190-22 | BD +33°4707 | 1.1 | — |
| 3943 | — | 29-30 | Wolf 1038 | 1.1 | M0 (af) |
| 3944 | — | — | — | 1.5 | sdM0 (ai) |
| 3945 | — | 68-16 | Ross 291 | 1.3 | K5: (af) |
| 3946 | — | 128-61 | — | 1.3 | K3 (af) |
| 3947 | 2155 | 29-33 | — | 1.1 | M0.5 V (bi), sdM (ag), sdM (bt) |
| 3948 | — | 29-35 | — | 1.8 | — |
| 3948a | — | 275-46 | — | 1.5 | — |
| 3949 | — | — | — | 1.5 | — |
| 3950 | — | — | — | 0.9 | M5: V (bc) |
| 3951 | — | 190-24 | — | 1.3 | — |
| 3952 | — | 29-36 | — | 1.3 | — |
| 3953 | — | 157-64 | — | 1.5 | — |
| 3954 | — | — | — | 2.8 | — |
| 3955 | — | — | — | 1.5 | — |
| 3956 | — | — | — | 1.5 | — |
| 3957 | — | 190-26 | — | 1.6 | — |
| 3958 | — | — | — | 2.7 | — |
| 3959 | — | — | — | 1.5 | M3: (af) |
| 3960 | — | 68-22 | Ross 674 | 1.1 | K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 3961 | — | — | — | 1.3 | M5: V (bc) |
| 3962 | — | — | — | 0.9 | — |
| 3963 | — | — | — | 1.7 | — |
| 3964 | — | — | — | — | — |
| 3965 | 896 A | 68-24 A | BD +19°5116 A | 1.8 | M4- V (ah), M3 (af), M4 V (bh) |
| 3966 | 896 B | 68-24 B | BD +19°5116 B | 1.9 | M4+ V (ah), M4.5 (af), M5 V (bh) |
| 3967 | — | 241-57 | — | 1.1 | — |
| 3967a | — | 157-69 | — | 1.3 | — |
| 3968 | — | 128-73 | — | 1.3 | — |
| 3969 | — | — | — | 1.6 | — |
| 3970 | — | — | — | 2.0 | — |
| 3971 | — | — | — | — | — |
| 3972 | — | — | — | 1.5 | — |
| 3973 | — | — | — | 2.2 | — |
| 3974 | — | — | — | 1.9 | — |
| 3975 | — | — | — | 1.5 | K0 (af) |
| 3976 | — | — | BD +30°4982 A | 0.6 | F9 V (be), G2 V (am) |
| 3977 | — | — | BD +30°4982 B | 1.7 | M3: (af) |
| 3978 | — | — | — | 1.8 | — |
| 3979 | — | 29-49 | Wolf 1533 | 1.5 | M2 (af) |
| 3980 | — | 171-5 | — | 1.5 | M0 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 3981 | — | 29-51 | — | 1.3 | — |
| 3982* | — | 68-31 | BD +17°4946 | 0.9 | G6 (af), G5 V (am) |
| 3983 | — | — | — | — | — |
| 3984 | — | — | — | — | — |
| 3985 | — | — | — | 1.6 | — |
| 3986 | — | 29-55 | — | 1.1 | K3 (bk) |
| 3987 | — | — | — | 2.5 | mid-M (ai) |
| 3988 | 1287 | — | — | 1.5 | — |
| 3989 | — | — | — | 0.6 | — |
| 3990 | — | 273-95 | — | 1.7 | — |
| 3991 | — | 171-8 | — | 1.7 | — |
| 3992 | — | — | — | 1.5 | — |
| 3993 | — | 157-90 | — | 1.3 | — |
| 3994 | 902 | — | CD -73°1672 | 1.1 | K3 V (be), K4 V (bf) |
| 3995* | 904 | — | ι Psc | 0.4 | F8 (af), F7 V (be), F7-8 V (am) |
| 3996 | — | — | — | — | — |
| 3997 | — | — | — | 1.9 | — |
| 3998 | — | — | — | 1.5 | — |
| 3999 | — | — | — | 1.5 | M2 (af) |
| 4000 | — | 275-83 | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 4001 | — | — | — | 1.5 | — |
| 4002 | — | 171-11 | — | 1.5 | M3 V (ai) |
| 4003 | 1289 | 130-4 | — | 1.1 | M5 V (al) |
| 4004 | — | 241-66 | BD +57°2787 | 0.6 | G2 V (am), G2 V (be) |
| 4005 | — | 157-93 | BD -8°6177 | 0.6 | — |
| 4005a | — | 217-18 | — | 1.1 | — |
| 4006 | — | 241-68 | Ross 676 | 1.1 | M1.5 (af), M1 (bk) |
| 4007 | — | 68-38 | — | 1.7 | — |
| 4008 | — | 130-8 | BD +28°4634 | 1.2 | K0 (af), K2 V (am) |
| 4009 | — | 273-130 | — | 2.1 | — |
| 4010 | — | — | — | 1.6 | sdM0 (ai), sd (bb) |
| 4011 | — | 273-134 | — | 1.9 | — |
| 4012 | — | — | — | 1.5 | — |
| 4013 | — | — | CD -42°16457 | 0.2 | A3 V (bf), A2 V (be), A3 (af) |
| 4014 | — | 273-137 | — | 1.7 | K3: (af) |
| 4015 | 907 | 171-19 | Ross 249 | 1.7 | M2 V (al), M1.5 (af) |
| 4016 | — | 275-106 | — | 1.3 | M3.5: (af) |
| 4017 | — | 29-66 | — | 1.1 | — |
| 4018 | — | 130-11 | — | 1.3 | — |
| 4019 | — | 130-15 | — | 0.6 | DA9 (br), DA8+ (ba) |
| 4020 | — | 29-72 | BD +2°4723 | 0.8 | G7 V (am) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|----------------|------------------------------|
| 4021 | — | 273-147 | — | 1.7 | — |
| 4022 | — | 29-73 | — | 1.3 | M1 (bk) |
| 4023 | — | — | — | 1.5 | — |
| 4024 | — | — | — | 2.0 | — |
| 4025 | — | — | — | — | — |
| 4026 | — | — | — | 1.3 | — |
| 4027 | 908.2 | — | — | 1.9 | M3.5 (af), M4 V (ai) |
| 4028 | — | — | — | 1.5 | — |
| 4029 | — | — | — | 1.5 | — |
| 4030 | — | 31-11 | Wolf 1046 | 1.3 | K4: (af) |
| 4031 | — | — | CD -62°1464 | 1.1 | K3 V[w] (bf) |
| 4032 | — | 273-151 | — | 1.8 | — |
| 4033 | — | — | — | -1.0 | — |
| 4034 | — | — | — | 1.8 | — |
| 4035 | — | — | — | 2.0 | — |
| 4036 | — | 158-2 | — | 1.5 | M3:: (af) |
| 4037 | — | 266-1 | — | 0.9 | K3: (af) |
| 4038 | — | — | — | 1.5 | M4 (af) |
| 4039 | — | 275-121 B | — | 1.8 | M3.5 (af) |
| 4040 | — | 275-121 A | — | 0.0 | DA (br), DAs (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 4041 | — | — | — | -0.1 | DA (br), DA (af) |
| 4042 | — | — | — | -0.2 | — |
| 4043 | — | 171-27 | — | 0.0 | DQ6 (br), DQ6+ (ba) |
| 4044 | — | 130-24 | BD +27°4642 | 0.9 | K1 (af), K1 V (am) |
| 4045 | — | 130-25 | — | 1.8 | — |
| 4046 | — | 31-15 | — | 1.5 | — |
| 4047 | 912 | 31-17 | BD -6°6318 | 2.1 | M2 (af) |
| 4048 | — | 266-8 | CD -27°16491 | 1.1 | — |
| 4049 | — | 31-18 | — | 1.8 | — |
| 4050 | — | 273-183 | — | 1.3 | — |
| 4051 | — | 158-15 | — | 1.6 | — |
| 4052 | — | 242-44 | — | 1.5 | — |
| 4053 | — | 242-45 | — | 1.5 | — |
| 4054 | 913 | 171-29 | BD +45°4378 | 1.6 | M0.5 V (bh), K7 (af) |
| 4055 | — | 266-21 | BD -20°6684 | 0.8 | G8 V (bf), G7 V (am), G8 (af) |
| 4056 | — | 171-33 | — | 1.5 | — |
| 4057 | — | — | — | 1.9 | M5 V (ai) |
| 4058 | — | 267-11 | — | 1.6 | M4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5001 | — | 266-42 | BD -21°6537 | 1.5 | G2-3 V (bf), G0 (af) |
| 5001a | — | 32-9 | BD +18°24 | 1.1 | K5 (bk) |
| 5002 | — | — | — | -0.3 | — |
| 5003 | — | — | — | 0.6 | — |
| 5004 | — | 31-43 | — | 1.1 | — |
| 5004a | — | — | — | 1.6 | M3: (af) |
| 5005 | — | — | — | 1.6 | — |
| 5006 | — | 242-55 | — | 1.3 | — |
| 5007 | — | 242-56 | — | 1.1 | K5 (af), K5 (bk) |
| 5008 | — | — | — | 1.5 | — |
| 5009 | — | 217-56 | — | 1.3 | — |
| 5010 | — | 32-30 | — | 1.1 | — |
| 5011 | — | 32-31 | — | 2.1 | — |
| 5012 | — | 32-36 | — | 0.9 | K7: (bk) |
| 5013 | — | 242-64 | — | 1.3 | — |
| 5014 | — | — | — | 1.5 | — |
| 5015 | — | — | — | 1.1 | — |
| 5016 | — | 69-31 | — | -0.2 | DA5 (br), DA (ag), DA5+ (ba) |
| 5017 | — | 132-40 | — | 1.1 | — |
| 5018 | — | — | — | 0.3 | — |
| 5019 | 50 | 270-118 | BD -10°216 | 1.1 | K7 (af) |
| 5020 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5021 | — | — | — | 1.7 | — |
| 5022 | — | — | — | 1.5 | — |
| 5023 | — | — | — | 0.6 | DC9/DC?9 (br), DC10 (ba) |
| 5024 | — | — | — | 0.6 | DC9 (br), DC12 (ba) |
| 5025 | — | — | — | 0.8 | — |
| 5026 | — | 243-59 | Wolf 53 | 1.5 | M3.5 (af) |
| 5027 | 53.1 A | 34-2 A | BD +22°176 A | 1.3 | K4 V (am), K4 (af) |
| 5028 | 53.1 B | 34-2 B | BD +22°176 B | — | M3 (af) |
| 5029 | — | — | — | 1.3 | — |
| 5030 | — | 243-67 | — | 1.3 | — |
| 5031 | — | 269-140 | — | 1.6 | — |
| 5032 | — | — | — | 1.9 | — |
| 5033 | — | 272-15 | — | 1.1 | — |
| 5033a | — | — | — | 1.6 | — |
| 5034 | — | — | — | 1.5 | — |
| 5035 | 58.2 | 34-32 | BD +20°226 | 1.1 | K2 V (am), K3 (af) |
| 5036 | — | — | CD -52°305 | 1.1 | — |
| 5037 | — | 271-102 | — | 1.1 | — |
| 5037a | — | 72-23 | — | 1.7 | — |
| 5038 | — | 271-130 | — | 1.3 | K4: (af) |
| 5039 | — | 3-13 | Wolf 1065 | 1.1 | K3 (af), K3 (bk) |
| 5040 | — | — | — | 0.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5041 | — | — | — | 1.5 | — |
| 5042 | — | — | — | 3.2 | — |
| 5043 | — | 274-106 | — | 2.0 | — |
| 5044 | — | 133-47 | — | 1.3 | — |
| 5045 | — | — | — | 1.5 | — |
| 5046 | — | — | — | >2.1 | — |
| 5047 | — | — | — | 2.7 | — |
| 5048 | — | 71-51 | BD +3°275 B | 1.9 | M1.5 (af) |
| 5049 | — | 71-50 | BD +3°275 A | 1.3 | K4 (af) |
| 5050 | — | 173-37 | — | 1.2 | — |
| 5051 | — | 35-30 | — | 1.3 | — |
| 5051a | — | — | BD +23°303 | 0.9 | G8 IV (be) |
| 5051b | — | 244-59 | BD +64°312 | 0.9 | G8 (af) |
| 5052 | — | — | — | 2.9 | — |
| 5053 | — | — | — | 1.1 | — |
| 5054 | — | — | — | 1.8 | — |
| 5055 | — | — | — | 1.5 | — |
| 5056 | — | — | — | 1.1 | — |
| 5057 | — | — | — | 1.6 | — |
| 5058 | — | — | — | 1.7 | — |
| 5059 | — | — | — | 1.3 | — |
| 5060 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5061 | — | 75-44 | — | 1.1 | — |
| 5062 | — | — | — | 2.4 | — |
| 5063 | — | — | BD -11°569 | 0.9 | — |
| 5064 | — | 76-48 | — | -0.2 | DA8 (br), DAwk (ag) |
| 5065 | — | — | — | 1.3 | — |
| 5066 | — | — | — | 1.3 | — |
| 5067 | — | — | — | 1.5 | — |
| 5068 | — | — | — | 1.3 | — |
| 5069 | — | — | — | 1.7 | — |
| 5070 | — | — | — | 0.1 | — |
| 5071 | — | — | — | 1.8 | — |
| 5072 | — | — | — | 1.6 | M2 (af) |
| 5073 | — | 78-35 | — | 1.5 | — |
| 5074 | — | 77-66 | — | 1.7 | — |
| 5075 | — | 79-54 | — | 1.1 | — |
| 5076 | — | — | — | 1.7 | — |
| 5077 | — | — | — | 1.5 | — |
| 5078 | — | — | — | 1.5 | — |
| 5079 | — | 160-17 | — | 1.3 | — |
| 5080 | — | 221-20 | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5081 | — | 221-21 | — | 1.5 | M0 (af) |
| 5082 | — | — | — | >1.9 | — |
| 5083 | — | — | — | 1.5 | — |
| 5084 | — | — | — | 0.6 | — |
| 5085 | — | 175-7 | — | 0.9 | — |
| 5087 | 156 | 160-35 | BD -7°699 | 1.5 | M0.5 V (bq), K7 (af) |
| 5088 | — | 80-38 | — | 1.3 | — |
| 5089 | — | — | — | 1.6 | — |
| 5090 | — | — | — | 1.6 | — |
| 5091 | — | 175-17 | Ross 27 | 1.9 | M3.5 (af) |
| 5092 | — | 160-53 | — | 1.3 | — |
| 5093 | — | 247-20 | — | 1.8 | — |
| 5094 | — | — | — | 1.5 | — |
| 5095 | — | 8-35 | — | 1.1 | — |
| 5096 | — | 39-14 | — | 0.9 | — |
| 5097 | — | — | — | 2.3 | — |
| 5098 | — | — | — | 1.3 | M1 (af) |
| 5098a* | — | — | CD -38°1631 | 1.3 | G5: (af) |
| 5099 | — | — | — | 1.3 | — |
| 5100 | — | 8-54 | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5101 | — | 84-42 | BD +0°989 | 1.7 | M0 (ag), M0 (bp) |
| 5102 | — | — | — | 1.1 | — |
| 5103 | — | — | — | 1.3 | — |
| 5104 | — | — | — | 1.1 | — |
| 5105 | — | — | — | 1.5 | — |
| 5106 | — | — | — | 1.5 | — |
| 5107 | — | 99-16 | BD -0°981 | 1.1 | G5 V (am) |
| 5108 | — | 86-45 | — | 1.3 | — |
| 5109 | — | — | Wolf 1457 | 1.6 | M4 (af) |
| 5110 | — | 97-55 | — | 1.5 | — |
| 5112 | — | — | CD -46°2096 | 1.5 | M0 (af) |
| 5113 | — | 106-35 | — | 1.7 | — |
| 5115 | — | — | — | 1.5 | — |
| 5116 | — | 103-34 | BD +27°1124 | 1.1 | K1 (af), K2 V (am) |
| 5117 | — | 105-41 | — | 1.3 | — |
| 5118 | — | — | — | 2.0 | — |
| 5119 | — | 250-19 | — | 1.1 | K0 (af) |
| 5120 | — | 108-37 | — | 2.2 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5121 | — | 107-32 | — | 1.8 | — |
| 5122 | — | — | — | 1.7 | — |
| 5122a | — | 107-58 | — | 1.1 | — |
| 5123 | — | 89-7 | — | 1.8 | — |
| 5124 | — | — | BD -12°1914 | 1.2 | K3 (af), K3 V (bf) |
| 5125 | — | — | — | 1.3 | — |
| 5126 | — | — | — | 2.2 | — |
| 5126a | — | 251-43 | — | 1.5 | — |
| 5127 | 1100 | — | Ross 391 | 1.5 | M0.5 (af) |
| 5128 | — | 50-8 | — | 1.4 | — |
| 5129 | — | — | — | 2.3 | — |
| 5130 | 290 | — | BD +80°238 | 0.9 | G8 V (be), G9 (af) |
| 5131 | — | 90-36 | Wolf 1059 | 0.6 | — |
| 5132 | — | — | — | 1.5 | — |
| 5133 | — | 40-7 A | BD +21°1764 A | 1.1 | — |
| 5134 | — | 40-7 B | BD +21°1764 B | 1.5 | — |
| 5135 | — | — | — | 1.3 | — |
| 5136 | — | 113-24 | BD -3°2288 | 0.6 | G4 (af) |
| 5137 | — | — | — | 1.7 | — |
| 5138 | — | — | — | -0.1 | — |
| 5139 | — | 115-11 | — | 1.6 | — |
| 5139aA* | 314 A | — | BD -22°2345 A | 0.8 | G3-5 V (bf), G6 IV (be), G6 (af) |
| 5139aB* | 314 B | — | BD -22°2345 B | — | — |
| 5140 | — | 9-19 | — | 0.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5141 | — | — | — | 1.5 | — |
| 5142 | — | — | — | 3.8 | M6 V (bi) |
| 5143 | — | — | — | 2.1 | — |
| 5144 | — | 41-26 | — | 1.5 | — |
| 5145 | — | — | — | 1.8 | — |
| | | | | | |
| 5146 | — | — | — | 2.4 | — |
| 5146a | — | — | — | 1.5 | — |
| 5146b | — | 47-28 | — | 2.7 | — |
| 5147 | — | — | — | 1.1 | — |
| 5148 | — | — | — | 1.5 | — |
| 5149 | — | — | CD -57°2585 | 1.1 | K/M V (bf) |
| 5150 | — | 253-23 | — | 1.5 | — |
| | | | | | |
| 5151 | — | — | — | 1.1 | — |
| 5152 | — | 48-15 | — | 1.6 | — |
| 5153 | — | 161-38 | BD -4°2639 | 1.9 | — |
| 5154 | — | — | — | 1.3 | — |
| 5155 | — | — | — | 1.7 | — |
| | | | | | |
| 5156 | — | — | — | 1.5 | — |
| 5157 | — | 195-46 | — | 1.7 | — |
| 5158 | — | 49-27 | Ross 96 | 1.2 | K3 (af) |
| 5159 | — | 48-52 | — | 1.8 | — |
| 5160 | — | — | — | 1.9 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5161 | — | 116-70 | — | 1.8 | — |
| 5162 | — | 116-71 | — | 1.7 | M0 V (al) |
| 5163 A | — | 195-52 A | BD +56°1421 A | 1.0 | G8 IV-V (am) |
| 5163 B | — | 195-52 B | BD +56°1421 B | — | — |
| 5164 | — | 43-22 | — | 1.5 | — |
| 5165 | — | — | — | 3.2 | — |
| 5166 | — | — | — | 2.1 | — |
| 5166a | 379.2 | — | CD -36°6180 | 0.6 | G3 V (bf), G1 (af) |
| 5166b | — | — | — | 1.6 | — |
| 5167* | 388 | 54-23 | BD +20°2465 | 1.6 | M3.5 V (ah), M3.5 (af), M3.5 V (bh) |
| 5168 | — | 118-51 | — | 1.1 | — |
| 5168a | — | — | BD -16°3030 | 0.9 | G8 V (bf), K0 (af) |
| 5169 | — | — | — | 2.1 | — |
| 5170 | — | 196-24 | — | 1.5 | — |
| 5171 | — | 44-19 | — | 1.1 | — |
| 5171a | — | 196-31 | — | 1.3 | — |
| 5172 | — | — | — | — | — |
| 5173 | — | — | — | 1.8 | — |
| 5174 | — | — | — | 2.1 | — |
| 5175 | — | — | — | 1.3 | — |
| 5176 | — | — | — | 1.5 | M3-4 (bp) |
| 5177 | — | 58-22 | — | 1.3 | — |
| 5178 | — | — | — | 1.7 | — |
| 5179 | — | — | — | 2.4 | — |
| 5180 | — | — | BD -13°3242 | 1.5 | K3 V (bf) |
| 5180a | 1139 | 253-40 | BD +76°404 | 1.3 | K4 (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5181 | — | 119-42 | BD +28°1952 | 1.1 | — |
| 5182 | — | — | — | 1.5 | — |
| 5183 | — | — | — | 1.3 | — |
| 5184 | — | — | — | 1.6 | — |
| 5185 | — | 176-4 | — | 1.1 | — |
| 5186 | — | — | — | 1.7 | — |
| 5187 | — | — | — | 1.3 | — |
| 5188 | — | — | CD -30°8970 | 1.3 | K5 (af) |
| 5189 | — | — | — | 1.5 | — |
| 5190 | — | — | — | 2.4 | — |
| 5191 | — | 56-34 | BD +15°2325 | 1.1 | K2 (af) |
| 5192 | — | 120-49 | — | 1.6 | — |
| 5193 | — | — | — | 1.8 | — |
| 5194 | — | — | — | 0.1 | — |
| 5195 | — | 120-67 | Ross 904 | 1.1 | K1 (af), G8± (ag) |
| 5196 | — | — | — | 1.9 | — |
| 5197 | — | — | — | 1.4 | — |
| 5198 | — | 57-21 | — | 1.5 | — |
| 5199 | — | — | — | 1.4 | — |
| 5200 | — | 57-24 | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5201 | — | — | — | 1.5 | — |
| 5202 | — | — | — | 0.4 | — |
| 5203 | — | 237-37 | Ross 452 | 0.9 | G4 (af) |
| 5204 | — | — | — | 1.7 | — |
| 5205 | — | — | — | 1.5 | M3 (af) |
| 5206 | 454 | — | BD -9°3413 | 0.9 | G8-M0 IV (be), K0 IV (am), G8 (af) |
| 5207 | — | 122-64 | — | 1.3 | — |
| 5208 | — | — | — | 1.5 | — |
| 5209 | — | — | — | 1.6 | — |
| 5210 | — | — | — | 1.7 | — |
| | | | | | |
| 5211 | — | 59-3 | — | 1.5 | — |
| 5212 | — | 237-56 | — | 0.0 | DC8 (br) |
| 5213 | — | 12-29 | — | 1.4 | — |
| 5214 | — | — | — | 1.5 | — |
| 5215 A* | — | 237-62 A | BD +74°493 A | 1.1 | G5 (af) |
| 5215 B* | — | 237-62 B | BD +74°493 B | — | composite with LHS 5215 A |
| 5215a | — | 253-59 | — | 1.5 | — |
| | | | | | |
| 5216 | — | 123-33 | — | 0.9 | M1 (bk) |
| 5217 | — | — | — | 1.5 | — |
| 5217a | — | 148-66 | — | 1.5 | — |
| 5218 | — | — | BD -13°3557 | 1.2 | K3-4 V (bf), K5 (af) |
| 5219 | — | 12-45 | Wolf 429 | 1.5 | M3.5: (af) |
| 5220 | — | — | — | 1.3 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5221 | — | — | — | 1.5 | — |
| 5222 | — | — | — | -0.3 | — |
| 5223 | — | — | — | 1.1 | — |
| 5224 | — | — | — | 1.3 | M1-2 (bp) |
| 5225 | — | 13-52 | — | 1.3 | — |
| 5226 | — | — | — | 1.5 | — |
| 5227 | — | — | — | 1.8 | — |
| 5228 | — | 14-2 | — | 1.6 | M1 (af) |
| 5229 | — | 14-3 | — | 1.1 | — |
| 5230 | — | 123-63 | — | 1.8 | — |
| 5230a | — | — | — | 1.5 | — |
| 5231 | — | 14-17 | — | 1.5 | — |
| 5232 | — | — | — | 1.8 | — |
| 5233 | — | — | — | 2.0 | — |
| 5234 | — | 238-21 | — | 1.5 | — |
| 5235 | — | — | — | 2.1 | — |
| 5236 | — | — | — | 1.7 | — |
| 5237 | — | — | — | 1.7 | — |
| 5238 | — | 149-40 | — | 1.6 | M3 (af) |
| 5239 | — | — | — | 2.3 | — |
| 5240 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5241 | — | — | — | 1.6 | — |
| 5242 | — | — | — | 1.3 | — |
| 5243 | — | 62-27 | — | 0.9 | — |
| 5244 | — | — | — | 1.5 | — |
| 5245 | — | 164-72 | — | 1.1 | — |
| 5246 | — | — | — | 2.1 | — |
| 5247 | — | — | CD -27°9236 | 1.4 | K7 (af) |
| 5248 | — | — | — | 1.5 | — |
| 5249 | 512 A | 14-55 A | Ross 486 A | 1.6 | M3.5 (af), M4 V (bh) |
| 5250 | 512 B | 14-55 B | ROss 486 B | 1.7 | M4 (af) |
| 5251 | — | 63-31 | — | 1.7 | — |
| 5252 | — | — | — | 1.7 | — |
| 5253 | — | 62-56 | — | 1.8 | M3 (af) |
| 5254 | — | 63-48 | Wolf 491 | 0.9 | M0 (af) |
| 5255 | — | — | CD -57°5188 | 1.1 | M0 (bp) |
| 5256 | — | 177-61 | — | 1.3 | — |
| 5257 | — | 223-27 | — | 1.3 | — |
| 5258 | — | — | — | 1.5 | — |
| 5259 | — | — | — | 2.0 | — |
| 5260 | — | — | — | 1.7 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|-----------------|------------------------------|
| 5261 | — | — | CD -45°8786 | 0.6 | G0: (af), G2 V (bf) |
| 5262 | — | — | — | 1.5 | — |
| 5263 | — | — | — | 1.1 | — |
| 5264 | — | — | — | — | — |
| 5265 | — | — | — | 1.5 | — |
| | | | | | |
| 5266 | — | 165-51 | BD +30°2490 | 1.2 | K7 (af) |
| 5267 | — | 165-53 | — | 1.9 | — |
| 5268 | — | 150-74 | — | 1.7 | — |
| 5269 | — | — | — | 1.7 | — |
| 5270 | — | 124-26 | — | 0.1 | — |
| | | | | | |
| 5271 | — | 178-21 | — | 1.6 | — |
| 5272 | — | — | — | 1.1 | — |
| 5273 | — | — | — | 2.5 | — |
| 5274 | — | — | — | 1.5 | — |
| 5275 | — | — | — | 1.1 | M1.5 (bp) |
| | | | | | |
| 5276 | — | — | — | 1.6 | — |
| 5277 | — | — | — | 1.5 | — |
| 5278 | — | 166-44 | — | 2.1 | — |
| 5279* | 567 | — | BD +19°2881 | 1.1 | K2 V (be), K2 V (am), G8 (af) |
| 5280 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5281 | — | — | — | 1.3 | — |
| 5282 | — | — | — | 1.3 | — |
| 5283 | — | 151-13 | — | 0.9 | — |
| 5284 | — | — | — | 1.1 | — |
| 5285 | — | 66-55 | Ross 1030b | 1.1 | K0 (af) |
| 5286 | — | — | — | 1.3 | — |
| 5287 | — | 201-33 | — | 1.5 | — |
| 5288 | — | — | — | 1.7 | — |
| 5289 | — | 256-19 | — | 1.5 | — |
| 5289a | — | 151-28 | BD -7°3963 | 0.5 | — |
| 5290 | — | 136-74 | Ross 996 | 1.6 | M2 (af) |
| 5291 | — | — | — | 2.0 | — |
| 5292 | — | 179-24 | — | 1.7 | — |
| 5293 | — | — | — | 1.3 | — |
| 5294 | — | 136-93 | BD +15°2847 | 1.1 | K2 (ag) |
| 5295 | — | — | — | 1.1 | K5 (af) |
| 5296 | — | — | — | 2.4 | — |
| 5296a | — | — | — | 0.9 | — |
| 5297 | — | — | — | 1.1 | — |
| 5298 | — | — | — | 1.1 | — |
| 5299 | — | — | — | 1.3 | — |
| 5299a | 599 A | — | CD -37°10500 A | 0.6 | G6 V (be), G6 IV (bf), G9 (af) |
| 5299b | 599 B | — | CD -37°10500 B | -0.1 | DA (af) |
| 5300 | — | — | — | 1.5 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5301 | — | 16-10 | — | 1.3 | — |
| 5302 | — | — | — | 1.5 | — |
| 5303 | — | — | — | 2.2 | — |
| 5304 | — | 137-66 | — | 1.1 | — |
| 5305 | — | 225-42 | — | 1.5 | — |
| 5306 | — | 152-69 | — | 1.3 | — |
| 5307 | 608 | 225-43 | BD +62°1446 | 1.5 | M0 V (ag) |
| 5308 | — | — | — | 2.2 | — |
| 5309 | — | 16-26 | — | 1.3 | — |
| 5310 | — | — | — | -0.4 | — |
| 5311 | — | 137-81 | BD +11°2910 B | 1.6 | — |
| 5312 | 610 | — | BD -20°4399 | 1.1 | K3-4 V (bf), K3 (af) |
| 5313 | — | 137-82 | BD +11°2910 A | 0.9 | — |
| 5314 | — | 168-33 | — | 1.6 | — |
| 5315 | 616.2 | 202-36 | BD +55°1823 | 1.5 | M1.5 (af), M1.5 V (bh), M1 V (cb) |
| 5316 | — | — | — | 1.3 | — |
| 5317 | — | 169-15 | — | 2.0 | M1 (bk) |
| 5318 | — | 180-61 | — | 1.3 | — |
| 5318a | — | 169-18 | BD +31°2873 | 0.5 | — |
| 5319 | — | 202-68 | — | 1.1 | M2.5 (bk) |
| 5320 | — | — | — | 1.3 | M1-2 (bp) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5321 | — | — | — | 1.9 | — |
| 5322 | — | — | — | 1.5 | — |
| 5323 | — | 181-16 | — | 1.6 | — |
| 5324 | 655 | 170-17 | Ross 863 | 1.5 | M3 V (al), M3 (af) |
| 5325 | — | — | — | 1.8 | — |
| 5326 | — | 265-34 | — | 1.8 | — |
| 5327 | — | 181-42 A | — | 1.8 | — |
| 5328 | — | 181-42 B | — | 2.2 | — |
| 5329 | — | — | — | 1.8 | — |
| 5330 | — | 240-64 A | — | 1.3 | — |
| 5331 | — | 240-64 B | — | 1.3 | — |
| 5332 | — | 140-37 | — | 1.8 | — |
| 5333 | — | — | BD -22°4585 | 1.1 | K1 V (bf) |
| 5334 | — | 154-51 | — | 0.9 | K4 (af) |
| 5335 | — | 205-18 | — | 1.6 | — |
| 5336 | — | — | — | 2.0 | — |
| 5337 | — | 21-12 | — | 0.9 | M0 (af) |
| 5337a | 2137 | — | CD -28°14630 | 1.3 | K[2] V (bf) |
| 5338 | — | — | — | 1.3 | — |
| 5339 | — | 21-22 | — | 0.6 | — |
| 5340 | — | 141-25 | Ross 138 | 1.1 | K5: (af) |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5341 | — | — | — | 1.5 | — |
| 5342 | — | 155-40 | — | 1.1 | — |
| 5343 | — | 141-48 | — | 0.8 | — |
| 5344 | — | — | — | 1.5 | — |
| 5345 | — | 259-39 | — | 1.3 | — |
| 5346 | — | — | CD -63°1418 | 1.1 | — |
| 5347 | 757 | — | CD -22°13916 | 1.3 | K4 (af), M1 (bp) |
| 5348 | — | — | — | 2.7 | — |
| 5349 | — | — | — | 1.7 | — |
| 5350 | — | — | — | 1.3 | — |
| 5350aA* | 771 A | — | $\beta$ Aql A | 1.1 | G8 IV (be), G7 (af) |
| 5350aB* | 771 B | — | $\beta$ Aql B | — | M3 (af) |
| 5351 | — | — | — | 1.3 | — |
| 5351aA* | 773.3 A | — | BD -10°5238 A | 0.5 | F8 V (be) |
| 5351aB* | 773.3 B | — | BD -10°5283 B | — | composite with LHS 5351aA |
| 5352 | — | 143-20 | Wolf 863 | 1.5 | K7 (af) |
| 5353 | — | — | 27 Cyg | 0.9 | K0 IV (be), K0 IV (am) |
| 5354 | 1250 | 125-62 | — | 1.9 | — |
| 5355 | — | — | — | 1.5 | — |
| 5356 | — | — | — | 2.2 | — |
| 5357 | — | 210-29 | — | 1.1 | — |
| 5358 | — | — | — | 1.7 | — |
| 5358a | 806.1 B | — | $\epsilon$ Cyg B | 1.6 | M3 (af) |
| 5358b* | 806.1 A | — | $\epsilon$ Cyg A | 1.1 | K0 III (be), G8 (af) |
| 5359 | — | — | — | 1.3 | — |
| 5360 | — | — | — | 3.0 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|-----|--------|--------|------------|------------|------------------------------|
| 5361 | — | 261-35 | — | 1.3 | — |
| 5362 | — | 212-12 | — | 1.3 | — |
| 5363 | 2151 | — | — | 0.6 | — |
| 5364 | — | 212-21 | — | 1.1 | — |
| 5365 | — | 212-24 | — | 1.2 | K3 (af) |
| 5366 | — | — | — | 1.5 | — |
| 5367 | — | 187-28 | — | 1.7 | — |
| 5368 | 825.3 | 25-25 | BD -0°4195 | 1.3 | K3 (af) |
| 5369 | — | — | — | 1.5 | — |
| 5370 | — | 212-37 | — | 1.3 | — |
| 5371 | — | — | — | 1.5 | — |
| 5372 | — | — | — | 1.8 | — |
| 5373 | — | — | — | 1.6 | — |
| 5374 | 838.6 | — | — | 1.5 | M1 (af) |
| 5375 | — | 188-32 | Wolf 1147 | 1.6 | M3 (af) |
| 5376 | — | 188-33 | — | 1.5 | — |
| 5377 | — | — | CD -53°9029 | 0.4 | G0 V (be), G0 V (bf) |
| 5378 | — | 18-23 | — | 1.6 | — |
| 5379 | — | 18-25 | Wolf 983 | 1.6 | M3 (af) |
| 5380 | — | — | — | 2.1 | — |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5381 | — | — | — | 1.5 | — |
| 5382 | — | — | — | 1.5 | — |
| 5383 | — | — | — | 1.5 | — |
| 5383a | — | 215-44 | — | 1.1 | — |
| 5384 | — | — | — | — | — |
| 5385 | — | 18-46 | — | 1.2 | — |
| 5386 | 1268 | 232-69 | — | 1.8 | — |
| 5387 | — | — | — | 1.5 | — |
| 5388 | — | 215-48 | — | 1.5 | — |
| 5389 | — | — | — | 1.3 | — |
| 5390 | — | — | — | 1.5 | — |
| 5391 | — | 128-2 | Ross 236 | 1.1 | G8 (af), G8 (bk) |
| 5392 | — | — | — | — | — |
| 5393 | — | — | — | 1.2 | — |
| 5394 | — | — | — | 1.8 | — |
| 5395 | — | 241-36 | — | 1.5 | — |
| 5396 | — | — | — | 1.6 | — |
| 5397 | — | — | — | 1.5 | — |
| 5398 | — | 233-47 | — | 1.1 | K7 (bk) |
| 5399 A* | — | — | CD -45°14980 A | 1.3 | K3 V (bf), K3 (af) |
| 5399 B* | — | — | CD -45°14980 B | — | composite with LHS 5399 A |
| 5400 | — | 242-30 | — | 1.5 | — |
| 5400aA* | — | 29-21 A | BD +4°4994 A | 1.1 | K1 (af) |
| 5400aB* | — | 29-21 B | BD +4°4994 B | — | composite with LHS 5400aA |

TABLE 5.1 — continued

| LHS | Gliese | Giclas | Other Name | $m_{pg} - m_R$ | Spectral Type and Reference |
|---|---|---|---|---|---|
| 5401 | — | 157-50 | — | 1.1 | — |
| 5402 | — | 157-58 | — | 0.9 | — |
| 5403 | — | — | — | 1.3 | — |
| 5404 | 895.1 | — | CD -46°14649 | 1.5 | M0 (af) |
| 5405* | 895.2 | 29-38 | — | 0.0 | DA (ag) |
| 5406 | — | 171-1 | Ross 247 | 1.5 | M3 (af) |
| 5407 | — | — | — | 1.5 | — |
| 5408 | — | 273-83 | — | 1.3 | — |
| 5409 | — | 30-22 | — | 1.3 | — |
| 5410 | — | 158-14 | BD -10°6206 | 0.6 | G4 (af) |
| 5411 | — | 129-48 | — | 2.0 | — |
| 5412 | — | 30-31 | Wolf 1050 | 1.1 | K3: (af) |
| 5413 | — | — | — | 2.3 | — |

TABLE 5.1 — continued

Legend for the spectral-type references:

aa = Ake & Greenstein 1980

ab = Bartkevičius 1984

ac = Bessell 1982

ad = Bessell 1991

ae = Bessell & Wickramasinghe 1979

af = Bidelman 1985

ag = Bidelman & Lee 1975

ah = Boeshaar 1976

ai = Boeshaar 1992

aj = Bopp 1987

ak = Carney 1979

al = Cowley & Hartwick 1982

am = Cowley, Hiltner, & Witt 1967

an = Dahn, Liebert, Kron, Spinrad, & Hintzen 1977

ao = Dawson & de Robertis 1988

ap = Dawson & de Robertis 1988a

aq = Dawson & de Robertis 1988b

ar = Dawson & de Robertis 1989

as = Doyle & Butler 1990

at = Eggen 1971

TABLE 5.1 — continued

au = Eggen 1979

av = Evans, Menzies, & Stoy 1957

aw = Evans, Menzies, & Stoy 1959

ax = Giampapa & Liebert 1986

ay = Green, Margon, & MacConnell 1991

az = Greenstein 1984

ba = Greenstein 1986

bb = Hartwick, Cowley, & Mould 1984

bc = Hintzen 1986

bd = Hintzen & Jensen 1979

be = Hoffleit & Jaschek 1982; Hoffleit, Saladyga, & Wlasuk 1983

bf = Houk 1978; Houk 1988; Houk & Cowley 1975; Houk & Smith-Moore 1988

bg = Ianna & Bessell 1986

bh = Joy & Abt 1974

bi = this thesis.

bj = Klemola, Harlan, & Wirtanen 1981

bk = Lee 1984

bl = Liebert, Dahn, Gresham, & Strittmatter 1979

bm = Liebert, Dahn, Harris, Allard, & Kirkpatrick 1993

bn = Liebert, Dahn, & Monet 1988

bo = Liebert & Strittmatter 1977

bp = MacConnell 1983

TABLE 5.1 — continued

bq = Mathioudakis & Doyle 1991

br = McCook & Sion 1987

bs = Oswalt, Hintzen, & Luyten 1988

bt = Petit 1979

bu = Przybylski & Kennedy 1965

bv = Reid 1982

bw = Rodgers & Eggen 1974

bx = Roman 1955

by = Sanduleak & Pesch 1988

bz = Thé & Staller 1974

ca = Turnshek, Turnshek, Craine, & Boeshaar 1985

cb = Veeder 1974

## TABLE 5.2

### CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|---|---|---|---|---|---|
| 1 | 1 | 34 B | 122 | 67 A | 1284 A |
| 2 | 1014 | 35 | 7 | 67 B | 1284 B |
| 3 | 1015 | 36 | 1154 | 68 | 1287 |
| 4 A | 1016 | 38 | 126 | 69 | 1291 |
| 4 B | 1017 | 40 A | 1159 | 70 | 1290 |
| 4.2 A | 1020 | 40 B | 1160 | 71 | 146 |
| 4.2 B | 1021 | 42 | 1163 | 73 | 1292 |
| 7 | 1026 | 45 | 128 | 75 | 1297 |
| 8 | 1027 | 46 | 129 | 78 | 1303 |
| 11 A | 1040 A | 47 | 1176 | 79 | 1307 |
| 11 B | 1040 B | 48 | 131 | 81 A | 1314 A |
| 12 | 1050 | 49 | 1179 | 81 B | 1314 B |
| 14 | 1053 | 50 | 5019 | 83.1 | 11 |
| 15 A | 3 | 51 | 1183 | 84 | 149 |
| 15 B | 4 | 52 | 136 | 84.1 A | 1337 |
| 17 | 5 | 52.1 | 1193 | 84.1 B | 1338 |
| 17.1 | 1061 | 52.2 | 137 | 84.2 | 1343 |
| 18 | 1067 | 53 A | 8 A | 85 | 150 |
| 19 | 6 | 53 B | 8 B | 85.1 | 1348 |
| 22 A | 114 A | 53.1 A | 5027 | 86 | 13 |
| 22 B | 115 | 53.1 B | 5028 | 87 | 14 |
| 22 C | 114 B | 53.2 | 1199 | 88 | 1357 |
| 25 A | 118 A | 54 | 1208 | 90 | 1371 |
| 25 B | 118 B | 54.1 | 138 | 91 | 1361 |
| 26 | 119 | 55 | 1220 | 91.3 | 153 |
| 27 | 1116 | 56 | 1225 | 92 A | 154 A |
| 27.1 | 1122 | 56.1 | 1228 | 92 B | 154 B |
| 27.2 | 1124 | 56.3 A | 1230 | 92.2 | 1383 |
| 28 | 1125 | 56.3 B | 1229 | 93 | 1379 |
| 29 | 1123 | 57 | 141 | 94 | 1388 |
| 31.4 | 1141 | 58.2 | 5035 | 95 | 1387 |
| 31.5 | 1139 | 64 | 1270 | 100 A | 1409 A |
| 33 | 121 | 65 A | 9 | 100 B | 1409 B |
| 34 A | 123 | 65 B | 10 | 100 C | 1408 |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|------|-------|------|-------|------|-------|
| 101 | 155 | 144 | 1557 | 184 | 28 |
| 102 | 1417 | 146 | 1563 | 186.1 A | 1724 |
| 105 A | 15 | 147 | 1569 | 186.1 B | 1727 |
| 105 B | 16 | 147.1 | 1577 | 188 | 1736 |
| 109 | 1439 | 150 | 1581 | 190 | 203 |
| 114 | 1453 | 151 | 179 | 191 | 29 |
| 114.1 | 1452 | 154 | 5087 | 197 | 1753 |
| 116 | 159 | 155 | 1591 | 200 A | 1754 |
| 118 | 160 | 155.1 | 1594 | 200 B | 1755 |
| 118.1 A | 1466 | 155.2 | 1613 | 200.1 | 1751 |
| 118.1 B | 1467 | 155.3 | 184 | 203 | 1761 |
| 119 A | 1475 | 156.2 | 1619 | 204 | 1763 |
| 119 B | 1476 | 157.1 | 1616 | 204.2 | 1766 |
| 120 | 163 | 157.2 | 185 | 205 | 30 |
| 122 | 1505 | 158 | 21 | 207.2 | 1769 |
| 123 | 1496 | 160.2 | 1628 | 211 | 1774 |
| 124 | 166 | 162 | 1634 | 212 | 1775 |
| 125 | 1507 | 163 | 188 | 213 | 31 |
| 127 A | 1515 A | 164 | 1642 | 215 | 1782 |
| 127 B | 1515 B | 166 A | 23 | 217 | 1783 |
| 129 | 169 | 166 B | 24 | 217.2 | 210 |
| 130 | 167 | 166 C | 25 | 218 | 1787 |
| 130.1 A | 1522 | 167 | 1650 | 220 | 1794 |
| 130.1 B | 1523 | 167.2 | 1651 | 223 | 1798 |
| 133 | 5072 | 169.1 A | 26 | 223.2 | 32 |
| 134 | 1528 | 169.1 B | 27 | 223.3 | 1797 |
| 136 | 171 | 170 | 1674 | 224 | 1803 |
| 138 | 172 | 171 | 1684 | 224.1 | 1796 |
| 139 | 19 | 172 | 1688 | 225.2 A | 1804 A |
| 141 | 1546 | 176 | 196 | 225.2 B | 1804 B |
| 142 | 1548 | 176.3 | 1701 | 226 | 215 |
| 143.2 A | 1551 | 180 | 1712 | 226.1 | 1814 |
| 143.2 B | 1552 | 181.1 | 199 | 228 A | 1830 A |
| 143.3 | 1554 | 183 | 200 | 228 B | 1830 B |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|------|-------|------|-------|------|-------|
| 229 | 1827 | 283 B | 234 | 319 B | 2042 B |
| 231.3 | 1836 | 284 | 1939 | 319 C | 2043 |
| 232 | 1846 | 285 | 1943 | 321 | 2047 |
| 234 A | 1849 | 286 | 1945 | 324 A | 2062 |
| 234 B | 1850 | 288 A | 237 | 324 B | 2063 |
| 238 | 1855 | 288 B | 237a | 325 A | 256 |
| 239 | 1858 | 289 | 239 | 325 B | 257 |
| 240.1 | 1868 | 290 | 5130 | 326 A | 2069 |
| 244 A | 219 A | 294 A | 1959 | 326 B | 2070 |
| 244 B | 219 B | 294 B | 1960 A | 328 | 255 |
| 246 | 1870 | 294 C | 1960 B | 330.1 | 2078 |
| 249 | 1874 | 295 | 242 | 331 A | 2084 |
| 250 A | 1875 | 296 | 1968 | 331 B | 2083 A |
| 250 B | 1876 | 296.1 | 1982 | 331 C | 2083 B |
| 251 | 1879 | 298 | 1985 | 332 A | 2093 A |
| 257 A | 222 A | 300 | 1989 | 332 B | 2093 B |
| 257 B | 222 B | 301 A | 1991 A | 333 | 2085 |
| 257.1 | 1890 | 301 B | 1991 B | 336 | 2113 |
| 261 | 1892 | 301.1 | 1998 | 337 A | 2114 A |
| 262 | 1893 | 302 | 245 | 337 B | 2114 B |
| 263 | 1895 | 308 A | 247 A | 338 A | 260 |
| 268 A | 226 A | 308 B | 247 B | 338 B | 261 |
| 268 B | 226 B | 308.1 | 2018 | 338.1 A | 264 A |
| 268.2 | 1908 | 308.2 | 2017 | 338.1 B | 264 B |
| 269 A | 1911 A | 309 | 249 | 339.1 | 262 |
| 269 B | 1911 B | 310 A | 251 A | 340 A | 2125 A |
| 270 | 1912 | 310 B | 251 B | 340 B | 2125 B |
| 273 | 33 | 314 A | 5139aA | 341 | 2128 |
| 275.2 A | 229 | 314 B | 5139aB | 343 | 2141 |
| 275.2 B | 230 A | 315 | 2033 | 345 | 268 |
| 275.2 C | 230 B | 316.1 | 2034 | 347 A | 2145 |
| 280 A | 233 A | 317 | 2037 | 347 B | 2146 |
| 280 B | 233 B | 318 | 253 | 349 | 2147 |
| 283 A | 235 | 319 A | 2042 A | 351.1 | 2154 |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|---|---|---|---|---|---|
| 352 A | 2151 A | 392 A | 2267 | 428 A | 2402 A |
| 352 B | 2151 B | 392 B | 2266 | 428 B | 2402 B |
| 353 | 2155 | 393 | 2272 | 429 A | 2407 |
| 354 A | 270 A | 397 | 2279 | 429 B | 2408 |
| 354 B | 270 B | 398 | 2285 | 429.2 | 2412 |
| 356 A | 2156 A | 398.1 | 2286 | 429.4 | 2417 |
| 356 B | 2156 B | 399 | 2295 | 430.1 | 2422 |
| 357 | 2157 | 401 A | 289 | 431 | 2423 |
| 358 | 2166 | 401 B | 290 | 432 A | 308 |
| 359 | 2171 | 402 | 294 | 432 B | 309 |
| 360 | 2176 | 403 | 295 | 433 | 2429 |
| 361 | 2173 | 405 | 2331 | 433.2 A | 2437 |
| 362 | 2178 | 406 | 36 | 433.2 B | 2436 |
| 363 | 2175 | 406.1 | 2334 | 435 | 2441 |
| 365 | 2180 | 411 | 37 | 436 | 310 |
| 366 | 2188 | 412 A | 38 | 438 | 2447 |
| 367 | 2182 | 412 B | 39 | 440 | 43 |
| 369 | 274 | 412.2 | 2354 | 442 A | 311 |
| 370 | 2201 | 413.1 | 2358 | 442 B | 313 |
| 373 | 2211 | 414 A | 2367 | 443 | 314 |
| 375 | 2213 | 414 B | 2366 | 445 | 2459 |
| 376 | 2216 | 414.1 A | 2368 | 447 | 315 |
| 377 | 277 | 414.1 B | 2369 | 448 A | 2462 A |
| 378 | 278 | 415 | 298 | 448 B | 2462 B |
| 379.2 | 5166a | 416 | 2370 | 449 | 2465 |
| 380 | 280 | 421 A | 2379 | 451 | 44 |
| 381 | 2230 | 421 B | 2380 | 452 A | 2470 |
| 383 | 2231 | 421 C | 2378 | 452 B | 2470a |
| 383.1 | 2237 | 422 | 40 | 452.1 | 2472 |
| 386 | 2244 | 423 A | 2390 | 453 | 319 |
| 388 | 5167 | 423 B | 2391 | 454 | 5206 |
| 389 A | 2253 | 423.1 | 2393 | 454.1 | 2494 |
| 389 B | 2254 | 424 | 41 | 455 | 2497 |
| 390 | 2259 | 427 | 304 | 456 | 2515 |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|------|-------|------|-------|------|-------|
| 458.1 A | 2524 A | 506 | 349 | 542 | 2892 |
| 458.1 B | 2524 B | 506.1 | 2715 | 542.1 A | 2891 A |
| 459.3 | 2544 | 507 A | 2716 | 542.1 B | 2891 B |
| 462 | 2548 | 507 B | 2717 | 543 | 368 |
| 463 | 2551 | 508.2 | 2724 | 544 A | 2894 |
| 465 | 45 | 508.3 | 2731 | 544 B | 2895 |
| 467 A | 328 | 509 A | 2728 A | 545 | 369 |
| 467 B | 329 | 509 B | 2728 B | 545.1 | 2900 |
| 469 | 2565 | 512 A | 5249 | 546 | 2903 |
| 469.1 | 2566 | 512 B | 5250 | 547 | 2907 |
| 471 | 2570 | 512.1 | 2740 | 548 A | 371 |
| 472 | 2577 | 513 | 351 | 548 B | 372 |
| 473 A | 333 A | 514 | 352 | 549 C | 2914 |
| 473 B | 333 B | 514.1 | 353 | 550.1 | 2918 |
| 475 | 2579 | 515 | 354 | 551 | 49 |
| 476 | 2582 | 518 | 46 | 552 | 373 |
| 477 | 2585 | 518.1 | 2766 | 553 | 374 |
| 478 | 2587 | 521.1 | 2773 | 553.1 | 2932 |
| 479 | 336 | 525 | 359 | 554 | 2931 |
| 480 | 338 | 526 | 47 | 555 | 2945 |
| 480.1 | 340 | 529 | 363 | 558 | 2948 |
| 482 A | 2604 | 530 | 2814 | 559 A | 50 |
| 482 B | 2605 | 531 | 2817 | 559 B | 51 |
| 486 | 341 | 533 | 2821 | 562 | 2974 |
| 491 A | 2656 A | 533.1 | 2820 | 563 | 2978 |
| 491 B | 2656 B | 534.3 | 2834 | 563.2 A | 380 |
| 492 | 2661 | 536 | 2842 | 563.2 B | 379 |
| 492 | 2663 | 537 A | 2849 | 563.3 | 2983 |
| 493.1 | 2664 | 537 B | 2850 | 565 | 383 |
| 494 | 2665 | 539 | 2859 | 567 | 5279 |
| 496.1 | 344 | 539.2 | 2870 | 568 A | 2997 A |
| 502 | 348 | 540 | 2865 | 568 B | 2997 B |
| 505 A | 2713 | 540.2 | 2880 | 569.1 | 384 |
| 505 B | 2714 | 541 | 48 | 570 A | 387 |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|---|---|---|---|---|---|
| 570 B | 386 A | 615 | 413 | 641 | 426 |
| 570 C | 386 B | 616 | 3171 | 642 | 3251 |
| 570.2 | 388 | 616.2 | 5315 | 643 | 427 |
| 576 | 3020 | 617 A | 3175 | 644 A | 428 A |
| 579 | 391 | 617 B | 3176 | 644 B | 428 B |
| 579.2 A | 53 | 618 A | 415 | 644 C | 429 |
| 579.2 B | 52 | 618 B | 416 | 649 | 3257 |
| 580 A | 393 A | 618.4 | 3185 | 651 | 3260 |
| 580 B | 393 B | 620 | 3186 | 653 | 431 |
| 581 | 394 | 620.2 | 3188 | 654 | 432 |
| 582 | 395 | 622 | 3191 | 655 | 5324 |
| 585 | 396 | 623 A | 417 A | 656 | 3268 |
| 588 | 397 | 623 B | 417 B | 660 A | 3269 A |
| 589 A | 399 | 626.2 | 3200 | 660 B | 3269 B |
| 589 B | 400 | 627 A | 3203 | 660.1 | 3271 |
| 590 | 3092 | 627 B | 3204 | 661 A | 433 |
| 592 | 3093 | 628 | 419 | 661 B | 434 |
| 595 | 54 | 629 | 3209 | 663 A | 437 |
| 597 | 404 | 629.2 A | 3215 | 663 B | 438 |
| 599 A | 5299a | 629.2 B | 3219 | 664 | 439 |
| 599 B | 5299b | 629.3 | 3223 | 666 A | 444 |
| 602 | 3127 | 630.1 A | 421 A | 666 B | 445 |
| 603 | 408 | 630.1 B | 422 | 667 A | 442 A |
| 606.2 | 3145 | 630.1 C | 421 B | 667 B | 442 B |
| 608 | 5307 | 631 | 3224 | 667 C | 443 |
| 609 | 411 | 632.1 | 3226 | 667.1 | 3285 |
| 609.2 | 3148 | 633 | 3233 | 671 | 3281 |
| 610 | 5312 | 634 | 3235 | 672 | 441 |
| 611 A | 3152 | 635 A | 3234 A | 672.1 | 3286 |
| 611 B | 3150 | 635 B | 3234 B | 673 | 447 |
| 611.3 A | 3156 A | 637 | 3242 | 674 | 449 |
| 611.3 B | 3156 B | 637.1 | 3238 | 675 | 3287 |
| 612 | 3153 | 639.1 | 3244 | 682 | 451 |
| 612.1 | 3155 | 639.2 | 3248 | 684 A | 3305 A |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|------|-------|------|-------|------|-------|
| 684 B | 3305 B | 731 | 3417 | 771 B | 5350aB |
| 685 | 3306 | 732 A | 469 A | 772 | 3501 |
| 686 | 452 | 732 B | 469 B | 773 A | 3502 |
| 687 | 450 | 739 | 3423 | 773 B | 3503 |
| 690.1 | 3316 | 740 | 470 | 773.3 A | 5351aA |
| 692.1 | 3319 | 741 | 3428 | 773.3 B | 5351aB |
| 693 | 454 | 742 | 3424 | 773.6 | 3508 |
| 694 | 3321 | 745 A | 3432 | 774 A | 3513 |
| 695 A | 3326 | 745 B | 3433 | 774 B | 3512 |
| 695 B | 3325 A | 747 A | 471 A | 775.1 | 3507 |
| 695 C | 3325 B | 747 B | 471 B | 776 | 484 |
| 695.1 | 3330 | 747.1 | 3437 | 776.1 | 3517 |
| 699 | 57 | 747.3 | 3439 | 777 A | 3510 |
| 699.1 | 56 | 748 A | 472 A | 777 B | 3509 |
| 700.2 | 3353 | 748 B | 472 B | 778 | 481 |
| 701 | 3356 | 748.2 A | 3447 | 779 | 3515 |
| 702 A | 458 | 748.2 B | 3448 | 780 | 485 |
| 702 B | 459 | 752 A | 473 | 781 | 482 |
| 706 | 3363 | 752 B | 474 | 781.1 A | 3524 |
| 708.2 | 3373 | 754 | 60 | 781.1 B | 3523 |
| 708.3 | 3374 | 756 | 3456 | 782 | 3526 |
| 711 | 3381 | 757 | 5347 | 783 A | 486 |
| 712 | 464 | 759 | 3463 | 783 B | 487 |
| 713 A | 3379 A | 762 | 3471 | 783.2 A | 3529 |
| 713 B | 3379 B | 762.1 | 3466 | 783.2 B | 3530 |
| 718 | 3392 | 763 | 3470 | 784 | 3531 |
| 720 A | 3394 | 764 | 477 | 784.2 A | 3533 |
| 720 B | 3395 | 766 A | 478 A | 784.2 B | 3532 |
| 723 | 3400 | 766 B | 478 B | 785 | 488 |
| 724 | 3403 | 767 A | 3482 | 786 | 3527 |
| 725 A | 58 | 767 B | 3483 | 788 | 3537 |
| 725 B | 59 | 768 | 3490 | 788.1 | 3542 |
| 728 | 3412 | 769 | 480 | 788.2 | 3540 |
| 729 | 3414 | 771 A | 5350aA | 790 | 3554 |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GL # | LHS # | GL # | LHS # |
|---|---|---|---|---|---|
| 791 | 3553 | 820 A | 62 | 848.3 B | 3765 |
| 791.2 | 3556 | 820 B | 63 | 849 | 517 |
| 792 | 3559 | 821 | 65 | 851.1 | 3771 |
| 793 | 3558 | 825 | 66 | 851.2 | 3782 |
| 794 | 3562 | 825.1 | 3652 | 851.5 | 3781 |
| 794.2 | 3569 | 825.3 | 5368 | 852 A | 3787 |
| 795 A | 3568 A | 825.4 A | 3655 | 852 B | 3788 |
| 795 B | 3568 B | 825.4 B | 3656 | 853 A | 3790 A |
| 796 | 3570 | 826.1 | 3657 | 853 B | 3790 B |
| 798 | 496 | 826.2 | 3666 | 855 | 3802 |
| 800 A | 497 A | 827 | 3674 | 855.1 | 520 |
| 800 B | 497 B | 827.1 | 3675 | 858 | 3807 |
| 802 | 498 | 829 | 508 | 860 A | 3814 |
| 804 | 3576 | 830 | 509 | 860 B | 3815 |
| 806 | 3577 | 831 A | 511 A | 861 | 522 |
| 806.1 A | 5358b | 831 B | 511 B | 862 | 3817 |
| 806.1 B | 5358a | 832 | 3685 | 863 | 3828 |
| 807 | 3578 | 836 | 513 | 863.1 A | 525 A |
| 808 | 499 | 836.2 | 3687 | 863.1 B | 525 B |
| 809 | 3595 | 836.4 | 3702 | 863.1 C | 525 C |
| 810 A | 501 | 836.5 | 3703 | 864 | 3833 |
| 810 B | 500 | 836.9 A | 3707 A | 865 | 3839 |
| 811.1 | 502 | 836.9 B | 3707 B | 866 A | 68 A |
| 812 A | 3602 | 838.1 A | 3717 | 866 B | 68 B |
| 812 B | 3601 | 838.1 B | 3720 | 872 A | 3851 |
| 812.1 | 503 | 838.6 | 5374 | 872 B | 3852 |
| 813 | 3605 | 839 | 3727 | 873 | 3853 |
| 815 A | 3609 A | 842 | 3741 | 874 | 3855 |
| 815 B | 3609 B | 843 | 3744 | 875.1 | 3861 |
| 815 C | 3609 C | 845 | 67 | 876 | 530 |
| 816 | 3612 | 846 | 3745 | 877 | 531 |
| 817 | 61 | 847 A | 3750 | 878 | 3871 |
| 818 | 3624 | 847 B | 3751 | 878.1 A | 3874 |
| 818.1 | 3635 | 848.3 A | 3764 | 878.1 B | 3875 |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GL # | LHS # | GJ # | LHS # | GJ # | LHS # |
|------|-------|------|-------|------|-------|
| 880 | 533 | 1001 | 102 | 1050 | 157 |
| 884 | 3885 | 1002 | 2 | 1051 | 1438 |
| 887 | 70 | 1003 | 103 | 1052 | 1442 |
| 889.1 | 3899 | 1004 | 1038 | 1053 | 18 |
| 891 | 3904 | 1005 A | 1047 A | 1055 | 1504 |
| 892 | 71 | 1005 B | 1047 B | 1057 | 168 |
| 894.4 | 3936 | 1006 A | 107 | 1058 | 1540 |
| 894.5 | 3939 | 1006 B | 108 | 1059 | 1541 |
| 895.1 | 5404 | 1007 | 1052 | 1060 A | 1549 |
| 895.2 | 5405 | 1010 A | 1065 | 1060 B | 1550 |
| 895.4 | 544 | 1010 B | 1066 | 1061 | 1565 |
| 896 A | 3965 | 1012 | 1084 | 1062 | 20 |
| 896 B | 3966 | 1013 | 113 | 1064 A | 180 |
| 899 | 545 | 1014 | 117 | 1064 B | 181 |
| 901 | 548 | 1017 | 1129 | 1064- | 182 |
| 902 | 3994 | 1019 | 120 | 1065 | 183 |
| 904 | 3995 | 1022 | 124 | 1068 | 22 |
| 905 | 549 | 1024 | 1168 | 1070 | 1667 |
| 907 | 4015 | 1025 | 130 | 1072 | 1706 |
| 908 | 550 | 1026 A | 1180 | 1073 | 198 |
| 908.2 | 4027 | 1026 B | 1181 | 1074 | 1721 |
| 912 | 4047 | 1028 | 134 | 1077 | 205 |
| 913 | 4054 | 1029 | 135 | 1080 | 206 |
| 914 A | 101 A | 1031 | 1197 | 1087 | 212 |
| 914 B | 101 B | 1034 | 139 | 1088 | 1831 |
| 915 | 1005 | 1035 | 140 | 1092 | 220 |
| | | 1037 | 1227 | 1093 | 223 |
| | | 1039 | 1247 | 1097 | 1920 |
| | | 1042 | 151 | 1099 | 1928 |
| | | 1045 | 1366 | 1100 | 5127 |
| | | 1046 | 154a | 1101 | 1956 |
| | | 1047 A | 1393 A | 1102 A | 240 |
| | | 1047 B | 1393 B | 1102 B | 239 |
| | | 1047 C | 1392 | 1103 A | 1951 |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GJ # | LHS # | GJ # | LHS # | GJ # | LHS # |
|------|-------|------|-------|------|-------|
| 1103 B | 1952 | 1159 B | 330 | 1214 | 3275 |
| 1104 | 241 | 1162 | 2595 | 1215 | 3277 |
| 1105 | 1963 | 1168 | 2695 | 1216 | 446 |
| 1110 | 2011 | 1169 | 2711 | 1218 | 3292 |
| 1111 | 248 | 1171 | 355 | 1219 | 448 |
| 1112 | 2022 | 1174 | 357 | 1220 | 3297 |
| 1114 | 2060 | 1178 | 2800 | 1221 | 455 |
| 1116 A | 2076 | 1179 A | 362 | 1222 | 3338 |
| 1116 B | 2077 | 1179 B | 361 | 1223 | 457 |
| 1118 | 258 | 1182 | 366 | 1224 | 3359 |
| 1119 | 2092 | 1185 | 2979 | 1225 | 460 |
| 1121 | 2111 | 1186 | 2995 | 1226 A | 463 A |
| 1123 | 263 | 1187 | 3006 | 1226 B | 463 B |
| 1124 | 2131 | 1188 | 389 | 1227 | 465 |
| 1125 | 2149 | 1189 | 3026 | 1230 A | 3405 |
| 1128 | 271 | 1190 | 3039 | 1230 B | 3404 |
| 1129 | 273 | 1192 | 3067 | 1231 | 3434 |
| 1131 | 2222 | 1193 | 3083 | 1232 | 3438 |
| 1132 | 281 | 1194 A | 402 | 1235 | 476 |
| 1134 | 287 | 1194 B | 403 | 1236 | 3457 |
| 1138 | 293 | 1195 | 405 | 1237 | 3465 |
| 1139 | 5180a | 1197 | 3158 | 1238 | 3461 |
| 1140 | 2333 | 1198 | 412 | 1242 | 3479 |
| 1146 | 301 | 1199 | 3163 | 1245 A | 3494 A |
| 1147 | 2435 | 1200 | 55 | 1245 B | 3495 |
| 1148 | 2443 | 1202 | 3210 | 1245 C | 3494 B |
| 1151 | 316 | 1203 | 3213 | 1248 | 3511 |
| 1154 | 2531 | 1204 | 3221 | 1250 | 5354 |
| 1155 A | 2541 | 1207 | 3255 | 1251 | 493 |
| 1155 B | 2542 | 1208 | 3254 | 1252 | 492 |
| 1156 | 324 | 1209 | 430 | 1253 | 3549 |
| 1157 | 2552 | 1210 | 3265 | 1254 | 494 |
| 1158 | 332 | 1212 | 3272 | 1255 A | 3565 A |
| 1159 A | 331 | 1213 | 435 | 1255 B | 3565 B |

TABLE 5.2 — continued

CROSS-LIST: GLIESE (GL/GJ) — LHS

| GJ # | LHS # | GJ # | LHS # | GJ # | LHS # |
|---|---|---|---|---|---|
| 1255 C | 3565 C | 2005 | 1070 | 2138 | 3398 |
| 1255- | 3592 | 2012 | 1126 | 2150 | 3579 |
| 1256 | 495 | 2028 | 1474 | 2151 | 5363 |
| 1257 | 3572 | 2034 | 1660 | 2155 | 3947 |
| 1258 | 3574 | 2049 | 1840 | | |
| 1259 | 3598 | 2050 | 1865 | | |
| 1263 | 3708 | 2062 | 1927 | | |
| 1265 | 3776 | 2080 | 2273 | | |
| 1266 | 3783 | 2085 | 303 | | |
| 1268 | 5386 | 2086 | 2477 | | |
| 1270 | 524 | 2090 | 2509 | | |
| 1271 | 528 | 2093 | 334 | | |
| 1273 | 3857 | 2095 | 2594 | | |
| 1274 | 3859 | 2096 | 2600 | | |
| 1275 | 529 | 2102 | 2754 | | |
| 1276 | 69 | 2111 | 3034 | | |
| 1277 | 532 | 2112 | 3064 | | |
| 1281 | 538 | 2116 | 406 | | |
| 1286 | 546 | 2121 | 3205 | | |
| 1287 | 3988 | 2132 | 3335 | | |
| 1289 | 4003 | 2135 | 3384 | | |
| 1292 | 551 | 2137 | 5337a | | |

TABLE 5.3

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|-----|-------|-----|-------|-----|-------|
| 1-2 | 1079 | 6-42 | 1616 | 10-25 | 305 |
| 1-9 | 1114 | 7-4 | 1593 | 10-29 | 2420 |
| 1-10 | 1118 | 7-12 | 1614 | 10-39 | 2434 |
| 1-17 | 1133 | 7-16 | 1617 | 10-42 | 2440 |
| 1-18 | 1137 | 7-17 | 185 | 10-45 | 2448 |
| 1-20 | 1141 | 7-39 | 1671 | 10-50 | 315 |
| 1-27 | 7 | 8-16 | 1644 | 10-53 | 2463 |
| 2-27 | 1212 | 8-22 | 1653 | 11-20 | 2455 |
| 2-33 | 1226 | 8-35 | 5095 | 11-31 | 2475 |
| 3-13 | 5039 | 8-41 | 1681 | 11-34 | 2494 |
| 3-14 | 1290 | 8-49 | 1692 | 11-35 | 320 |
| 3-17 | 1292 | 8-50 | 1695 | 11-36 | 2507 |
| 3-27 | 1309 | 8-54 | 5100 | 11-37 | 2510 |
| 3-29 | 1319 | 8-55 | 196 | 11-40 | 2515 |
| 3-33 | 11 | 8-57 | 1703 | 11-42 | 2518 |
| 3-36 | 12 | 9-7 | 2011 | 11-45 A | 2524 A |
| 3-39 | 1333 | 9-9 | 2027 | 11-45 B | 2524 B |
| 3-44 | 152 | 9-11 | 2029 | 12-4 | 1472 |
| 4-21 | 1403 | 9-13 | 2033 | 12-12 | 2482 |
| 4-29 | 156 | 9-19 | 5140 | 12-24 | 2526 |
| 4-43 | 1453 | 9-25 | 2059 | 12-25 | 2527 |
| 5-7 | 163 | 9-28 | 2060 | 12-26 | 2537 |
| 5-16 | 1509 | 9-38 | 2076 | 12-29 | 5213 |
| 5-22 | 169 | 9-39 | 2078 | 12-30 | 324 |
| 5-26 | 1527 | 10-2 | 2353 | 12-35 | 2547 |
| 5-34 | 1544 | 10-4 | 2365 | 12-37 | 2562 |
| 5-35 | 1545 | 10-8 | 2381 | 12-38 | 2565 |
| 5-43 | 1554 | 10-9 | 2383 | 12-39 | 2570 |
| 6-18 | 1568 | 10-10 | 2388 | 12-42 | 2575 |
| 6-24 | 1573 | 10-11 | 2392 | 12-43 A | 333 A |
| 6-25 | 1574 | 10-17 | 301 | 12-43 B | 333 B |
| 6-30 | 179 | 10-19 | 303 | 12-44 | 2582 |
| 6-31 | 1586 | 10-22 | 2406 | 12-45 | 5219 |
| 6-39 | 1610 | 10-23 | 2408 | 13-22 A | 2531 A |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 13-22 B | 2531 B | 15-26 | 3084 | 19-7 | 3255 |
| 13-26 A | 2541 | 16-10 | 5301 | 19-13 | 431 |
| 13-26 B | 2542 | 16-11 | 3123 | 19-14 | 432 |
| 13-43 | 2566 | 16-17 | 409 | 19-15 A | 3269 A |
| 13-44 A | 2567 | 16-18 | 410 | 19-15 B | 3269 B |
| 13-44 B | 2568 | 16-26 | 5309 | 19-16 | 3271 |
| 13-47 | 2586 | 16-29 A | 3156 A | 19-20 | 3278 |
| 13-51 | 2595 | 16-29 B | 3156 B | 19-21 | 3279 |
| 13-52 | 5225 | 16-32 | 3161 | 19-24 | 447 |
| 14-1 | 2634 | 16-34 | 3164 | 20-1 | 3289 |
| 14-2 | 5228 | 17-8 A | 3172 A | 20-9 | 3315 |
| 14-3 | 5229 | 17-8 B | 3172 B | 20-12 | 3323 |
| 14-4 | 2638 | 17-14 | 3194 | 20-22 | 3356 |
| 14-5 | 2641 | 17-19 | 3202 | 21-7 | 3374 |
| 14-17 | 5231 | 17-21 | 420 | 21-9 | 3377 |
| 14-19 | 2663 | 17-25 | 3215 | 21-10 A | 463 A |
| 14-35 | 2682 | 17-27 | 3219 | 21-10 B | 463 B |
| 14-39 | 2701 | 17-28 | 424 | 21-12 | 5337 |
| 14-42 | 2709 | 17-38 | 3246 | 21-18 | 3393 |
| 14-45 | 2715 | 18-1 | 3722 | 21-22 | 5339 |
| 14-55 A | 5249 | 18-14 | 3742 | 21-23 | 467 |
| 14-55 B | 5250 | 18-16 | 3745 | 22-1 | 468 |
| 14-56 | 2741 | 18-23 | 5378 | 22-5 | 3419 |
| 14-57 | 353 | 18-25 | 5379 | 22-10 | 470 |
| 14-58 | 354 | 18-31 | 3760 | 22-12 | 3426 |
| 15-1 | 3012 | 18-36 | 3773 | 22-14 | 3430 |
| 15-4 | 389 | 18-42 | 3795 | 22-15 | 3431 |
| 15-5 | 3020 | 18-45 | 3801 | 22-18 A | 472 A |
| 15-9 | 3030 | 18-46 | 5385 | 22-18 B | 472 B |
| 15-13 | 3034 | 18-48 A | 3808 | 22-20 | 3444 |
| 15-15 | 3039 | 18-48 B | 3809 | 22-21 A | 3447 |
| 15-20 | 3067 | 18-51 | 522 | 22-21 B | 3448 |
| 15-21 | 3070 | 18-56 | 3828 | 22-22 A | 473 |
| 15-25 | 3078 | 19-4 | 426 | 22-22 B | 474 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 22-26 | 3457 | 27-14 B | 3765 | 31-11 | 4030 |
| 23-5 | 3470 | 27-16 | 517 | 31-15 | 4046 |
| 23-8 | 3479 | 27-32 | 3825 | 31-17 | 4047 |
| 23-19 | 3505 | 27-36 | 3833 | 31-18 | 4049 |
| 23-24 | 3511 | 27-38 | 3840 | 31-31 | 1033 |
| 24-9 | 3532 | 27-45 | 3847 | 31-39 | 1052 |
| 24-10 | 3533 | 28-20 | 3860 | 31-43 | 5004 |
| 24-15 | 3550 | 28-21 | 3865 | 31-52 | 1082 |
| 24-16 | 3556 | 28-34 | 3897 | 31-53 | 1084 |
| 24-17 | 3557 | 28-39 | 3899 | 32-6 | 107 |
| 24-19 | 3561 | 28-41 | 3900 | 32-7 | 108 |
| 24-20 | 3564 | 28-43 | 537 | 32-9 | 5001a |
| 24-23 A | 3568 A | 29-21 A | 5400aA | 32-30 | 5010 |
| 24-23 B | 3568 B | 29-21 B | 5400aB | 32-31 | 5011 |
| 25-1 | 3579 | 29-30 | 3943 | 32-35 | 117 |
| 25-3 | 3584 | 29-33 | 3947 | 32-36 | 5012 |
| 25-8 | 3593 | 29-35 | 3948 | 32-59 | 1168 |
| 25-9 | 3599 | 29-36 | 3952 | 33-35 A | 1180 |
| 25-10 | 3604 | 29-38 | 5405 | 33-35 B | 1181 |
| 25-11 | 3607 | 29-43 | 545 | 33-39 | 1195 |
| 25-16 | 3624 | 29-49 | 3979 | 33-40 | 1199 |
| 25-25 | 5368 | 29-51 | 3981 | 33-41 | 1200 |
| 25-32 | 3677 | 29-53 | 548 | 33-43 | 1204 |
| 26-5 A | 3682 A | 29-55 | 3986 | 33-49 | 1227 |
| 26-5 B | 3682 B | 29-66 | 4017 | 33-56 | 1246 |
| 26-7 A | 511 A | 29-68 | 550 | 34-2 A | 5027 |
| 26-7 B | 511 B | 29-72 | 4020 | 34-2 B | 5028 |
| 26-13 | 3689 | 29-73 | 4022 | 34-12 | 1221 |
| 26-14 A | 3686 | 30-22 | 5409 | 34-15 | 139 |
| 26-14 B | 3688 | 30-31 | 5412 | 34-32 | 5035 |
| 26-21 | 3696 | 30-38 | 1009 | 35-8 | 1289 |
| 26-29 | 3706 | 30-45 | 1022 | 35-24 | 1335 |
| 26-30 | 3708 | 30-48 | 104 | 35-30 | 5051 |
| 27-14 A | 3764 | 30-55 | 1050 | 35-35 | 1366 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 36-22 | 1410 | 41-18 | 2094 | 46-34 | 267 |
| 36-24 | 1417 | 41-26 | 5144 | 46-35 | 2129 |
| 36-28 | 1428 | 41-35 | 2133 | 46-40 | 2140 |
| 36-31 | 1439 | 41-37 | 2141 | 47-5 | 2048 |
| 36-41 | 1468 | 41-43 | 2154 | 47-9 | 2063 |
| 36-48 | 1485 | 42-17 | 2173 | 47-26 | 2113 |
| 37-8 | 159 | 42-19 | 2184 | 47-28 | 5146b |
| 37-26 | 1501 | 42-24 | 2206 | 47-31 | 2121 |
| 37-32 | 1525 | 42-25 | 2207 | 48-15 | 5152 |
| 37-34 | 1533 | 43-3 | 2194 | 48-20 | 2149 |
| 37-40 | 174 | 43-22 | 5164 | 48-21 | 2161 |
| 37-45 | 1571 | 43-24 | 2217 | 48-25 | 2164 |
| 38-1 | 173 | 43-34 | 2234 | 48-27 | 2168 |
| 38-3 | 1562 | 43-36 | 2235 | 48-29 | 2169 |
| 38-10 | 1579 | 43-54 | 2273 | 48-30 | 2170 |
| 38-11 | 1585 | 44-19 | 5171 | 48-42 | 2198 |
| 38-12 | 1587 | 44-24 | 2283 | 48-52 | 5159 |
| 38-17 | 1605 | 44-25 | 2284 | 49-18 | 2163 |
| 38-25 | 187 | 44-27 | 2285 | 49-20 | 2171 |
| 38-26 | 1634 | 44-40 | 294 | 49-23 | 2181 |
| 38-30 | 1659 | 44-42 | 295 | 49-27 | 5158 |
| 39-9 | 1667 | 44-43 | 2320 | 49-32 | 2212 |
| 39-14 | 5096 | 44-46 | 2325 | 50-4 | 1943 |
| 39-32 | 1698 | 45-20 | 36 | 50-5 | 1949 |
| 39-37 | 1705 | 45-27 | 296 | 50-6 | 1950 |
| 39-40 | 1710 | 45-33 | 2348 | 50-8 | 5128 |
| 39-41 | 1715 | 45-39 | 2374 | 50-16 | 1972 |
| 39-42 | 1716 | 46-1 A | 2042 A | 50-22 | 35 |
| 39-43 | 1719 | 46-1 B | 2042 B | 51-6 | 1998 |
| 39-44 | 1722 | 46-2 | 2043 | 51-10 | 2007 |
| 40-2 | 1966 | 46-4 | 2050 | 51-13 A | 247 A |
| 40-3 | 1977 | 46-5 | 2056 | 51-13 B | 247 B |
| 40-7 A | 5133 | 46-9 | 255 | 51-15 | 248 |
| 40-7 B | 5134 | 46-30 | 2119 | 51-16 | 2022 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 51-27 | 2057 | 60-55 | 2664 | 63-53 | 47 |
| 52-15 | 2019 | 60-57 | 2665 | 63-54 | 2800 |
| 53-28 | 2230 | 60-67 | 2681 | 63-60 | 2809 |
| 53-38 | 2242 | 61-21 | 343 | 64-7 | 2770 |
| 53-40 | 2251 | 61-26 | 2660 | 64-24 | 2799 |
| 54-23 | 5167 | 61-33 | 2680 | 64-26 | 2804 |
| 54-26 | 2260 | 61-35 | 347 | 64-29 | 2832 |
| 54-29 | 2271 | 61-41 | 2695 | 64-31 | 2835 |
| 54-30 | 2281 | 61-44 | 2705 | 64-35 | 2842 |
| 55-16 | 2265 | 62-15 | 345 | 64-42 | 2857 |
| 55-24 | 2272 | 62-18 | 2699 | 64-47 | 2863 |
| 55-35 | 2295 | 62-27 | 5243 | 64-48 | 2869 |
| 55-37 | 2298 | 62-33 | 2722 | 64-52 | 2875 |
| 55-44 | 2321 | 62-34 | 2725 | 64-60 | 2883 |
| 56-29 | 2389 | 62-44 | 2747 | 65-2 | 2801 |
| 56-34 | 5191 | 62-49 | 2754 | 65-12 | 2821 |
| 56-41 | 2409 | 62-53 | 46 | 65-19 | 2830 |
| 56-44 | 2415 | 62-54 | 2766 | 65-22 | 2846 |
| 56-50 | 2442 | 62-56 | 5253 | 65-33 | 2873 |
| 57-21 | 5198 | 62-60 | 2773 | 65-35 | 2878 |
| 57-24 | 5200 | 62-66 | 2787 | 65-39 | 366 |
| 58-14 | 2304 | 63-5 | 2689 | 65-47 | 2907 |
| 58-22 | 5177 | 63-6 | 2690 | 65-49 | 2913 |
| 58-25 | 2318 | 63-9 | 2693 | 66-5 | 2941 |
| 58-40 | 2344 | 63-18 A | 2713 | 66-6 | 2942 |
| 59-3 | 5211 | 63-18 B | 2714 | 66-7 | 2944 |
| 59-9 | 2538 | 63-31 | 5251 | 66-10 | 2949 |
| 59-14 | 2549 | 63-32 | 351 | 66-18 | 2956 |
| 60-23 | 2593 | 63-34 | 352 | 66-21 | 2965 |
| 60-24 | 338 | 63-40 | 2765 | 66-22 | 2968 |
| 60-27 | 2616 | 63-43 | 2767 | 66-31 | 2983 |
| 60-32 | 341 | 63-45 | 2774 | 66-32 | 2984 |
| 60-33 | 2636 | 63-48 | 5254 | 66-41 | 2999 |
| 60-54 | 2661 | 63-52 | 359 | 66-55 | 5285 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 66-65 | 3024 | 71-51 | 5048 | 77-45 | 1532 |
| 67-8 | 3838 | 72-21 | 1275 | 77-47 | 1539 |
| 67-15 | 528 | 72-23 | 5037a | 77-48 | 1540 |
| 67-23 | 3857 | 73-35 | 14 | 77-49 | 1546 |
| 67-30 | 3867 | 73-37 | 1369 | 77-50 | 1547 |
| 67-37 | 533 | 73-67 | 1419 | 77-61 | 1555 |
| 67-42 | 3892 | 73-70 | 15 | 77-64 | 1561 |
| 68-8 | 543 | 73-71 | 16 | 77-65 | 1566 |
| 68-16 | 3945 | 74-4 | 1348 | 77-66 | 5074 |
| 68-22 | 3960 | 74-7 | 151 | 78-7 A | 1458 A |
| 68-24 A | 3965 | 74-10 | 1368 | 78-7 B | 1458 B |
| 68-24 B | 3966 | 74-14 | 1388 | 78-11 | 1486 |
| 68-31 | 3982 | 74-18 | 1392 | 78-18 | 1499 |
| 68-38 | 4007 | 74-19 A | 1393 A | 78-19 | 1507 |
| 69-10 | 119 | 74-19 B | 1393 B | 78-26 | 170 |
| 69-16 | 120 | 74-21 | 1400 | 78-31 | 1528 |
| 69-18 | 1138 | 74-43 | 1448a | 78-35 | 5073 |
| 69-26 | 1156 | 74-52 | 1483 | 78-42 | 177 |
| 69-31 | 5016 | 75-9 | 1404 | 79-18 | 1520 |
| 69-38 | 1172 | 75-30 | 1426 | 79-32 | 1538 |
| 69-40 | 1175 | 75-37 | 1435 | 79-54 | 5075 |
| 69-47 | 135 | 75-39 | 1442 | 79-59 | 178 |
| 69-65 A | 1237 | 75-43 | 1457 | 79-69 | 1589 |
| 69-65 B | 1236 | 75-44 | 5061 | 79-75 | 1607 |
| 70-28 | 130 | 75-45 | 1460 | 80-15 | 1577 |
| 70-44 | 1213 | 75-47 | 161 | 80-22 | 1594 |
| 70-50 | 1229 | 75-57 | 1487 | 80-23 | 1598 |
| 70-51 | 1230 | 76-20 | 1429 | 80-24 | 1599 |
| 70-55 A | 1240 | 76-48 | 5064 | 80-29 | 1608 |
| 70-55 B | 1241 | 76-58 | 1496 | 80-38 | 5088 |
| 71-24 | 1272 | 76-62 | 1504 | 81-21 | 1674 |
| 71-45 | 1318 | 76-66 | 1512 | 81-25 | 1675 |
| 71-47 | 1324 | 77-31 | 168 | 81-30 | 1696 |
| 71-50 | 5049 | 77-41 | 1526 | 81-38 | 1708 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 81-39 | 198 | 87-36 | 1914 | 99-10 | 206 |
| 81-42 | 1714 | 87-37 | 1917 | 99-11 | 1762 |
| 82-4 | 1645 | 87-38 | 1919 | 99-12 | 1763 |
| 82-5 | 1646 | 87-48 | 1934 | 99-14 | 1766 |
| 82-6 | 1649 | 88-9 | 1899 | 99-15 | 30 |
| 82-9 | 1655 | 88-43 | 1933 | 99-16 | 5107 |
| 82-13 | 1661 | 88-48 | 1942 | 99-24 | 1776 |
| 82-25 | 1675 | 89-7 | 5123 | 99-26 | 1779 |
| 82-37 | 1689 | 89-19 | 33 | 99-27 | 1778 |
| 83-22 | 1686 | 90-25 | 241 | 99-31 | 1780 |
| 83-46 | 1718 | 90-34 | 1961 | 99-33 | 211 |
| 83-53 | 1732 | 90-36 | 5131 | 99-43 | 1798 |
| 84-42 | 5101 | 90-39 | 1975 | 99-44 | 32 |
| 84-45 A | 1754 | 91-11 | 238 | 99-45 | 1800 |
| 84-45 B | 1755 | 92-34 | 3493 | 99-47 | 212 |
| 85-19 | 1706 | 92-40 | 3501 | 100-44 | 1794 |
| 85-42 | 1738 | 93-25 | 3695 | 100-54 A | 1811 |
| 85-44 | 1740 | 93-40 | 3717 | 100-54 B | 1812 |
| 85-48 | 1743 | 93-41 | 3720 | 101-16 | 1813 |
| 85-54 | 1745 | 95-30 | 1541 | 101-30 | 1835 |
| 86-27 | 1742 | 95-54 | 1588 | 101-42 | 1851 |
| 86-39 | 1759 | 95-57 A | 180 | 102-22 | 31 |
| 86-44 | 1765 | 95-57 B | 181 | 102-33 | 1790 |
| 86-45 | 5108 | 95-59 | 182 | 102-34 | 1791 |
| 87-3 | 1866 | 96-28 | 1746 | 102-53 A | 1830 A |
| 87-4 | 1867 | 96-50 | 209 | 102-53 B | 1830 B |
| 87-5 | 1869 | 96-51 | 1783 | 103-34 | 5116 |
| 87-7 | 1870 | 96-52 | 1784 | 103-46 | 218 |
| 87-8 | 220 | 97-42 | 1761 | 103-51 | 1862 |
| 87-12 | 1879 | 97-55 | 5110 | 104-37 | 1846 |
| 87-15 | 1884a | 98-25 | 1789 | 104-49 | 1858 |
| 87-26 A | 226 A | 98-38 | 1814 | 104-50 | 1860 |
| 87-26 B | 226 B | 98-46 | 1824 | 105-23 | 216 |
| 87-33 | 1912 | 98-49 | 1828 | 105-30 | 1838 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 105-41 | 5117 | 112-50 | 1951 | 118-51 | 5168 |
| 105-46 | 1857 | 113-24 | 5136 | 118-61 | 2270 |
| 106-25 | 1819 | 113-40 | 2017 | 118-66 | 2274 |
| 106-26 | 1820 | 114-13 | 2040 | 119-11 | 2278 |
| 106-35 | 5113 | 114-19 | 2055 | 119-22 | 2290 |
| 106-49 A | 1849 | 114-25 | 2080 | 119-25 | 2292 |
| 106-49 B | 1850 | 114-26 A | 2082 A | 119-29 | 2307 |
| 107-27 | 1874 | 114-26 B | 2082 B | 119-32 | 2308 |
| 107-32 | 5121 | 115-4 | 2016 | 119-36 | 293 |
| 107-34 | 1880 | 115-5 | 2014 | 119-37 | 2317 |
| 107-36 | 1883 | 115-10 | 2028 | 119-42 | 5181 |
| 107-42 | 1890 | 115-11 | 5139 | 119-52 | 37 |
| 107-55 | 1903 | 115-18 | 2041 | 119-57 | 297 |
| 107-56 | 1906a | 115-23 | 2047 | 119-59 | 2366 |
| 107-58 | 5122a | 115-27 | 2053 | 119-60 | 2367 |
| 107-63 | 1913a | 115-39 | 2081 | 119-64 | 2373 |
| 107-67 | 1915 | 115-42 | 2092 | 119-65 | 2382 |
| 107-69 | 229 | 115-47 | 2097 | 120-30 | 2387 |
| 107-70 A | 230 A | 115-50 | 2103 | 120-32 | 2394 |
| 107-70 B | 230 B | 115-57 | 2111 | 120-45 | 304 |
| 108-37 | 5120 | 115-63 A | 2117 | 120-49 | 5192 |
| 108-40 | 1884 | 115-63 B | 2118 | 120-51 | 2411 |
| 108-43 | 1886 | 116-23 | 2131 | 120-56 | 2418 |
| 108-48 | 1891 | 116-36 | 2155 | 120-57 | 2422 |
| 109-16 | 1861 | 116-42 | 2180 | 120-61 | 2431 |
| 109-35 | 223 | 116-46 | 2183 | 120-67 | 5195 |
| 110-17 | 1871 | 116-48 | 2185 | 120-68 | 310 |
| 111-18 | 1931 | 116-61 | 2203 | 121-12 | 2450 |
| 111-45 | 1958 | 116-70 | 5161 | 121-14 | 2451 |
| 111-47 | 1963 | 116-71 | 5162 | 121-27 | 2467 |
| 111-61 | 1988 | 116-77 | 2220 | 121-43 | 2495 |
| 112-21 | 1920 | 117-61 | 276 | 121-45 | 2497 |
| 112-27 | 1928 | 118-48 | 2245 | 121-68 | 2529 |
| 112-28 | 232 | 118-50 | 2248 | 121-77 | 2544 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 122-2 A | 2368 | 124-51 | 2940 | 129-48 | 5411 |
| 122-2 B | 2369 | 124-57 | 2957 | 130-4 | 4003 |
| 122-30 | 2426 | 124-72 | 2979 | 130-8 | 4008 |
| 122-34 | 2430 | 124-76 | 2982 | 130-11 | 4018 |
| 122-36 | 2432 | 124-81 | 2985 | 130-15 | 4019 |
| 122-40 | 2443 | 125-4 | 3450 | 130-24 | 4044 |
| 122-42 | 2449 | 125-6 | 3458 | 130-25 | 4045 |
| 122-45 | 2453 | 125-13 | 3467 | 130-36 | 1004 |
| 122-46 | 2458 | 125-24 | 3473 | 130-43 | 103 |
| 122-49 | 316 | 125-27 | 3478 | 130-49 | 1028 |
| 122-51 | 44 | 125-31 A | 3482 | 130-50 | 1029 |
| 122-62 | 2491 | 125-31 B | 3483 | 130-53 | 1037 |
| 122-64 | 5207 | 125-35 | 3489 | 130-56 | 1041 |
| 122-66 | 2498 | 125-45 | 3497 | 130-57 | 1043 |
| 122-67 | 321 | 125-55 | 3509 | 130-61 | 1054 |
| 122-68 | 2501 | 125-62 | 5354 | 130-68 | 1068 |
| 123-26 | 2548 | 126-4 | 508 | 131-66 | 1073 |
| 123-29 | 2556 | 126-5 | 3680 | 132-14 | 1120 |
| 123-33 | 5216 | 126-27 | 3703 | 132-15 | 1125 |
| 123-55 | 2613 | 126-60 | 3767 | 132-32 | 1153 |
| 123-60 | 2633 | 126-62 A | 3770 A | 132-35 | 1161 |
| 123-61 | 2637 | 126-62 B | 3770 B | 132-36 | 1162 |
| 123-63 | 5230 | 127-11 | 3781 | 132-40 | 5017 |
| 123-74 | 2654 | 128-2 | 5391 | 132-52 | 1185 |
| 123-82 | 2666 | 128-3 | 3854 | 132-57 | 137 |
| 123-84 | 2672 | 128-7 | 528 | 132-61 | 1211 |
| 124-23 | 368 | 128-8 | 3861 | 133-7 | 1242 |
| 124-25 | 369 | 128-10 | 3862 | 133-8 | 1244 |
| 124-24 A | 2894 | 128-11 | 3869 | 133-21 | 1266 |
| 124-24 B | 2895 | 128-34 | 536 | 133-29 | 1285 |
| 124-26 | 5270 | 128-48 | 3931 | 133-39 | 1296 |
| 124-27 | 2899 | 128-61 | 3946 | 133-47 | 5044 |
| 124-29 | 2904 | 128-73 | 3968 | 134-1 | 1343 |
| 124-47 | 374 | 129-47 | 551 | 134-22 | 153 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 134-24 | 1383 | 137-82 | 5313 | 141-25 | 5340 |
| 135-10 | 2844 | 138-8 | 3163 | 141-41 | 3415 |
| 135-13 | 2853 | 138-25 | 418 | 141-42 | 3416 |
| 135-35 | 2888 | 138-34 A | 3203 | 141-48 | 5343 |
| 135-44 | 2905 | 138-34 B | 3204 | 142-11 | 3488 |
| 135-47 | 2908 | 138-37 | 3210 | 142-12 | 3442 |
| 135-56 | 373 | 138-39 | 3213 | 142-52 | 479 |
| 135-61 | 2937 | 138-43 | 3221 | 143-20 | 5352 |
| 135-67 | 376 | 138-44 | 3225 | 143-26 | 3519 |
| 136-13 | 2974 | 138-49 | 3230 | 143-34 | 3529 |
| 136-14 | 2977 | 138-56 | 3236 | 143-35 | 3530 |
| 136-27 | 2995 | 138-59 | 425 | 143-41 | 3536 |
| 136-39 | 3005 | 138-64 | 3240 | 143-48 | 3544 |
| 136-47 | 3011 | 138-67 | 3251 | 144-25 | 495 |
| 136-69 | 3027 | 139-12 | 3265 | 144-29 | 3573 |
| 136-74 | 5290 | 139-21 | 3275 | 144-34 | 3576 |
| 136-76 | 3033 | 139-29 | 3277 | 144-40 | 3587 |
| 136-77 | 3036 | 139-39 | 448 | 144-44 | 3598 |
| 136-78 | 3037 | 139-48 | 3304 | 144-50 | 3610 |
| 136-85 | 3046 | 140-11 | 3329 | 144-58 | 3619 |
| 136-93 | 5294 | 140-16 | 3336 | 144-60 | 3621 |
| 136-102 | 3068 | 140-19 | 3338 | 144-61 | 3622 |
| 136-103 | 396 | 140-24 | 57 | 144-62 | 3625 |
| 137-8 | 3073 | 140-29 | 3349 | 145-23 | 3641 |
| 137-22 | 3083 | 140-37 | 5332 | 145-35 | 3651 |
| 137-25 | 400 | 140-39 | 3357 | 145-37 | 3667 |
| 137-26 | 399 | 140-46 | 3366 | 146-6 | 278 |
| 137-35 | 3101 | 140-47 | 3369 | 146-11 | 2225 |
| 137-60 | 3128 | 140-49 | 3373 | 146-15 | 2238 |
| 137-66 | 5304 | 140-52 | 3375 | 146-23 | 2249 |
| 137-71 | 3136 | 141-4 | 464 | 146-35 | 2268 |
| 137-74 | 3142 | 141-8 | 3387 | 146-39 | 2279 |
| 137-78 | 411 | 141-9 | 3388 | 146-58 | 287 |
| 137-81 | 5311 | 141-24 | 3399 | 146-72 | 2327 |

## TABLE 5.3 — continued

## CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 146-75 | 2332 | 152-49 | 3115 | 157-50 | 5401 |
| 147-11 | 2337 | 152-50 | 3117 | 157-54 | 3939 |
| 147-13 | 2340 | 152-69 | 5306 | 157-58 | 5402 |
| 148-23 | 2481 | 153-27 | 412 | 157-59 | 3941 |
| 148-66 | 5217a | 153-57 | 3205 | 157-64 | 3953 |
| 149-33 A | 2674 A | 153-58 | 419 | 157-69 | 3967a |
| 149-33 B | 2674 B | 153-59 | 3207 | 157-77 | 546 |
| 149-40 | 5238 | 154-8 | 3316 | 157-90 | 3993 |
| 149-44 | 2679 | 154-9 | 3320 | 157-93 | 4005 |
| 149-70 | 2711 | 154-19 | 3327 | 158-2 | 4036 |
| 149-81 | 350 | 154-34 | 3340 | 158-14 | 5410 |
| 149-88 | 2733 | 154-36 A | 3345 A | 158-15 | 4051 |
| 149-94 | 355 | 154-36 B | 3345 B | 158-22 | 1006 |
| 150-9 | 2749 | 154-41 | 3352 | 158-27 | 2 |
| 150-15 | 2761 | 154-44 | 3359 | 158-31 | 1023 |
| 150-25 | 2771 | 154-51 | 5334 | 158-45 | 1044 |
| 150-34 | 2792 | 155-15 | 3384 | 158-50 A | 1047 A |
| 150-36 | 2795 | 155-26 | 3396 | 158-50 B | 1047 B |
| 150-54 | 2837 | 155-27 | 466 | 158-53 | 109 |
| 150-74 | 5268 | 155-29 | 3398 | 158-86 | 1086 |
| 151-6 | 2993 | 155-30 | 3400 | 158-87 | 1087 |
| 151-13 | 5283 | 155-33 | 3403 | 158-94 | 1091 |
| 151-20 | 3015a | 155-40 | 5342 | 158-95 | 113 |
| 151-28 | 5289a | 156-31 A | 68 A | 158-103 | 1106 |
| 151-34 | 392 | 156-31 B | 68 B | 159-3 | 1302 |
| 151-41 | 3049 | 156-43 | 3846 | 159-34 | 1332 |
| 151-45 | 3056 | 156-57 | 530 | 159-46 | 1358 |
| 151-46 | 394 | 156-63 | 3872 | 159-50 | 1365 |
| 151-49 | 3062 | 156-64 | 3875 | 159-53 | 1372 |
| 152-31 | 3076 | 156-65 | 3874 | 160-5 | 20 |
| 152-32 | 3077 | 157-32 | 3913 | 160-17 | 5079 |
| 152-37 | 3086 | 157-33 | 3914 | 160-19 | 1582 |
| 152-40 | 3093 | 157-35 | 3917 | 160-22 | 1590 |
| 152-46 | 3110 | 157-44 | 3929 | 160-28 | 183 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 160-35 | 5087 | 164-72 | 5245 | 167-33 | 3054 |
| 160-42 | 186 | 164-73 | 2735 | 167-34 | 3058 |
| 160-43 | 1624 | 165-7 | 1745 | 167-47 | 3080 |
| 160-53 | 5092 | 165-17 | 2763 | 167-51 | 3091 |
| 160-60 A | 24 | 165-25 | 2784 | 168-14 | 3124 |
| 160-60 B | 25 | 165-29 | 2791 | 168-20 | 3138 |
| 161-24 | 2137 | 165-38 | 2833 | 168-32 | 3158 |
| 161-25 | 2138 | 165-40 | 2845 | 168-33 | 5314 |
| 161-30 | 2142 | 165-47 | 364 | 169-6 | 3192 |
| 161-33 | 2145 | 165-48 | 2861 | 169-7 | 3193 |
| 161-34 | 2146 | 165-51 | 5266 | 169-15 | 5317 |
| 161-38 | 5153 | 165-53 | 5267 | 169-18 | 5318a |
| 161-51 | 2158 | 165-60 | 2886 | 169-20 | 3226 |
| 161-52 | 2159 | 165-61 | 2887 | 169-34 | 3254 |
| 161-74 | 2186 | 165-62 | 2890 | 169-38 | 3257 |
| 161-80 | 274 | 166-22 | 2903 | 170-12 | 430 |
| 162-32 | 2240 | 166-25 | 2915 | 170-17 | 5324 |
| 162-38 | 2244 | 166-27 | 371 | 170-19 | 3266 |
| 162-52 | 2259 | 166-28 | 372 | 170-37 | 3288 |
| 163-23 | 2328 | 166-29 | 2918 | 170-50 | 3302 |
| 163-27 | 2333 | 166-33 | 2925 | 170-55 | 452 |
| 163-52 | 2356 | 166-36 | 2947 | 170-61 | 3319 |
| 163-59 | 299 | 166-38 | 2948 | 170-62 | 3324 |
| 163-74 | 2393 | 166-40 | 2962 | 171-1 | 5406 |
| 164-12 | 2612 | 166-44 | 5278 | 171-5 | 3980 |
| 164-13 | 2614 | 166-52 | 2996 | 171-8 | 3991 |
| 164-17 | 2624 | 166-53 A | 2997 A | 171-10 | 549 |
| 164-53 | 2703 | 166-53 B | 2997 B | 171-11 | 4002 |
| 164-55 | 2708 | 166-57 | 388 | 171-19 | 4015 |
| 164-64 | 2716 | 166-58 | 3007 | 171-27 | 4043 |
| 164-65 | 2717 | 167-12 | 3015 | 171-29 | 4054 |
| 164-68 | 2724 | 167-19 | 391 | 171-33 | 4056 |
| 164-71 A | 2728 A | 167-22 | 3026 | 171-39 | 1014 |
| 164-71 B | 2728 B | 167-32 | 3052 | 171-40 A | 1016 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 171-40 B | 1017 | 176-3 | 2336 | 179-57 | 3122 |
| 171-44 | 1053 | 176-4 | 5185 | 180-8 | 3129 |
| 171-47 | 3 | 176-11 | 38 | 180-9 | 3130 |
| 171-48 | 4 | 176-12 | 39 | 180-17 | 3137 |
| 171-51 | 1062 | 176-34 | 2403 | 180-23 | 3146 |
| 172-11 | 1104 | 176-40 | 307 | 180-27 | 3150 |
| 172-14 | 1111 | 176-53 | 312 | 180-31 | 3153 |
| 172-30 | 1169 | 177-4 | 2651 | 180-33 | 3155 |
| 173-14 | 1277 | 177-13 | 2670 | 180-56 | 3201 |
| 173-34 | 1330 | 177-25 | 2686 | 180-57 | 3200 |
| 173-37 | 5050 | 177-27 | 2702 | 180-58 | 3199 |
| 174-1 | 155 | 177-44 | 2762 | 180-61 | 5318 |
| 174-14 | 1446 | 177-48 | 2772 | 181-16 | 5323 |
| 174-18 | 1473 | 177-51 | 357 | 181-24 | 3261 |
| 174-19 | 1475 | 177-52 | 2777 | 181-30 | 3267 |
| 174-20 | 1476 | 177-53 | 2778 | 181-33 | 3276 |
| 174-27 | 1488 | 177-57 | 2785 | 181-37 | 3282 |
| 174-31 | 1495 | 177-58 | 2789 | 181-39 | 3281 |
| 174-33 | 1498 | 177-61 | 5256 | 181-42 A | 5327 |
| 174-38 | 1518 | 178-10 | 2884 | 181-42 B | 5328 |
| 174-41 A | 1522 | 178-18 | 2901 | 182-19 | 3312 |
| 174-41 B | 1523 | 178-19 | 2902 | 182-34 | 3350 |
| 175-7 | 5085 | 178-21 | 5271 | 182-35 | 3353 |
| 175-8 | 1597 | 178-31 | 2931 | 182-36 | 457 |
| 175-13 | 1618 | 178-37 | 2943 | 183-5 | 3333 |
| 175-14 | 1621 | 178-44 | 2963 | 183-23 | 3355 |
| 175-17 | 5091 | 178-55 | 2998 | 183-26 | 3361 |
| 175-19 | 1642 | 179-9 | 3016 | 183-28 | 3364 |
| 175-34 A | 26 | 179-20 | 3035 | 183-31 | 3368 |
| 175-34 B | 27 | 179-24 | 5292 | 183-32 | 3371 |
| 175-37 | 1683 | 179-25 | 3051 | 183-44 | 3392 |
| 175-39 | 1684 | 179-33 | 3075 | 184-19 | 3405 |
| 175-42 | 1688 | 179-43 A | 402 | 184-29 | 3412 |
| 175-45 | 1697 | 179-43 B | 403 | 184-35 | 3417 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 184-42 | 3425 | 189-28 | 3835 | 193-67 | 1947 |
| 184-48 | 3432 | 189-38 | 3859 | 193-70 | 1948 |
| 184-49 | 3433 | 189-53 | 3879 | 193-75 | 1954 |
| 185-8 | 3435 | 190-13 | 3903 | 193-81 | 1964 |
| 185-12 | 3445 | 190-17 | 3923 | 193-83 | 1973 |
| 185-13 | 3446 | 190-20 | 3936 | 194-7 | 1976 |
| 185-18 | 476 | 190-22 | 3942 | 194-19 | 1996 |
| 185-19 | 3456 | 190-24 | 3951 | 194-22 | 2000 |
| 185-37 A | 478 A | 190-26 | 3957 | 194-41 | 2054 |
| 185-37 B | 478 B | 191-11 | 1702 | 194-50 | 259 |
| 186-7 | 3506 | 191-15 | 1721 | 194-57 | 2109 |
| 186-11 | 481 | 191-19 | 28 | 195-17 | 260 |
| 186-31 | 3562 | 191-21 | 1733 | 195-18 | 261 |
| 186-35 | 3567 | 191-29 | 1757 | 195-19 | 262 |
| 187-8 | 3589 | 191-30 | 1758 | 195-22 | 265 |
| 187-9 | 3605 | 191-48 | 1772 | 195-36 | 2175 |
| 187-28 | 5367 | 191-50 | 1773 | 195-46 | 5157 |
| 187-30 A | 3637 A | 191-51 | 1775 | 195-47 | 2205 |
| 187-30 B | 3637 B | 191-53 | 1786 | 195-52 A | 5163 A |
| 187-39 | 3653 | 192-8 | 1799 | 195-52 B | 5163 B |
| 187-43 | 3673 | 192-13 | 1805 | 195-57 | 2224 |
| 188-15 | 3698 | 192-14 | 1806 | 195-59 | 2232 |
| 188-24 | 3704 | 192-15 | 1809 | 196-9 | 280 |
| 188-26 | 3713 | 192-26 | 1848 | 196-13 | 2237 |
| 188-28 | 3725 | 192-30 | 1854 | 196-22 | 2262 |
| 188-30 | 3731 | 192-32 | 1856 | 196-23 | 2263 |
| 188-32 | 5375 | 192-39 A | 1864 A | 196-24 | 5170 |
| 188-33 | 5376 | 192-39 B | 1864 B | 196-28 | 2275 |
| 188-37 | 3743 | 192-58 | 1882 | 196-29 | 2277 |
| 188-46 | 3771 | 193-27 | 224 | 196-31 | 5171a |
| 188-51 | 3784 | 193-38 | 1907 | 196-45 | 2312 |
| 189-11 | 3796 | 193-59 | 1940 | 196-51 | 2331 |
| 189-12 | 3797 | 193-60 | 1941 | 196-58 | 2349 |
| 189-23 | 3823 | 193-62 | 1946 | 197-14 | 2410 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|-----|-------|-----|-------|-----|-------|
| 197-15 | 2413 | 201-7 | 2957 | 207-16 A | 471 A |
| 197-16 | 2414 | 201-27 | 3006 | 207-16 B | 471 B |
| 197-32 | 2461 | 201-33 | 5287 | 207-18 | 3434 |
| 197-38 | 2486 | 201-37 | 3031 | 207-30 | 3459 |
| 197-47 | 2522 | 201-48 | 3069 | 208-22 | 3465 |
| 198-19 | 2503 | 201-55 | 3082 | 208-39 | 3485 |
| 198-58 | 2571 | 202-32 | 3166 | 208-44 A | 3494 A |
| 199-7 | 2546 | 202-36 | 5315 | 208-44 B | 3494 B |
| 199-17 A | 331 | 202-45 A | 417 A | 208-45 | 3495 |
| 199-17 B | 330 | 202-45 B | 417 B | 209-33 | 3559 |
| 199-24 | 2574 | 202-61 | 3214 | 209-41 | 3577 |
| 199-31 | 2584 | 202-68 | 5319 | 210-19 | 491 |
| 199-33 | 2588 | 203-42 | 3262 | 210-29 | 5357 |
| 199-35 | 2617 | 203-51 A | 433 | 210-31 | 3574 |
| 199-41 | 2639 | 203-51 B | 434 | 210-38 | 3591 |
| 199-42 | 2640 | 203-52 | 435 | 210-48 A | 3609 A |
| 199-45 | 2646 | 203-63 | 446 | 210-48 B | 3609 B |
| 199-51 | 2659 | 203-71 | 3298 | 211-15 | 3646 |
| 199-60 | 2684 | 204-24 | 3313 | 212-12 | 5362 |
| 199-64 | 2700 | 204-27 | 3321 | 212-21 | 5364 |
| 199-72 | 2751 | 204-32 | 3334 | 212-24 | 5365 |
| 200-14 | 2839 | 204-39 | 3343 | 212-29 | 3638 |
| 200-15 | 2840 | 204-48 | 3365 | 212-37 | 5370 |
| 200-16 A | 2849 | 204-57 | 461 | 212-39 | 3678 |
| 200-16 B | 2850 | 204-58 | 462 | 212-56 | 3705 |
| 200-24 | 2882 | 205-5 | 3363 | 212-59 | 3711 |
| 200-29 | 2889 | 205-18 | 5335 | 213-9 | 3700 |
| 200-31 | 2897 | 205-20 | 3385 | 215-2 | 3693 |
| 200-32 | 2898 | 205-30 | 3394 | 215-20 | 3727 |
| 200-38 | 2914 | 205-32 | 3395 | 215-21 | 3729 |
| 200-46 | 2936 | 205-40 | 3420 | 215-22 | 3730 |
| 200-58 | 2973 | 205-55 | 3429 | 215-44 | 5383a |
| 200-59 | 2990 | 206-38 A | 3401 | 215-46 | 3810 |
| 200-62 | 384 | 206-38 B | 3402 | 215-48 | 5388 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 215-49 | 3818 | 224-57 | 3044 | 231-17 | 3590 |
| 215-50 | 524 | 224-74 | 3089 | 231-19 | 3595 |
| 216-16 | 3853 | 224-79 | 3105 | 231-27 | 64 |
| 217-1 | 3930 | 225-40 | 3139 | 231-39 | 3649 |
| 217-11 | 544 | 225-42 | 5305 | 231-42 | 3670 |
| 217-18 | 4005a | 225-43 | 5307 | 231-44 | 3676 |
| 217-27 | 1002a | 225-57 | 3175 | 231-53 A | 3699 A |
| 217-37 | 1038 | 225-58 | 3176 | 231-53 B | 3699 B |
| 217-38 | 1039 | 225-65 | 3212 | 232-54 | 3758 |
| 217-55 | 1088 | 225-67 A | 421 A | 232-69 | 5386 |
| 217-56 | 5009 | 225-67 B | 421 B | 232-71 | 3812 |
| 217-59 | 1105 | 225-68 | 422 | 232-75 A | 3814 |
| 218-17 | 126 | 226-9 | 3208 | 232-75 B | 3815 |
| 219-5 | 1234 | 226-45 | 3264 | 233-17 A | 525 A |
| 221-1 | 1418 | 226-62 | 3293 | 233-17 B | 525 B |
| 221-5 | 18 | 226-64 | 3299 | 233-17 C | 525 C |
| 221-12 | 1553 | 226-66 | 3306 | 233-31 | 3871 |
| 221-20 | 5080 | 226-107 | 1067 | 233-47 | 5398 |
| 221-21 | 5081 | 227-28 | 3380 | 234-33 | 2008 |
| 221-22 | 1596 | 227-29 | 465 | 234-35 | 2018 |
| 221-26 | 1623 | 227-30 | 3386 | 234-37 | 250 |
| 221-28 | 1631 | 227-46 | 58 | 234-38 A | 251 A |
| 222-2 | 1643 | 227-47 | 59 | 234-38 B | 251 B |
| 222-4 | 1677 | 228-12 | 3341 | 234-42 | 2032 |
| 222-11 | 215 | 229-16 | 3410 | 234-43 | 2038 |
| 223-22 | 2788 | 229-33 | 3466 | 234-45 | 252 |
| 223-27 | 5257 | 229-35 | 3472 | 234-47 | 2051 |
| 223-35 | 2824 | 230-18 | 3499 | 234-48 | 2066 |
| 223-38 | 2827 | 230-25 | 3518 | 234-51 | 2086 |
| 223-43 | 2864 | 230-26 | 482 | 234-52 | 2087 |
| 223-74 | 2952 | 230-37 | 3543 | 234-54 | 2102 |
| 224-9 | 2929 | 230-40 | 3549 | 234-55 | 2105 |
| 224-39 | 3009 | 230-42 | 494 | 235-35 | 2176 |
| 224-44 | 3018 | 231-13 | 498 | 235-36 | 2178 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 235-40 | 2191 | 240-38 | 3258 | 242-81 | 1344 |
| 235-46 | 2197 | 240-63 | 450 | 243-30 A | 114 A |
| 235-48 | 2202 | 240-64 A | 5330 | 243-30 B | 115 |
| 235-49 | 2211 | 240-64 B | 5331 | 243-30 C | 114 B |
| 235-55 | 2222 | 240-72 | 455 | 243-48 | 1170 |
| 235-62 | 2239 | 241-1 | 3783 | 243-50 | 1176 |
| 236-22 | 2250 | 241-12 | 3829 | 243-52 | 1179 |
| 236-34 | 283 | 241-13 | 3830 | 243-55 | 1183 |
| 236-46 | 2334 | 241-24 | 3858 | 243-59 | 5026 |
| 236-65 | 41 | 241-31 | 3877 | 243-60 | 136 |
| 236-80 | 42 | 241-32 | 3881 | 243-62 | 1198 |
| 237-37 | 5203 | 241-33 | 3882 | 243-63 | 1206 |
| 237-38 | 2488 | 241-36 | 5395 | 243-67 | 5030 |
| 237-54 | 2536 | 241-42 | 3894 | 244-31 | 1283 |
| 237-56 | 5212 | 241-44 | 534 | 244-33 | 1291 |
| 237-62 A | 5215 A | 241-45 | 535 | 244-41 | 1313 |
| 237-62 B | 5215 B | 241-57 | 3967 | 244-42 | 1312 |
| 237-63 | 2551 | 241-66 | 4004 | 244-56 | 1371 |
| 237-68 | 2576 | 241-68 | 4006 | 244-59 | 5051b |
| 237-81 | 2649 | 241-76 A | 1040 A | 244-60 | 1397 |
| 237-88 | 2677 | 241-76 B | 1040 B | 245-25 | 1254 |
| 238-21 | 5234 | 242-30 | 5400 | 245-34 | 1310 |
| 238-26 | 2687 | 242-32 | 3938 | 245-45 | 1350 |
| 238-35 | 2727 | 242-44 | 4052 | 245-61 | 1478 |
| 238-39 | 2748 | 242-45 | 4053 | 245-65 | 1505 |
| 238-42 | 2752 | 242-51 | 1065 | 245-71 | 5072 |
| 238-54 | 2820 | 242-52 | 1066 | 246-13 | 1455 |
| 238-55 | 2819 | 242-55 | 5006 | 246-14 | 1456 |
| 239-21 | 2946 | 242-56 | 5007 | 246-22 | 1494 |
| 239-29 | 2976 | 242-60 | 1101 | 246-30 | 1521 |
| 239-32 | 2991 | 242-64 | 5013 | 246-32 | 1530 |
| 239-48 | 3057 | 242-73 | 1167 | 246-38 | 175 |
| 239-58 | 3103 | 242-76 | 131 | 246-44 | 1583 |
| 240-25 | 3238 | 242-77 | 1182 | 246-49 | 1602 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|-----|-------|-----|-------|-----|-------|
| 246-53 | 1613 | 252-17 | 2030 | 256-20 | 3017 |
| 247-14 | 1637 | 252-19 | 2031 | 257-20 | 404 |
| 247-15 | 1638 | 252-24 A | 256 | 258-28 | 3351 |
| 247-20 | 5093 | 252-24 B | 257 | 258-33 | 3376 |
| 247-22 | 1679 | 252-25 | 2088 | 259-12 | 3309 |
| 247-23 | 1680 | 252-26 | 2091 | 259-15 | 3297 |
| 247-45 | 1728 | 252-27 | 2101 | 259-17 | 3318 |
| 247-50 | 1741 | 252-30 A | 264 A | 259-21 | 56 |
| 248-10 | 1619 | 252-30 B | 264 B | 259-22 | 3344 |
| 248-12 | 1629 | 252-31 | 2124 | 259-31 | 3391 |
| 248-18 | 1664 | 252-33 | 2126 | 259-39 | 5345 |
| 248-19 | 1663 | 252-44 | 2188 | 260-1 | 460 |
| 249-2 | 1752 | 253-2 | 1962 | 260-15 | 3424 |
| 249-18 | 1782 | 253-6 | 1956 | 261-1 | 3436 |
| 249-27 | 213 | 253-18 | 2095 | 261-6 | 3461 |
| 249-28 | 214 | 253-21 | 2123 | 261-19 | 3527 |
| 249-32 | 1808 | 253-23 | 5150 | 261-22 | 3545 |
| 249-36 | 1817 | 253-31 | 2196 | 261-23 | 3547 |
| 249-46 | 217 | 253-37 | 2291 | 261-28 A | 3565 A |
| 249-51 | 1853 | 253-40 | 5180a | 261-28 B | 3565 B |
| 250-19 | 5119 | 253-49 | 2404 | 261-28 C | 3565 C |
| 250-29 A | 221 A | 253-50 | 2405 | 261-29 | 3592 |
| 250-29 B | 221 B | 253-59 | 5215a | 261-35 | 5361 |
| 250-31 | 1885 | 254-16 | 2359 | 261-38 | 3631 |
| 250-32 | 1888 | 254-24 | 2424 | 261-39 | 3642 |
| 250-38 | 1897 | 254-27 | 2439 | 261-45 | 3687 |
| 251-16 | 1865 | 254-29 | 2459 | 261-46 | 514 |
| 251-43 | 5126a | 254-35 | 2513 | 262-15 | 3558 |
| 251-44 | 236 | 255-17 | 2610 | 262-27 | 3586 |
| 251-51 | 1983 | 255-49 | 2866 | 263-21 | 3822 |
| 251-52 | 1984 | 255-50 | 2868 | 264-17 | 3749 |
| 251-58 | 1993 | 255-51 | 2865 | 265-8 | 140 |
| 252-10 | 2001 | 255-52 | 2922 | 265-34 | 5326 |
| 252-13 | 2025 | 256-19 | 5289 | 266-1 | 4037 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # | G # | LHS # | G # | LHS # |
|---|---|---|---|---|---|
| 266-8 | 4048 | 268-38 | 1140 | 271-163 | 1301 |
| 266-20 | 552 | 268-53 | 1154 | 271-168 | 1303 |
| 266-21 | 4055 | 268-60 | 1159 | 272-4 | 1238 |
| 266-36 | 1011 | 268-76 | 1165 | 272-15 | 5033 |
| 266-42 | 5001 | 268-77 | 127 | 272-58 | 1271 |
| 266-55 | 1025 | 268-110 | 134 | 272-61 A | 9 |
| 266-57 | 1026 | 268-135 | 138 | 272-61 B | 10 |
| 266-72 | 1045 | 268-145 | 1224 | 272-36 | 142 |
| 266-73 | 1046 | 268-146 | 1225 | 272-81 | 1286 |
| 266-87 | 1057 | 269-49 | 1163 | 272-102 | 5037 |
| 266-88 | 110 | 269-63 | 129 | 272-114 | 1307 |
| 266-89 | 111 | 269-67 | 1171 | 272-137 | 1325 |
| 266-132 | 1099 | 269-87 | 1186 | 272-148 | 149 |
| 266-135 | 1102 | 269-106 | 1197 | 273-1 A | 540 A |
| 266-152 | 1124 | 269-112 | 1207 | 273-1 B | 540 B |
| 266-157 | 1126 | 269-125 | 1217 | 273-15 | 3932 |
| 267-11 | 4058 | 269-138 | 1232 | 273-83 | 5408 |
| 267-16 | 1003 | 269-140 | 5031 | 273-95 | 3990 |
| 267-18 | 1008 | 269-160 | 1247 | 273-130 | 4009 |
| 267-23 | 1012 | 269-161 | 1249 | 273-134 | 4011 |
| 267-25 | 1 | 269-166 | 1251 | 273-137 | 4014 |
| 267-45 | 1036 | 269-171 | 1253 | 273-147 | 4021 |
| 267-58 | 1048 | 270-23 | 1112 | 273-151 | 4032 |
| 267-106 | 1077 | 270-26 | 1113 | 273-183 | 4050 |
| 267-107 | 1078 | 270-28 | 1115 | 274-53 | 1255a |
| 267-121 | 1092 | 270-39 | 1128 | 274-83 | 1278 |
| 267-128 A | 1097 | 270-118 | 5019 | 274-90 | 1293 |
| 267-128 B | 1098 | 270-154 | 1203 | 274-106 | 5043 |
| 267-138 | 1108 | 270-155 | 1205 | 274-136 | 1321 |
| 267-141 A | 1110 A | 270-188 | 1228 | 274-143 | 1329 |
| 267-141 B | 1110 B | 271-34 | 1231 | 274-145 | 1337 |
| 267-149 | 1119 | 271-84 | 1256 | 274-146 | 1338 |
| 267-157 | 1127 | 271-115 | 1270 | 274-149 | 1339 |
| 267-168 | 1144 | 271-130 | 5038 | 275-6 | 3898 |

TABLE 5.3 — continued

CROSS-LIST: GICLAS (G) — LHS

| G # | LHS # |
|---|---|
| 275-13 | 3904 |
| 275-14 | 3905 |
| 275-29 | 3927 |
| 275-46 | 3948a |
| 275-83 | 4000 |
| 275-90 | 72 |
| 275-92 | 73 |
| 275-106 | 4016 |
| 275-121 B | 4039 |
| 275-121 A | 4040 |

TABLE 5.4

CROSS-LIST: COMMON NAME — LHS

| Common Name | LHS # |
|---|---|
| Achird | 122/123 |
| Als[c]hai[r]n | 5350aAB |
| Altair | 3490 |
| A[l]thafi | 477 |
| Alula Australis/El Acola | 2390/2391 |
| Arcturus | 48 |
| Caph | 1027 |
| Chara | 2579 |
| Chort | 2858 |
| Denebola | 2462 AB |
| Fornacis | 1515 AB |
| Gienah Cygni | 5358b |
| Keid/Kied | 23/24/25 |
| Marfak[a] | 8 AB |
| Pollux | 1945 |
| Porrima | 2604/2605 |
| Procyon | 233 AB |
| Proxima Centauri | 49 |
| Rana | 1557 |
| Rigel Kentaurus | 50/51 |
| Sirius | 219 AB |
| Talit[h]a | 2083 AB/2084 |
| Zavijava | 2465 |

[a] This name is not unique to LHS 8 AB.

TABLE 5.5

CROSS-LIST: BAYER DESIGNATION — LHS

| Bayer | LHS # | Bayer | LHS # | Bayer | LHS # |
|---|---|---|---|---|---|
| $\alpha$ Aql | 3490 | $o^2$ Eri B | 24 | $\varsigma^1$ Ret | 171 |
| $\beta$ Aql A | 5350aA | $o^2$ Eri C | 25 | $\varsigma^2$ Ret | 172 |
| $\beta$ Aql B | 5350aB | $r^6$ Eri | 1591 | $\kappa$ Ret A | 1551 |
| $\lambda$ Aur | 1753 | $\chi$ Eri A | 1314 A | $\kappa$ Ret B | 1552 |
| $\alpha$ Boo | 48 | $\chi$ Eri B | 1314 B | $\epsilon$ Sco | 3244 |
| $\beta$ Cas | 1027 | $\alpha$ For A | 1515 A | $\gamma$ Ser | 408 |
| $\eta$ Cas A | 123 | $\alpha$ For B | 1515 B | $\eta$ Ser | 3381 |
| $\eta$ Cas B | 122 | $\epsilon$ For | 1489 | $\delta$ Tri A | 154 A |
| $\mu$ Cas A | 8 A | $\beta$ Gem | 1945 | $\delta$ Tri B | 154 B |
| $\mu$ Cas B | 8 B | $\varsigma$ Her A | 3234 A | $\varsigma$ Tuc | 5 |
| $\alpha$ Cen A | 50 | $\varsigma$ Her B | 3234 B | $\theta$ UMa A | 270 A |
| $\alpha$ Cen B | 51 | $\mu$ Her A | 3326 | $\theta$ UMa B | 270 B |
| $\theta$ Cen | 2858 | $\mu$ Her B | 3325 A | $\iota$ UMa A | 2084 |
| $\eta$ Cep | 3578 | $\mu$ Her C | 3325 B | $\iota$ UMa B | 2083 A |
| $r$ Cet | 146 | $\chi$ Her | 3127 | $\iota$ UMa C | 2083 B |
| $\alpha$ CMa A | 219 A | $\beta$ Hyi | 6 | $\xi$ UMa A | 2390 |
| $\alpha$ CMa B | 219 B | $\epsilon$ Ind | 67 | $\xi$ UMa B | 2391 |
| $\alpha$ CMi A | 233 A | $\nu$ Ind | 520 | $\beta$ Vir | 2465 |
| $\alpha$ CMi B | 233 B | $\beta$ Leo A | 2462 A | $\gamma$ Vir A | 2604 |
| $\pi^1$ Cnc A | 2114 A | $\beta$ Leo B | 2462 B | $\gamma$ Vir B | 2605 |
| $\pi^1$ Cnc B | 2114 B | $\delta$ Lep | 1792 | | |
| $\rho^1$ Cnc A | 2062 | $\nu^2$ Lup | 395 | | |
| $\rho^1$ Cnc B | 2063 | $\pi$ Men | 208 | | |
| $\beta$ Com | 348 | $\gamma$ Pav | 3674 | | |
| $\rho$ CrB | 3145 | $\delta$ Pav | 485 | | |
| $\beta$ CVn | 2579 | $\phi^2$ Pav | 3569 | | |
| $\epsilon$ Cyg A | 5358b | $\xi$ Peg A | 3851 | | |
| $\epsilon$ Cyg B | 5358a | $\xi$ Peg B | 3852 | | |
| $\sigma$ Dra | 477 | $\sigma$ Peg A | 3864 | | |
| $\chi$ Dra A | 3379 A | $\sigma$ Peg B | 3865 | | |
| $\chi$ Dra B | 3379 B | $\iota$ Per | 166 | | |
| $\delta$ Eri | 1581 | $\nu$ Phe | 1220 | | |
| $\epsilon$ Eri | 1557 | $\gamma$ Psc | 3920 | | |
| $o^2$ Eri A | 23 | $\iota$ Psc | 3995 | | |

TABLE 5.6

CROSS-LIST: FLAMSTEED DESIGNATION — LHS

| Flamst. | LHS # | Flamst. | LHS # | Flamst. | LHS # |
|---------|-------|---------|-------|---------|-------|
| 31 Aql | 3463 | 61 Dra | 477 | 49 Peg B | 3865 |
| 53 Aql | 3490 | 12 Eri A | 1515 A | 85 Peg A | 101 A |
| 60 Aql A | 5350aA | 12 Eri B | 1515 B | 85 Peg B | 101 B |
| 60 Aql B | 5350aB | 18 Eri | 1557 | 6 Psc | 3920 |
| 15 Aur | 1753 | 23 Eri | 1581 | 17 Psc | 3995 |
| 16 Boo | 48 | 27 Eri | 1591 | 54 Psc | 1116 |
| 11 Cas | 1027 | 40 Eri A | 23 | 107 Psc | 1287 |
| 24 Cas A | 123 | 40 Eri B | 24 | 171 Pup | 237 |
| 24 Cas B | 122 | 40 Eri C | 25 | 18 Sco | 3171 |
| 30 Cas A | 8 A | 78 Gem | 1945 | 26 Sco | 3244 |
| 30 Cas B | 8 B | 1 Her | 3127 | 5 Ser A | 3059 |
| 5 Cen | 2858 | 40 Her A | 3234 A | 5 Ser B | 3060 |
| 3 Cep | 3578 | 40 Her B | 3234 B | 39 Ser | 3131 |
| 52 Cet | 146 | 72 Her | 441 | 41 Ser | 408 |
| 9 CMa A | 219 A | 86 Her A | 3326 | 58 Ser | 3381 |
| 9 CMa B | 219 B | 86 Her B | 3325 A | 15 Sge | 3515 |
| 10 CMi A | 233 A | 86 Her C | 3325 B | 10 Tau | 1569 |
| 10 CMi B | 223 B | 83 Leo A | 2407 | 104 Tau | 1736 |
| 55 Cnc A | 2062 | 83 Leo B | 2408 | 8 Tri A | 154 A |
| 55 Cnc B | 2063 | 94 Leo A | 2462 A | 8 Tri B | 154 B |
| 81 Cnc A | 2114 A | 94 Leo B | 2462 B | 9 UMa A | 2084 |
| 81 Cnc B | 2114 B | 15 Lep | 1792 | 9 UMa B | 2083 A |
| 43 Com | 348 | 49 Lib | 3143 | 9 UMa C | 2083 B |
| 15 CrB | 3145 | 11 LMi A | 2156 A | 10 UMa A | 2093 A |
| 8 CVn | 2579 | 11 LMi B | 2156 B | 10 UMa B | 2093 B |
| 27 Cyg | 5353 | 20 LMi | 2216 | 25 UMa A | 270 A |
| 53 Cyg A | 5358b | 12 Oph | 3224 | 25 UMa B | 270 B |
| 53 Cyg B | 5358a | 36 Oph A | 437 | 53 UMa A | 2390 |
| 61 Cyg A | 62 | 36 Oph B | 438 | 53 UMa B | 2391 |
| 61 Cyg B | 63 | 70 Oph A | 458 | 5 Vir | 2465 |
| 26 Dra A | 3305 A | 70 Oph B | 459 | 29 Vir A | 2604 |
| 26 Dra B | 3305 B | 46 Peg A | 3851 | 29 Vir B | 2605 |
| 44 Dra A | 3379 A | 46 Peg B | 3852 | 33 Vir | 2631 |
| 44 Dra B | 3379 B | 49 Peg A | 3864 | 61 Vir | 349 |
|  |  |  |  | 70 Vir | 2740 |

TABLE 5.7

CROSS-LIST: HR — LHS

| HR # | LHS # | HR # | LHS # | HR # | LHS # |
|---|---|---|---|---|---|
| 6 | 1020 | 1083 A | 1551 | 3522 B | 2063 |
| 21 | 1027 | 1083 B | 1552 | 3569 | 2084 |
| 77 | 5 | 1084 | 1557 | 3579 A | 2093 A |
| 98 | 6 | 1101 | 1569 | 3579 B | 2093 B |
| 159 A | 118 A | 1136 | 1581 | 3650 A | 2114 A |
| 159 B | 118 B | 1173 | 1591 | 3650 B | 2114 B |
| 166 | 1116 | 1325 | 23 | 3775 A | 270 A |
| 173 | 1124 | 1614 | 200 | 3775 B | 270 B |
| 176 | 1123 | 1656 | 173 | 3815 A | 2156 A |
| 219 | 123 | 1729 | 1753 | 3815 B | 2156 B |
| 222 | 121 | 1925 | 1774 | 3951 | 2216 |
| 321 A | 8 A | 2022 | 208 | 4098 | 2267 |
| 321 B | 8 B | 2035 | 1792 | 4158 | 2286 |
| 370 | 1220 | 2067 | 1803 | 4328 | 2354 |
| 483 A | 1284 A | 2083 | 1797 | 4374 | 2391 |
| 483 B | 1284 B | 2102 | 1796 | 4375 | 2390 |
| 493 | 1287 | 2401 | 1868 | 4414 A | 2407 |
| 509 | 146 | 2491 A | 219 A | 4414 B | 2408 |
| 511 | 1297 | 2491 B | 219 B | 4458 | 308 |
| 566 A | 1314 A | 2576 | 1878 | 4486 A | 2437 |
| 566 B | 1314 B | 2643 | 1893 | 4486 B | 2436 |
| 637 | 13 | 2692 | 1899 | 4523 | 311 |
| 660 A | 154 A | 2943 A | 233 A | 4534 A | 2462 A |
| 660 B | 154 B | 2943 B | 233 B | 4534 B | 2462 B |
| 672 | 1382 | 2990 | 1945 | 4540 | 2465 |
| 683 | 1387 | 2997 | 5130 | 4550 | 44 |
| 753 | 15 | 2998 | 1939 | 4587 | 5206 |
| 914 | 1489 | 3018 | 237 | 4657 | 322 |
| 937 | 166 | 3138 | 1959 | 4710 | 2553 |
| 963 A | 1515 A | 3259 | 245 | 4734 | 2560 |
| 963 B | 1515 B | 3384 | 249 | 4785 | 2579 |
| 1006 | 171 | 3430 A | 5139aA | 4825 | 2604 |
| 1008 | 19 | 3430 B | 5139aB | 4826 | 2605 |
| 1010 | 172 | 3522 A | 2062 | 4849 | 2631 |

TABLE 5.7 — continued

CROSS-LIST: HR — LHS

| HR # | LHS # | HR # | LHS # | HR # | LHS # |
|---|---|---|---|---|---|
| 4983 | 348 | 6401 | 438 | 7875 | 3569 |
| 5019 | 349 | 6402 | 437 | 7898 | 3570 |
| 5072 | 2740 | 6416 | 444 | 7949 A | 5358b |
| 5183 | 2798 | 6426 A | 442 A | 7949 B | 5358a |
| 5189 | 2807 | 6426 B | 442 B | 7957 | 3578 |
| 5209 | 2814 | 6458 | 441 | 8061 | 3635 |
| 5288 | 2858 | 6518 | 3287 | 8085 | 62 |
| 5340 | 48 | 6573 A | 3305 A | 8086 | 63 |
| 5356 A | 2891 A | 6573 B | 3305 B | 8148 A | 3655 |
| 5356 B | 2891 B | 6623 | 3326 | 8148 B | 3656 |
| 5384 | 2907 | 6752 | 458 | 8181 | 3674 |
| 5455 | 2953 | 6806 | 3363 | 8387 | 67 |
| 5459 | 50 | 6869 | 3381 | 8477 | 3782 |
| 5460 | 51 | 6927 A | 3379 A | 8501 A | 3790 A |
| 5553 | 5279 | 6927 B | 3379 B | 8501 B | 3790 B |
| 5568 | 387 | 7293 | 3440 | 8515 | 520 |
| 5659 A | 3036 | 7294 | 3441 | 8665 A | 3851 |
| 5659 B | 3037 | 7373 | 3463 | 8665 B | 3852 |
| 5694 A | 3059 | 7386 | 3464 | 8697 A | 3864 |
| 5694 B | 3060 | 7462 | 477 | 8697 B | 3865 |
| 5699 | 395 | 7557 | 3490 | 8829 | 3912 |
| 5864 A | 5299a | 7602 A | 5350aA | 8832 | 71 |
| 5864 B | 5299b | 7602 B | 5350aB | 8852 | 3920 |
| 5911 | 3131 | 7637 A | 5351aA | 8969 | 3995 |
| 5914 | 3127 | 7637 B | 5351aB | 9088 A | 101 A |
| 5933 | 408 | 7644 | 484 | 9088 B | 101 B |
| 5954 | 3143 | 7665 | 485 | 9107 | 1013 |
| 5968 | 3145 | 7670 A | 3510 | | |
| 6014 | 3161 | 7670 B | 3509 | | |
| 6060 | 3171 | 7672 | 3515 | | |
| 6171 | 3224 | 7689 | 5353 | | |
| 6212 A | 3234 A | 7703 | 486 | | |
| 6212 B | 3234 B | 7722 | 488 | | |
| 6241 | 3244 | 7783 | 3537 | | |

TABLE 5.8

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|---|---|---|---|
| -22°2345 A | 5139aA | -17°3336 | 2379 |
| -22°2345 B | 5139aB | -17°3337 | 2380 |
| -22°3005 | 1840 | -17°3723 A | 2647 A |
| -22°4585 | 5333 | -17°3723 B | 2647 B |
| -22°5504 | 3572 | -17°3813 | 349 |
| -22°13916 | 5347 | -17°6856 | 552 |
| -21°784 | 1628 | -16°214 | 1225 |
| -21°1377 | 1827 | -16°295 | 146 |
| -21°3781 | 363 | -16°1591 A | 219 A |
| -21°4009 | 3008 | -16°1591 B | 219 B |
| -21°4352 | 3191 | -16°3030 | 5168a |
| -21°5703 | 490 | -16°3469 | 2564 |
| -21°6537 | 5001 | -16°3543 | 2642 |
| -20°465 A | 1409 A | -16°4196 | 3143 |
| -20°465 B | 1409 B | -15°1776 | 1913 |
| -20°643 | 1548 | -15°2546 | 2036 |
| -20°1211 | 1792 | -15°4041 | 52 |
| -20°4123 A | 386 A | -15°4042 | 53 |
| -20°4123 B | 386 B | -15°6290 | 530 |
| -20°4125 | 387 | -14°1750 | 1900 |
| -20°4399 | 5312 | -14°2757 | 2108 |
| -20°5385 | 3427 | -14°3277 | 2370 |
| -20°5833 | 3526 | -14°4454 | 3222 |
| -20°6185 | 3657 | -14°6437 A | 540 A |
| -20°6684 | 4055 | -14°6437 B | 540 B |
| -19°5899 A | 497 A | -14°6437 C | 541 |
| -19°5899 B | 497 B | -13°2439 A | 1991 A |
| -18°287 | 1286 | -13°2439 B | 1991 B |
| -18°359 | 149 | -13°3242 | 5180 |
| -18°3019 A | 289 | -13°3557 | 5218 |
| -18°3019 B | 290 | -13°3834 | 2872 |
| -18°4031 | 3053 | -13°4246 | 3115 |
| -17°400 | 1346 | -13°4807 A | 3345 A |
| -17°3088 | 2231 | -13°4807 B | 3345 B |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|------|-------|------|-------|
| -13°5069 | 3403 | -9°3964 | 2940 |
| -13°5945 | 509 | -9°6149 | 3913 |
| -12°1871 | 1910 | -9°6150 | 3914 |
| -12°1914 | 5124 | -8°4352 A | 428 A |
| -12°2449 | 245 | -8°4352 B | 428 B |
| -12°2889 | 2137 | -8°4352 C | 427 |
| -12°2918 A | 2151 A | -8°5980 A | 3874 |
| -12°2918 B | 2151 B | -8°5980 B | 3875 |
| -12°4523 | 419 | -8°6177 | 4005 |
| -12°5594 A | 3502 | -7°699 | 5087 |
| -12°5594 B | 3503 | -7°780 | 23 |
| -11°569 | 5063 | -7°781 A | 24 |
| -11°2741 | 274 | -7°781 B | 25 |
| -11°2918 | 2286 | -7°3632 | 354 |
| -11°3759 | 2945 | -7°3856 | 374 |
| -11°3770 | 2953 | -7°3963 | 5289a |
| -11°6064 | 3939 | -7°4003 | 394 |
| -10°109 | 1106 | -7°4242 | 3171 |
| -10°216 | 5019 | -6°855 | 1646 |
| -10°728 | 1581 | -6°6318 | 4047 |
| -10°3216 | 298 | -5°642 | 1546 |
| -10°4149 | 405 | -5°1123 | 200 |
| -10°5238 A | 5351aA | -5°1844 A | 1875 |
| -10°5238 B | 5351aB | -5°1844 B | 1876 |
| -10°6206 | 5410 | -5°2678 | 2080 |
| -9°122 | 1112 | -5°3063 | 2265 |
| -9°256 | 1231 | -5°3763 | 2799 |
| -9°697 | 1557 | -5°5715 | 517 |
| -9°1094 | 1799 | -4°2468 | 2055 |
| -9°3070 | 2259 | -4°2639 | 5153 |
| -9°3413 | 5206 | -4°3049 | 2393 |
| -9°3468 | 322 | -4°3665 A | 2894 |
| -9°3595 A | 2656 A | -4°3665 B | 2895 |
| -9°3595 B | 2656 B | -4°4225 | 431 |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|---|---|---|---|
| -4°4226 | 432 | -0°2532 | 2510 |
| -3°592 | 1577 | -0°2601 A | 2604 |
| -3°1061 A | 1754 | -0°2601 B | 2605 |
| -3°1061 B | 1755 | -0°2944 A | 393 A |
| -3°1110 | 1763 | -0°2944 B | 393 B |
| -3°1123 | 30 | -0°3676 | 3444 |
| -3°2288 | 5136 | -0°4195 | 5368 |
| -3°2525 A | 2082 A | -0°4470 | 537 |
| -3°2525 B | 2082 B | +0°659 | 1599 |
| -3°3508 | 2773 | +0°989 | 5101 |
| -3°3746 | 3039 | +0°3593 | 426 |
| -3°3968 A | 3215 | +0°4810 | 3745 |
| -3°3968 B | 3219 | +1°131 | 1141 |
| -3°4233 | 3356 | +1°410 | 1382 |
| -3°5059 | 3596 | +1°543 | 1496 |
| -3°5577 | 3900 | +1°1600 | 1884 |
| -2°3481 | 2524 | +1°2341p | 2169 |
| -2°3528 | 2566 | +1°2447 | 2272 |
| -2°4211 | 3224 | +1°2920 | 2907 |
| -2°4599 | 3381 | +1°3071 | 3067 |
| -2°5588 | 3696 | +1°3942 A | 3447 |
| -1°167 A | 1230 | +1°3942 B | 3448 |
| -1°167 B | 1229 | +1°4774 | 550 |
| -1°306 | 1365 | +2°84 | 1114 |
| -1°2457 | 2321 | +2°348 | 14 |
| -1°2505 | 2388 | +2°1041 | 1779 |
| -1°2754 | 2663 | +2°1085 | 1798 |
| -1°2832 | 2747 | +2°2098 | 255 |
| -1°2892 | 2842 | +2°2489 | 2465 |
| -1°4323 | 3833 | +2°2585 | 2641 |
| -0°572 | 1569 | +2°2944 A | 3059 |
| -0°981 | 5107 | +2°2944 B | 3060 |
| -0°1520 | 1886 | +2°3101 | 3194 |
| -0°2326 | 2251 | +2°3312 | 447 |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|------|-------|------|-------|
| +2°3482 A | 458 | +6°398 B | 16 |
| +2°3482 B | 459 | +6°2182 | 2147 |
| +2°4648 | 3920 | +6°2697 | 2681 |
| +2°4723 | 4020 | +6°2932 | 2968 |
| +3°275 A | 5049 | +6°2986 | 3020 |
| +3°275 B | 5048 | +6°3169 | 3161 |
| +3°2502 | 2407 | +6°3455 | 3304 |
| +3°2503 | 2408 | +6°4357 A | 5350aA |
| +3°3203 | 3202 | +6°4357 B | 5350aB |
| +4°123 | 121 | +6°4741 | 3624 |
| +4°415 | 1419 | +7°2031 | 2050 |
| +4°2568 | 2507 | +7°2690 | 2798 |
| +4°2729 | 2722 | +7°2692 | 2801 |
| +4°3195 | 420 | +7°2850 | 2983 |
| +4°3509 | 3329 | +7°3125 A | 3172 A |
| +4°3561a | 57 | +7°3125 B | 3172 B |
| +4°4048 A | 473 | +7°3967 | 3431 |
| +4°4048 B | 474 | +8°482 | 1520 |
| +4°4157 | 3470 | +8°2735 | 2766 |
| +4°4510 A | 3568 A | +8°3689 | 3387 |
| +4°4510 B | 3568 B | +8°3692 | 3388 |
| +4°4994 A | 5400aA | +8°4236 | 3490 |
| +4°4994 B | 5450aB | +8°4887 | 3828 |
| +4°5035 | 3995 | +9°73 | 1118 |
| +4°435 | 1487 | +9°946 | 1780 |
| +5°1668 | 33 | +9°2636 | 2570 |
| +5°1739 A | 233 A | +9°2776 | 2754 |
| +5°1739 B | 233 B | +9°3001 | 3024 |
| +5°2791 | 2787 | +9°4529 | 3550 |
| +5°3640 | 3366 | +9°4955 | 3742 |
| +5°3993 | 470 | +9°5076 | 3838 |
| +5°4011 | 3426 | +9°5122 A | 3864 |
| +5°4874 | 3717 | +9°5122 B | 3865 |
| +6°398 A | 15 | +10°1032 A | 1830 A |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|------|-------|------|-------|
| +10°1032 B | 1830 B | +15°2325 | 5191 |
| +10°1857 A | 2042 A | +15°2383 A | 2462 A |
| +10°1857 B | 2042 B | +15°2383 B | 2462 B |
| +10°1857 C | 2043 | +15°2620 | 47 |
| +10°2122 | 2234 | +15°2847 | 5294 |
| +10°2468 | 2631 | +15°4026 | 3507 |
| +10°2519 A | 2689 | +15°4074 A | 3529 |
| +10°2519 B | 2690 | +15°4074 B | 3530 |
| +10°2703 A | 2941 | +15°4733 | 533 |
| +10°2703 B | 2942 | +16°120 | 1199 |
| +10°4379 | 3584 | +16°2658 | 373 |
| +11°468 | 1545 | +16°2849 | 408 |
| +11°2439 | 2526 | +16°4121 | 3515 |
| +11°2576 | 352 | +17°197 | 1239 |
| +11°2910 A | 5313 | +17°202 | 1246 |
| +11°2910 B | 5311 | +17°1320 | 1858 |
| +11°3833 | 3463 | +17°2611 A | 2713 |
| +11°4875 A | 3851 | +17°2611 B | 2714 |
| +11°4875 B | 3852 | +17°2785 | 2974 |
| +12°1888 | 2033 | +17°3729 | 3412 |
| +12°4499 | 3598 | +17°4519 | 3640 |
| +12°4797 | 3786 | +17°4708 A | 3770 A |
| +13°1036 | 1803 | +17°4708 B | 3770 B |
| +13°2618 | 2665 | +17°4946 | 3982 |
| +13°2721 | 2821 | +18°24 | 5001a |
| +13°3024 | 3131 | +18°683 | 196 |
| +13°3578 | 3373 | +18°779 | 1736 |
| +13°4614 | 3625 | +18°1719 | 1942 |
| +14°2151 | 2194 | +18°2700 | 2693 |
| +14°2621 | 2740 | +18°2776 | 359 |
| +14°3384 | 3349 | +18°3182 A | 3203 |
| +15°395 | 1453 | +18°3182 B | 3204 |
| +15°2003 A | 2114 A | +18°3421 | 452 |
| +15°2003 B | 2114 B | +18°3911 | 3425 |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|------|-------|------|-------|
| +19°279 | 287 | +24°2733 B | 372 |
| +19°869 | 1745 | +24°2735 | 2918 |
| +19°1185 A | 1811 | +24°2824 | 3026 |
| +19°1185 B | 1812 | +24°3737 | 3464 |
| +19°2777 | 48 | +24°4460 | 3704 |
| +19°2881 | 5279 | +25°495 | 1501 |
| +19°2939 A | 3036 | +25°2874 | 391 |
| +19°2939 B | 3037 | +25°3020 | 3148 |
| +19°4499 | 3576 | +25°3173 | 3257 |
| +19°5116 A | 3965 | +26°2251 | 2450 |
| +19°5116 B | 3966 | +26°2677 A | 3054 |
| +20°85 | 1116 | +26°2677 B | 3055 |
| +20°226 | 5035 | +26°3151 | 3353 |
| +20°2465 | 5167 | +26°4734 A | 101 A |
| +21°607 | 1644 | +26°4734 B | 101 B |
| +21°1528 | 1899 | +27°262 | 1275 |
| +21°1731 | 1966 | +27°273 | 1289 |
| +21°1764 A | 5133 | +27°1124 | 5116 |
| +21°1764 B | 5134 | +27°2888 A | 3326 |
| +21°1949 | 2078 | +27°2888 B | 3325 A |
| +21°2247 | 2318 | +27°2888 C | 3325 B |
| +21°2649 | 2915 | +27°4642 | 4044 |
| +21°3198 | 3319 | +27°28217 | 310 |
| +22°176 A | 5027 | +28°1463 | 1945 |
| +22°176 B | 5028 | +28°1660 A | 2062 |
| +22°301 | 1335 | +28°1660 B | 2063 |
| +22°2340 | 2387 | +28°1952 | 5181 |
| +22°3406 | 3392 | +28°2193 | 348 |
| +22°3908 | 481 | +28°2503 | 3138 |
| +22°4567 | 3767 | +28°4562 | 3931 |
| +23°303 | 5051a | +28°4634 | 4008 |
| +23°2359 | 2422 | +29°1441 | 1893 |
| +23°2751 | 2996 | +29°1664 | 242 |
| +24°2733 A | 371 | +29°1883 A | 2125 A |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
| --- | --- | --- | --- |
| +29°1883 B | 2125 B | +32°1964 | 2216 |
| +29°2091 | 2308 | +32°2132 A | 2390 |
| +29°2279 | 2544 | +32°2132 B | 2391 |
| +29°2405 A | 2728 A | +32°2896 | 441 |
| +29°2405 B | 2728 B | +32°3474 | 3469 |
| +29°3872 A | 3510 | +33°529 | 159 |
| +29°3872 B | 3509 | +33°622 | 1533 |
| +29°4550 | 3737 | +33°1505 | 1912 |
| +30°206 A | 1237 | +33°1694 | 2007 |
| +30°206 B | 1236 | +33°1814 | 2113 |
| +30°421 | 1428 | +33°2663 | 3145 |
| +30°2490 | 5266 | +33°3433 | 3458 |
| +30°2512 | 2903 | +33°4018 A | 5358b |
| +30°4633 | 3771 | +33°4018 B | 5358a |
| +30°4824 | 3862 | +33°4707 | 3942 |
| +30°4982 A | 3976 | +33°4828 | 1013 |
| +30°4982 B | 3977 | +34°796 | 21 |
| +31°1684 | 241 | +34°927 | 1719 |
| +31°1781 | 1998 | +34°2541 | 2948 |
| +31°2238a | 2366 | +35°2436 A | 2716 |
| +31°2240 A | 2367 | +35°2436 B | 2717 |
| +31°2240 B | 2366 | +35°2439 | 2724 |
| +31°2873 | 5318a | +35°2774 | 3155 |
| +31°2875 | 3226 | +35°3659sf | 3467 |
| +31°2884 A | 3234 A | +35°3959 | 5353 |
| +31°2884 B | 3234 B | +36°1970 | 2155 |
| +31°3330 A | 3401 | +36°1979 A | 2156 A |
| +31°3330 B | 3402 | +36°1979 B | 2156 B |
| +31°3767 A | 3482 | +36°2147 | 37 |
| +31°3767 B | 3483 | +36°2165 | 2373 |
| +32°719 | 187 | +36°2500 | 2931 |
| +32°1398 A | 1866 | +37°748 | 1528 |
| +32°1398 B | 1867 | +37°1312 | 1783 |
| +32°1695 | 1987 | +37°1748 | 1934 |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|---|---|---|---|
| +37°1912 | 2053 | +43°2182 | 2498 |
| +37°2926 | 3312 | +43°2796 | 3321 |
| +38°2285 | 44 | +43°4035 | 3705 |
| +38°3095 | 3363 | +43°4305 | 3853 |
| +38°4343 | 62 | +43°4445 | 3936 |
| +38°4344 | 63 | +44°1142 | 1746 |
| +39°154 | 1125 | +44°2051 A | 38 |
| +39°1248 | 1753 | +44°2051 B | 39 |
| +39°1998 | 1944 | +44°4548 | 1014 |
| +39°2519 | 2556 | +45°669 A | 1458 A |
| +39°2947 A | 3152 | +45°669 B | 1458 B |
| +39°2947 B | 3150 | +45°992 | 1708 |
| +39°2950 | 3153 | +45°1947 A | 2437 |
| +40°45 | 1053 | +45°1947 B | 2436 |
| +40°2197 | 2131 | +45°2505 A | 433 |
| +40°2442 | 2432 | +45°2505 B | 434 |
| +41°328 A | 1284 A | +45°2743 | 3394 |
| +41°328 B | 1284 B | +45°3561 | 3678 |
| +41°750 | 180 | +45°4378 | 4054 |
| +41°750a | 181 | +45°4408 A | 1016 |
| +41°931 | 1696 | +45°4408 B | 1017 |
| +41°3306 | 3450 | +46°1405 | 2016 |
| +42°1899 | 2028 | +46°1635 | 2279 |
| +42°1922 | 2047 | +47°1276 | 1835 |
| +42°1956 A | 2093 A | +47°1355 | 1874 |
| +42°1956 B | 2093 B | +47°2072 | 2762 |
| +42°2163 | 2332 | +47°2112 A | 2849 |
| +42°2296 | 2548 | +47°2112 B | 2850 |
| +42°2321 | 2579 | +47°2420 | 3260 |
| +42°2648 | 3127 | +48°1469 | 1890 |
| +42°2810 | 435 | +48°1707 A | 2084 |
| +43°44 A | 3 | +48°1707 B | 2083 A |
| +43°44 B | 4 | +48°1707 C | 2083 B |
| +43°1953 | 2180 | +48°1829 | 278 |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|------|-------|------|-------|
| +48°1964 | 2453 | +56°2783 A | 3814 |
| +49°857 | 166 | +56°2783 B | 3815 |
| +49°1961 A | 2267 | +56°2966 | 71 |
| +49°1961 B | 2266 | +57°150 A | 123 |
| +49°2959 | 3441 | +57°150 B | 122 |
| +49°2959a | 3440 | +57°2787 | 4004 |
| +49°3009 | 3465 | +58°3 | 1027 |
| +50°1725 | 280 | +58°1929 | 3466 |
| +51°697 | 1518 | +58°2605 | 544 |
| +51°1094 | 1772 | +59°1915 A | 58 |
| +51°1696 | 312 | +59°1915 B | 59 |
| +52°857 | 1688 | +60°170 | 1206 |
| +52°911 | 28 | +60°762 | 1613 |
| +52°1401 A | 270 A | +60°1266 | 2275 |
| +52°1401 B | 270 B | +61°195 | 1179 |
| +52°2815 | 3590 | +61°513 A | 1492 |
| +52°3112 | 3758 | +61°513 B | 1494 |
| +53°934 | 1774 | +61°1678 A | 3305 A |
| +53°935 | 1775 | +61°1678 B | 3305 B |
| +53°1320 | 260 | +61°2050 | 3578 |
| +53°1321 | 261 | +61°2068 | 3595 |
| +53°1395 | 2237 | +62°780 | 1782 |
| +53°2911 A | 525 A | +62°1257 | 2639 |
| +53°2911 B | 525 B | +62°1446 | 5307 |
| +53°2911 C | 525 C | +63°229 | 1291 |
| +54°223 A | 8 A | +63°238 | 1297 |
| +54°223 B | 8 B | +63°869 | 2211 |
| +54°1175 | 1948 | +64°312 | 5051b |
| +54°1216 | 2000 | +66°34 A | 114 A |
| +54°1716 | 384 | +66°34 B | 115 |
| +55°900 | 1684 | +66°34 C | 114 B |
| +55°1823 | 5315 | +66°137 | 136 |
| +56°1421 A | 5163 A | +66°145 | 1283 |
| +56°1421 B | 5163 B | +66°268 | 175 |

TABLE 5.8 — continued

CROSS-LIST: BD — LHS

| BD # | LHS # | BD # | LHS # |
|---|---|---|---|
| +66°550 | 2008 | +75°752 C | 3565 C |
| +66°717 | 41 | +76°404 | 5180a |
| +66°1281 | 3537 | +76°785 | 3527 |
| +67°191 | 1371 | +77°361 A | 264 A |
| +67°552 A | 251 A | +77°361 B | 264 B |
| +67°552 B | 251 B | +79°212 | 1868 |
| +67°935 A | 3175 | +80°238 | 5130 |
| +67°935 B | 3176 | +81°465 | 2865 |
| +67°1014 | 3287 | | |
| +67°1498 | 3894 | | |
| +68°60 | 1167 | | |
| +68°714 | 2687 | | |
| +68°883 | 3238 | | |
| +68°946 | 450 | | |
| +68°1345 A | 3882 | | |
| +68°1345 B | 3881 | | |
| +69°1053 | 477 | | |
| +70°68b | 131 | | |
| +70°169 | 1397 | | |
| +70°639 | 2334 | | |
| +71°482 | 256 | | |
| +71°482a | 257 | | |
| +72°395 | 1984 | | |
| +72°659 | 2991 | | |
| +72°839 A | 3379 A | | |
| +72°839 B | 3379 B | | |
| +73°407 | 2001 | | |
| +73°925 | 3631 | | |
| +74°493 A | 5215 A | | |
| +74°493 B | 5215 B | | |
| +74°889 | 3592 | | |
| +75°154 | 1619 | | |
| +75°752 A | 3565 A | | |
| +75°752 B | 3565 B | | |

TABLE 5.9

CROSS-LIST: CD — LHS

| CD # | LHS # | CD # | LHS # |
|---|---|---|---|
| -85°33 | 1511 | -63°1596 | 3912 |
| -84°102 | 2221 | -62°39 | 128 |
| -80°195 | 208 | -62°1464 | 4031 |
| -80°328 | 268 | -61°282 | 1267 |
| -79°878 | 3766 | -61°6571 | 3652 |
| -77°15 | 6 | -60°118 | 1123 |
| -77°568 | 2600 | -60°3532 A | 2402 A |
| -75°967 | 3285 | -60°3532 B | 2402 B |
| -73°1547 | 3635 | -60°5077 | 2871 |
| -73°1672 | 3994 | -60°6576 | 3268 |
| -70°340 | 210 | -60°7508 | 3569 |
| -70°1402 | 3184 | -60°7821 | 3741 |
| -70°1800 | 3608 | -59°1024 | 204 |
| -68°47 | 1208 | -59°1224 | 1818 |
| -68°74 | 1281 | -59°1773 | 1959 |
| -68°1095 | 2577 | -59°1774 A | 1960 A |
| -68°2378 | 1015 | -59°1774 B | 1960 B |
| -67°2385 | 484 | -59°2351 | 2128 |
| -67°2593 | 3921 | -59°7305 | 3491 |
| -67°2594 | 3922 | -58°2884 | 2208 |
| -66°38 | 1139 | -58°5564 | 2892 |
| -66°1212 | 1553 | -58°7734 | 3542 |
| -66°2367 | 485 | -58°8156 A | 3707 A |
| -65°253 | 195 | -58°8156 B | 3707 B |
| -65°1143 A | 2456 | -57°806 | 1620 |
| -65°1143 B | 2457 | -57°1633 | 1896 |
| -65°3918 | 3674 | -57°2585 | 5149 |
| -64°12 | 116 | -57°5188 | 5255 |
| -63°9 | 1094 | -57°6303 | 413 |
| -63°112 A | 1551 | -57°8454 | 3802 |
| -63°112 B | 1552 | -56°1071 A | 1724 |
| -63°218 | 1796 | -56°1071 B | 1727 |
| -63°295 | 1908 | -56°1692 | 1881 |
| -63°1418 | 5346 | -56°3980 | 2417 |

TABLE 5.9 — continued

CROSS-LIST: CD — LHS

| CD # | LHS # | CD # | LHS # |
|------|-------|------|-------|
| -56°5169 | 2815 | -49°14337 A | 1020 |
| -56°5542 | 2961 | -49°14337 B | 1021 |
| -56°8316 | 3675 | -48°1011 | 1563 |
| -55°4825 | 2644 | -48°7414 | 2558 |
| -55°9220 | 3889 | -48°7426 | 2560 |
| -54°487 | 1379 | -48°12818 | 3423 |
| -54°9222 A | 3790 A | -47°7000 | 2433 |
| -54°9222 B | 3790 B | -47°9919 | 395 |
| -53°70 | 1063 | -47°10664 | 3182 |
| -53°570 | 1452 | -47°12773 | 3439 |
| -53°889 | 1650 | -47°13548 | 3582 |
| -53°8617 | 496 | -47°13670 | 3613 |
| -53°9029 | 5377 | -47°13695 | 3629 |
| -52°305 | 5036 | -46°76 | 1061 |
| -52°394 A | 1314 A | -46°293 | 133 |
| -52°394 B | 1314 B | -46°346 | 1220 |
| -51°89 | 1064 | -46°790 | 1436 |
| -51°95 | 1091 | -46°1936 A | 1770 |
| -51°273 | 1193 | -46°1936 B | 1771 |
| -51°532 | 13 | -46°2096 | 5112 |
| -51°887 | 1584 | -46°3046 A | 1911 A |
| -51°5974 | 2447 | -46°3046 B | 1911 B |
| -51°6859 | 336 | -46°5238 | 2150 |
| -51°7244 | 344 | -46°9361 | 2926 |
| -51°13248 | 519 | -46°10351 | 3114 |
| -50°1492 | 1701 | -46°11288 | 3270 |
| -50°1977 | 1797 | -46°11370 A | 444 |
| -50°8092 | 2817 | -46°11370 B | 445 |
| -50°12780 | 3508 | -46°11540 | 449 |
| -50°13411 | 3692 | -46°14649 | 5404 |
| -49°451 | 1268 | -45°1841 | 29 |
| -49°2676 | 1902 | -45°3283 | 1929 |
| -49°9033 | 2970 | -45°5378 | 2182 |
| -49°13515 | 3685 | -45°5627 | 2213 |

TABLE 5.9 — continued

CROSS-LIST: CD — LHS

| CD # | LHS # | CD # | LHS # |
| --- | --- | --- | --- |
| -45°7872 | 2585 | -40°9712 | 397 |
| -45°8786 | 5261 | -40°10550 | 3228 |
| -45°13178 | 3460 | -40°12743 | 3407 |
| -45°13677 | 3531 | -39°31 | 1036 |
| -45°14980 A | 5399 A | -39°3869 | 1968 |
| -45°14980 B | 5399 B | -39°7301 | 311 |
| -44°170 | 1122 | -39°8857 | 2900 |
| -44°397 | 1245 | -39°14192 | 66 |
| -44°545 B | 1306 | -38°1058 | 167 |
| -44°3045 A | 222 A | -38°1631 | 5098a |
| -44°3045 B | 222 B | -38°5760 | 2165 |
| -44°3484 | 1922 | -38°8457 | 2726 |
| -44°3675 | 1939 | -38°8635 | 2760 |
| -44°11909 | 451 | -38°11019 | 3209 |
| -44°14214 | 503 | -37°205 A | 1110 A |
| -44°14334 | 3639 | -37°205 B | 1110 B |
| -43°1028 | 19 | -37°1501 | 184 |
| -43°7228 | 2441 | -37°8082 | 2615 |
| -43°11010 | 3235 | -37°10500 A | 5299a |
| -42°469 | 141 | -37°10500 B | 5299b |
| -42°594 | 1288 | -37°10765 A | 415 |
| -42°654 | 1305 | -37°10765 B | 416 |
| -42°1269 | 1603 | -37°15492 | 1 |
| -42°2503 | 1845 | -36°1091 A | 1466 |
| -42°5678 | 2201 | -36°1091 B | 1467 |
| -42°8521 | 2750 | -36°2458 | 1787 |
| -42°15867 | 3792 | -36°6180 | 5166a |
| -42°16457 | 4013 | -36°13940 A | 486 |
| -41°556 | 1323 | -36°13940 B | 487 |
| -41°6879 | 2485 | -36°15693 | 70 |
| -41°14804 | 3782 | -35°170 A | 1097 |
| -40°239 | 1188 | -35°170 B | 1098 |
| -40°5404 | 2166 | -35°360 | 1186 |
| -40°7705 | 2678 | -35°9019 A | 2807 |

TABLE 5.9 — continued

CROSS-LIST: CD — LHS

| CD # | LHS # | CD # | LHS # |
|---|---|---|---|
| -35°9019 B | 2806 | -29°1177 B | 1515 B |
| -35°9260 | 2858 | -29°5555 | 1982 |
| -34°11285 | 3244 | -29°8019 | 277 |
| -34°11626 A | 442 A | -29°8875 | 2354 |
| -34°11626 B | 442 B | -28°302 | 129 |
| -34°11626 C | 443 | -28°657 A | 1337 |
| -33°143 | 1078 | -28°657 B | 1338 |
| -33°1180 | 1534 | -28°987 | 1489 |
| -33°4113 | 237 | -28°3554 | 1878 |
| -33°9467 | 2834 | -28°14630 | 5337a |
| -33°12476 | 3330 | -28°15936 | 3468 |
| -32°828 | 1361 | -28°16676 | 3553 |
| -32°5613 | 253 | -27°16 | 1026 |
| -32°8179 | 308 | -27°108 | 1067 |
| -31°325 | 1163 | -27°9236 | 5247 |
| -31°682 | 1278 | -27°9894 | 2938 |
| -31°909 | 1377 | -27°11772 | 3310 |
| -31°943 | 1391 | -27°14659 | 488 |
| -31°1454 | 1560 | -27°16491 | 4048 |
| -31°2902 A | 1804 A | -26°828 | 1387 |
| -31°2902 B | 1804 B | -26°8883 | 319 |
| -31°2902 C | 1804 C | -26°9470 | 2669 |
| -31°6229 | 249 | -26°9804 | 2759 |
| -31°7195 | 2130 | -26°10340 | 2933 |
| -31°9113 | 2429 | -26°10870 | 3071 |
| -31°10833 | 2841 | -26°12026 A | 437 |
| -31°17597 | 3554 | -26°12026 B | 438 |
| -30°731 | 1339 | -26°12036 | 439 |
| -30°990 | 1432 | -26°15541 A | 3655 |
| -30°8970 | 5188 | -26°15541 B | 3656 |
| -30°11195 | 2870 | -26°16501 | 3904 |
| -30°15026 | 3347 | -25°225 A | 118 A |
| -30°19175 | 3817 | -25°225 B | 118 B |
| -29°1177 A | 1515 A | -25°10271 A | 2891 A |

TABLE 5.9 — continued

CROSS-LIST: CD — LHS

| CD # | LHS # |
| --- | --- |
| -25°10271 B | 2891 B |
| -25°10553 A | 380 |
| -25°10553 B | 379 |
| -24°263 | 1124 |
| -24°12677 | 3186 |
| -24°16193 | 3570 |
| -24°17814 | 72 |
| -23°315 | 1154 |
| -23°325 | 1159 |
| -23°693 | 1307 |
| -23°1565 | 1591 |
| -23°2865 | 1769 |
| -23°9765 | 2358 |
| -23°10062 | 2427 |
| -23°11329 | 2814 |
| -23°11940 | 383 |
| -23°17699 | 3885 |
| -22°526 | 142 |
| -22°3005 | 1840 |
| -22°6442 A | 5139aA |
| -22°6442 B | 5139aB |
| -22°12618 | 5333 |
| -22°13916 | 5347 |
| -22°14919 | 3572 |

## TABLE 5.10

### CROSS-LIST: CP — LHS

| CP # | LHS # | CP # | LHS # |
|------|-------|------|-------|
| -85°38 | 1511 | -63°234 B | 1552 |
| -84°263 | 2221 | -63°498 | 1796 |
| -80°161 | 208 | -63°703 | 1908 |
| -80°349 | 268 | -63°4514 | 5346 |
| -70°1190 | 3766 | -63°4862 | 3912 |
| -77°16 | 6 | -62°75 | 128 |
| -77°859 | 2600 | -62°265 | 172 |
| -75°1368 | 3285 | -62°6446 | 4031 |
| -73°2192 | 3635 | -61°122 | 1267 |
| -73°2299 | 3994 | -61°6537 | 3652 |
| -72°2690 | 520 | -60°46 | 1123 |
| -70°447 | 210 | -60°2911 A | 2402 A |
| -70°2196 | 3184 | -60°2911 B | 2402 B |
| -70°2814 | 3608 | -60°5215 | 2871 |
| -68°41 | 1208 | -60°5483 A | 50 |
| -68°77 A | 1281 | -60°5483 B | 51 |
| -68°77 B | 1279 | -60°6718 | 3268 |
| -68°1684 | 2577 | -60°7419 | 3569 |
| -68°3597 | 1015 | -60°7528 | 3741 |
| -67°3703 | 484 | -59°444 | 204 |
| -67°3959 | 3921 | -59°584 | 1818 |
| -67°3960 | 3922 | -59°944 | 1959 |
| -66°53 | 1139 | -59°1362 | 2128 |
| -66°1752 | 2553 | -59°7535 | 3491 |
| -66°3474 | 485 | -58°1695 | 2208 |
| -65°13 | 5 | -58°5131 | 5255 |
| -65°361 | 195 | -58°5467 | 2892 |
| -65°1714 A | 2456 | -58°7893 A | 3707 A |
| -65°1714 B | 2457 | -58°7893 B | 3707 B |
| -65°2751 | 3674 | -57°612 | 1620 |
| -64°51 | 116 | -57°1139 | 1896 |
| -63°51 | 1094 | -57°1976 | 5149 |
| -63°217 | 171 | -57°7690 | 413 |
| -63°234 A | 1551 | -57°10015 | 67 |

TABLE 5.10 — continued

CROSS-LIST: CP — LHS

| CP # | LHS # | CP # | LHS # |
| --- | --- | --- | --- |
| -56°767 | 1724 | -49°11858 A | 1020 |
| -56°768 | 1727 | -49°11858 B | 1021 |
| -56°1199 | 1881 | -48°376 | 1563 |
| -56°4554 | 2417 | -48°4791 | 2558 |
| -56°5970 | 2815 | -48°4799 | 2560 |
| -56°6368 | 2961 | -47°7075 | 395 |
| -56°9645 | 3675 | -47°7610 | 3182 |
| -55°5262 | 2644 | -47°9196 | 3439 |
| -54°10055 A | 3790 A | -47°9633 | 3629 |
| -54°10055 B | 3790 B | -46°29 | 1061 |
| -53°77 | 1063 | -46°127 | 1220 |
| -53°672 | 1650 | -46°254 | 1436 |
| -53°9928 | 496 | -46°609 A | 1770 |
| -53°10224 | 5377 | -46°609 B | 1771 |
| -52°187 | 5036 | -46°1360 A | 1911 A |
| -52°241 A | 1314 A | -46°1360 B | 1911 B |
| -52°241 B | 1314 B | -46°3701 | 2150 |
| -51°48 | 1071 | -46°6822 | 2926 |
| -51°162 | 1193 | -46°7681 | 3114 |
| -51°282 | 13 | -46°8446 | 3270 |
| -51°443 | 1584 | -46°8513 A | 444 |
| -51°4413 | 2447 | -46°8513 B | 445 |
| -51°5356 | 336 | -46°8664 | 449 |
| -51°5750 | 344 | -45°1588 | 1929 |
| -51°11806 | 519 | -45°3978 | 2182 |
| -50°637 | 1701 | -45°6592 | 5261 |
| -50°869 | 1797 | -45°9704 | 3460 |
| -50°6387 | 2817 | -45°9899 | 3531 |
| -50°11256 | 3508 | -45°10407 A | 5399 A |
| -50°11576 | 3692 | -45°10407 B | 5399 B |
| -49°211 | 1268 | -44°228 B | 1306 |
| -49°1163 | 1902 | -44°612 | 29 |
| -49°7339 | 2970 | -44°1190 A | 222 A |
| -49°11439 | 3685 | -44°1190 B | 222 B |

TABLE 5.10 — continued

CROSS-LIST: CP — LHS

| CP # | LHS # | CP # | LHS # |
|---|---|---|---|
| -44°1617 | 1922 | -36°296 A | 1466 |
| -44°1829 | 1939 | -36°296 B | 1467 |
| -44°9918 | 503 | -36°4124 | 5166a |
| -43°354 | 19 | -36°9037 A | 486 |
| -43°5524 | 2441 | -36°9037 B | 487 |
| -42°366 | 1603 | -36°9694 | 70 |
| -42°915 | 1845 | -35°60 | 1097 |
| -42°4101 | 2201 | -35°108 | 1186 |
| -42°9607 | 4013 | -35°3546 | 2834 |
| -41°183 | 1323 | -35°5974 | 2807 |
| -41°5653 | 2485 | -35°6109 | 2858 |
| -41°9759 | 3782 | -34°6635 | 3244 |
| -40°98 | 1188 | -34°6803 A | 442 A |
| -40°3789 | 2166 | -34°6803 B | 442 B |
| -40°7021 | 397 | -33°1748 | 237 |
| -40°7392 | 3228 | -33°4608 | 3330 |
| -40°8627 | 3407 | -32°3122 | 308 |
| -39°6 | 1036 | -31°92 | 1163 |
| -39°1929 | 1968 | -31°273 | 1391 |
| -39°5265 | 311 | -31°976 A | 1804 A |
| -39°6278 | 2900 | -31°976 B | 1804 B |
| -39°8920 | 66 | -31°976 C | 1804 C |
| -38°463 | 5098a | -31°2448 | 249 |
| -38°5760 | 2165 | -31°2717 | 2130 |
| -38°5484 | 2726 | -31°6268 | 3554 |
| -38°5542 | 2760 | -30°324 | 1432 |
| -38°6422 | 3209 | -30°5103 | 3347 |
| -38°7124 | 3337 | -30°6641 | 3817 |
| -37°57 A | 1110 A | -29°362 A | 1515 A |
| -37°57 B | 1110 B | -29°362 B | 1515 B |
| -37°3945 | 1 | -29°2316 | 1982 |
| -37°5339 | 2615 | -29°3437 | 2354 |
| -37°6571 A | 5299a | -28°302 | 1489 |
| -37°6571 B | 5299b | -28°1525 | 1878 |

TABLE 5.10 — continued

CROSS-LIST: CP — LHS

| CP # | LHS # | CP # | LHS # |
|---|---|---|---|
| -28°6572 | 5337a | -22°7859 | 3572 |
| -28°6957 | 3468 | -21°5830 | 3008 |
| -27°25 | 1067 | -21°5912 | 3038 |
| -27°4721 | 5247 | -21°6162 | 3191 |
| -27°5682 | 3310 | | |
| -27°6972 | 488 | | |
| -26°214 | 1387 | | |
| -26°4626 | 319 | | |
| -26°4871 | 2669 | | |
| -26°5012 | 2759 | | |
| -26°5300 | 2933 | | |
| -26°5457 | 3071 | | |
| -26°5858 A | 437 | | |
| -26°5858 B | 438 | | |
| -26°5863 | 439 | | |
| -26°7193 A | 3655 | | |
| -26°7193 B | 3656 | | |
| -25°64 A | 118 A | | |
| -25°64 B | 118 B | | |
| -25°5397 A | 2891 A | | |
| -25°5397 B | 2891 B | | |
| -24°60 | 1124 | | |
| -24°7050 | 3570 | | |
| -23°95 | 1154 | | |
| -23°101 | 1159 | | |
| -23°215 | 1307 | | |
| -23°414 | 1591 | | |
| -23°829 | 1769 | | |
| -23°5802 | 2814 | | |
| -23°5999 | 383 | | |
| -23°8259 | 3885 | | |
| -22°3752 A | 5139aA | | |
| -22°3752 B | 5139aB | | |
| -22°6738 | 5333 | | |

TABLE 5.11

CROSS-LIST: WOLF — LHS

| Wolf | LHS # | Wolf | LHS # | Wolf | LHS # |
|---|---|---|---|---|---|
| 12 | 1125 | 279 | 1835 | 433 | 338 |
| 24 A | 123 | 287 | 1858 | 437 | 341 |
| 24 B | 122 | 294 | 1879 | 438 | 2636 |
| 25 | 121 | 308 | 2016 | 440 | 2641 |
| 28 | 7 | 315 | 2028 | 457 | 2661 |
| 33 | 126 | 320 | 2041 | 461 | 2664 |
| 40 | 1170 | 324 | 2078 | 462 | 2665 |
| 44 | 1176 | 335 | 276 | 477 | 2689 |
| 46 | 1179 | 358 | 294 | 478 | 2690 |
| 47 | 1183 | 359 | 36 | 482 | 2731 |
| 53 | 5026 | 362 | 2353 | 485a | 354 |
| 54 | 136 | 364 | 2361 | 487 | 2747 |
| 56 | 1198 | 365 | 2365 | 489 | 46 |
| 57 | 1206 | 368 | 2374 | 491 | 5254 |
| 109 A | 5049 | 373 | 2383 | 496 | 2787 |
| 109 B | 5048 | 376 | 2388 | 497 | 359 |
| 110 | 12 | 385 | 5191 | 498 | 47 |
| 113 | 1335 | 386 | 303 | 503 | 2799 |
| 124 | 14 | 391 | 2406 | 504 | 2801 |
| 125 | 152 | 393 | 2407 | 530 | 2853 |
| 127 | 1369 | 394 | 2408 | 534 | 368 |
| 134 | 169 | 395 | 2409 | 536 | 2956 |
| 194 | 177 | 397 | 305 | 537 | 2965 |
| 204 | 1573 | 398 | 2415 | 540 | 2968 |
| 205 | 1574 | 406 | 2515 | 553 | 2985 |
| 219 | 179 | 408 | 2544 | 561 | 3039 |
| 225 A | 180 | 409 | 2549 | 562 | 394 |
| 225 B | 181 | 414 | 2565 | 563 | 3062 |
| 227 | 1610 | 417 | 2570 | 620 | 3138 |
| 232 | 1745 | 422 | 2575 | 623 | 255 |
| 237 | 1784 | 424 A | 333 A | 629 | 427 |
| 261 | 1813 | 424 B | 333 B | 630 A | 428 A |
| 262 A | 1811 | 427 | 2582 | 630 B | 428 B |
| 262 B | 1812 | 429 | 5219 | 635 | 431 |

TABLE 5.11 — continued

CROSS-LIST: WOLF — LHS

| Wolf | LHS # | Wolf | LHS # | Wolf | LHS # |
|---|---|---|---|---|---|
| 636 | 432 | 1037 | 522 | 1325 | 1528 |
| 648 | 3267 | 1038 | 3943 | 1328 A | 3764 |
| 672 A | 3278 | 1039 | 545 | 1328 B | 3765 |
| 672 B | 3279 | 1040 | 548 | 1329 | 517 |
| 692 A | 3282 | 1041 | 4005 | 1332 | 3780 |
| 692 B | 3283 | 1046 | 4030 | 1340 | 3745 |
| 718 | 447 | 1050 | 473 | 1346 | 3562 |
| 760 | 3304 | 1055 | 473 | 1373 | 3605 |
| 816 | 3361 | 1056 | 119 | 1421 | 238 |
| 830 | 3368 | 1057 | 178 | 1426 | 2495 |
| 834 | 3371 | 1058 | 1828 | 1435 | 2518 |
| 851 | 467 | 1059 | 3549 | 1437 | 2526 |
| 863 | 5352 | 1061 | 419 | 1438 | 2527 |
| 865 | 3507 | 1062 A | 472 A | 1429 | 2538 |
| 866 | 3515 | 1062 B | 472 B | 1448 | 2872 |
| 867 | 481 | 1065 | 5039 | 1449 | 1763 |
| 873 | 3529 | 1069 | 3549 | 1450 | 1766 |
| 891 | 3596 | 1084 | 498 | 1453 | 30 |
| 896 | 502 | 1106 | 64 | 1457 | 5109 |
| 901 | 3607 | 1108 | 3472 | 1463 | 3393 |
| 906 | 3612 | 1122 | 3499 | 1465 | 466 |
| 918 | 65 | 1129 | 3518 | 1466 | 3400 |
| 921 A | 3682 A | 1130 | 482 | 1471 | 3315 |
| 921 B | 3682 B | 1132 | 1438 | 1478 | 2932 |
| 922 A | 511 A | 1143 | 3731 | 1481 | 2945 |
| 922 B | 511 B | 1147 | 5375 | 1504 | 1138 |
| 923 | 3689 | 1148 | 3737 | 1506 | 1175 |
| 926 | 3693 | 1184 | 3771 | 1515 | 1199 |
| 940 | 3708 | 1201 A | 3808 | 1516 | 1227 |
| 945 | 3711 | 1201 B | 3809 | 1530 | 1292 |
| 962 | 3742 | 1216 | 3797 | 1533 | 3979 |
| 983 | 5379 | 1322 | 1616 | 1561 | 3787 |
| 990 | 3760 | 1323 | 159 | 1567 | 3730 |
| 1014 | 3773 | 1324 | 170 | | |

TABLE 5.12

CROSS-LIST: ROSS — LHS

| Ross | LHS # | Ross | LHS # | Ross | LHS # |
|---|---|---|---|---|---|
| 5 | 1053 | 84 | 2154 | 200 B | 3699 B |
| 9 | 1234 | 85 | 2173 | 206 | 3702 |
| 11 | 1277 | 86 A | 3345 A | 226 | 3871 |
| 17 | 1348 | 86 B | 3345 B | 236 | 5391 |
| 18 | 1368 | 90 | 2163 | 237 | 3869 |
| 19 | 1388 | 92 | 2171 | 247 | 5406 |
| 21 | 155 | 93 | 2181 | 248 | 549 |
| 25 | 1618 | 96 | 5158 | 249 | 4015 |
| 27 | 5091 | 99 | 2284 | 257 | 3576 |
| 28 | 1642 | 107 | 2331 | 258 | 3587 |
| 31 | 1683 | 108 | 2349 | 270 A | 3770 A |
| 33 | 196 | 109 | 2410 | 270 B | 3770 B |
| 34 | 173 | 110 A | 2413 | 279 | 3833 |
| 36 | 1588 | 110 B | 2414 | 288 | 3847 |
| 41 | 1761 | 119 | 2472 | 291 | 3945 |
| 47 | 31 | 122 | 2482 | 311 | 1118 |
| 48 | 1776 | 127 | 2527 | 318 | 131 |
| 49 | 1780 | 128 | 315 | 319 | 1175 |
| 51 | 2962 | 129 | 2475 | 322 | 137 |
| 52 A | 2997 A | 130 | 373 | 331 | 1483 |
| 52 B | 2997 B | 131 | 3310 | 335 | 1533 |
| 53 | 388 | 133 | 3320 | 341 | 1495 |
| 54 | 1895 | 136 | 464 | 345 | 1518 |
| 55 | 1900 | 138 | 5340 | 364 | 1475 |
| 58 | 5124 | 154 | 3414 | 365 | 1476 |
| 59 | 1794 | 160 | 3417 | 367 | 1488 |
| 60 | 1814 | 162 | 5347 | 370 A | 1522 |
| 62 | 1824 | 163 | 3456 | 370 B | 1523 |
| 64 | 1846 | 165 A | 478 A | 371 | 1530 |
| 65 | 1759 | 165 B | 478 B | 373 | 1527 |
| 66 | 1789 | 188 | 3559 | 382 | 1718 |
| 79 A | 1830 A | 193 | 3602 | 388 | 1740 |
| 79 B | 1830 B | 197 | 3649 | 390 | 1930 |
| 83 | 2141 | 200 A | 3699 A | 391 | 5127 |

TABLE 5.12 — continued

CROSS-LIST: ROSS — LHS

| Ross | LHS # | Ross | LHS # | Ross | LHS # |
|------|-------|------|-------|------|-------|
| 394 | 1933 | 512 | 3083 | 651 A | 3447 |
| 398 | 1689 | 513 | 399 | 651 B | 3448 |
| 406 | 1765 | 522 | 3166 | 652 | 473 |
| 413 | 1819 | 528 | 3183 | 666 | 3812 |
| 414 | 1825 | 529 | 3191 | 668 A | 525 A |
| 417 | 1836 | 555 | 1303 | 668 B | 525 B |
| 419 | 1867 | 556 | 1439 | 668 C | 525 C |
| 422 | 1886 | 566 | 1597 | 671 | 533 |
| 434 | 2188 | 578 | 20 | 674 | 3960 |
| 436 | 2138 | 584 | 5087 | 676 | 4006 |
| 437 | 2137 | 585 | 174 | 679 | 1004 |
| 438 | 2142 | 587 | 1634 | 680 | 1054 |
| 439 | 2145 | 588 | 1594 | 682 | 2050 |
| 440 A | 2151 A | 589 | 1607 | 683 | 2056 |
| 440 B | 2151 B | 591 | 187 | 690 | 2551 |
| 445 | 2240 | 593 | 1659 | 695 | 45 |
| 446 | 2272 | 594 | 1674 | 697 | 2564 |
| 447 | 2334 | 597 | 1653 | 704 | 2620 |
| 451 | 42 | 600 | 1695 | 705 | 2642 |
| 452 | 5203 | 612 | 1891 | 713 | 3393 |
| 458 | 2665 | 614 A | 1849 | 719 | 3400 |
| 476 | 353 | 614 B | 1850 | 720 | 3403 |
| 484 | 2715 | 619 | 35 | 727 | 3437 |
| 486 A | 5249 | 622 | 2060 | 730 | 3432 |
| 486 B | 5250 | 623 | 255 | 731 | 3433 |
| 490 | 352 | 624 A | 2082 A | 733 | 3445 |
| 491 | 2766 | 624 B | 2082 B | 734 | 3446 |
| 492 | 2789 | 626 | 2308 | 747 | 3458 |
| 494 | 2837 | 627 | 304 | 751 A | 497 A |
| 495 | 5266 | 637 | 2518 | 751 B | 497 B |
| 499 | 2978 | 640 | 3200 | 765 | 3590 |
| 501 | 2994 | 641 | 3215 | 766 | 3574 |
| 508 | 396 | 644 | 3251 | 769 | 61 |
| 510 | 3073 | 650 | 3444 | 770 | 506 |

TABLE 5.12 — continued

CROSS-LIST: ROSS — LHS

| Ross | LHS # | Ross | LHS # | Ross | LHS # |
|------|-------|------|-------|------|-------|
| 775 | 508 | 903 | 2422 | 1030b | 5285 |
| 778 | 3677 | 904 | 5195 | 1038 | 3034 |
| 780 | 530 | 905 | 310 | 1041 | 2998 |
| 781 | 3888 | 906 | 2430 | 1044 | 389 |
| 786 | 537 | 907 | 2451 | 1047 | 3030 |
| 791 | 163 | 908 | 2467 | 1051 | 3018 |
| 800 | 2869 | 910 | 2434 | 1057 | 404 |
| 802 | 3093 | 912 | 2448 | 1069a | 3499 |
| 804 | 3110 | 920 | 2494 | 1069b | 482 |
| 806 | 3129 | 943 | 321 | | |
| 808 | 3146 | 985 | 2731 | | |
| 819 | 3315 | 986 A | 226 A | | |
| 825 A | 3637 A | 986 B | 226 B | | |
| 825 B | 3637 B | 988 | 1919 | | |
| 828 | 3590 | 990 | 1934 | | |
| 835 | 2821 | 991 | 2633 | | |
| 837 | 2830 | 992 | 2884 | | |
| 838 | 2846 | 993 | 2963 | | |
| 844 | 2872 | 994 | 2977 | | |
| 845 | 2880 | 996 | 5290 | | |
| 848 | 369 | 999 | 3194 | | |
| 849 | 2904 | 1001 | 3366 | | |
| 854 | 3186 | 1003 | 2443 | | |
| 858 | 3301 | 1008 | 2724 | | |
| 860 | 3257 | 1011 | 2735 | | |
| 863 | 5324 | 1015 | 2784 | | |
| 864 | 3266 | 1018 | 2791 | | |
| 873 | 1616 | 1020 | 350 | | |
| 882 | 1943 | 1020b | 2749 | | |
| 887 | 2161 | 1022 | 2771 | | |
| 888 | 2164 | 1026 | 357 | | |
| 889 | 2169 | 1027 | 2840 | | |
| 893 | 2271 | 1028b | 2999 | | |
| 899 | 2373 | 1030a | 3012 | | |

## TABLE 5.13

## CROSS-LIST: VARIABLE STAR DESIGNATION — LHS

| Variable | LHS # | Variable | LHS # | Variable | LHS # |
|---|---|---|---|---|---|
| GQ And | 4 | YZ CMi | 1943 | V577 Mon A | 1849 |
| GX And | 3 | AZ Cnc | 2034 | V577 Mon B | 1850 |
| HH And | 549 | DX Cnc | 248 | V1054 Oph A | 428 A |
| V1298 Aql | 474 | EI Cnc | 2076 | V1054 Oph B | 428 B |
| V1412 Aql | 3532 | TY CrB | 3146 | V2133 Oph | 3224 |
| EZ Aqr A | 68 A | V1513 Cyg | 482 | V2215 Oph | 439 |
| EZ Aqr B | 68 B | V1581 A | 3494 A | V1201 Ori | 212 |
| FG Aqr | 3787 | V1581 B | 3494 B | EQ Peg | 3965 |
| FR Aqr | 3602 | HU Del | 3556 | GT Peg | 3861 |
| TZ Ari | 11 | AS Dra A | 5215 A | II Peg | 4044 |
| VX Ari | 1439 | AS Dra B | 5215 B | SX Phe | 4013 |
| QY Aur A | 226 A | CM Dra A | 421 A | ZZ Psc | 5405 |
| QY Aur B | 226 B | CM Dra B | 421 B | MQ Ser | 3059 |
| RR Cae | 1660 | CR Dra | 5315 | RY Sex | 2285 |
| V388 Cas | 1183 | DY Eri | 23 | V1216 Sgr | 3414 |
| V547 Cas A | 114 A | V749 Her | 3254 | CF UMa[a] | 44 B[a] |
| V547 Cas B | 114 B | V774 Her | 3392 | SZ UMa | 41 |
| V645 Cen | 49 | EV Lac | 3853 | WX UMa | 39 |
| DO Cep | 3815 | AD Leo | 5167 | FI Vir | 315 |
| VW Cep A | 3565 A | CN Leo | 36 | FL Vir A | 333 A |
| VW Cep B | 3565 B | SV LMi A | 2156 A | FL Vir B | 333 B |
| VW Cep C | 3565 C | SV LMi B | 2156 B | FN Vir | 2664 |
| UV Cet | 10 | BF Lyn | 2131 | GL Vir | 324 |
| YZ Cet | 138 | AX Mic | 66 | GQ Vir | 2880 |

[a] This object may not be real. See entry for LHS 44 in Table 5.17.

TABLE 5.14

CROSS-LIST: MISCELLANEOUS NAME — LHS

| vB # | LHS # | Name | LHS # |
|------|-------|------|-------|
| 1 | 1781 | Barnard's Star | 57 |
| 2 | 1820 | Hubble 1 | 126 |
| 3 | 237a | Hubble 3 | 295 |
| 4 | 309 | Hubble 4 | 2325 |
| 5 | 313 | Hubble 10 | 2914 |
| 6 | 2484 | Kapteyn's Star | 29 |
| 7 | 2839 | Kruger 60 A | 3814 |
| 8 | 429 | Kruger 60 B | 3815 |
| 9 | 3395 | Lacaille 9352 | 70 |
| 10 | 474 | Lalande 21185 | 37 |
| 11 | 3601 | Lalande 27137 | 5279 |
| 12 | 541 | Lalande 39866 A | 3568 A |
| 16 | 220 | Lalande 39866 B | 3568 B |
| 17 | 1926 | Luyten's Star | 33 |
| 24a | 402 | McCarthy 45 | 1070 |
| 24b | 403 | Plaut 1 | 412 |
| 26 | 3253 | Stein 2051 A | 26 |
| 29 | 3676 | Stein 2051 B | 27 |
| | | van Maanen's Star | 7 |

## TABLE 5.15

### LHS OBJECTS BETWEEN 1001 AND 5413 WITH $m_{pg} - m_R \geq 2.5$

| LHS # | Spec. | Dist.(pc) | LHS # | Spec. | Dist.(pc) |
|---|---|---|---|---|---|
| 1035 | — | — | 2049 | M6 V | — |
| 1109 | — | — | 2065 | M9 V | 8.5±0.1[a] |
| 1135 | — | — | 2067 | sdM5 | — |
| 1146 | — | — | 2112 | M4: V | — |
| 1151 | M4 V | — | 2179 | M5 V | — |
| 1166 | sdM | 80.0±7.8[a] | 2214 | — | — |
| 1252 | M6 V | — | 2215 | M6 V | — |
| 1265 | — | — | 2236 | M5 V | — |
| 1294 | — | — | 2238 | sdM | — |
| 1299 | — | — | 2243 | M8 V | — |
| 1317 | M6.5: V | — | 2314 | M6 V | 24.3±1.4[a] |
| 1367 | — | — | 2330 | — | — |
| 1396 | — | — | 2335 | — | — |
| 1413 | — | — | 2339 | — | — |
| 1420 | — | 40.2±1.8[a] | 2347 | M5 V | — |
| 1422 | — | — | 2351 | M6.5 V | — |
| 1491 | — | — | 2352 | sdM | — |
| 1564 | — | — | 2377 | — | — |
| 1604 | — | 14.7±0.4[a] | 2397 | M5 V | — |
| 1630 | — | — | 2397a | M8 V | 14.3±0.4[a] |
| 1660a | — | — | 2419 | sdM4.5 | — |
| 1691 | sdM | — | 2429 | M2 V | 11.8±1.1[c] |
| 1742a | sdM5: | 74.6±5.6[a] | 2479 | — | — |
| 1784 | M4 | 31.3±13.6[b] | 2487 | — | — |
| 1802 | — | 26.9±0.8[a] | 2500 | sdM0.5-1: | — |
| 1807 | — | — | 2502 | M6+ V | — |
| 1826 | sdM | — | 2555a | — | — |
| 1829 | — | — | 2629 | — | — |
| 1839 | M4.5 V | — | 2632 | M7 V | — |
| 1921 | — | 36.2±1.3[a] | 2643 | M4.5 V | — |
| 1937 | — | — | 2645 | M7 V | — |
| 2026 | M6 V | 19.6±0.2[a] | 2657 | — | — |
| 2039 | — | — | 2729 | — | — |
| 2045 | sdM | 90.1±7.4 | 2755 | — | — |

TABLE 5.15 — continued

| LHS # | Spec. | Dist.(pc) | LHS # | Spec. | Dist.(pc) |
|-------|-------|-----------|-------|-------|-----------|
| 2758 | — | — | 3197 | — | — |
| 2810 | — | — | 3275 | — | $13.1 \pm 0.9^d$ |
| 2825 | — | — | 3478 | — | $33.2 \pm 4.1^d$ |
| 2826 | M4.5 V | — | 3481 | — | $149 \pm 16^a$ |
| 2841 | K7 | $50.0 \pm 19.9^b$ | 3681 | — | — |
| 2847 | M5.5: V | — | 3762 | — | — |
| 2852 | M0.5 | $30.3 \pm 12.7^b$ | 3768 | — | — |
| 2855 | M6 V | — | 3785 | — | $43.5 \pm 1.7^a$ |
| 2859 | — | — | 3837 | — | — |
| 2887 | M4.5 V | — | 3866 | — | — |
| 2893 | M1.5 | — | 3873 | — | — |
| 2924 | M9 V | $11.0 \pm 0.2^a$ | 3926 | — | — |
| 2950 | — | — | 3933 | — | — |
| 2980 | M7 V | — | 3954 | — | — |
| 3002 | M7 V | — | 3958 | — | — |
| 3003 | M6.5 V | — | 3987 | — | — |
| 3042 | — | — | 5042 | — | — |
| 3099 | — | — | 5047 | — | — |
| 3104 | — | — | 505? | — | — |
| 3106 | M6 V | — | 5142 | M6 V | — |
| 3111 | — | — | 5146b | — | — |
| 3121 | — | — | 5165 | — | — |
| 3126 | — | — | 5273 | — | — |
| 3168 | — | $172 \pm 21^a$ | 5348 | — | — |
| 3170 | — | — | 5360 | — | $110 \pm 36^a$ |
| 3178 | — | $141 \pm 20^a$ | | | |

[a] Trigonometric parallax from Monet et al. 1992.
[b] Trigonometric parallax from Jenkins 1963.
[c] Trigonometric parallax from Jenkins 1952.
[d] Trigonometric parallax from Harrington & Dahn 1980.

TABLE 5.16

SPECTROSCOPIC OBSERVATIONS OF OBJECTS LISTED IN TABLE 5.15

| LHS Number | Other Name | Adopted Sp.Type | Date Obs.(UT) | Integ. (sec) |
|---|---|---|---|---|
| 2243 | LP 315-53 | M8 V | 1992 Feb 25 | 2386 |
| 2632 | LP 321-222 | M7 V | 1992 Feb 25 | 2390 |
| 2645 | LP 218-8 | M7 V | 1992 Feb 25 | 2385 |
| 2980 | LP 441-17 | M6.5 V | 1992 Feb 25 | 2388 |
| 5142 | LP 606-35 | M6.5 V | 1990 Jan 21 | 900 |
| 1252 | LP 587-65 | M6 V | 1991 Nov 13 | 2400 |
| 2826 | LP 912-32 | M4.5 V | 1992 Feb 15 | 888 |
| 2887 | G 165-61 | M4.5 V | 1992 Feb 25 | 354 |
| 2352 | LP 263-78 | sdM | 1992 Feb 25 | 2387 |
| 2045 | LP 545-45 | sdM | 1990 Nov 23 | 1200 |
| 2238 | G 146-15 | sdM | 1992 Feb 25 | 300 |
| 1691 | LP 415-315 | sdM | 1991 Nov 13 | 1200 |

TABLE 5.17

LIST OF CONFIRMED OR SUSPECTED MULTIPLE SYSTEMS
GIVEN AS SINGLE LHS ENTRIES

LHS 3 (SB?) — Spectroscopic binary with range of 30 km/s (Joy 1047). No radial velocity variations detected at the $\sigma = 1.3$ km/s level over 4 years by Pettersen & Griffin (1980) or at the $\sigma = 0.22$ km/s level over 1000 days by Marcy & Benitz (1989). No evidence of a companion via infrared speckle imaging down to a limiting magnitude of $M_K = 11.1$ at a separation of 0.6 arcsecond (Henry & McCarthy 1990).

LHS 8 AB (Conf.) — Astrometric binary (Wagman 1961) of period 18.5 years (Lippincott & Wyckoff 1964). Companion detected at 0.98 arcsecond separation by McCarthy (1983); the mass is 0.15 $M_\odot$.

LHS 15 (As) — Astrometric binary of period 50 years (Lippincott 1973). Martin & Ianna (1975) find a 60-year period and a companion mass of 0.12 $M_\odot$. Companion not detected by photographic speckle interferometry (Hartkopf & McAlister 1984) or by infrared speckle techniques down to $K = 7.8$ (McCarthy 1986).

LHS 26 (As) — Astrometric binary of period 23 years; secondary is probably substellar (Strand 1977). Companion not detected by infrared speckle imaging (McCarthy 1986; Henry 1991), but would be fainter than the detection limits.

LHS 30 (Speck?) — Star may be resolved at a position angle of 25° and $\Delta m_K = 5.2$ (Henry 1991). No astrometric perturbations suspected (Lippincott 1974; Breakiron, Upgren, & Weis 1982). Young, Sadjadi, & Harlan (1987) find radial velocities to be constant to the $\sigma = 4.4$ km/s level over 43 days; Marcy & Benitz (1989) find it to be constant to the $\sigma = 0.23$ km/s level over 553 days.

LHS 33 (As) — Astrometric binary with possible 2-year period; companion could be planetary (Hershey & Lippincott 1982). No radial velocity variations detected to the $\sigma = 0.32$ km/s level over 1197 days (Marcy & Benitz 1989). Possible detection of companion via infrared speckle imaging at 1.6 microns, with separation changing from 0.49 to 0.34 arcsecond over 8 months, by Henry & McCarthy (1990). Later speckle studies find no companion at a level 5.3 magnitudes fainter at $K$ that the primary for separations between 1 and 10 AU (Henry 1991).

TABLE 5.17 — continued

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LHS 37 (As?) — Previous astrometric perturbations suggested a planetary companion with period of 22 years (Hershey & Lippincott 1984), but re-analysis of former data augmented by new astrometric results shows essentially flat residuals with no clear periodicity (Heintz 1991). Marcy & Benitz (1989) report no radial velocity variations to a level of $\sigma = 0.19$ km/s over 1196 days. No evidence of a companion via infrared speckle imaging down to a limiting magnitude of $M_K = 10.9$ at a separation of 0.8 arcsecond (Henry & McCarthy 1990).

LHS 44 (Flare?) — The otherwise unseen companion, designated as CF UMa, has only been detected during what are reported to be flaring events, though Heintz (1984) is skeptical that the flares are real. Schaefer (1989) suggests that the flares are rare flashes of the G star itself. Griffin (1984) notes no radial velocity variations to a level of $\sigma = 0.15$ km/s over 10 years. Duquennoy & Mayor (1991) see no velocity variations to a level of $\sigma = 0.33$ km/s over 4646 days.

LHS 57 (As) — Astrometric perturbations suggest either one planet-sized body in a highly elliptical orbit (van de Kamp 1969a), two such bodies in circluar orbits (van de Kamp 1969b), or a solar system having from three to five planets (Jensen & Ulrych 1973). No evidence via infrared speckle imaging of companions down to $M_K = 11.7$ (Henry & McCarthy 1990). Marcy & Benitz (1989) noted no radial velocity variations to a level of $\sigma$ 0.23 km/s over 1383 days.

LHS 58/59 (As?) — Only slight evidence for astrometric perturbations (Eichhorn & Alden 1960; Kamper 1966; van de Kamp, Gökkaya, & Heintz 1968). Henry (1991) notes no companions down to $M_K = 10.7$ at separations of 1 to 10 AU.

LHS 62/63 (As?) — Astrometric perturbations with a period of 4.8 years discussed by Strand (1957). Astrometric perturbation of 6 years found by Deich (1978) and Deich & Orlova (1977), with additional perrturbations of 7 and 12 years suggested. See additonal discussion of perturbations by Josties (1981). Heintz (1988) sees no periodic astrometric perturbations in either component over 75 years. No detections via speckle interferometry (McAlister et al. 1987). Campbell, Walker, & Yang (1988) find no radial velocity variations to the $\sigma = 10.2$ m/s level around LHS 62. Marcy & Benitz (1989) find no radial velocity variations to the $\sigma = 0.21$ km/s level in either LHS 62 or 63.

TABLE 5.17 — continued

LHS 68 AB (Conf.) — Duplicity independently discovered through infrared speckle interferometry by Leinert, Jahreiss, & Haas (1986) and McCarthy (1986). Binarity not suspected through astrometry (Ianna 1979).

LHS 101 AB (Conf.) — Visual binary with 26.27-year period and semi-major axis of 0.83 arcsecond (Hall 1949). Verified through infrared speckle interferometry by McCarthy (1983).

LHS 114 AB (Conf.) — Astrometric perturbation first discussed by Alden (1947); period of 16 years determined by Hershey (1973). Partially resolved phtographically by McNamara (1984) and confirmed through infrared speckle imaging by McCarthy et al. (1991).

LHS 118 AB (Conf.) — Visual double star of period 25 years (Eggen 1956a).

LHS 123 (As??) — Periodic astrometric perturbations noted but considered inconclusive (van de Kamp & Flather 1955). No perturbation seen by Strand (1969). Spectroscopic orbit with 9.2-day period determined by Abt & Levy (1976) but refuted by Morbey & Griffin (1987). Radial velocity not seen to vary to the $\sigma = 13.7$ m/s level by McMillan & Smith (1987).

LHS 154 AB (Conf.) — Spectroscopic binary of period 9.9 days (Pierce 1924). Astrometric perturbations noted by Binnendijk (1950). Gómez & Abt (1982) unable to see spectral lines from the secondary, concluding that it was at least a late M star. Detected as a double-lines spectroscopic binary by Duquennoy & Mayor (1991).

LHS 181 (SB) — Carney & Latham (1987) report this companion to LHS 180 is itself a spectroscopic binary with a range of 19.83 km/s.

LHS 200 (SB?) — Reported by Gliese (1969) as a spectroscopic binary. No evidence of variable radial velocity (Kamper 1985). No evidence for astrometric perturbations over 23 years (Heintz 1987).

LHS 219 AB (Conf.) — Astrometric perturbation announced in 1844 by Fredrich Bessell. The companion, Sirius B, was first sighted visually by Alvan Clark in 1862.

LHS 221 AB (Conf.) — Companion first suggested by Borgman (see Heintz 1986) and resolved by infrared speckle interferometry (McCarthy 1986).

TABLE 5.17 — continued

LHS 222 AB (Conf.) — Visual binary noted by Luyten (1941).

LHS 225 (Opt?) — Kuiper (Bidelman 1985) gives two spectral types. "Secondary" is probably the companion 3 arcseconds distant listed in Luyten (1955).

LHS 226 AB (Conf.) — Given as a spectroscopic binary in Joy (9147). Astrometric perturbations show evidence for an 18-year period (Appelbaum 1992). Perturbations not seen by Lippincott & Worth (1976). Seen as a double-lined spectroscopic binary by Tomkin & Pettersen (1986); period of 10.4 days. Double M dwarf.

LHS 229 (As) — Astrometric binary with period of 0.94 year (Harrington, Christy, & Strand 1981). No companion found down to $M_K = 12.0$ via infrared speckle interferometry (McCarthy 1986).

LHS 230 AB (Conf.) — Partially resolved white dwarf pair of period 20.5 years (Harrington, Christy, & Strand 1981).

LHS 233 AB (Conf.) — Astrometric perturbations noted by Auwers in 1861. The companion, Procyon B, was first sighted visually in 1896 by Schaeberle.

LHS 241 (SB?) — Listed as a possible radial velocity variable in Carney & Latham (1987) and Stryker et al. (1985), the object shows no systematic trends in its astrometric residuals (Heintz 1973), and Lu et al. (1987) find no evidence for binarity via speckle interferometry .

LHS 242 (As) — Small, periodic perturbation noted in the astrometric residuals (Hershey 1980).

LHS 247 AB (Conf.) — Equal magnitude binary with 0.6-arcsecond separation (Eggen 1979).

LHS 251 AB (Conf.) — Astrometric perturbations suggest an unseen companion with period of 23 years (Lippincott 1973). Companion resolved at $M_K = 5.8$ by infrared speckle interferometry by McCarthy (1986).

LHS 258 (Opt?) — Given as a possible double in Gliese & Jahreiss (1979). "Secondary" is probably the companion 6 arcseconds distant listed in Luyten (1955).

TABLE 5.17 — continued

LHS 260/261 (Speck?) — Morbey & Griffin (1987) refute earlier findings by Abt & Levy (1976) that both stars are spectroscopic binaries. However, Chang (1972) finds LHS 261 to be overmassive; Kirkpatrick, Henry, & McCarthy (1991) find LHS 261 to have an earlier (bluer) spectral type than its primary, LHS 260; and Henry (1991) suspects that one or both of these stars is resolved via infrared speckle imaging.

LHS 264 AB (Conf.) — Visual binary seen by Worley (1962a) and Heintz (1974). Orbital period is given as 50 years by Baize (1964).

LHS 270 AB (Conf.) — Visual binary with 5-arcsecond separation.

LHS 294 (As??) — Earlier reports of astrometric perturbations not verified by Alden (1951) or Lippincott (1974). Infrared speckle techniques find no companion at $K$ down to 4 magnitudes fainter than the primary at a separation of 1 AU (Henry 1991).

LHS 333 AB (Conf.) — Visual binary (see Reuyl 1941). Confirmation via infrared speckle imaging by Henry et al. (1992).

LHS 352 (As?) — Astrometric perturbation with 15- to 20-year period suggested (Bieger 1964). No perturbation seen in follow-up work (Lippincott & Borgman 1979). Infrared speckle imaging finds no companion at $K$ down to 4.7 magnitudes fainter than the primary (Henry 1991).

LHS 359 (As/Opt) — Astrometric perturbation with 1000-day period noted by Osvalds (1957). Optical companion (Burt & Weis 1976), 1 magnitude fainter than the primary, seen at a separation of 20 arcseconds by Worley (1962b).

LHS 374 (Opt) — Optical companion (Burt & Weis 1976), 3 magnitudes fainter than the primary, noted by Worley (1962b).

LHS 386 AB (Conf.) — Possible double lines seen in spectra, and radial velocity variations noted (Marcy, Lindsay, & Wilson 1987). Period of 308 days found (Duquennoy & Mayor 1988; Marcy & Benitz 1989). Companion resolved by infrared speckle enterferometry by Mariotti et al. (1990).

LHS 393 AB (Conf.) — Visual binary with rapid motion (Eggen 1956b).

TABLE 5.17 — continued

LHS 417 AB (Conf.) — Astrometric binary of period 3.72 years (Lippincott & Borgman 1978). Companion detected through infrared speckle interferometry (McCarthy 1983; McCarthy & Henry 1987). Derived mass indicates an object near the stellar/substellar break (Marcy & Moore 1989).

LHS 419 (SB?) — Listed as a spectroscopic binary in Joy (1947). No convincing astrometric perturbations reported (Heintz 1988). No evidence for a companion seen to $M_K = 11.6$ at a separation of 0.5 arcsecond by Henry & McCarthy (1990).

LHS 421 AB (Conf.) — Found to be an eclipsing binary (Eggen & Sandage 1967) of period 1.6 days (Lacy 1977). A binary M dwarf system.

LHS 427 (SB) — Noted as a spectroscopic binary by Joy (1947). Unresolved via speckle interferometric methods at 7000 and 8000 Å by Blazit, Bonneau, & Foy (1987).

LHS 428 AB (Conf.) — Discovered as a visual binary by Kuiper (1934). Period of 1.715 years determined by Voûte (1946). Resolved with a separation of 0.2 arcsecond at 7000 and 8000 Å via speckle interferometry (Blazit, Bonneau, & Foy 1987). Astrometric measurements indicate the fainter component to be ~2 to 3 times more massive that the primary! (Fleischer 1957; Weis 1982).

LHS 429 (As) — Astrometric perturbation seen by Harrington, Kallarakal, & Dahn (183). Companion 1 arcsecond away and 3 magnitudes fainter than the primary at 2.2 microns reported by McCarthy, Probst, & Low (1985) via infrared speckle interferometry. Non-confirmation of the object at 2.2 microns by Perrier & Mariotti (1987) suggests that the earlier "detection" was due to an "airmass-induced differential seeing effect." Companion also not found via direct imaging at $K$ and $L'$ (Skrutskie, Forrest, & Shure 1987).

LHS 442 AB (Conf.) — Visual double (see Hirst 1950).

LHS 450 (As/SB) — Astrometric evidence for a companion by van de Kamp & Lippincott (1949). Period of 26.37 years determined by Lippincott (1977). Companion not detected at 7000 Å between separations of 0.05 to 1 arcsecond and $\Delta m < 3$ (Blazit, Bonneau, & Foy 1987). Companion also not detected via infrared speckle imaging down to $\Delta m = 3.5$ at $H$ and $K$ (Henry & McCarthy 1990). Apparently unrelated to the astrometric binary (Lippincott 1978), this star is also listed as a probable spectroscopic binary by Wilson (1967).

TABLE 5.17 — continued

LHS 452 (As?) — Astrometric perturbation reported by Bieger (1964) but questioned by Heintz (1976).

LHS 458/459 (As) — Astrometric perturbation suggests a third component with period of 17 years (Reuyl & Holmberg 1943). Very slight evidence for an astrometric companion with 13-year period (Wagman 1951)

LHS 463 AB (Conf.) — Visual double with confirmed common proper motion (Vilkki 1984).

LHS 469 AB (Conf.) — Double star with 12-arcsecond separation (Gliese 1969; Luyten 1979).

LHS 471 AB (Conf.) — Double star resolved at a separation of 0.148 arcsecond by Blazit, Bonneau, & Foy (1987).

LHS 472 AB (Conf.) — Astrometric perturbation with period of 2.3 years discovered by Harrington (1977). Companion detected at 2.2 microns and 0.17 arcsecond separation by McCarthy (1983). Duquennoy & Mayor (1991) give a period of 878 days and a secondary mass of 0.09 $M_\odot$.

LHS 474 (As?) — Astrometric perturbation with 4.9-year period suggested by Harrington, Kallarakal, & Dahn (1983). Perturbation not confirmed by Monet et al. (1992). No companion found to $M_K = 12.2$ from 5 to 10 AU via infrared speckle imaging (Henry 1991).

LHS 478 AB (Conf.) — Visual binary (Kuiper 1936).

LHS 482 (SB) — Noted as a spectroscopic binary by Joy (1947).

LHS 488 (SB?) — Given as "probably SB" in Gliese (1969).

LHS 497 AB (Conf.) — Visual binary with optical companions (Eggen 1956b; Gliese 1969).

LHS 501 (Opt?) — "May have a 16-mag. companion, 2 arcseconds distant" (Luyten 1979).

TABLE 5.17 — continued

LHS 511 AB (Conf.) — Astrometric perturbation with 1.9-year period reported by Lippincott (1979) and confirmed by McNamara, Ianna, & Fredrick (1987). Companion has a mass of 0.12 $M_\odot$. Resolved at 2.2 microns by McCarthy (1983) and at 7000 Å and a separation of 0.2 arcsecond by Blazit, Bonneau, & Foy (1987).

LHS 520 (Vis?) — Suggested to be a binary with almost equal components separated by 0.1 arcsecond (Finsen 1941). Gliese (1969), who assignes the binary a designation of GL 855.1 AB, remarks that the separation was 0.1 arcsecond in 1928, but that the companion "not seen since 1933." Duplicity questioned by Evans, Menzies, & Stoy (1957) and Przybylski (1962). Also listed as a double star in The Bright Star Catalogue (Hoffleit & Jaschek 1982). Other data suggest that the star is actually single (Lambert & McWilliam 1986). A prime target for speckle interferometric measurements.

LHS 522 (SB) — Listed as a spectroscopic binary in Joy (1947).

LHS 525 ABC (Conf.) — Close binary measured at 0.47-arcsecond separation by McAlister et al. (1989). A proper motion companion 10 arcseconds distant was first noted by Kuiper, and it and the close double were listed as separate entries in the LFT Catalogue (LFT 1724/1725 — Luyten 1955) and in the LTT Catalogue (LTT 16615/16616 — Luyten 1961). Inexplicably, the distant companion was dropped in the compilation of the LHS Catalogue (Luyten 1979). For completeness, LHS 525 is listed here as a triple.

LHS 533 (SB?) — Listed as a spectroscopic binary in Joy (1947) and Wilson (1967). No periodic astrometric perturbations seen by Binnendijk (1950) or Alden (1957), though Lippincott & Hershey (1983) mention weak evidence for a ~5-year period. Blazit, Bonneau, & Foy (1987) see no companion at 7700 Å via speckle interferometry, and Marcy & Benitz (1989) see no velocity variations down to a level of $\sigma = 0.21$ km/s over 1112 days.

LHS 540 AB (Conf.) — Visual binary measured at separations of 0.72 arcsecond by Worley (1957) and 0.21 arcsecond by Kuiper (1961).

LHS 1016 (SB) — Listed as a spectroscopic binary in Joy (1947).

TABLE 5.17 — continued

LHS 1027 (Opt?/SB?) — A companion, ADS 107 B, with $\Delta m = 11.3$ and separation of 31.3 arcseconds noted in The Bright Star Catalogue (Hoffleit & Jaschek 1982). This companion is given as optical only in the LFT and LTT Catalogues (Luyten 1955; 1961), although Proust, Ochsenbein, & Pettersen (1981) indicate that there is "slow orbital motion." LHS 1027 is also listed as a spectroscopic binary with 27-day period (Mellor 1927), although Abt (1965) found the radial velocity to be constant to a level of $\sigma = 2.5$ km/s.

LHS 1040 AB (Conf.) — Visual double, but the only two recorded observations are from 1935 and 1954 (see Lippincott 1983). Because $\Delta m$ is small, no astrometric perturbations expected, and none found over 50 years (Heintz 1990).

LHS 1047 AB (Conf.) — Astrometric perturbation first noted by Ianna (1979). Companion subsequently confirmed visually (Heintz 1987) and by infrared speckle interferometry by Ianna, Rohde, & McCarthy (1988). The companion has a period of 4.63 years and a mass of $0.055 \pm 0.032 \ M_\odot$, indicating that it is possibly substellar.

LHS 1110 AB (Conf.) — Nearly equal-magnitude binary with 0.2 arcsecond separation (Lutyen 1979; Eggen 1987).

LHS 1163 (SB?) — Originally reported as a spectroscopic binary (Joy 1947), but not supported by Evans, Menzies, & Stoy (1957).

LHS 1179 (SB?) — Reported as "probably a spectroscopic binary" by Joy & Mitchell (1948). Neither Upgren et al. (1985) nor Heintz (1986) mention astrometric perturbations. This star has common proper motion with LHS 1183.

LHS 1206 (SB) — A spectroscopic binary with a velocity range of 17.3 km/s (Carney & Latham 1987) and a period near 1600 days (Jasniewicz & Mayor 1988). Lu et al. (1987) find no evidence for a companion via speckle interferometry.

LHS 1284 AB (Conf.) — Astrometric perturbation with 18.5-year period noted by Lippincott & Lanning (1976). Companion resolved via infrared speckle interferometry; period revised to 19.5 years (Lippincott, Braun, & McCarthy 1983).

TABLE 5.17 — continued

LHS 1314 AB (Conf.) — Visual binary with a large visual magnitude difference of ~7.0 (Eggen 1956b).

LHS 1343 (As?) — Astrometry shows "systematic but so far not periodic residuals" (Heintz 1987).

LHS 1368 (SB?) — Listed as a possible radial velocity variable, with an observed range of 2.5 km/s, in Carney & Latham (1987).

LHS 1393 AB (Conf.) — Listed as a double of 1 arcsecond separation in Gliese & Jahreiss (1979).

LHS 1409 AB (Conf.) — Visual double of separation 0.6 arcsecond (Jeffers, van den Bos, & Greeby 1963).

LHS 1428 (SB?) — Listed as a possible radial velocity variable in Carney & Latham (1987). See also individual velocity measurements in Abt & Levy (1969).

LHS 1452 (Opt) — Listed as part of a common proper motion pair in Gliese (1969), although no companion is listed in Luyten (1979). The Preliminary Version of the Third Catalogue of Nearby Stars (Gliese & Jahreiss 1991) confirms that the companion is not physically related to LHS 1452.

LHS 1458 AB (Conf.) — Visual binary (see Heintz & Borgman 1984) with a 171.5-year period (Heintz 1984).

LHS 1466 (SB?) — Listed as a spectroscopic binary in Gliese (1969).

LHS 1501 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed range of 5.7 km/s. Lu et al. (1987) find no evidence for a companion via speckle interferometry.

LHS 1515 AB (Conf.) — Visual binary (see Eggen 1956b); separation was 2.4 arcseconds in 1975 (Holden 1975).

LHS 1555 (SB) — Variable radial velocity, with an amplitude of at least 30 km/s noted by Dearborn et al. (1986); the period is 245.5 days.

TABLE 5.17 — continued

LHS 1557 (As?/Speck?) — Astrometric perturbation with a 25-year period found (van de Kamp 1974), though disputed by Heintz (1978). Resolved via speckle interferometry by Blazit et al. (1977) at 7000 Å but unconfirmed by Hartkipf & McAlister (1984).

LHS 1569 (SB?) — Listed as a possible spectroscopic binary in Duquennoy & Mayor (1991).

LHS 1602 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed velocity range of 5.1 km/s.

LHS 1642 (As?) — Some evidence of a short-period astrometric perturbation (Hershey 1980); unresolved by infrared speckle imaging (Henry 1991).

LHS 1736 (Vis?/Speck?) — Although given the double star designation ADS 3701 and frequently referred to as a visual binary (e.g., Flather 1957), Hartkopf & McAlister (1984) note that the pair has never been split by speckle interferometric methods despite the fact that various orbits predict the companion to be easily observable. Heintz & Borgman (1984) note that twenty measurements of the position angle are so scattered that no orbit represents them well; they conclude that the companion is spurious. However, Tokovinin (1985) reports splitting the pair at a separation of 0.04 arcsecond as measured by a photographic phase-grating interferometer. Further studies are warranted.

LHS 1746 (Opt?) — Luyten (1979) notes a possibly optical companion 2 arcseconds away.

LHS 1780 (SB?) — Listed a a possible radial velocity variable, with an observed range of 5.1 km/s, in Carney & Latham (1987).

LHS 1804 ABC (Conf.) — Visual triple with separations of 2.42 arcseconds for AC and 0.82 arcsecond for AB (Wilson 1982).

LHS 1830 AB (Conf.) — Visual binary with 1-arcsecond separation (van de Kamp 1950).

LHS 1864 AB (Conf.) — Visual double. The common proper motion companion, $\Delta m_V = 2.5$, lies 1.8 arcseconds away and is seen on some of the USNO parallax plates (Dahn et al. 1988).

TABLE 5.17 — continued

LHS 1868 (SB??) — Listed as a single-lined spectroscopic binary with a 60-day period in Abt & Levy (1976). Morbey & Griffin (1987) show that a re-analysis of the same data supports no claim for real velocity variations. McAlister (1978) finds no evidence for a companion via speckle interferometry.

LHS 1911 AB (Conf.) — Visual binary which Eggen (1965) describes as "a puzzling pair" whose orbit determination gives a total mass of 0.05 $M_\odot$!

LHS 1929 (Opt?) — Possibly optical companion noted by Kuiper (Bidelman 1985) at a separation of 7 arcseconds; spectral type of companion given as "K?."

LHS 1945 (Opt) — Although listed as ADS 6335, all companions are optical (Hoffleit & Jaschek 1982; Luyten 1979). No companions found via infrared speckle imaging (Henry 1991).

LHS 1955 AB (Conf.) — Noted as a double star with 0.8-arcsecond separation (Luyten 1979; Eggen 1987).

LHS 1960 AB (Conf.) — Noted as a double with 2-arcsecond separation (Gliese 1969; Luyten 1979).

LHS 1991 AB (Conf./SB?) — Visual binary with 64.65-year period (Heintz 1974). There is a possibility of a third component since the pair is listed as a spectroscopic binary by Duquennoy & Mayor (1991), who give the period as 195 days and the mass of the tertiary as 0.10 $M_\odot$.

LHS 2042 AB (Conf./SB) — A close visual double with separation of 2 arcseconds (Worley 1962b). A third common proper motion component, LHS 2043, may not be bound to LHS 2042 AB (van de Kamp & Burton 1962). Wilson (1967) notes that LHS 2042 is a possible spectroscopic binary, suggesting a fourth member of the system. The velocity variations are confirmed by Duquennoy & Mayor (1988), who find a period of 21 days and suggest that the unseen companion would most likely have a spectral type around M7.

LHS 2082 AB (Conf.) — A double-lined spectroscopic binary whose orbital parameters are presented in Latham et al. (1988). See also Greenstein & Saha (1986).

LHS 2083 AB (Conf.) — Visual double with a separation of ~0.2 arcsecond in 1970 (van Beisbroeck 1974). The period is 39 years (Eggen 1956b).

TABLE 5.17 — continued

LHS 2084 (SB) — Given as a spectroscopic binary (Abt 1965) with semi-amplitude of 6.0 km/s and period of 11 years. Another component, apparently unrelated to the spectroscopic binary, is suggested at a separation of 1 arcsecond by speckle interferometry at 5000 Å (Morgan, Beckman, & Scaddan 1980).

LHS 2093 AB (Conf.) — Visual binary discovered by Kuiper (see van de Kamp 1947); period is 22.2 years (Underhill 1963).

LHS 2114 AB (Conf.) — A double-lined spectroscopic binary whose duplicity was first reported visually by Finsen (1959). See Griffin (1982) for a concise review of this pair. The period is 986.5 days (Heintz 1984).

LHS 2125 AB (Conf.) — Visual binary with 34.2-year period (Lippincott 1958).

LHS 2151 AB (Conf.) — Visual binary observed by Kuiper (1943); astrometric perturbation also noted by Tifft (1955).

LHS 2156 AB (Conf.) — Visual binary with $\Delta m \sim 8.5$ (Eggen 1956b). Period of 201.0 years (Duquennoy & Mayor 1991).

LHS 2165 (Vis?) — Kuiper's observation of this star has the note "close binary?" (Bidelman 1985).

LHS 2169 (SB) — Listed as a spectroscopic binary, with an observed velocity range of 6.9 km/s, in Carney & Latham (1987).

LHS 2188 (As?) — Astrometric perturbation with period of 460 days suggested by Alden (1951) but not confirmed by later measurements (Alden et al. 1957; Titter, Mesrobian, & Upgren 1972).

LHS 2194 (SB) — Listed as a probable spectroscopic binary of period $\sim$7600 days by Abt & Levy (1969). Stryker et al. (1985) list it as a certain binary. Carney & Latham (1987) refer to it as a possible radial velocity variable with an observed range of 4.7 km/s.

TABLE 5.17 — continued

LHS 2286 (Opt) — Duquennoy & Mayor (1991) list this as GL 398.1 A and B and denote it as a common proper motion pair (although, see their "Note added in proof"). Luyten (1979), however, lists the 10.5-magnitude component as an optical companion only. Gliese (1969) gives the 1958 separation of the faint star from the bright star as 14.4 arcseconds at a position angle of 75°. Assuming no proper motion for the faint component and taking the proper motion per annum of 0.722 arcsecond at $\theta = 159.5°$ for LHS 2286 (Luyten 1979), the separation of the companion is predicted to be 24.2 arcseconds at $\theta = 15.8°$ during 1987. This is in very close agreement with Sinachopoulos' (1988) measurement of $\rho = 23.95$ arcseconds and $\theta = 12.02°$ during 1987. Thus, the two stars are physically unrelated. (Curiously, Duquennoy & Mayor (1991) find that this unrelated star is a spectroscopic binary with a velocity range of 20 km/s.)

LHS 2327 (As) — Astrometric perturbation with 6.7-year period noted by Behall & Harrington (1976). Mass of the unseen secondary would be around 0.16 $M_\odot$. The binary has not been resolved via infrared speckle imaging (Henry 1991).

LHS 2380 (SB) — Listed as a spectroscopic binary, range 40 km/s, by Joy (1947).

LHS 2390 (SB) — A spectroscopic binary of period 669.2 days with velocity range of ~16 km/s (Berman 1931). Derived mass of the secondary is 0.31 $M_\odot$ (Heintz 1967). Faint component not seen via speckle interferometry (Hartkopf & McAlister 1984; Henry 1991). This star is also a companion to LHS 2391.

LHS 2391 (SB) — A spectroscopic binary of period 3.98 days with a velocity range of ~10 km/s (Berman 1931).

LHS 2402 AB (Conf.) — Visual binary (Evans, Menzies, & Stoy 1957; Evans, Menzies, & Stoy 1959) with 4-arcsecond separation and 300-year period (Luyten 1979).

LHS 2424 (SB?) — Listed as a possible radial velocity variable, with an observed range of 2.8 km/s, in Carney & Latham (1987).

LHS 2436 (SB) — Listed as a spectroscopic binary of period 23.5 days (see Gliese 1969; Bakos 1974). Radial velocity curve presented in Duquennoy & Mayor (1991). Unresolved at 7000 Å via speckle interferometry by Blazit, Bonneau, & Foy (1987).

TABLE 5.17 — continued

LHS 2437 (SB) — Listed as a spectroscopic binary of period 3.4 days by Bakos (1974).

LHS 2462 AB (Conf.) — Luyten (1979) notes that the 15.5-magnitude neighbor listed in Aitken (1932) is a physical companion.

LHS 2465 (SB?) — Campbell, Walker, & Yang (1988) list this as a possible, small-amplitude velocity variable, as do Duquennoy & Mayor (1991), though Heintz (1991) makes no mention of astrometric perturbations. Hartkopf & McAlister (1984) find no evidence for a companion via speckle interferometry.

LHS 2505 AB (Conf.) — Visual binary with $\Delta m = 2$ and separation of 0.8 arcsecond (see Eggen 1987).

LHS 2524 (Opt?) — Luyten (1979) notes a faint companion 2 arcseconds distant at $\theta = 5°$. Duquennoy & Mayor (1991) find constant radial velocity, to the 0.42-km/s level, over 2362 days.

LHS 2531 (Opt) — Optical companion 5 arcseconds east of LHS 2531 according to Weis & Upgren (1982).

LHS 2566 (SB) — A spectroscopic binary with a well determined orbit and a period of 25.9 days (Latham et al. 1988). This is confirmed by Jasniewicz & Mayor (1988) who find that there is a 90% chance that the secondary has a mass between 0.10 and 0.25 $M_\odot$.

LHS 2647 AB (Conf./SB) — Component B is 1.9 arcseconds distant, with $\Delta m = 4.5$; the A component itself is a spectroscopic binary with a well determined period of 12.4 days. The mass of this unconfirmed C component is between 0.14 and 0.60 $M_\odot$ (Mayor & Turon 1982).

LHS 2656 AB (Conf.) — Visual pair separated by 1.5 arcseconds (Eggen 1956b).

LHS 2664 (SB) — No astrometric perturbations now suspected (Heintz & Borgman 1984). Listed as a possible spectroscopic binary in Gliese (1969) and Pettersen (1991). Joy (1947) gives it as a spectroscopic binary with a range of 54 km/s.

LHS 2665 (SB) — Given as a spectroscopic binary with a period of 1348 days in Duquennoy & Mayor (1991). The secondary, with a computed mass of 0.04 $M_\odot$, is an excellent brown dwarf candidate.

TABLE 5.17 — continued

LHS 2693 (SB) — Variations in the radial velocity noted by Latham et al. (1989), who find a period of 84 days and a companion mass given by $M \sin i = 0.011 \pm 0.001 M_\odot$. This mass falls in the regime of brown dwarfs for inclinations greater than $8°$, and investigations have been launched in an effort to put constraints upon the possible values of $\sin i$. Robinson et al. (1990) find no evidence for eclipses in the system, meaning that the orbital inclination is less than $89°$. From high-precision radial velocity measures, Cochran, Hatzes, & Hancock (1991) derived rotational and macroturbulent velocities consistent with $\sin i_{rot} \leq 0.14$. If the orbital and rotational axes are nearly aligned, this suggests a companion mass in the stellar regime. Lack of periodic photometric variations also support the pole-on orientation. However, other interpretations of the data are also possible. This system clearly deserves further study.

LHS 2708 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed range of 2.9 km/s.

LHS 2728 AB (Conf.) — A double with a period of 229.0 years (Amburster 1978). Binarity confirmed via speckle observations by McAlister et al. (1989) — separation 1.3 arcseconds.

LHS 2747 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed range of 2.5 km/s.

LHS 2845 (Vis?) — Luyten (1979) notes that this "could be a close double."

LHS 2883 (Opt?) — Rodgers & Eggen (1974) note a faint, probably optical companion 1 arcsecond away.

LHS 2891 AB (Conf.) — Visual binary with a separation of 3 arcseconds (Eggen 1987; Luyten 1979; Gliese 1969).

LHS 2989 (Vis?) — Luyten (1979) lists this as a companion to LHS 2990 and adds that LHS 2989 "may itself be double again."

LHS 2997 AB (Conf.) — Binary of 0.6-arcsecond separation as confirmed through speckle observations (McCarthy 1986; McAlister et al. 1989). Period is 34.1 years (Heintz 1990).

LHS 3008 (As) — Luyten (1979) notes, without reference, that this star has an invisible companion with a period of ~1300 days.

TABLE 5.17 — continued

LHS 3020 (SB?/As) — Noted as a possible spectroscopic binary by Dyer (1954). Astrometric perturbations noted by Alden et al. (1957), who suggest a 700-day period. No companion seen at 7500 Å via speckle interferometry by Bonneau et al. (1986).

LHS 3064 (Vis?) — Eggen (1980) notes that "in good seeing, this appears as a possible double of equal components."

LHS 3076 (As) — Astrometric perturbations of period 5.96 years noted by Harrington & Dahn (1988); mass of the secondary is around 0.1 $M_\odot$. Companion not seen via infrared speckle imaging (Henry 1991).

LHS 3148 (SB) — A spectroscopic binary of period 4451 days (Duquennoy & Mayor 1991). Unresolved at 6000 and 7500 Å via speckle interferometry by Bonneau et al.(1986).

LHS 3156 AB (Conf./SB) — There is a 14th-magnitude common proper motion companion 2 arcseconds away which is not noted by Luyten (1979) presumably because it is variable — it is frequently invisible on the Sproul plate series (Lippincott 1983). A third component could be present since the primary is a noted spectroscopic binary with range 36 km/s (Joy 1947).

LHS 3172 AB (Conf.) — Visual binary with 2-arcsecond (and increasing) separation (see Heintz & Borgman 1984; Heintz 1975; Heintz 1956; Worley 1956).

LHS 3199 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed range of 3.5 km/s.

LHS 3215 (SB) — A spectroscopic binary (whose effects are unrelated to its companion, LHS 3219, 19.5 arcminutes away). The close companion has a period of 133.3 days (Mayor & Turon 1982).

LHS 3234 AB (Conf./As?) — A visual binary first detected by William Herschel. The magnitude difference of the pair is 2.6, the period is 34.33 years, and the mass of the secondary is 0.78 $M_\odot$ (Lippincott 1981). Though Baize (1967) finds evidence for a third component, of mass ~0.19 $M_\odot$ and spectral type around M4 or M5, Lippincott (1981) sees no astrometric perturbations which would indicate more than two stars in the system. Radial velocity data by Scarfe et al. (1983) rule out the companion proposed by Baize, but have difficulty ruling out a third body all together.

TABLE 5.17 — continued

LHS 3269 AB (Conf.) — Visual binary of 0.6-arcsecond separation. Because the masses are assumed to be equal, Lippincott (1983) sees no astrometric indication of the orbital motion. The period is 33.5 years (Heintz 1991).

LHS 3277 (As) — Astrometric perturbation with a period of 10 years noted by Christy (1978). Two alternative solutions for the masses of the components are given in Dahn et al. (1988): the first solution yields masses of 0.13 and 0.09 $M_\odot$ for the components, and the second yields masses of 0.14 and 0.04 $M_\odot$. In either case, the secondary, which has not been imaged via infrared speckle techniques (Henry 1991), would be an excellent brown dwarf candidate.

LHS 3287 (SB?) — Noted as a spectroscopic binary with range of 28 km/s in Gliese (1969). Nineteen measurements of the radial velocity over 860 days show no evidence for variations to the $\sigma$ = 2.6 km/s level (Beavers & Eitter 1986).

LHS 3305 AB (Conf.) — A visual binary of period 74 years and 1.5-arcsecond separation (Hall 1948).

LHS 3325 AB (Conf.) — Visual binary of period 43.2 years (Heintz 1987).

LHS 3326 (As) — Heintz (1987) finds this to be a "new unresolved binary of large amplitude" with a period of 63 years and $a$ = 0.248 arcsecond.

LHS 3345 AB (Conf.) — Visual binary of 0.43-arcsecond separation (see Carney & Latham 1987).

LHS 3379 AB (Conf.) — A spectroscopic binary of period 280 days; companion confirmed via speckle interferometry. See Tomkin et al. (1987) for a review of this system.

LHS 3463 (Vis?/SB?) — Although a companion with $\Delta m$ = 3.5 and a separation of 105.6 arcseconds is listed by Hoffleit & Jaschek (1982), Luyten (1979) makes no mention of a second object. LHS 3463 is also listed as a probable velocity variable in Evans, Menzies, & Stoy (1957) and as a possible spectroscopic binary in Duquennoy & Mayor (1991). No companion has been found via speckle interferometry by either Bonneau et al. (1980) or Lu et al. (1987).

LHS 3494 AB (Conf.) — Astrometric perturbations first noted by Harrington & Kallarakal (1982). Companion, whose mass is near the stellar/substellar break, confirmed by McCarthy et al.(1988).

TABLE 5.17 — continued

LHS 3509 (Vis?) — Heintz (1988) notes that a plate taken on 1971.42 shows a faint companion of magnitude ~15.5 with a separation of 4.4 arcseconds and position angle of 114°. A deep-field exposure by Harrington in 1973 shows no object, whether it be a fixed background star or a common proper motion companion. Heintz's conclusion is that the object is variable and possibly a flaring, third member of the LHS 3509/3510 system. McAlister et al. (1987) find no tertiary component via speckle interferometry.

LHS 3556 (As) — Astrometric perturbation first noted by Harrington (1971). The companion has a period of 1.49 years and a mass in the range 0.06 to 0.11 $M_\odot$.

LHS 3557 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed range of 3.2 km/s.

LHS 3558 (Opt?/As?) — Worley (1962b) notes a possibly optical companion at 35 arcseconds with $\Delta m = 2$. Also, a very uncertain astrometric perturbation is noted by van de Kamp & Lippincott (1949).

LHS 3565 ABC (Conf.) — A W Ursae Majoris-type eclipsing variable with a period of 0.278 days. The two components have masses of 0.9 and 0.25 $M_\odot$ (Hill 1989). Astrometric orbital motion with a period of 30.45 years was investigated by Hershey (1975); this third component with $\Delta m = 2.9$ and mass of 0.58 $M_\odot$, was confirmed visually by Heintz (see Hershey 1975) at a separation of 0.6 arcsecond from the eclipsing pair. LHS 3592 is listed by Heintz (1978) as a very distant, common proper motion, fourth component of this system.

LHS 3568 AB (Conf./SB) — A visual binary of period 37.0 years (Morel 1969). The A component of the system has been shown to be a spectroscopic binary with a period of 2.5 years by Duquennoy (1987), who claims to have detected lines from the tertiary in the spectrum of A at periastron. Duquennoy's estimate of the tertiary's mass (0.28 $M_\odot$) is disputed by Heintz (1989), who supports a mass less than 0.2 $M_\odot$.

LHS 3577 (As?) — Lippincott (1979) notes an astrometric perturbation with a period of 6.3 years. Marcy & Benitz (1989) find no statistically significant velocity variations, and McCarthy (1986) finds no evidence for a companion at 2.2 microns.

TABLE 5.17 — continued

LHS 3595 (SB?/As?) — Listed by Wilson (1967) as a probable spectroscopic binary with range of 11.0 km/s. Heintz (1981) also finds a variation with a range of 15 km/s. Variable proper motion, with a period of 17 years, suspected by Lippincott & Worth (1976), but not confirmed by Heintz (1991). Five radial velocity measurements over an eight-day period by Young, Sadjadi, & Harlan (1987) show no evidence of variation. Henry (1991) sees no companion down to $M_K = 11.0$.

LHS 3609 ABC (Conf.) — Known as a visual binary (see Lippincott 1975), the primary star was also found to be a 3.2756-day double-lined spectroscopic binary by Fekel, Bopp, & Lacy (1978). The masses of this triple system are 0.9, 0.6, and 0.5 $M_\odot$ as determined by Russell & Gatewood (1980) and 0.4, 0.3, and 0.3 $M_\odot$ as determined by Duquennoy & Mayor (1988).

LHS 3635 (Vis?/CPM?) — Although listed in Gliese (1969) as a close double star, both Hoffleit & Jaschek (1982) and Eggen (1987) call it an unconfirmed binary. Gliese (1969) also lists a common proper motion, third component at a separation of ~8 arcseconds; no such object is noted in the Bruce Proper Motion Survey (Luyten 1963).

LHS 3637 AB (Conf.) — Shown to be a visual double with common proper motion by Vilkki (1984).

LHS 3655 (SB?) — Listed as a spectroscopic binary in Gliese (1969) and Augensen & Buscombe (1978). The object is unresolved at 7000 Å via speckle interferometry by Blazit, Bonneau, & Foy (1987).

LHS 3682 AB (Conf.) — Both Kuiper (Bidelman 1985) and Luyten (1979) list this as a close visual double.

LHS 3699 AB (Conf.) — Luyten (1979) notes this as a visual binary of 2-arcsecond separation and $\Delta m = 3$.

LHS 3707 AB (Conf.) — A double star whose orbit is somewhat uncertain — periods range from 6.32 to 12.65 years (Finsen & Worley 1970). The longer period makes for better agreement between the trigonometric, dynamical, and photometric parallaxes.

LHS 3731 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed range of 3.9 km/s.

TABLE 5.17 — continued

LHS 3770 AB (Conf./SB) — Lu et al. (1987) discovered via speckle interferometry a companion at a separation of 0.205 arcsecond and position angle of 126.7°. The primary is also listed as a spectroscopic binary with an observed range of 11.9 km/s in Carney & Latham (1987). The period of this suspected tertiary around LHS 3770 A is 219.38 days (Latham et al. 1988).

LHS 3790 AB (Conf.) — Visual double star (Eggen 1956b).

LHS 3814 (As??) — Systematic runs in the residuals of the orbital and mass-ratio solutions of Krüger 60 AB led Lippincott (1953) to propose, "with great caution," a companion to A having a period of 16 years and mass between 0.009 and 0.025 $M_\odot$. Heintz (1986) does not find a continuation of these trends in later data.

LHS 3833 (Opt?) — Worley (1962b) lists a possible companion 15 arcseconds distant with $\Delta m = 4$. This companion is too faint to be measured on plates taken by Upgren & Kuzma (1983).

LHS 3839 (Opt?) — Luyten (1979) notes that this star might have a common proper motion companion 13 arcseconds distant.

LHS 3853 (As?/Ecl?/Speck?) — van de Kamp & Worth (1972) find astrometric evidence for a second body with a period of 28.9 years and mass between 0.01 and 0.03 $M_\odot$. Roĭzman (1984) finds evidence for an eclipsing body (mass $\leq 0.04 M_\odot$) having a period coincident with EV Lacertae's photometric period of 4.378 days. However, Weis, Nations, & Upgren (1983) find no significant trends in their astrometric residuals; Marcy & Benitz (1989) see no radial velocity variations to the $\sigma = 0.24$ km/s level over 694 days; Blazit, Bonneau, & Foy (1987) are unable to resolve a companion at 7700 Å via speckle interferometry; and Henry (1991) sees no companion to $M_K \sim 10.8$ via infrared speckle imaging, though earlier results (Henry & McCarthy 1990) suggest a possible companion with $\Delta m \sim 4$ at a separation of 0.4 arcsecond. Young, Sadjadi, & Harlan (1987) also list it as a possible, low-amplitude spectroscopic binary.

LHS 3869 (SB?) — Listed in Carney & Latham (1987) as a possible radial velocity variable with an observed range of 3.0 km/s.

TABLE 5.17 — continued

LHS 3982 (As/SB) — An astrometric perturbation with a period of ~12 years noted by Russell & Gatewood (1975). LHS 3982 is also listed as a spectroscopic binary with an observed range of 8.75 km/s by Carney & Latham (1987). Observations by Hartkopf & McAlister (1984) have not revealed either companion via speckle interferometry.

LHS 3995 (SB?) — Listed as a possible spectroscopic binary in Duquennoy & Mayor (1991).

LHS 5098a (Opt?) — Kuiper (Bidelman 1985) notes close companions to this star; they are probably optical only.

LHS 5139a AB (Conf./As/SB) — A visual double star of separation 1.9 arcseconds; the period has had estimates of 214 years (see Eggen 1956b), 140-145 years (Abt, Sanwal, & Levy 1980), and 123 years (Heintz 1990). There is also an astrometric perturbation with a period of ~35 years (Eggen 1956b), and Abt, Sanwal, & Levy (1980) note small-amplitude velocity variations with a period of ~500 days.

LHS 5163 AB (Conf.) — Lutyen (1979) notes a 14.5-magnitude companion at a separation of 1.5 arcseconds. Kuiper (Bidelman 1985) also noted that this was a close double.

LHS 5167 (As?/Speck?/Radio?) — Variable proper motion first noted by Reuyl (1943) and verified with subsequent data by Lippincott (1969). The companion, at 0.08-arcsecond separation, was resolved at 7800 Å via speckle interferometry by Balega, Bonneau, & Foy (1984). However, the companion was not found to a limit of $M_K = 11.0$ via infrared speckle imaging (Henry 1991). Likewise, Marcy & Benitz (1989) find no radial velocity variations to the $\sigma = 0.20$ km/s level over 1224 days. Heintz (1990) discounts all previously reported astrometric perturbations and notes that the alleged interferometric confirmation must be spurious. Curiously, Robinson, Slee, & Little (1976) report a weak radio emission source 1.85 arcminutes southeast of AD Leonis which they interpret as a companion object with a linear separation of ~550 AU.

LHS 5215 AB (Conf.) — A double-lined spectroscopic binary apparently containing two G-type stars with a period of 5.41 days (Greenstein, Hack, & Struve 1957). See also recent observations by Mayor & Mazeh (1987).

TABLE 5.17 — continued

LHS 5279 (SB) — A single-lined spectroscopic binary with a well determined orbit of period 125.37 days (Kamper & Lyons 1981; Beavers & Salzer 1983). The companion has not been verified through speckle interferometry by either Hartkopf & McAlister (1984) or Blazit, Bonneau, & Foy (1987) at 7000 and 7500 Å.

LHS 5350a AB (Conf./SB?) — A visual binary with a separation of 12 arcseconds (Eggen 1956b). Campbell, Walker, & Yang (1988) see possible radial velocity variations in component A, but state that the observed acceleration could be caused by B alone. Duquennoy & Mayor (1991) find the velocity to be constant over 3927 days.

LHS 5351a AB (Conf.) — A visual double (see van den Bos 1963) with a period of 9.70 years, $\Delta m = 0.5$, and total mass of 2.1 $M_\odot$ (Baize 1992). The visual orbit presented in Duquennoy & Mayor (1991) has a period of 1790 days — half as long as that computed by Baize.

LHS 5358b (SB) — Listing this object as a spectroscopic binary, Hartkopf & McAlister (1984) find no companion via speckle interferometry.

LHS 5399 AB (Conf./As?) — A visual double star with a separation of 1.3 arcseconds and $\Delta m = 2.0$ (Holden 1978). An astrometric perturbation with period of 1170 days also suspected (van Altena & Sawada 1983).

LHS 5400a AB (Conf.) — A visual double star with $\Delta m = 0.9$ (e.g., see Worley 1957 and van den Bos 1958).

LHS 5405 (Phot?) — Excess infrared radiation between 2 and 5 microns detected for this white dwarf by Zuckerman & Becklin (1987) who attribute it to a possible 1200 K brown dwarf companion. Infrared imaging by Tokunaga et al. (1988) does not resolve the companion, implying that the separation from the primary is < 5.6 AU or that the excess is caused by dust. Slit scans by Haas & Leinert (1990) show an "extension" of G 29-38 which suggests a companion at 0.23-arcsecond (3.2-AU) separation. Photometry of G 29-38 at 10 microns by Graham et al. (1990) shows a flux level which is three times larger than predicted by the suspected brown dwarf — thus favoring a model based on dust. Infrared broad- and narrow-band data by Tokunaga, Becklin, & Zuckerman (1990) confirm the strong emission at 10 microns and further suggest that the excess radiation comes from orbiting particulate matter.

TABLE 5.18

POSSIBLE VERY LATE TYPE STARS, BROWN DWARF CANDIDATES,
AND EXTREME SUBDWARFS FROM *THE STARS OF LOW
LUMINOSITY* (LUYTEN 1977)

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|------|-----------|-----|----------------|------|
| 704-43 | 0:02 | -11 | 3.7 | |
| 704-45 | 0:03 | -10 | 3.3 | |
| 704-58 | 0:04 | -9 | 3.0 | |
| 524-78 | 0:07 | +8 | 3.3 | |
| 704-59 | 0:09 | -10 | 3.3 | |
| 824-434 | 0:11 | -20 | > 3.1 | LHS 106; real? |
| 824-385 | 0:11 | -25 | 3.1 | |
| 192-47 | 0:12 | +40 | 3.1 | |
| 404-64 | 0:13 | +20 | 3.2 | |
| 348-50 | 0:14 | +26 | 3.1 | |
| 824-442 | 0:17 | -22 | 3.0 | |
| 585-22 | 0:22 | -2 | 3.0 | |
| 349-21 | 0:24 | +23 | 3.2 | |
| 465-27 | 0:27 | +10 | 3.4 | |
| 465-38 | 0:29 | +9 | 3.2 | |
| 765-71 | 0:30 | -18 | 3.0 | |
| 645-52 | 0:33 | -3 | 3.4 | |
| 405-39 | 0:35 | +16 | 3.6 | |
| 150-33 | 0:36 | +49 | 3.2 | |
| 465-63 | 0:37 | +11 | 3.0 | |
| 350-6 | 0:45 | +22 | 3.3 | |
| 406-45 | 0:55 | +18 | 3.0 | |
| 766-89 | 0:58 | -19 | 3.5 | |
| 938-71 | 1:00 | -37 | > 2.9 | LHS 132 |
| 526-62 | 1:03 | +4 | 3.1 | |
| 647-13 | 1:07 | -3 | 3.1 | |
| 407-20 | 1:10 | +19 | 3.1 | |
| 467-31 | 1:13 | +13 | 3.7 | |
| 407-27 | 1:14 | +19 | 3.3 | |
| 587-65 | 1.25 | +1 | > 3.2 | LHS 1252, M6 (this thesis) |
| 708-98 | 1:31 | -11 | 3.7 | |
| 708-117 | 1:32 | -9 | 3.1 | LHS 1265 |
| 648-86 | 1:42 | -7 | 3.1 | |

TABLE 5.18 — continued

| LP # | RA (1950) Dec | | $m_{pg} - m_R$ | Note |
|------|------|------|------|------|
| 828-71 | 1:43 | -23 | 3.0 | |
| 828-72 | 1:44 | -23 | 3.0 | |
| 352-43 | 1:46 | +26 | 3.3 | LHS 1299 |
| 529-6 | 1:55 | +6 | 3.1 | |
| 589-14 | 1:58 | +2 | 3.1 | |
| 651-63 | 2:01 | -2 | 3.1 | |
| 353-21 | 2:11 | +26 | 3.3 | |
| 829-42 | 2:14 | -22 | 3.0 | |
| 52-51 | 2:15 | +66 | 3.0 | |
| 885-45 | 2:16 | -27 | 3.4 | |
| 353-59 | 2:22 | +23 | 3.5 | |
| 353-61 | 2:23 | +23 | 3.2 | |
| 245-42 | 2:25 | +34 | 3.0 | |
| 410-39 | 2:28 | +20 | 3.7 | |
| 245-57 | 2:34 | +36 | 3.1 | |
| 245-62 | 2:35 | +36 | 3.2 | |
| 710-82 | 2:41 | -14 | 3.1 | |
| 651-13 | 2:45 | -8 | 3.0 | |
| 471-17 | 2:47 | +11 | 3.2 | |
| 830-59 | 2:51 | -23 | 3.2 | |
| 471-43 | 3:01 | +12 | 3.2 | |
| 53-48 | 3:13 | +67 | 3.1 | |
| 54-4 | 3:14 | +63 | 3.1 | |
| 412-31 | 3:18 | +18 | 3.4 | |
| 532-71 | 3:19 | +3 | 3.2 | |
| 832-9 | 3:21 | -25 | 3.2 | |
| 54-20 | 3:32 | +66 | 3.2 | |
| 533-23 | 3:33 | +5 | 3.2 | |
| 832-29 | 3:33 | -22 | 3.3 | |
| 888-37 | 3:34 | -30 | 3.2 | |
| 300-23 | 3:35 | +32 | 3.3 | |
| 713-22 | 3:38 | -9 | 3.1 | |
| 54-23 | 3:38 | +64 | 3.8 | |
| 533-49 | 3:40 | +6 | 3.0 | |
| 248-18 | 3:44 | +35 | 3.0 | |

TABLE 5.18 — continued

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|---|---|---|---|---|
| 889-3 | 3:47 | -32 | 3.1 | |
| 593-68 | 3:48 | -1 | 3.3 | LHS 1604 |
| 889-13 | 3:53 | -27 | 3.0 | |
| 833-38 | 4:03 | -21 | 3.0 | |
| 54-45 | 4:09 | +69 | 3.7 | |
| 302-9 | 4:17 | +32 | 3.0 | |
| 302-27 | 4:25 | +31 | 3.0 | |
| 302-34 | 4:31 | +30 | 3.0 | |
| 84-37 | 4:35 | +60 | 3.3 | |
| 157-34 | 4:47 | +45 | 3.1 | |
| 776-26 | 4:50 | -19 | 3.1 | |
| 536-23 | 4:54 | +3 | 3.7 | |
| 84-55 | 4:55 | +61 | 3.0 | |
| 536-25 | 4:56 | +5 | 3.7 | |
| 776-44 | 5:00 | -20 | 3.3 | |
| 892-18 | 5:10 | -27 | 3.2 | |
| 892-27 | 5:13 | -28 | 3.1 | |
| 85-28 | 5:22 | +62 | 3.0 | |
| 119-42 | 5:23 | +55 | 3.0 | Comp. to LP 119-41, 5″ away |
| 477-33 | 5:28 | +9 | 3.1 | |
| 538-3 | 5:30 | +4 | 3.5 | |
| 837-11 | 5:34 | -25 | 3.2 | |
| 538-7 | 5:35 | +6 | 3.2 | |
| 159-8 | 5:35 | +49 | 3.1 | |
| 893-16 | 5:43 | -32 | 3.2 | |
| 538-21 | 5:43 | +4 | 3.0 | |
| 538-22 | 5:44 | +5 | 3.0 | |
| 538-24 | 5:44 | +3 | 3.3 | |
| 894-4 | 5:56 | -31 | > 3.2 | |
| 719-7 | 5:58 | -10 | 3.0 | |
| 159-41 | 5:59 | +46 | 3.3 | |
| 779-8 | 5:59 | -17 | > 3.0 | |
| 159-47 | 6:01 | +47 | 3.5 | |
| 779-28 | 6:08 | -17 | 3.1 | |
| 121-4 | 6:10 | +52 | > 3.6 | |
| 121-11 | 6:18 | +50 | 3.3 | |

TABLE 5.18 — continued

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|---|---|---|---|---|
| 121-16 | 6:21 | +51 | 3.4 | |
| 121-21 | 6:22 | +52 | 3.1 | |
| 160-38 | 6:30 | +50 | 3.8 | |
| 720-30 | 6:36 | -12 | 3.4 | |
| 895-31 | 6:42 | -31 | 3.6 | |
| 205-32 | 6:46 | +41 | 3.3 | |
| 308-23 | 7:03 | +28 | 3.2 | |
| 308-27 | 7:06 | +31 | 3.3 | |
| 161-260 | 7:09 | +47 | 3.0 | |
| 482-18 | 7:16 | +13 | 3.0 | |
| 123-9 | 7:27 | +54 | 3.1 | |
| 256-25 | 7:28 | +37 | 3.3 | |
| 365-19 | 7:29 | +26 | 3.7 | |
| 123-46 | 7:46 | +54 | 3.0 | |
| 366-23 | 7:53 | +21 | 3.0 | |
| 366-28 | 7:54 | +23 | 3.2 | |
| 545-37 | 8:36 | +2 | 3.0 | |
| 545-45 | 8:41 | +6 | 3.3 | LHS 2045, sdM (this thesis) |
| 606-35 | 8.49 | +0 | 3.8 | LHS 5142, M6.5 (this thesis) |
| 165-5 | 8:56 | +46 | 3.4 | |
| 901-4 | 8:56 | -31 | 3.5 | |
| 165-28 | 9:05 | +48 | 3.3 | |
| 903-32 | 9:07 | -33 | 3.3 | |
| 547-10 | 9:11 | +7 | 3.1 | |
| 369-27 | 9.16 | +22 | 3.1 | |
| 727-47 | 9:17 | -14 | 3.1 | |
| 427-31 | 9:18 | +15 | 3.4 | |
| 125-69 | 9:19 | +54 | 3.1 | |
| 427-38 | 9:22 | +17 | 3.8 | |
| 547-46 | 9:23 | +3 | 3.2 | |
| 667-26 | 9:25 | -7 | 3.0 | |
| 314-28 | 9:34 | +27 | 3.0 | |
| 548-15 | 9:35 | +5 | 3.1 | |
| 314-44 | 9:36 | +29 | 3.0 | |
| 488-15 | 9:36 | +12 | 3.2 | |
| 846-23 | 9:38 | -26 | 3.5 | |

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TABLE 5.18 — continued

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|---|---|---|---|---|
| 548-29 | 9:43 | +4 | 3.2 | |
| 370-59 | 9:45 | +21 | 3.1 | |
| 314-69 | 9:46 | +31 | 3.1 | |
| 370-69 | 9:48 | +25 | 3.1 | |
| 166-28 | 9:48 | +44 | > 2.9 | Real? Not in LHS Catalogue |
| 608-54 | 9:52 | -0 | 3.5 | |
| 609-1 | 9:53 | +1 | 3.5 | |
| 315-11 | 9:54 | +26 | 3.7 | |
| 315-13 | 9:55 | +30 | 3.4 | |
| 315-15 | 9:55 | +29 | 3.5 | |
| 609-19 | 9:58 | +1 | 3.3 | |
| 166-56 | 9:58 | +45 | 3.8 | |
| 609-24 | 10:00 | -0 | 3.2 | LHS 5165 |
| 609-25 | 10:00 | +0 | 3.0 | |
| 903-27 | 10:04 | -28 | 3.2 | |
| 609-34 | 10:05 | +0 | 3.0 | |
| 789-28 | 10:05 | -19 | 3.0 | |
| 167-7 | 10:05 | +48 | 3.3 | |
| 903-34 | 10:07 | -29 | 3.1 | |
| 212-34 | 10:07 | +40 | 3.4 | |
| 315-40 | 10:08 | +27 | 3.0 | Comp. to LP 315-39, 14″ away |
| 789-44 | 10:11 | -15 | 3.2 | |
| 315-49 | 10:12 | +27 | 3.3 | |
| 212-40 | 10:12 | +40 | 3.1 | |
| 315-53 | 10:13 | +28 | 3.4 | LHS 2243, M8 (this thesis) |
| 489-65 | 10:16 | +9 | 3.1 | |
| 790-24 | 10:24 | -18 | 3.2 | |
| 904-21 | 10:25 | -29 | 3.5 | |
| 490-28 | 10:26 | +12 | 3.0 | |
| 551-3 | 10:41 | +5 | 3.4 | |
| 611-5 | 10:42 | +1 | 3.3 | |
| 551-13 | 10:46 | +5 | 3.1 | LHS 2314, M6 (Bessell 1991) |
| 551-18 | 10:48 | +7 | 3.5 | |
| 551-30 | 10:53 | +6 | 3.2 | |
| 731-72 | 10:53 | -12 | 3.0 | |
| 905-32 | 10:54 | -28 | 3.1 | |

TABLE 5.18 — continued

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|------|-----------|-----|----------------|------|
| 731-78 | 10:56 | -14 | 3.5 | |
| 263-62 | 10:59 | +35 | 3.3 | |
| 551-63 | 11:03 | +4 | 3.2 | LHS 2351, M6.5 (Bessell 1991) |
| 263-78 | 11:04 | +33 | 3.0 | LHS 2352, sdM (this thesis) |
| 168-70 | 11:07 | +46 | 3.1 | |
| 672-19 | 11:14 | -9 | 3.6 | |
| 672-65 | 11:16 | -3 | > 2.9 | |
| 732-20 | 11:17 | -14 | 3.3 | LHS 2397, M5 (Bessell 1991) |
| 672-70 | 11:19 | -4 | 3.3 | |
| 732-23 | 11:20 | -12 | 3.1 | |
| 215-4 | 11:20 | +42 | 3.0 | |
| 672-73 | 11:20 | -4 | 3.4 | |
| 264-47 | 11:20 | +34 | 3.2 | |
| 374-43 | 11:22 | +24 | 3.1 | |
| 672-35 | 11:22 | -6 | 3.2 | |
| 672-37 | 11:24 | -6 | 3.0 | |
| 612-55 | 11:25 | -0 | 3.2 | |
| 793-2 | 11:29 | -19 | 3.8 | |
| 673-10 | 11:31 | -5 | 3.0 | |
| 169-59 | 11:32 | +47 | 3.5 | |
| 433-20 | 11:33 | +19 | 3.1 | |
| 907-10 | 11:36 | -28 | > 3.4 | |
| 793-56 | 11:40 | -19 | 3.1 | |
| 533-34 | 11:41 | +4 | 3.1 | |
| 907-20 | 11:42 | -30 | 3.6 | |
| 433-60 | 11:46 | +16 | 3.0 | |
| 907-301 | 11:52 | -31 | > 3.0 | |
| 434-13 | 11:56 | +16 | 3.0 | |
| 907-48 | 11:56 | -27 | 3.5 | LHS 2487 |
| 794-8 | 11:58 | -19 | 3.0 | |
| 434-29 | 12:00 | +17 | 3.3 | LHS 2500, sdM0.5-1: (Boes. '92) |
| 907-63 | 12:00 | -33 | 3.2 | |
| 434-33 | 12:00 | +17 | 3.8 | LHS 2502, M6+ (Bessell 1991) |
| 434-36 | 12:01 | +15 | 3.7 | |
| 376-6 | 12:01 | +22 | 3.2 | |
| 266-10 | 12:02 | +36 | 3.1 | |

TABLE 5.18 — continued

| LP # | RA (1950) Dec | | $m_{pg} - m_R$ | Note |
|------|------|------|------|------|
| 734-22 | 12:03 | -11 | 3.1 | |
| 434-46 | 12:04 | +16 | 3.1 | |
| 494-38 | 12:04 | +13 | 3.2 | Comp. BD + 13°2493, 66″ away |
| 376-19 | 12:05 | +20 | 3.0 | |
| 734-77 | 12:06 | -10 | 3.4 | |
| 908-27 | 12:08 | -30 | 3.0 | |
| 908-33 | 12:11 | -27 | 3.1 | |
| 266-28 | 12:13 | +32 | 3.1 | |
| 434-75 | 12:13 | +16 | 3.1 | |
| 170-90 | 12:17 | +46 | 3.2 | |
| 908-47 | 12:17 | -31 | > 3.0 | |
| 555-15 | 12:21 | +5 | 3.2 | |
| 496-1 | 12:41 | +9 | 3.1 | |
| 853-33 | 12:43 | -23 | 3.0 | |
| 321-222 | 12:44 | +32 | 3.1 | LHS 2632, M7 (this thesis) |
| 853-43 | 12:46 | -27 | 3.0 | |
| 496-23 | 12:47 | +13 | 3.2 | |
| 217-82 | 12:48 | +40 | 3.1 | Comp. 102″ away |
| 171-70 | 12:48 | +48 | 3.1 | |
| 218-8 | 12:50 | +40 | 3.2 | LHS 2645, M7 (this thesis) |
| 616-45 | 12:55 | -3 | 3.2 | |
| 796-36 | 13:01 | -21 | 3.5 | |
| 616-75 | 13:03 | -1 | 3.2 | |
| 797-5 | 13:06 | -16 | 3.2 | |
| 497-35 | 13:12 | +9 | 3.2 | |
| 854-46 | 13:15 | -22 | 3.3 | |
| 677-20 | 13:16 | -4 | 3.3 | |
| 497-58 | 13:16 | +13 | 3.0 | |
| 677-65 | 13:17 | -9 | 3.2 | |
| 218-81 | 13:18 | +42 | > 3.1 | |
| 737-25 | 13:20 | -9 | 3.3 | |
| 737-26 | 13:21 | -11 | 3.2 | |
| 677-41 | 13:25 | -4 | 3.1 | Comp. to LP 677-40, 8″ away |
| 497-97 | 13:26 | +9 | 3.8 | Comp. BD + 10°2550, 79″ away |
| 497-105 | 13:28 | +10 | 3.4 | |

TABLE 5.18 — continued

| LP # | RA (1950) Dec | | $m_{pg} - m_R$ | Note |
|---|---|---|---|---|
| 855-33 | 13:31 | -24 | 3.0 | LHS 2755 |
| 855-39 | 13:34 | -24 | 3.0 | |
| 855-41 | 13:34 | -22 | 3.8 | |
| 911-38 | 13:36 | -28 | > 2.9 | |
| 855-49 | 13:36 | -25 | 3.0 | |
| 438-46 | 13:41 | +20 | 3.0 | |
| 911-56 | 13:43 | -31 | 3.1 | |
| 558-46 | 13:45 | +5 | 3.1 | |
| 381-4 | 13:45 | +26 | 3.1 | |
| 912-12 | 13:46 | -31 | 3.4 | |
| 498-70 | 13:47 | +9 | 3.1 | |
| 738-16 | 13:48 | -12 | 3.0 | |
| 558-51 | 13:48 | +3 | 3.2 | |
| 558-52 | 13:49 | +7 | 3.2 | |
| 912-24 | 13:49 | -29 | 3.0 | |
| 220-13 | 13:54 | +43 | 3.2 | |
| 912-47 | 14:02 | -33 | 3.4 | |
| 912-49 | 14:03 | -30 | 3.2 | LHS 2859 |
| 499-39 | 14:06 | +12 | 3.0 | |
| 912-63 | 14:09 | -31 | 4.0 | Largest $m_{pg} - m_R$ in the list |
| 913-5 | 14:09 | -28 | 3.1 | |
| 499-47 | 14:09 | +10 | 3.2 | |
| 799-31 | 14:10 | -21 | 3.1 | |
| 559-57 | 14:10 | +7 | 3.2 | |
| 799-33 | 14:12 | -21 | 3.1 | |
| 220-71 | 14:15 | +44 | 3.1 | |
| 499-62 | 14:15 | +13 | 3.4 | Comp. to LP 499-63, 20″ away |
| 440-7 | 14:16 | +20 | 3.3 | LHS 2893, M1.5 (Boeshaar '92) |
| 913-10 | 14:17 | -30 | 3.3 | |
| 134-7 | 14:21 | +51 | 3.5 | |
| 620-17 | 14:25 | -1 | 3.1 | |
| 620-19 | 14:26 | +1 | 3.3 | |
| 271-25 | 14:26 | +33 | 3.0 | LHS 2924, M9 (this thesis) |
| 325-56 | 14:31 | +29 | 3.0 | |
| 440-52 | 14:36 | +18 | 3.1 | LHS 377, sdM5 (Giampapa & Liebert 1986) |

TABLE 5.18 — continued

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|------|-----------|-----|----------------|------|
| 560-62 | 14:37 | +3 | 3.0 | |
| 271-50 | 14:38 | +37 | 3.2 | |
| 271-53 | 14:39 | +33 | 3.0 | |
| 858-19 | 14:41 | -26 | 3.0 | Comp. to LP 858-18, 12″ away |
| 914-14 | 14:41 | -32 | 3.4 | |
| 914-16 | 14:42 | -29 | 3.3 | |
| 271-61 | 14:45 | +36 | 3.0 | |
| 326-27 | 14:45 | +26 | 3.1 | |
| 441-17 | 14:45 | +16 | 3.3 | LHS 2980, M6.5 (this thesis) |
| 175-31 | 14:46 | +49 | 3.1 | |
| 272-5 | 14:48 | +35 | 3.0 | |
| 175-36 | 14:48 | +50 | 3.2 | |
| 382-40 | 14:54 | +23 | 3.4 | |
| 441-34 | 14:54 | +18 | 3.5 | LHS 3002, M7 (Boeshaar 1992) |
| 801-38 | 14:56 | -17 | > 3.0 | |
| 801-39 | 14:56 | -18 | 3.5 | |
| 222-23 | 14:56 | +41 | 3.2 | |
| 326-61 | 14:57 | +31 | 3.0 | |
| 621-62 | 15:01 | +0 | 3.4 | |
| 681-56 | 15:02 | -3 | 3.1 | |
| 176-12 | 15:11 | +48 | 3.2 | |
| 742-41 | 15:16 | -14 | 3.1 | |
| 562-29 | 15:16 | +5 | 3.0 | |
| 327-309 | 15:16 | +28 | 3.0 | |
| 742-18 | 15:23 | -10 | 3.5 | |
| 273-25 | 15:25 | +37 | 3.3 | |
| 176-46 | 15:26 | +46 | 3.0 | |
| 273-32 | 15:28 | +33 | 3.0 | |
| 623-7 | 15:32 | -0 | 3.2 | |
| 803-9 | 15:33 | -19 | 3.1 | |
| 273-46 | 15:35 | +35 | 3.0 | Comp. to LP 273-45, 13.5″ away |
| 683-26 | 15:39 | -3 | 3.6 | |
| 916-19 | 15:39 | -33 | 3.4 | LHS 3106, M6 (Bessell 1991) |
| 223-47 | 15:42 | +44 | 3.2 | |
| 684-37 | 15:45 | -3 | 3.4 | |

TABLE 5.18 — continued

| LP # | RA (1950) Dec | | $m_{pg} - m_R$ | Note |
|---|---|---|---|---|
| 803-33 | 15:45 | -19 | 4.0 | Largest $m_{pg} - m_R$ in the list |
| 803-34 | 15:45 | -15 | 3.2 | |
| 860-36 | 15:47 | -23 | 3.0 | |
| 328-55 | 15:50 | +27 | 3.4 | |
| 743-49 | 15:50 | -13 | 3.0 | |
| 860-47 | 15:51 | -24 | 3.0 | |
| 860-49 | 15:53 | -22 | 3.0 | |
| 274-27 | 15:53 | +36 | 3.0 | |
| 178-1 | 16:12 | +48 | 3.2 | |
| 275-10 | 16:13 | +37 | 3.1 | LHS 3170 |
| 861-50 | 16:15 | -26 | 3.5 | |
| 505-3 | 16:17 | +12 | 3.6 | |
| 565-3 | 16:17 | +5 | 3.2 | |
| 745-4 | 16:19 | -11 | 3.1 | |
| 225-14 | 16:21 | +39 | 3.0 | |
| 178-15 | 16:21 | +49 | > 3.0 | |
| 178-18 | 16:23 | +45 | 3.2 | |
| 625-14 | 16:24 | -2 | 3.0 | |
| 745-9 | 16:24 | -12 | 3.2 | |
| 445-45 | 16:37 | +17 | 3.1 | |
| 626-13 | 16:50 | +0 | 3.3 | |
| 746-30 | 16:53 | -14 | 3.4 | |
| 746-32 | 16:54 | -13 | 3.4 | |
| 566-29 | 17:01 | +3 | 3.0 | |
| 566-33 | 17:01 | +3 | 3.0 | |
| 179-42 | 17:15 | +45 | 3.2 | |
| 508-2 | 17:28 | +12 | 3.2 | |
| 688-2 | 17:30 | -7 | > 2.9 | |
| 688-11 | 17:37 | -6 | 3.0 | |
| 508-20 | 17:39 | +9 | 3.1 | |
| 508-41 | 17:50 | +11 | 3.2 | |
| 688-32 | 17:51 | -7 | 3.3 | |
| 508-45 | 17:51 | +9 | 3.3 | |
| 508-46 | 17:52 | +12 | 3.1 | |
| 181-17 | 18:02 | +46 | 3.7 | |

TABLE 5.18 — continued

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|------|-----------|-----|----------------|------|
| 228-23 | 18:04 | +44 | 3.1 | |
| 140-34 | 18:36 | +55 | 3.0 | |
| 813-4 | 19:34 | -18 | 3.1 | |
| 925-33 | 19:39 | -32 | 3.1 | |
| 869-29 | 19:42 | -24 | 3.0 | |
| 925-44 | 19:45 | -32 | 3.2 | |
| 870-14 | 19:51 | -21 | 3.1 | |
| 926-41 | 20:08 | -29 | 3.0 | |
| 754-37 | 20:13 | -11 | 3.2 | |
| 754-41 | 20:14 | -10 | 3.3 | |
| 575-18 | 20:27 | +6 | 3.4 | Comp. to LP 575-17, 77″ away |
| 815-50 | 20:39 | -20 | 3.1 | |
| 515-42 | 20:40 | +13 | 3.1 | |
| 756-10 | 20:48 | -12 | 3.1 | |
| 636-23 | 20:51 | +1 | 3.0 | LHS 5360; Comp. 2.5″ away |
| 928-32 | 20:52 | -28 | 3.0 | |
| 696-17 | 20:53 | -6 | 3.0 | |
| 756-22 | 20:53 | -12 | 3.1 | |
| 696-20 | 20:54 | -5 | 3.1 | |
| 756-34 | 21:00 | -11 | 3.2 | |
| 756-46 | 21:05 | -10 | 3.0 | |
| 517-21 | 21:14 | +14 | 3.1 | |
| 697-19 | 21:14 | -5 | > 3.2 | |
| 397-13 | 21:15 | +25 | 3.0 | |
| 697-24 | 21:17 | -3 | 3.0 | |
| 873-36 | 21:20 | -25 | 3.3 | |
| 697-32 | 21:21 | -7 | 3.6 | |
| 697-33 | 21:22 | -4 | > 3.0 | |
| 929-54 | 21:27 | -31 | 3.1 | LHS 3681 |
| 929-63 | 21:31 | -31 | 3.3 | |
| 458-7 | 21:31 | +19 | 3.2 | |
| 398-24 | 21:39 | +25 | 3.1 | |
| 930-29 | 21:40 | -32 | 3.2 | |
| 818-27 | 21:41 | -18 | 3.2 | |
| 578-40 | 21:47 | +9 | 3.4 | |
| 458-51 | 21:49 | +20 | 3.3 | |

TABLE 5.18 — continued

| LP # | RA (1950) | Dec | $m_{pg} - m_R$ | Note |
|---|---|---|---|---|
| 759-1 | 21:53 | -11 | 3.0 | |
| 819-18 | 21:59 | -14 | 3.3 | |
| 759-17 | 21:59 | -11 | > 3.2 | |
| 519-21 | 22:01 | +14 | 3.0 | |
| 759-25 | 22:02 | -11 | 3.7 | |
| 699-33 | 22:03 | -4 | 3.1 | |
| 699-36 | 22:04 | -4 | 3.5 | |
| 639-30 | 22:06 | -2 | 3.4 | |
| 287-32 | 22:08 | +33 | 3.1 | |
| 819-42 | 22:08 | -19 | 3.6 | LHS 3768 |
| 76-8 | 22:11 | +68 | 3.2 | |
| 519-45 | 22:12 | +12 | 3.0 | |
| 819-60 | 22:13 | -20 | 3.1 | |
| 819-61 | 22:13 | -18 | 3.0 | |
| 819-68 | 22:17 | -17 | 3.3 | |
| 700-5 | 22:19 | -2 | 3.0 | |
| 700-56 | 22:35 | -5 | > 3.1 | LHS 3837 |
| 934-57 | 22:37 | -31 | 3.1 | |
| 876-53 | 22:40 | -21 | 3.2 | |
| 761-44 | 22:43 | -13 | 3.4 | |
| 821-15 | 22:43 | -15 | 3.2 | |
| 761-46 | 22:43 | -13 | 3.1 | |
| 289-4 | 22:44 | +38 | 3.2 | |
| 400-63 | 22:47 | +25 | 3.4 | |
| 761-61 | 22:49 | -9 | 3.6 | |
| 877-4 | 22:51 | -23 | 3.1 | |
| 521-43 | 22:52 | +14 | 3.2 | |
| 521-44 | 22:52 | +10 | 3.0 | |
| 345-18 | 22:53 | +28 | 3.4 | |
| 521-56 | 22:56 | +11 | 3.3 | |
| 289-34 | 22:57 | +37 | 3.0 | |
| 581-47 | 22:57 | +8 | 3.2 | |
| 401-41 | 23:01 | +27 | 3.1 | |
| 877-10 | 23:01 | -25 | 3.4 | |
| 238-39 | 23:14 | +39 | 3.2 | |
| 702-59 | 23:14 | -4 | 3.2 | |

TABLE 5.18 — continued

| LP # | RA (1950) Dec | | $m_{pg} - m_R$ | Note |
|------|------|------|------|------|
| 522-33 | 23:17 | +11 | 3.0 | LHS 3933 |
| 762-9 | 23:19 | -9 | 3.3 | |
| 702-87 | 23:22 | -4 | 3.1 | |
| 702-91 | 23:23 | -5 | 3.0 | |
| 290-32 | 23:24 | +36 | 3.0 | |
| 878-47 | 23:28 | -26 | 3.0 | |
| 402-58 | 23:34 | +21 | > 2.9 | |
| 763-39 | 23:35 | -10 | 3.1 | |
| 763-41 | 23:35 | -12 | 3.3 | |
| 763-51 | 23:39 | -8 | 3.2 | |
| 763-67 | 23:45 | -8 | 3.3 | |
| 403-11 | 23:46 | +27 | 3.0 | |
| 879-22 | 23:47 | -26 | 3.4 | |
| 583-58 | 23:48 | +7 | 3.2 | |
| 823-59 | 23:49 | -15 | 3.2 | |
| 763-15 | 23:50 | -8 | 3.2 | |
| 192-8 | 23:53 | +41 | 3.1 | |
| 824-420 | 23:56 | -26 | 3.1 | |
| 824-75 | 23:59 | -22 | 3.1 | |

TABLE 5.19

OBJECTS WITH THE HIGHEST PROPER MOTIONS (AS OF 1992)

| LHS # | Other Name | $\mu('' \text{yr}^{-1})$ | $m_V{}^a$ | Spec. | In 1927 list?[b] |
|---|---|---|---|---|---|
| 57 | Barnard's Star | 10.27 | 9.5 | M4 | ✓ |
| 29 | Kapteyn's Star | 8.73 | 8.8 | M1 | ✓ |
| 44 | BD +38°2285 | 7.04 | 6.5 | G5 | ✓ |
| 70 | CD −36°15693 | 6.90 | 7.4 | M2 | ✓ |
| 1 | CD −37°15492 | 6.08 | 8.6 | M3 | ✓ |
| 35 | Ross 619 | 5.40 | 12.8 | M4.5 | |
| 62 | 61 Cyg A | 5.20 | 5.2 | K5 | ✓ |
| 63 | 61 Cyg B | 5.20 | 6.0 | K7 | ✓ |
| 37 | BD +36°2147 | 4.78 | 7.5 | M2 | ✓ |
| 36 | Wolf 359 | 4.71 | 13.5 | M6 | ✓ |
| 67 | ε Ind | 4.69 | 4.7 | K5 | ✓ |
| 38 | BD +44°2051 A | 4.53 | 8.8 | M1 | ✓ |
| 39 | BD +44°2051 B | 4.53 | 14.5 | M5 | |
| 23 | $o^2$ Eri A | 4.08 | 4.4 | K0 | ✓ |
| 24 | $o^2$ Eri B | 4.08 | 9.5 | DA | ✓ |
| 25 | $o^2$ Eri C | 4.08 | 11.2 | M4.5 | ✓ |
| 46 | Wolf 489 | 3.87 | 14.7 | DZ | ✓ |
| 49 | α Cen C | 3.85 | 11.1 | M5.5 | ✓ |
| 33 | Luyten's Star | 3.76 | 9.8 | M3.5 | |
| 8 A | μ Cas A | 3.75 | 5.2 | G5 | ✓ |
| 8 B | μ Cas B | 3.75 | >8.2 | ? | |
| 50 | α Cen A | 3.69 | 0.0 | G2 | ✓ |
| 51 | α Cen B | 3.69 | 1.3 | K0 | ✓ |
| 53 | BD −15°4042 | 3.68 | 9.0 | G6 | ✓ |
| 52 | BD −15°4041 | 3.68 | 9.4 | K0 | ✓ |

TABLE 5.19 — continued

| LHS # | Other Name | $\mu('' \text{yr}^{-1})$ | $m_V{}^a$ | Spec. | In 1927 list?[b] |
|---|---|---|---|---|---|
| 56 | GL 699.1 | 3.62 | 14.3 | DA | |
| 66 | CD $-39°14192$ | 3.46 | 6.7 | M0 | √ |
| 9 | GL 65 A | 3.36 | 12.5 | M5.5 | |
| 10 | GL 65 B | 3.36 | 13.0 | M6 | |
| 68 A | GL 866 A | 3.25 | 12 | M5 | |
| 68 B | GL 866 B | 3.25 | 12 | M5 | |
| 42 | Ross 451 | 3.20 | 11 | K4 | |
| 19 | CD $-43°1028$ | 3.14 | 4.3 | G7 | √ |
| 20 | Ross 578 | 3.06 | 13.0 | M2 | |
| 7 | van Maanen's Star | 2.98 | 12.4 | DZ | √ |

[a] Magnitudes are from Gliese 1969.

[b] Refers to Table XV in Russell, Dugan, & Stewart 1927.

TABLE 5.20

OBJECTS WITH PROPER MOTIONS EXCEEDING $0.57''\text{yr}^{-1}$
WHICH ARE NOT INCLUDED IN THE LHS CATALOGUE

| Name | RA (1950) | Dec | Spec. | $m_V$ | $\mu('' \text{yr}^{-1})$ | Ref. |
|------|-----------|-----|-------|-------|--------------------------|------|
| GJ 2045 | 05:39:45.5 | -05:29:42 | ? | ~14.9 | ~3 | 1 (star 50) |
| ER 8 | 13:10:03.6 | -47:12:13 | wd | ~17.2 | 2.128 | 2 |
| LP 251-35 | 05:18:38 | +38:12:24 | sdM | ~18.0 | 1.725 | 3,4 |
| unnamed | ~11:30 | ~-30 | ? | — | ~1.1 | 5 |
| ER 2 | ? | ? | dM | ~12.7 | 1.04 | 6 |
| ESO 320-24 | ? | ? | K6 | ~15 | 0.969 | 7 |
| CD −32°828 | 02:11:40 | -32:16:00 | M? | ~10.2 | 0.942 | 8 (GL 91) |
| unnamed | ~11:30 | ~-30 | ? | — | ~0.80 | 5 |
| ER 6 | ? | ? | dM | ~16.3 | 0.78 | 6 |
| unnamed | ~11:30 | ~-30 | ? | — | ~0.65 | 5 |
| LP 114-28 | 01:54:19 | +52:53:48 | ? | ~17.3 | 0.708 | 3 |
| LP 304-36 | 05:07:08 | +27:09:18 | ? | ~18.0 | 0.675 | 3 |
| LP 868-34 | 19:03:47 | -24:19:06 | ? | ~17.8 | 0.654 | 3 |
| LP 111-19 | 23:53:55 | +52:54:18 | ? | ~16.6 | 0.597 | 3 |
| CD −27°101 | 00:19:52 | -27:18:18 | K3 | 8.3 | 0.591 | 8(GL 17.2) |
| LP 662-7 | 07:14:47 | -04:55:18 | ? | 15.6 | 0.590 | 3 |
| Ross 29 A | 04:09:27 | +50:24:12 | M5: | ~15 | 0.572 | 8 (GL 165 |
| Ross 29 B | 04:09:27 | +50:24:12 | ? | ? | 0.572 | 8  A & B) |

REFERENCES. — (1) Ohtani & Ichikawa 1977; (2) Ruiz, Maza, Wischnjewsky, & González 1986; (3) Luyten & Hughes 1982; (4) Liebert et al. 1993; (5) Ruiz, Maza, Mendez, & Wischnjewsky 1988; (6) Ruiz & Maza 1987; (7) Ruiz, Maza, Wischnjewsky, & González 1988; (8) Gliese 1969.

# CHAPTER 6

## SUMMARY

Nature is wont to hide herself.
— Heraclitus, <u>On the Universe</u>, fragment 10 (c. 540 - c. 480 B.C.)

...And thus does the lowest luminosity stellar component of our galaxy remain largely hidden, but this thesis has attempted to lay some of the groundwork upon which a more complete understanding of these objects can be based. Briefly:

● A spectroscopic sequence obtained at wavelengths between 6000 and 9000 Å has been established for dwarfs of type K5 to M9. In total, 125 spectra comprise this set of standards, among which a few representative subdwarf and giant spectra are given for comparison. Atomic and molecular features usable as criteria for spectral and luminosity classification are tabulated.

● To supplement this spectral sequence, a few of the objects were also observed in the near infrared. The resulting 0.6-to-1.5 micron sequence of dwarf stars shows many temperature-sensitive features which can be used for spectral classification. This wavelength region is a logical choice for studies of M dwarfs since these objects emit their peak fluxes there.

● Recently, model atmospheres for M dwarfs have been produced which more closely duplicate observed spectroscopic properties. The modelled spectra have

been fit against the observed sequence in the red and near-infrared to produce a new temperature scale for main sequence M stars — previous temperature determinations relied almost exclusively on fitting a blackbody to observed spectra or spectrophotometry. The new determination, however, brings the temperature scale into much better agreement with theoretical models of the main sequence and assigns the later dwarfs hotter temperatures that had previously been estimated.

- One spectrum was uncovered which can not be predicted by current atmospheric theory. This peculiar object, GD 165 B, though now in a class by itself, may represent the first clear example of a numerous population of brown dwarfs. Its spectrum is compared to those of late M dwarfs and of planets in an attempt to link the two sets of objects. This object should also be spectroscopically studied in the near infrared.

- A search for low-mass stars and brown dwarf candidates was conducted using the data bases provided by the CTI. This search uncovered many late M dwarfs but only two objects of type M7 or later, demonstrating the difficulty which exists in trying to find objects of faint absolute magnitude.

- Luminosity functions have been produced at $I$ and at $V$ which are in excellent agreement with previous determinations using photometric surveys of the field. There is a stricking difference, however, between these luminosity functions and the luminosity function calculated for nearby stars. It has been shown that this difference is largely based on the fact that binaries are much more easily resolved in the nearby sample. The resulting mass function is difficult to estimate due to the lack of observational data on the $M_I$ vs. Mass plane, but unless the upward tail seen in the CTI luminosity function is indicative of a still undetected, large

population of objects, M dwarfs and brown dwarfs do not comprise the local missing mass.

Somewhat unexpectedly, this thesis has also uncovered several lines of evidence which point to the conclusion that some of the objects currently referred to as "M dwarfs" may actually be the brown dwarfs researchers have fought so hard to find. It has been shown that:

• If the trend of decreasing mass with later spectral type is extrapolated linearly to the hydrogen-burning limit, it suggest that objects typed as $\sim$M7 and later are brown dwarfs.

• Differential spectroscopy on composite systems with low-mass secondaries indicates that two prime brown dwarf candidates, LHS 1047 B and Ross 614 B, have spectral types no later than $\sim$M6.5.

• The minimum in the CTI luminosity function occurs at $M_I \sim 12.5$, with the number density of objects rising for fainter magnitudes. Other studies have suggested that this is the contribution from substellar objects. The CTI objects comprising this upward tail in the luminosity function all have spectral types of M6 or later.

• When the trend of $M_I$ with mass is linearly extrapolated to the stellar cutoff of $0.08 M_\odot$, the resulting magnitude is found to be $M_I = 12.3$, corresponding to the minimum in the luminosity function and giving credence to the idea that the subsequent rise is caused by a population of brown dwarfs. Again, these CTI objects having $12.5 < M_I < 13.5$ have been classified as late M dwarfs.

This upward tail in the luminosity function can be verified only if the census of nearby objects is more accurately known at lower luminosities. Luyten's extensive lists of proper motion objects should be studied in a systematic way

to uncover possibly nearby objects. Such a systematic search is currently under-way to obtain spectroscopic identifications of objects which Luyten found to be extremely red.

These proper motion surveys have not been, however, sensitive to those objects having extremely large motions. As a result, faint objects having very high values of $\mu$ will have escaped detection, and such objects are likely to be members of the immediate solar vicinity. A project to search for these candidates will commence in the near future.

Nearby objects do not necessarily have to exhibit large proper motions, so even these surveys will miss some of the sun's neighbors. An all-sky photomet-ric survey, preferrably in the infrared and to very faint magnitudes, is perhaps marginally feasible, with the most complete search — an all-sky parallax survey to faint magnitudes — being unthinkable.

For the present at least, Nature keeps herself hidden. Faint, previously unrecognized M dwarfs continue to be discovered in the solar neighborhood, and the possibility still exists that the Sun could have a brown dwarf companion which has so far gone undetected. Slowly, more is being learned about the physics of and the interconnections between the lowest mass stars, brown dwarfs, and planets. The years ahead promise to provide many new insights into the composition of our own galactic environs... and of our Universe in general.

# APPENDIX A

## FINDER CHARTS FOR CTI SPECTROSCOPIC TARGETS

Each of the following pages is divided into three sections: a finder chart for every CTI target which was spectroscopically observed at the Multiple Mirror Telescope (MMT) during the course of the thesis, the spectrum of the object, and a section of notes relating to that object. These targets are listed in order of increasing right ascension, beginning with $0^h$.

Above each finder chart is printed the CTI designation — a code, denoted by hhmmss.s+ddmmss, giving the coordinates (in equinox 1987.5) of each object. The box enclosing each finder chart is 8 arcminutes long and 3 arcminutes wide. North is at the top and east is to the left. The finders are made from reduced CTI frames taken at the filter position and on the date listed below the chart. Finders made from coadded frames do not have a specific date listed and in general are slightly more magnified than finders made from a single night's data.

All of the spectra were obtained at the MMT using the setup described in Chapter 3. The vertical scale is in units of $F_\lambda$ normalized to one at 7500 Å. The exposure time and date of observation are given above each spectrum. Spectra taken on or before 1990 May 23 have a dead column at wavelength $\sim$6410 Å and a partially dead column at $\sim$8075 Å. Features useful as temperature and luminosity indicators in this spectral region are discussed in Chapter 3.

Below each spectrum is listed the object's 1950 coordinates, the spectral type

as determined via the least-squares minimization technique, and the photometry. The $R_{CTI}$, $(R - I)_{CTI}$, and $(V - I)_{CTI}$ values were taken directly from the CTI data base; the $I_{KC}$ and $(V - I)_{KC}$ values are estimates based on the values of the CTI photometry together with the photometric calibrations presented in Chapter 4. In some cases, this Kron-Cousins photometry was actually measured at the U.S. Naval Observatory in Flagstaff, Arizona, in which case a note is added saying, "Actual USNO $VI$ photometry." The notes also contain information regarding variability for the giants as well as proper motions for those objects which appear to have moved (as measured by eye) since the original Palomar Sky Survey.

# CTI 000055.2+280432
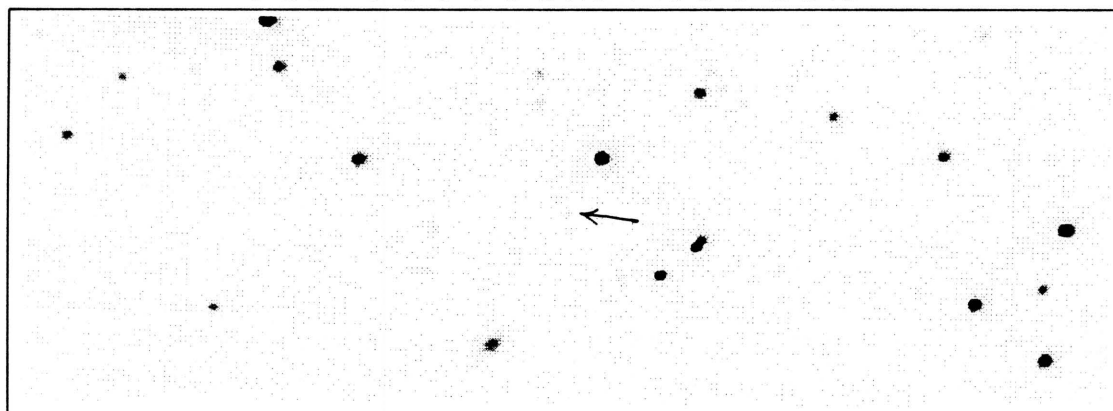


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 2100 sec          Obs. (UT) 1989 Jul 14
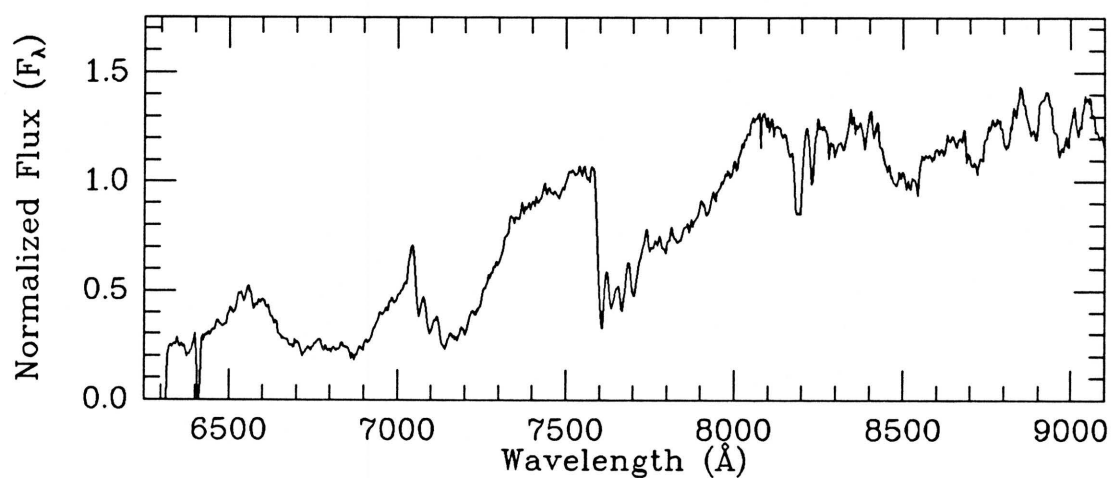


Coordinates:  $\alpha$ (1950) = 23:59:00.0          $\delta$ (1950) = +27:52:00

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = 16.29          $R_{CTI}$ = 17.57

$(V-I)_{KC}$=3.17±.16          $(R-I)_{CTI}$=1.29±.07          $(V-I)_{CTI}$=3.17±.05

Notes:

# CTI 000139.9+275821
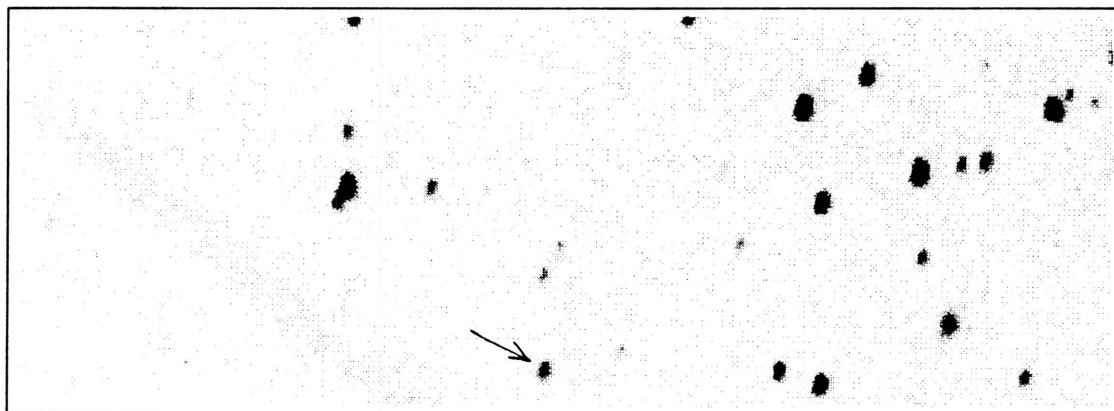


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 1800 sec          Obs. (UT) 1991 Jun 24
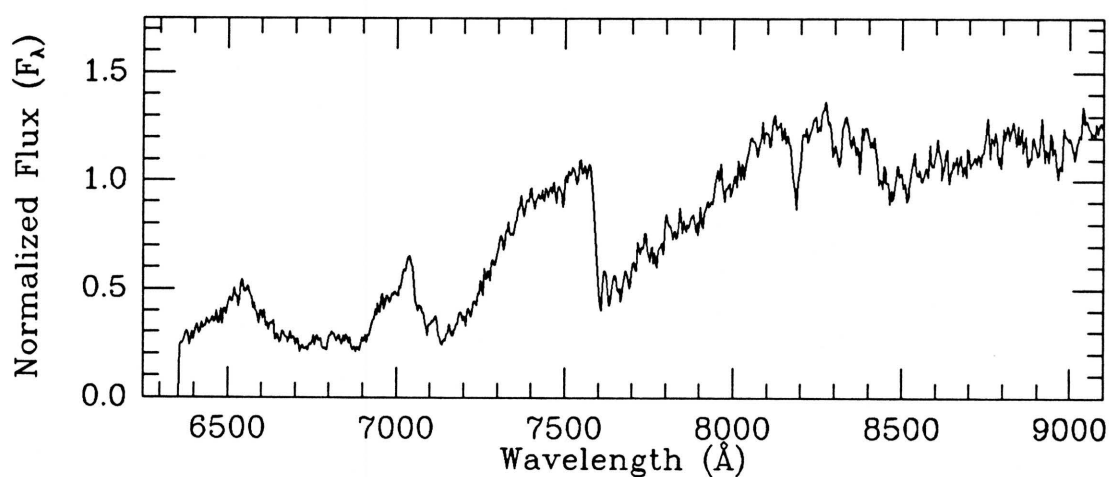


Coordinates:  $\alpha$ (1950) = 23:59:44.5          $\delta$ (1950) = +27:45:49

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = 16.56          $R_{CTI}$ = 18.39

 $(V-I)_{KC}$=3.98±.18          $(R-I)_{CTI}$=1.86±.08          $(V-I)_{CTI}$=3.18±.06

Notes:

# CTI 000351.3+280138
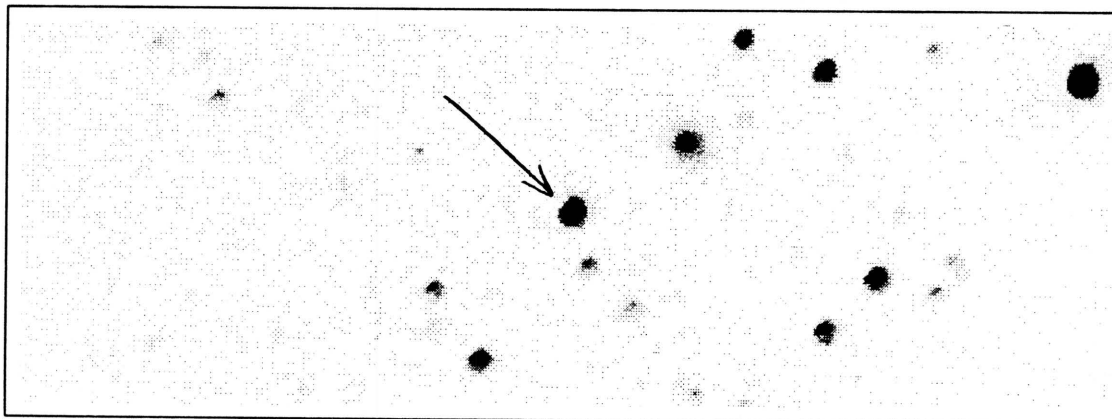


CTI FINDER CHART       I filter       Obs. (UT) 1989 Nov 03

MMT SPECTRUM       Exposure: 360 sec       Obs. (UT) 1990 Nov 22
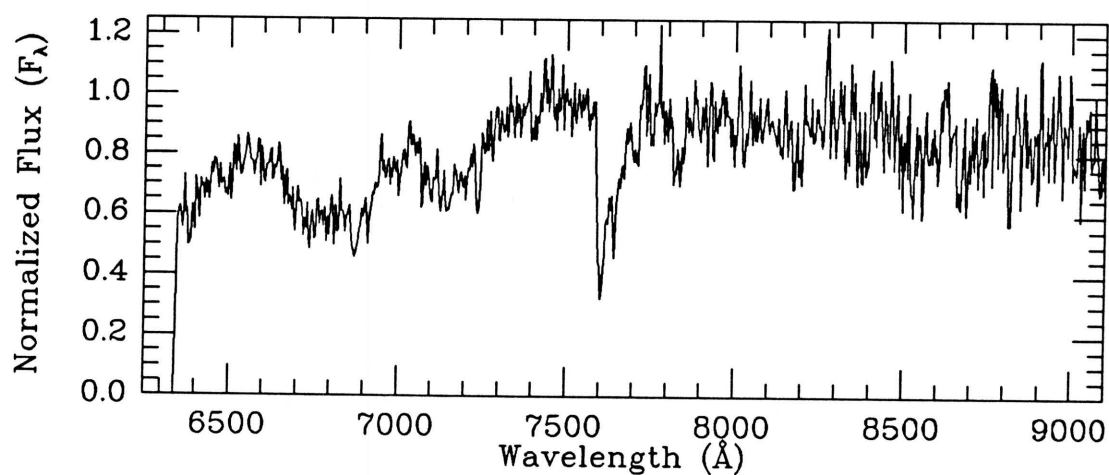


Coordinates: $\alpha$ (1950) = 00:01:55.7       $\delta$ (1950) = +27:49:06

Spectral Type: sdM0

Photometry:       $I_{KC}$ = unknown       $R_{CTI}$ = 14.05

    $(V-I)_{KC}$=unknown       $(R-I)_{CTI}$=0.50±.01       $(V-I)_{CTI}$=1.91±.01

Notes:

# CTI 000455.2+280301
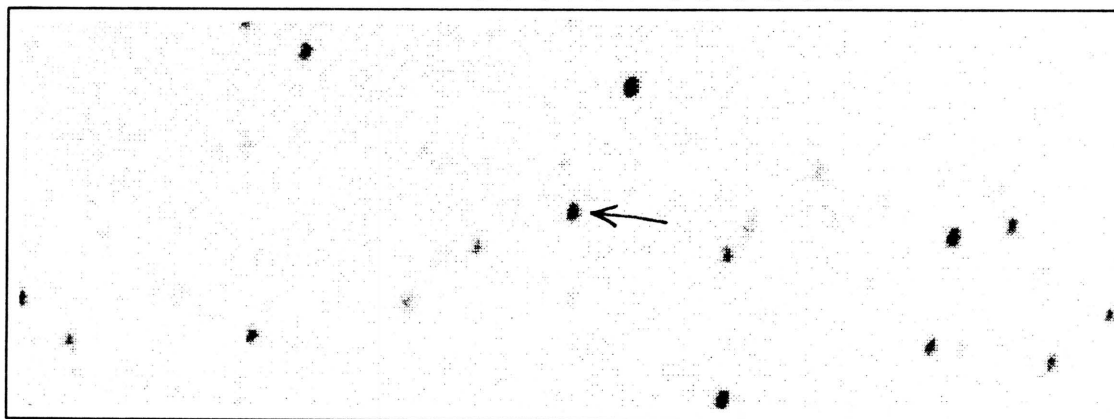


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Sep 13
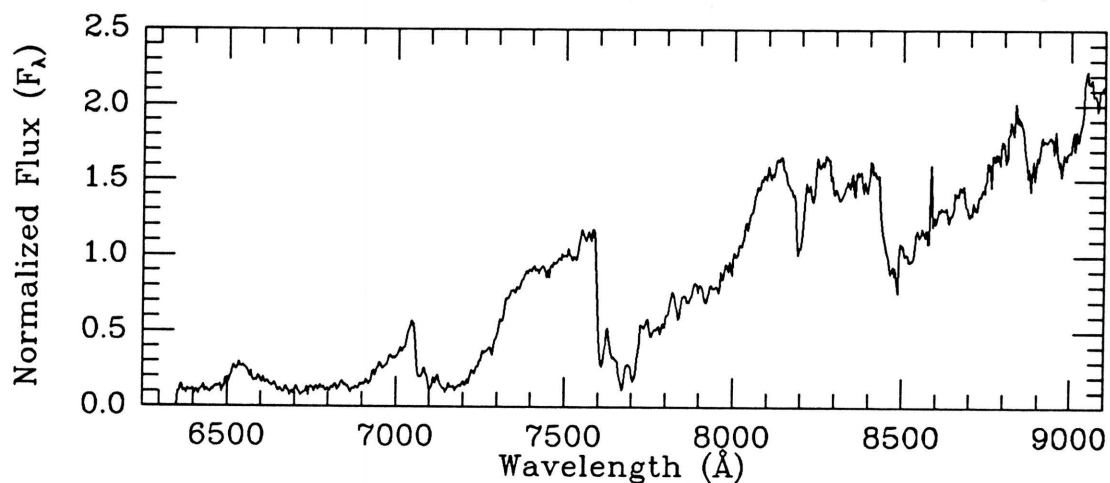


Coordinates:  $\alpha$ (1950) = 00:02:59.5          $\delta$ (1950) = +27:50:29

Spectral Type:  M6 V

Photometry:          $I_{KC}$ = 16.28          $R_{CTI}$ = 18.27

   $(V-I)_{KC}$=4.18±.19          $(R-I)_{CTI}$=2.00±.08          $(V-I)_{CTI}$=4.08±.08

Notes: Large proper motion?  Object not found on POSS E print.

# CTI 000537.5+275850
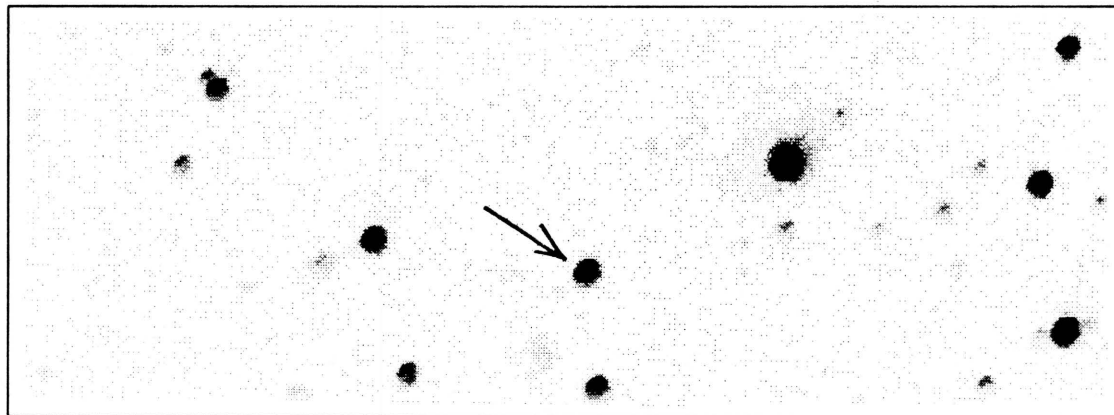


CTI FINDER CHART · I filter · Obs. (UT) 1989 Nov 03

MMT SPECTRUM · Exposure: 900 sec · Obs. (UT) 1990 Nov 22
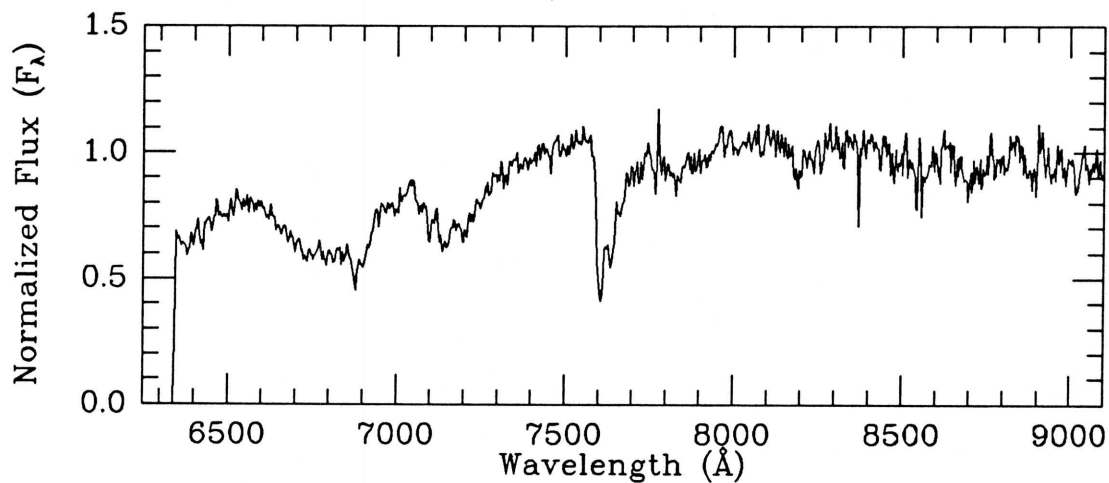


Coordinates:  $\alpha$ (1950) = 00:03:41.2      $\delta$ (1950) = +27:46:18

Spectral Type:  M1 V

Photometry:      $I_{KC}$ = 14.28        $R_{CTI}$ = 14.91

  $(V-I)_{KC}$=2.11±.10      $(R-I)_{CTI}$=0.55±.01      $(V-I)_{CTI}$=2.01±.01

Notes:

# CTI 000928.8+280436
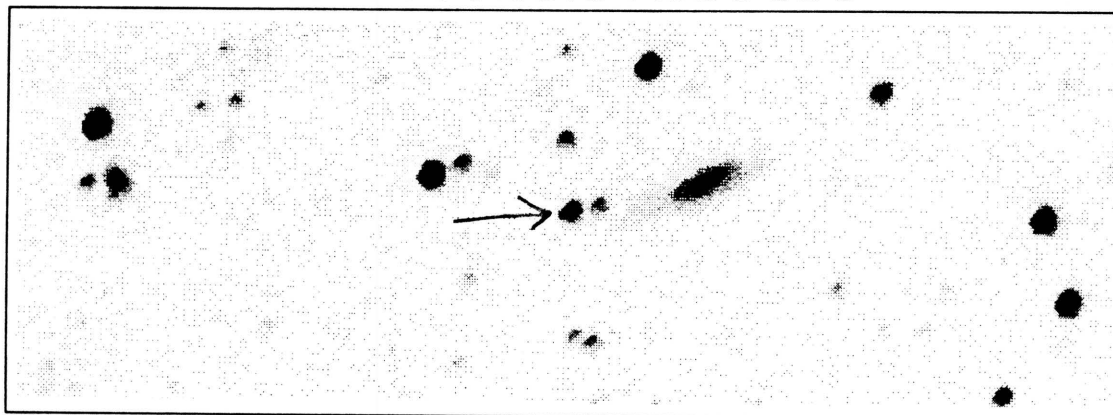


CTI FINDER CHART          I filter          Obs. (UT) 1989 Nov 03

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 Nov 23
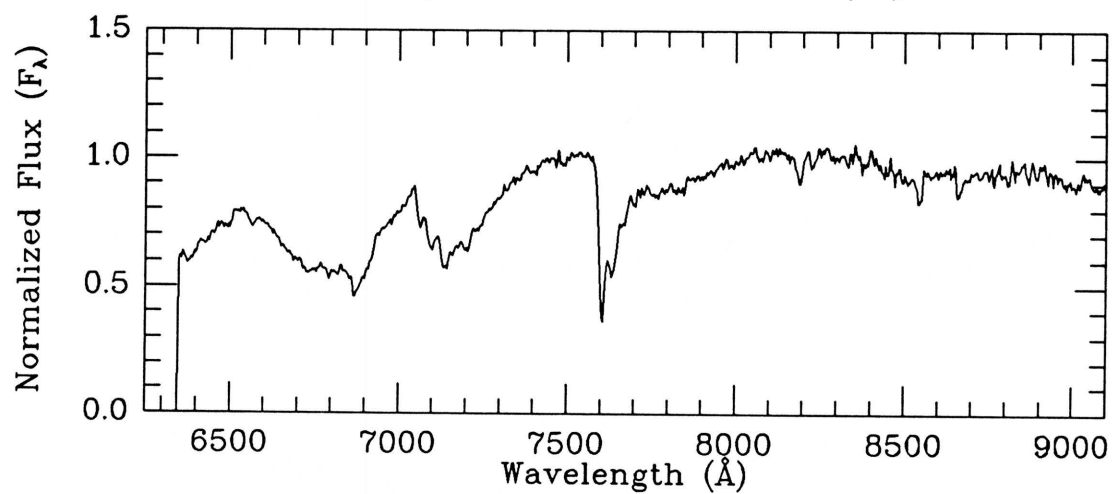


Coordinates:  α (1950) = 00:07:32.5     δ (1950) = +27:52:05

Spectral Type:  M1.5 V

Photometry:     $I_{KC}$ = 14.72     $R_{CTI}$ = 15.37

  $(V-I)_{KC}$=2.17±.10     $(R-I)_{CTI}$=0.59±.01     $(V-I)_{CTI}$=2.01±.01

Notes:

# CTI 001251.1+280535 A
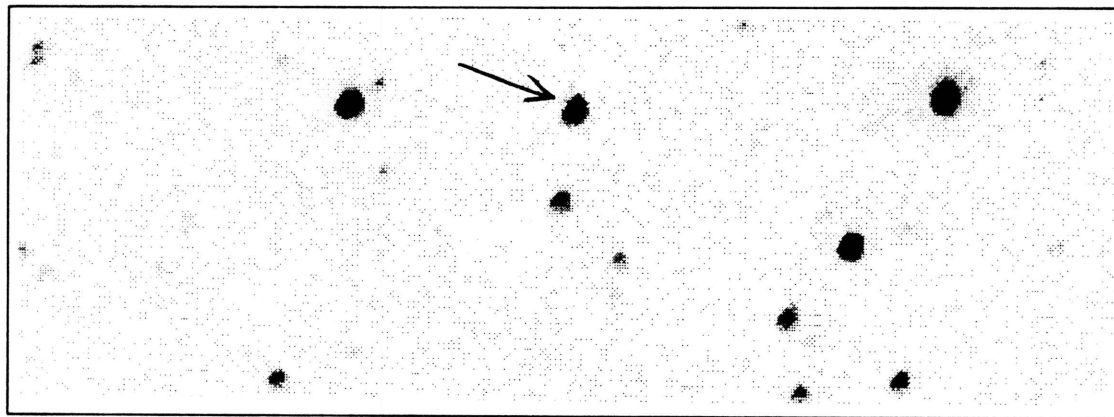


CTI FINDER CHART          I filter          Obs. (UT) 1989 Nov 03
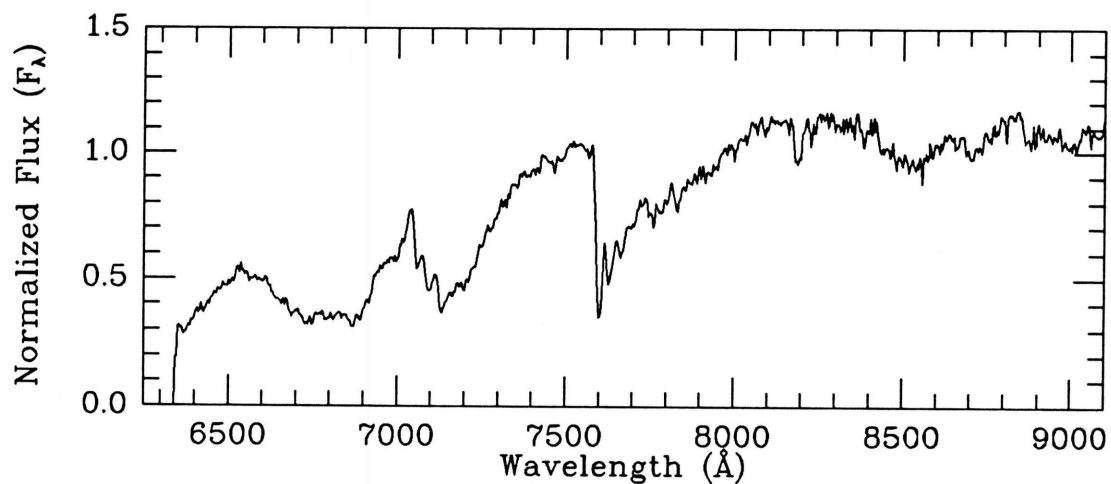
MMT SPECTRUM          Exposure: 1170 sec          Obs. (UT) 1990 Nov 22



Coordinates:   $\alpha$ (1950) = 00:10:54.4      $\delta$ (1950) = +27:53:04

Spectral Type:   M3.5 V

Photometry:      $I_{KC}$ = 14.33          $R_{CTI}$ = 15.44

   $(V-I)_{KC}$=2.80±.12      $(R-I)_{CTI}$=1.03±.02      $(V-I)_{CTI}$=2.67±.01

Notes: Close double star (see next page).  Photometry is a composite of both stars.

# CTI 001251.1+280535 B
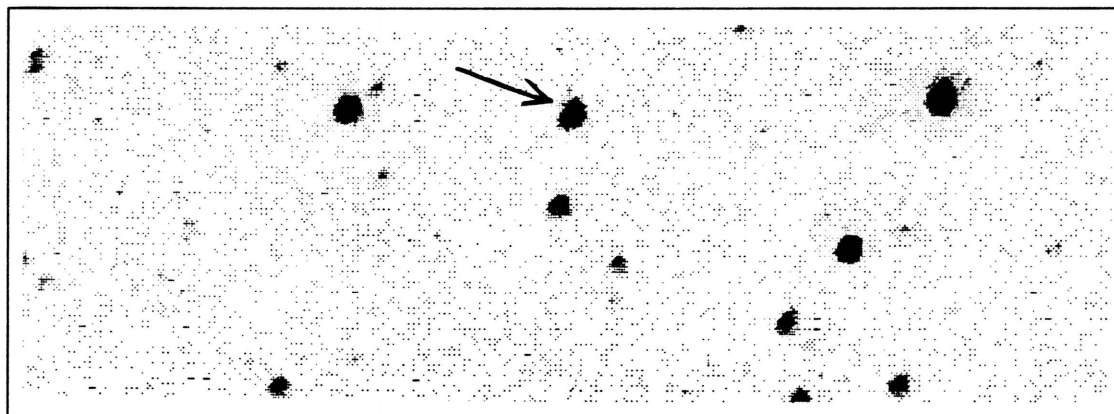


CTI FINDER CHART          I filter          Obs. (UT) 1989 Nov 03
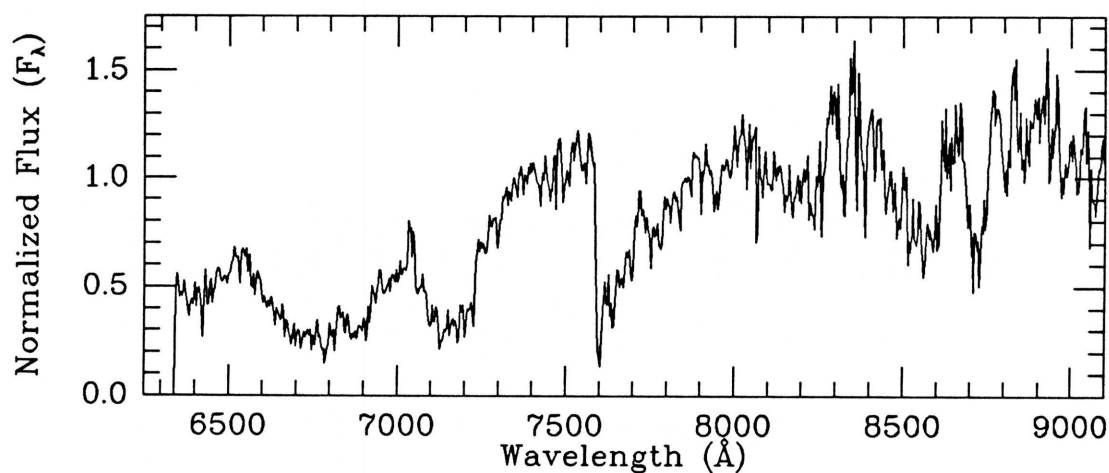
MMT SPECTRUM          Exposure: 1170 sec          Obs. (UT) 1990 Nov 22



Coordinates:   $\alpha$ (1950) = 00:10:54.4      $\delta$ (1950) = +27:53:04

Spectral Type:  M3.5: V

Photometry:      $I_{KC}$ = 14.33          $R_{CTI}$ = 15.44

 $(V-I)_{KC}$=2.80±.12      $(R-I)_{CTI}$=1.03±.02      $(V-I)_{CTI}$=2.67±.01

Notes: Close double star (see previous page). Photometry is a composite of both stars.

# CTI 002142.1+280548
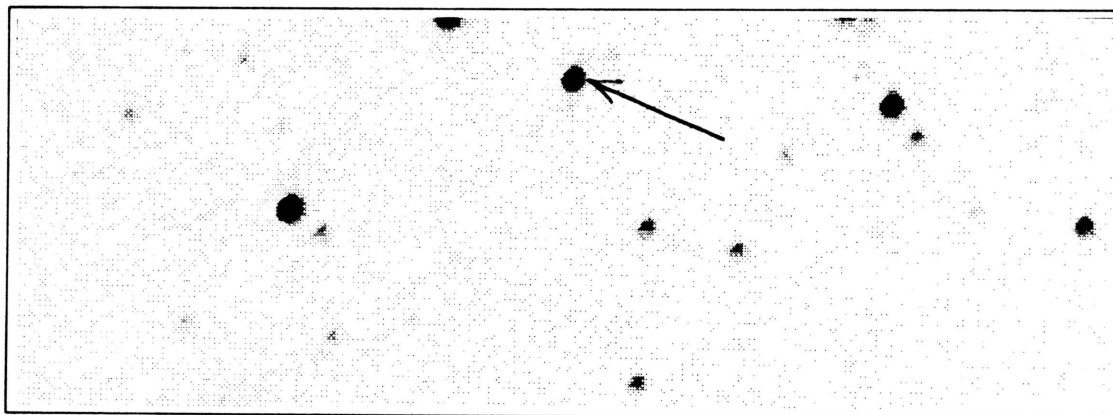


CTI FINDER CHART          I filter          Obs. (UT) 1989 Nov 03

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 Nov 23
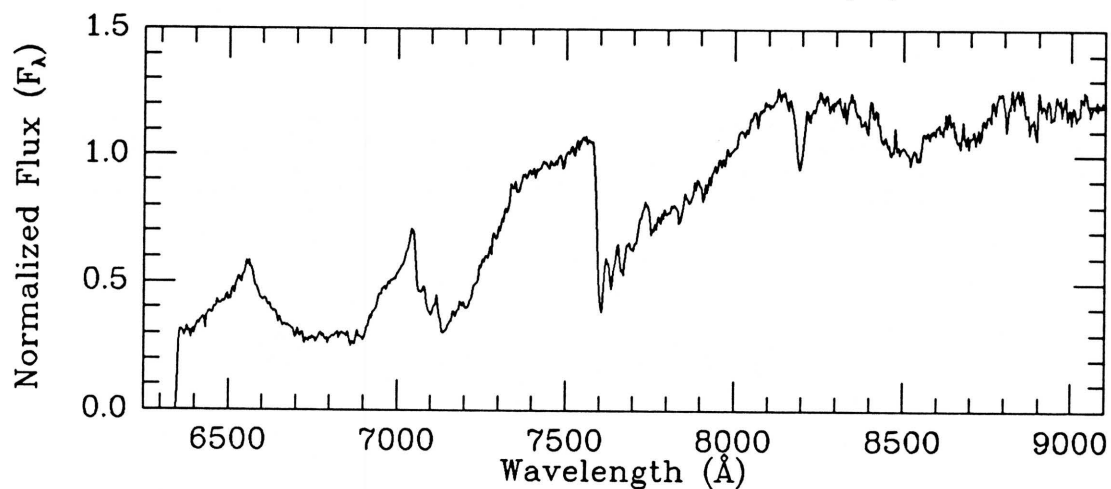


Coordinates:   $\alpha$ (1950) = 00:19:44.4      $\delta$ (1950) = +27:53:19

Spectral Type:   M4 V

Photometry:       $I_{KC}$ = 14.57          $R_{CTI}$ = 15.83

  $(V-I)_{KC}$=3.03±.12      $(R-I)_{CTI}$=1.19±.02      $(V-I)_{CTI}$=2.85±.02

Notes:

# CTI 002352.0+280605
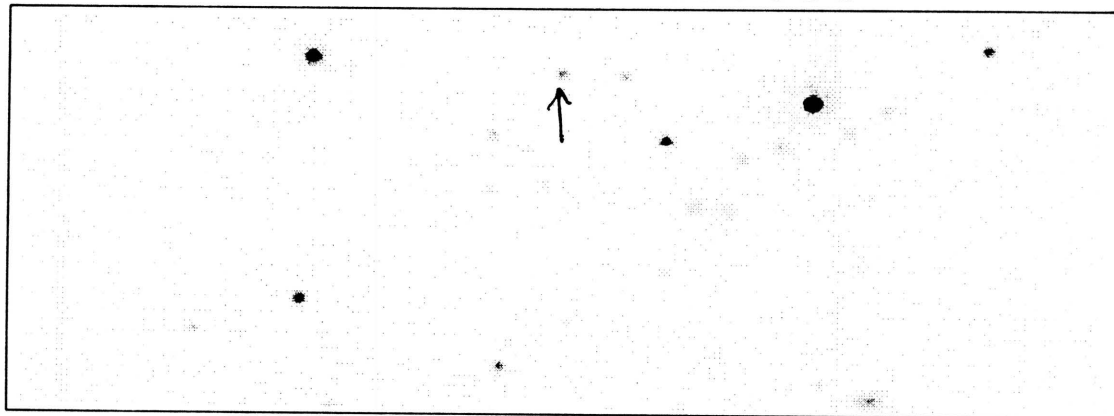


CTI FINDER CHART      V filter      Obs. (UT) 1987 Oct 20

MMT SPECTRUM      Exposure: 300 sec      Obs. (UT) 1989 Jul 13
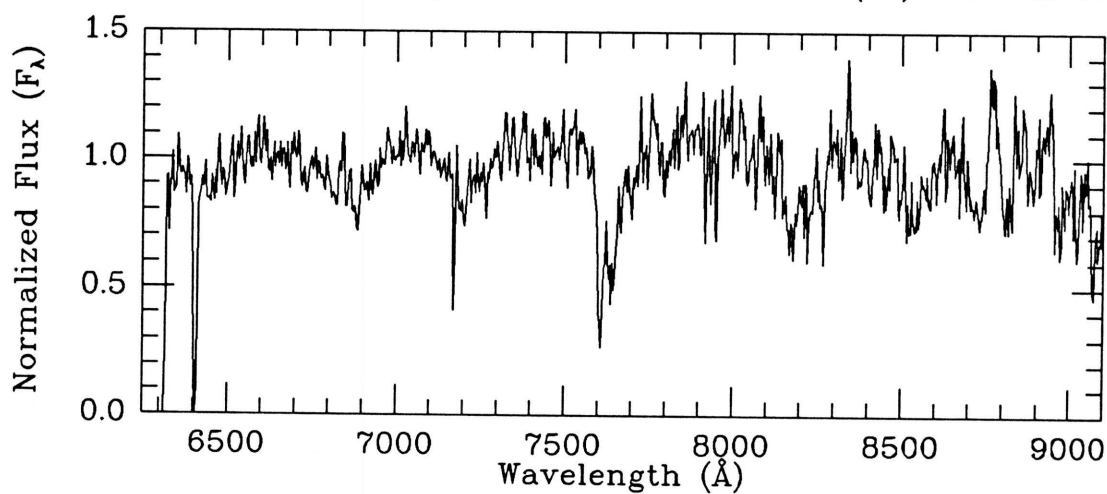


Coordinates:  $\alpha$ (1950) = 00:21:54.1      $\delta$ (1950) = +27:53:37

Spectral Type:  K7 V

Photometry:      $I_{KC}$ = 16.85      $R_{CTI}$ = 16.98

$(V-I)_{KC}$=1.57±.14      $(R-I)_{CTI}$=0.17±.07      $(V-I)_{CTI}$=1.40±.04

Notes:

# CTI 002603.4+275922
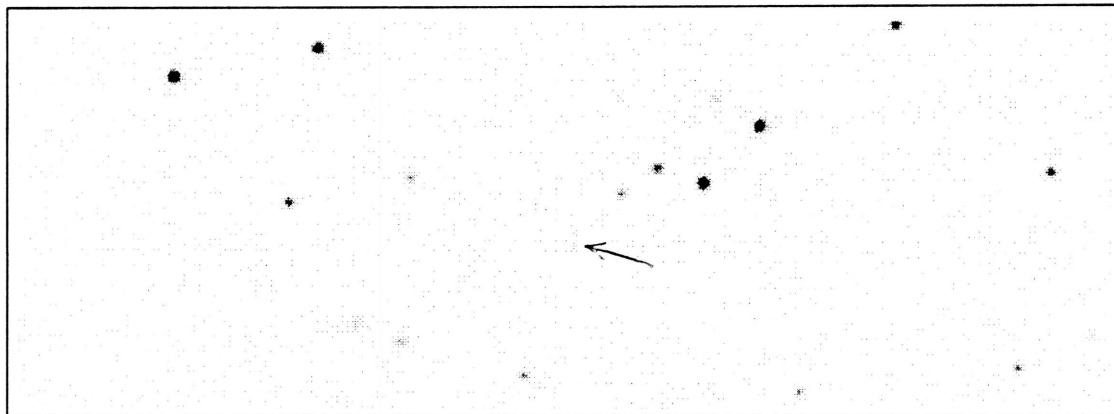


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 2100 sec          Obs. (UT) 1990 Jan 22
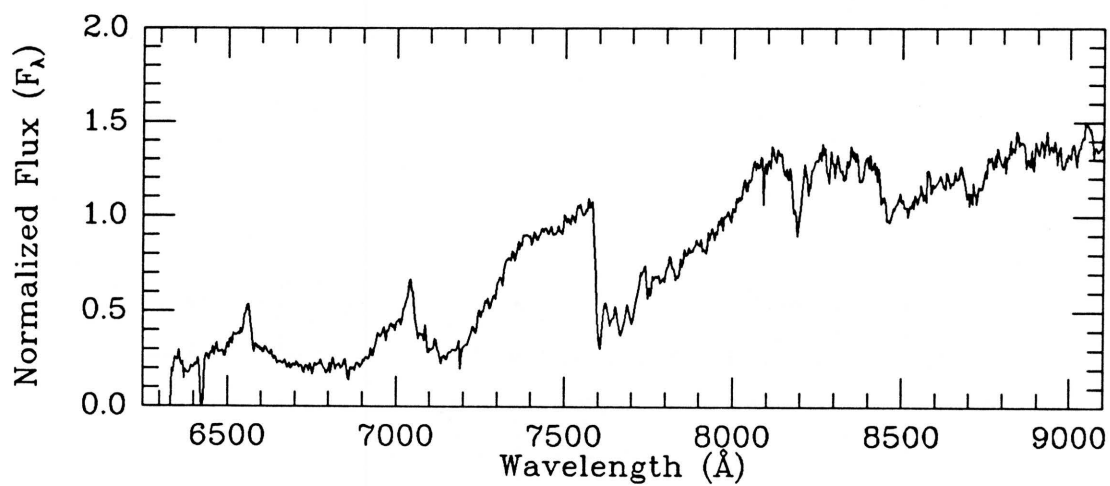


Coordinates:  $\alpha$ (1950) = 00:24:05.2      $\delta$ (1950) = +27:46:55

Spectral Type:  M5.5 V

Photometry:      $I_{KC}$ = 16.50          $R_{CTI}$ = 17.90

   $(V-I)_{KC}$=3.35±.16      $(R-I)_{CTI}$=1.42±.07      $(V-I)_{CTI}$=3.21±.05

Notes:

# CTI 003439.1+280309
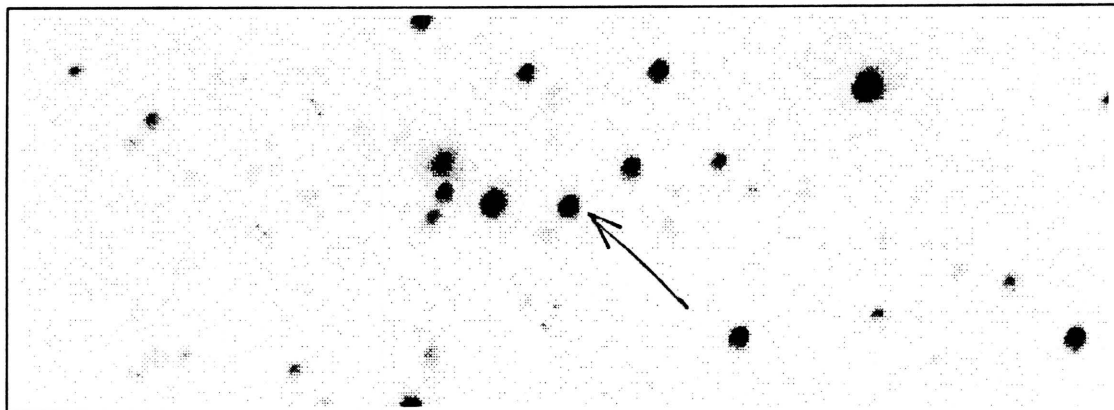


CTI FINDER CHART             I filter          Obs. (UT) 1989 Nov 03

MMT SPECTRUM          Exposure: 1200 sec       Obs. (UT) 1990 Nov 23
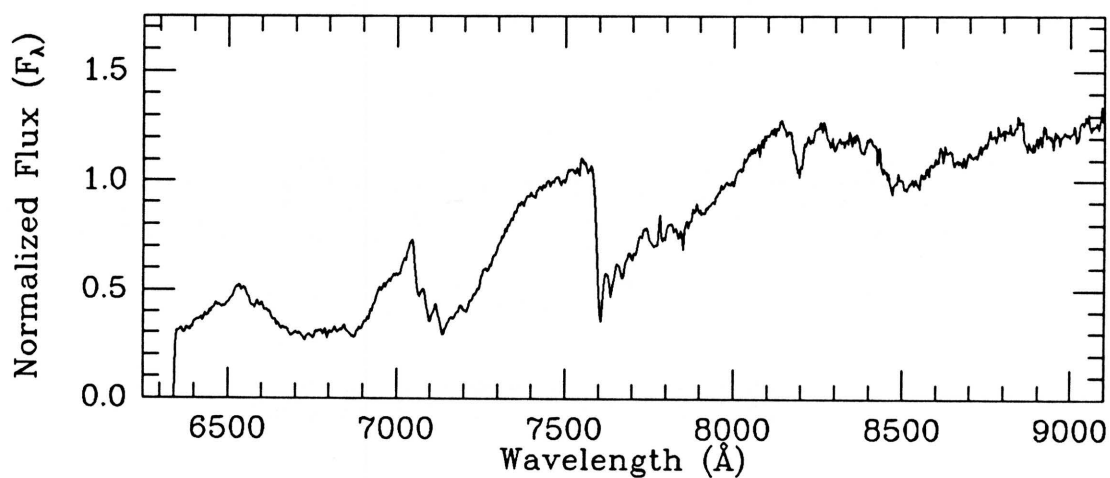


Coordinates:  $\alpha$ (1950) = 00:32:39.9      $\delta$ (1950) = +27:50:45

Spectral Type:  M4 V

Photometry:      $I_{KC}$ = 14.58        $R_{CTI}$ = 15.83

$(V-I)_{KC}$=3.01±.12      $(R-I)_{CTI}$=1.18±.02      $(V-I)_{CTI}$=2.84±.01

Notes: Small proper motion (~0.2 arcsec/yr) to the SE
evident when chart is compared to POSS E print.

# CTI 004244.4+280140
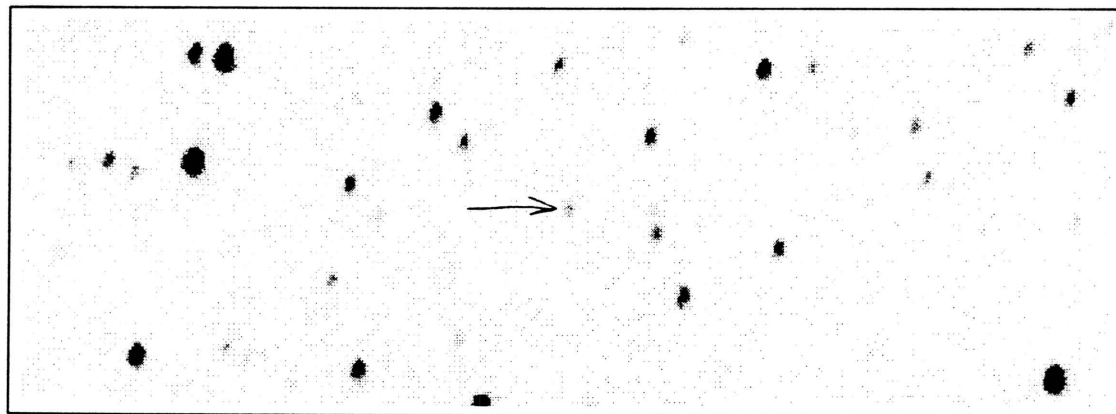


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Sep 13
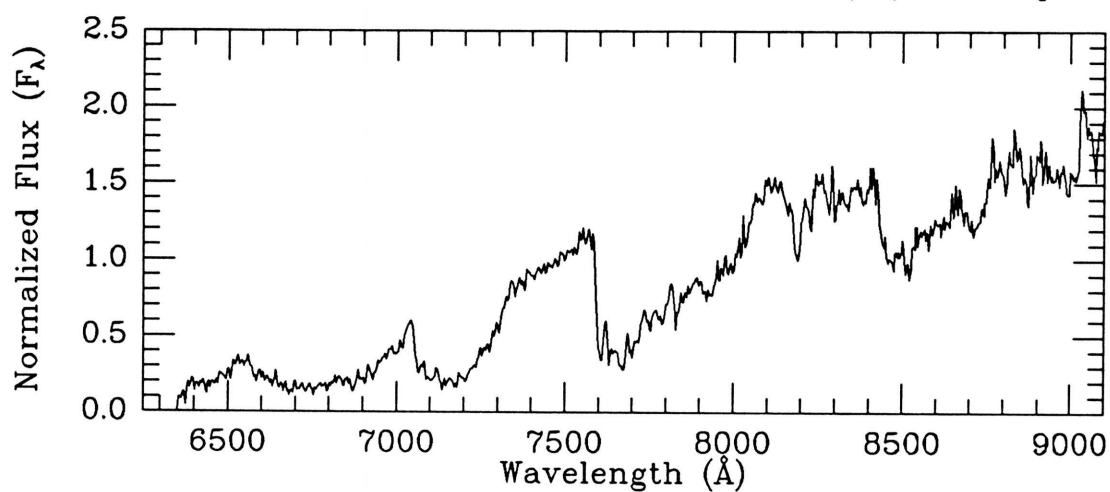


Coordinates:  $\alpha$ (1950) = 00:40:44.3      $\delta$ (1950) = +27:49:21

Spectral Type:  M6 V

Photometry:          $I_{KC}$ = 17.43          $R_{CTI}$ = 19.30

 $(V-I)_{KC}$=4.10±.27      $(R-I)_{CTI}$=1.94±.16      $(V-I)_{CTI}$=unknown

Notes:  Object not found on the POSS E print; large proper
  motion?

# CTI 004406.7+280336
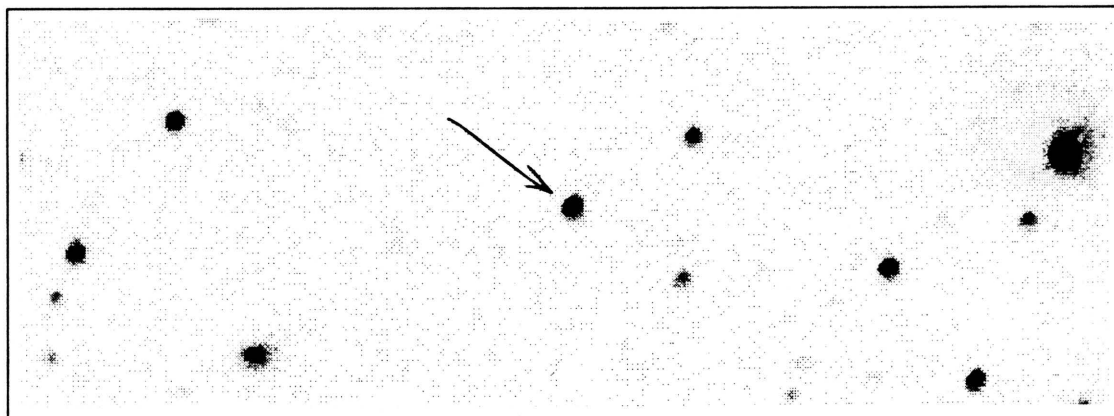


CTI FINDER CHART          I filter          Obs. (UT) 1989 Nov 03

MMT SPECTRUM          Exposure: 1200 sec          Obs. (UT) 1990 Nov 23
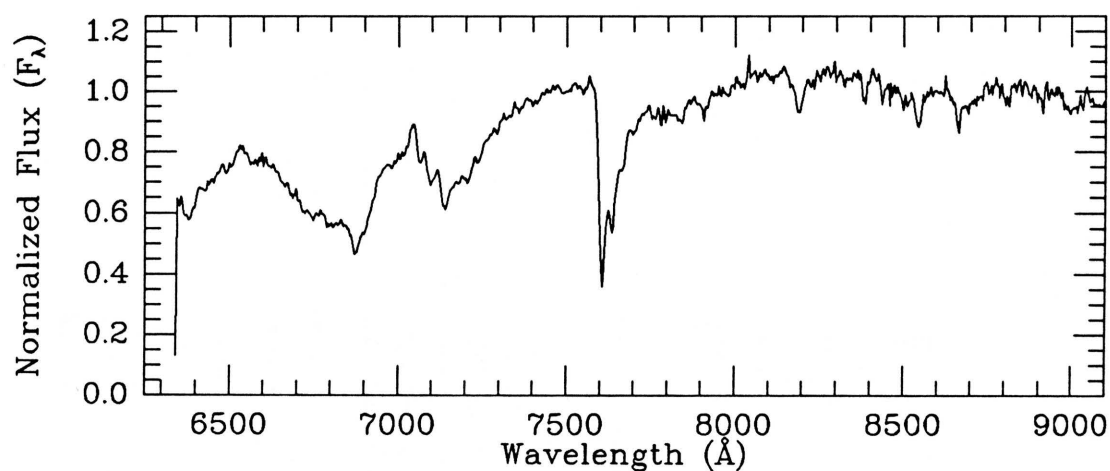


Coordinates:  $\alpha$ (1950) = 00:42:06.4      $\delta$ (1950) = +27:51:18

Spectral Type:  M1.5 V

Photometry:      $I_{KC}$ = 14.69          $R_{CTI}$ = 15.32

  $(V-I)_{KC}$=2.14±.10      $(R-I)_{CTI}$=0.57±.01      $(V-I)_{CTI}$=2.00±.01

Notes:

# CTI 004525.7+280437
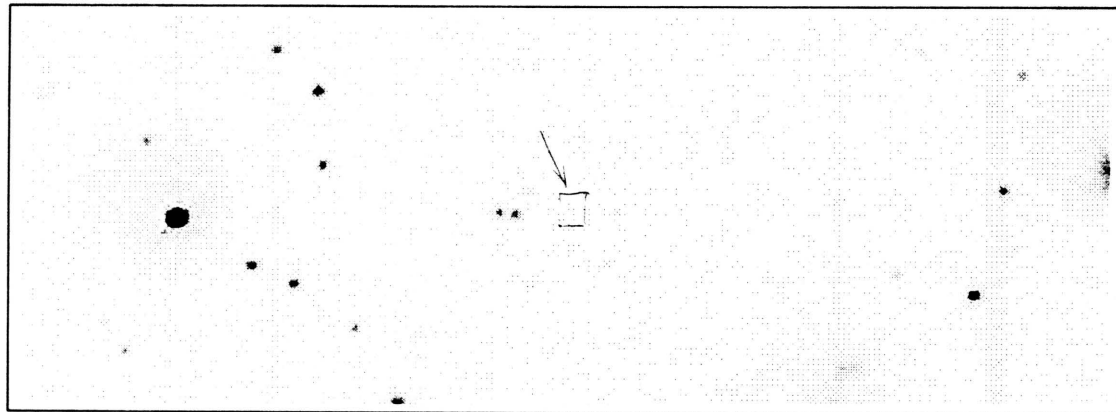


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 2100 sec          Obs. (UT) 1989 Jul 13
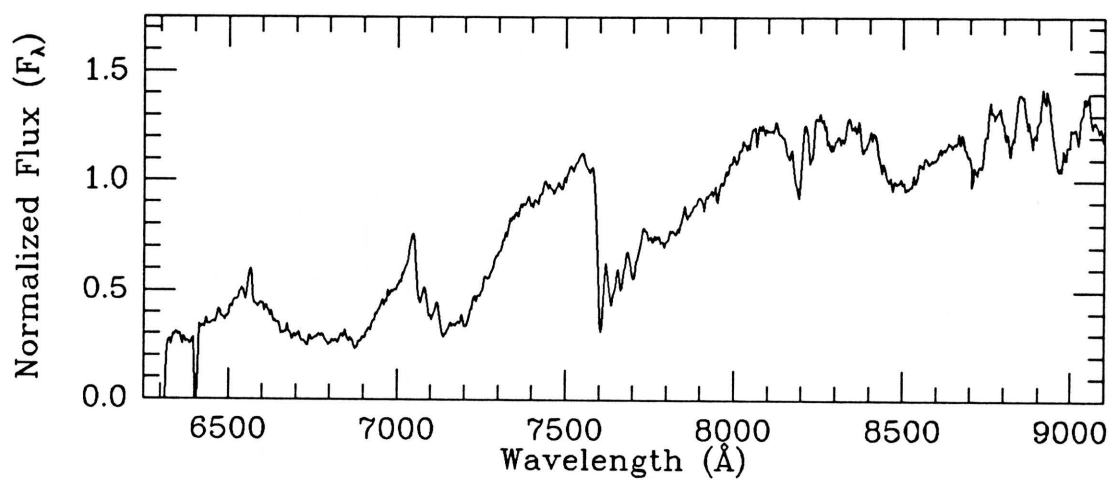


Coordinates:  $\alpha$ (1950) = 00:43:25.3          $\delta$ (1950) = +27:52:19

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = 16.12          $R_{CTI}$ = 17.30

   $(V-I)_{KC}$=3.03±.13          $(R-I)_{CTI}$=1.19±.04          $(V-I)_{CTI}$=3.17±.03

Notes:

# CTI 004911.4+275952
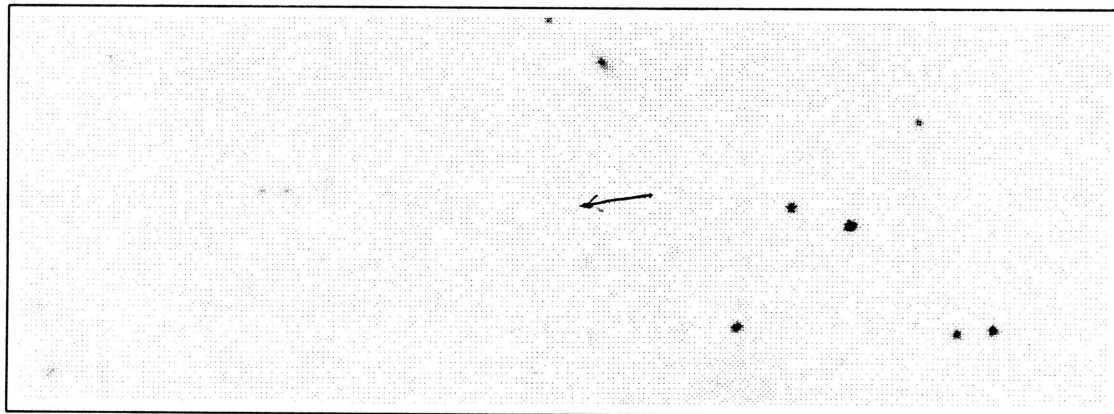


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 22
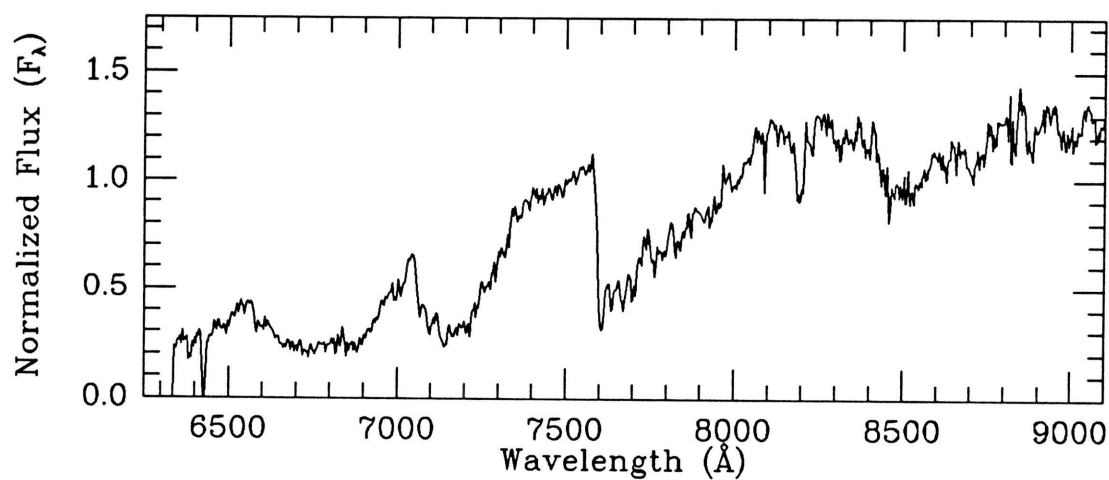


Coordinates:  $\alpha$ (1950) = 00:47:10.6      $\delta$ (1950) = +27:47:37

Spectral Type:  M4.5 V

Photometry:      $I_{KC}$ = 16.90          $R_{CTI}$ = 18.33

$(V-I)_{KC}$=3.43±.18      $(R-I)_{CTI}$=1.47±.09      $(V-I)_{CTI}$=3.29±.07

Notes:

# CTI 005100.5+280430
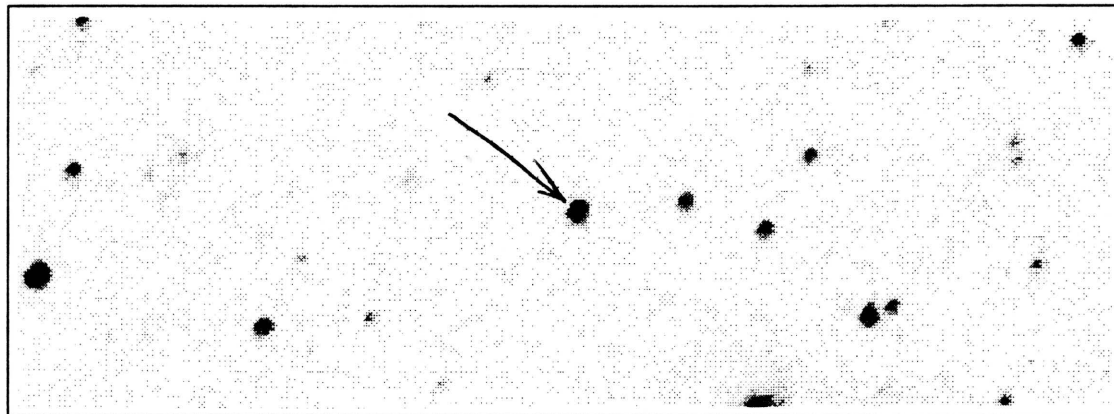


CTI FINDER CHART      I filter      Obs. (UT) 1989 Nov 03

MMT SPECTRUM      Exposure: 1200 sec      Obs. (UT) 1990 Nov 23
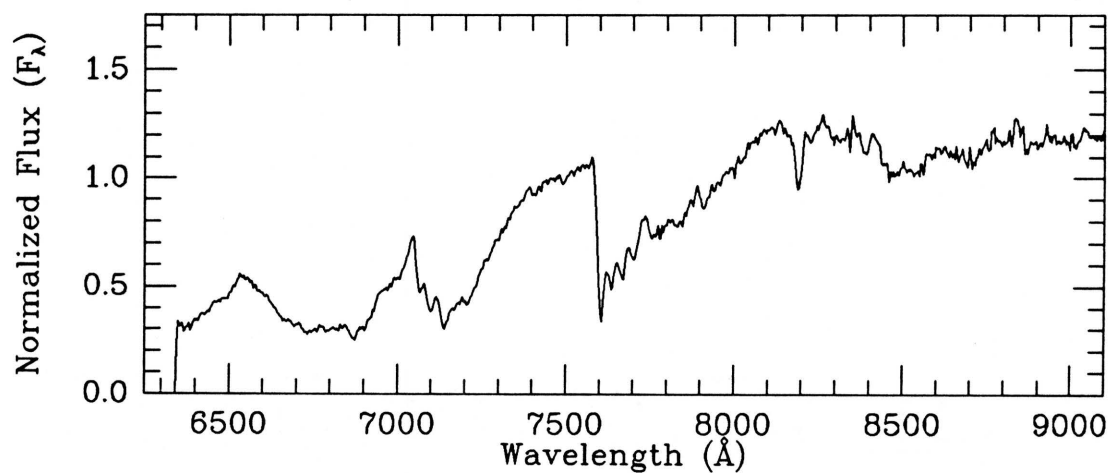


Coordinates: $\alpha$ (1950) = 00:48:59.5      $\delta$ (1950) = +27:52:16

Spectral Type: M4 V

Photometry:      $I_{KC}$ = 14.64      $R_{CTI}$ = 15.87

     $(V-I)_{KC}$=3.00±.12      $(R-I)_{CTI}$=1.17±.02      $(V-I)_{CTI}$=2.86±.01

Notes:

# CTI 010332.0+280234
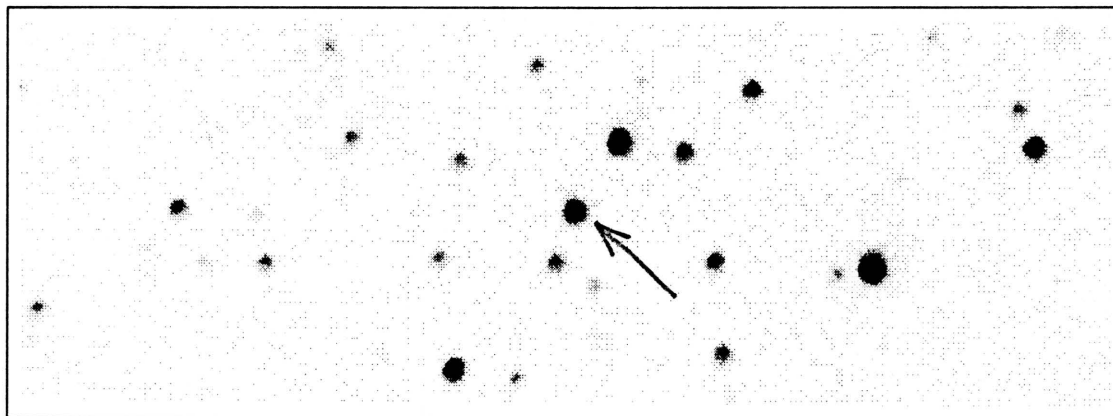


CTI FINDER CHART                    I filter              Obs. (UT) 1989 Nov 03

MMT SPECTRUM          Exposure: 1200 sec      Obs. (UT) 1990 Nov 23
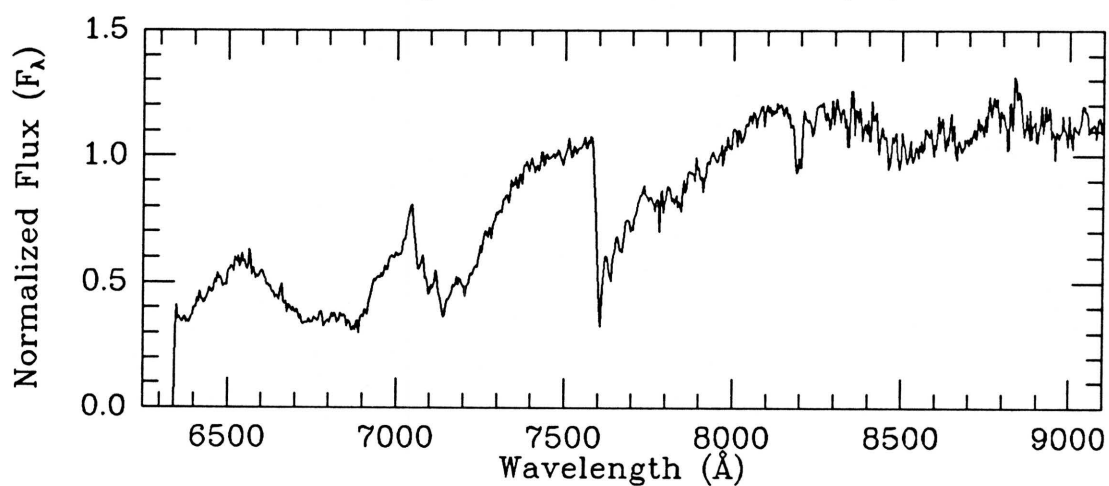


Coordinates:  $\alpha$ (1950) = 01:01:29.6      $\delta$ (1950) = +27:50:30

Spectral Type:  M3.5 V

Photometry:        $I_{KC}$ = 14.29          $R_{CTI}$ = 15.37

  $(V-I)_{KC}$=2.75±.12        $(R-I)_{CTI}$=1.00±.01        $(V-I)_{CTI}$=2.56±.01

Notes:

# CTI 011708.6+275850
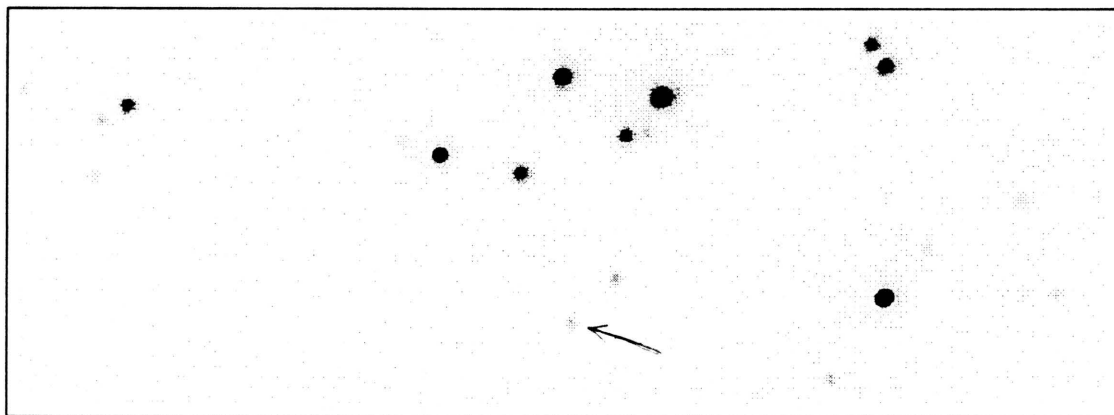


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 1200 sec          Obs. (UT) 1989 Jul 14
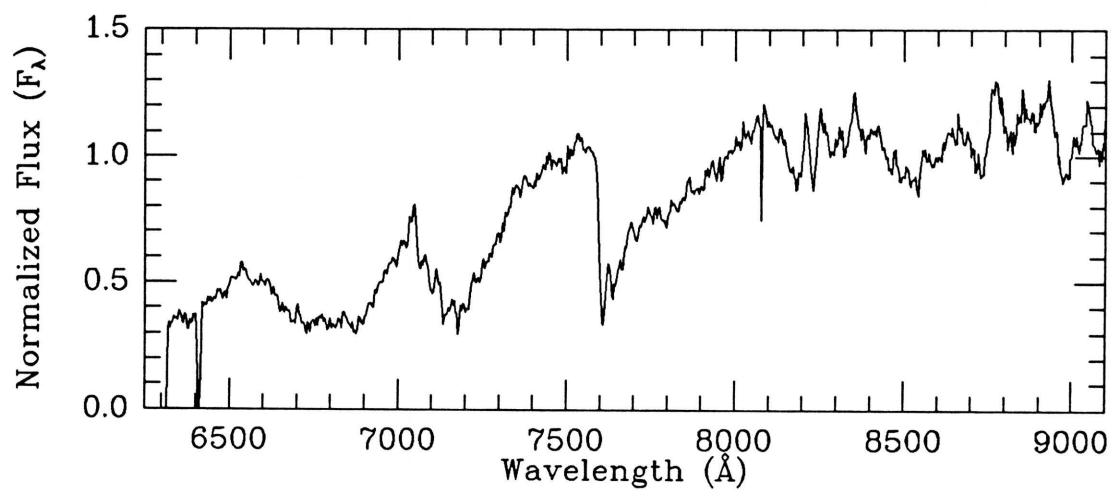


Coordinates:  $\alpha$ (1950) = 01:15:04.7      $\delta$ (1950) = +27:46:59

Spectral Type:  M3.5 V

Photometry:      $I_{KC}$ = 15.96          $R_{CTI}$ = 17.00

  $(V-I)_{KC}$=2.81±.14      $(R-I)_{CTI}$=1.04±.05      $(V-I)_{CTI}$=2.75±.03

Notes:

# CTI 011826.7+280514
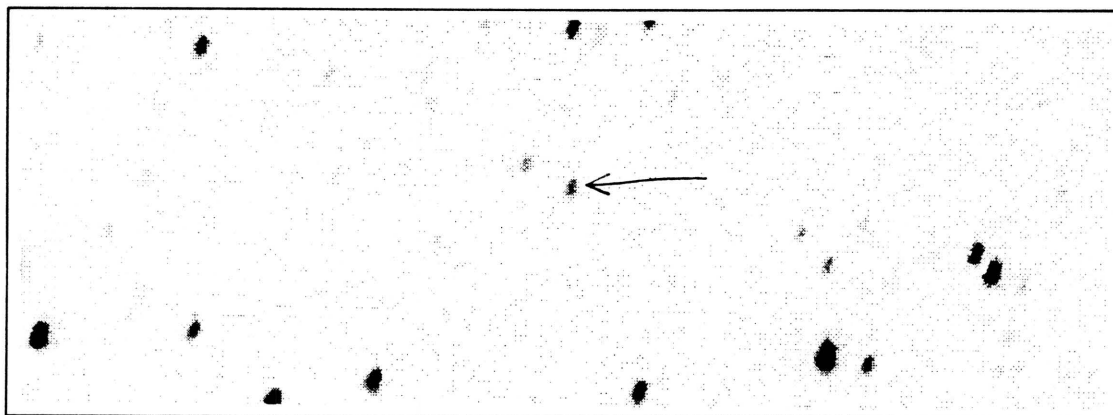


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 4200 sec          Obs. (UT) 1990 Nov 23
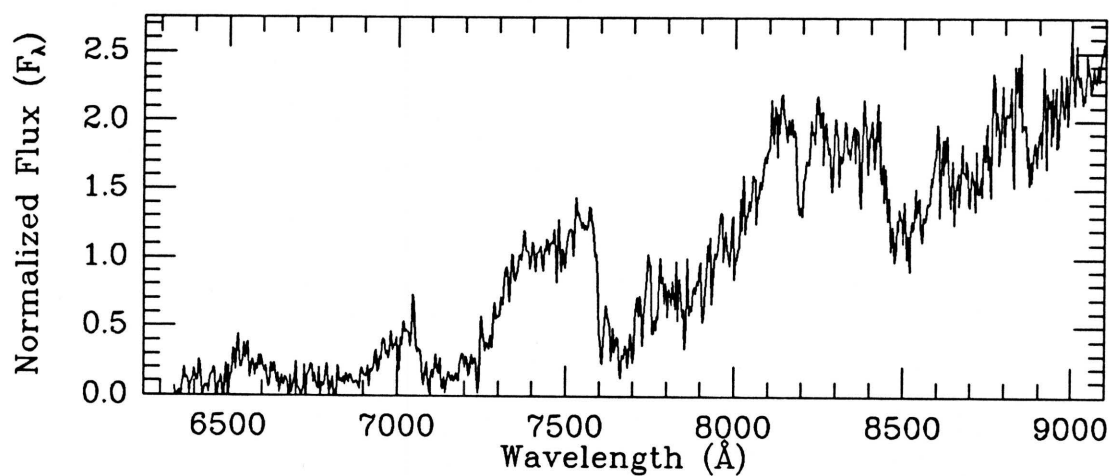


Coordinates:  $\alpha$ (1950) = 01:16:22.6          $\delta$ (1950) = +27:53:25

Spectral Type:  M6 V

Photometry:          $I_{KC}$ = 17.22          $R_{CTI}$ = 19.01

$(V-I)_{KC}$=3.97±.33          $(R-I)_{CTI}$=1.85±.21          $(V-I)_{CTI}$=unknown

Notes: Proper motion of ~1 arcsec/yr to the WSW suspected from comparison to POSS E print.

# CTI 012023.2+280320 A
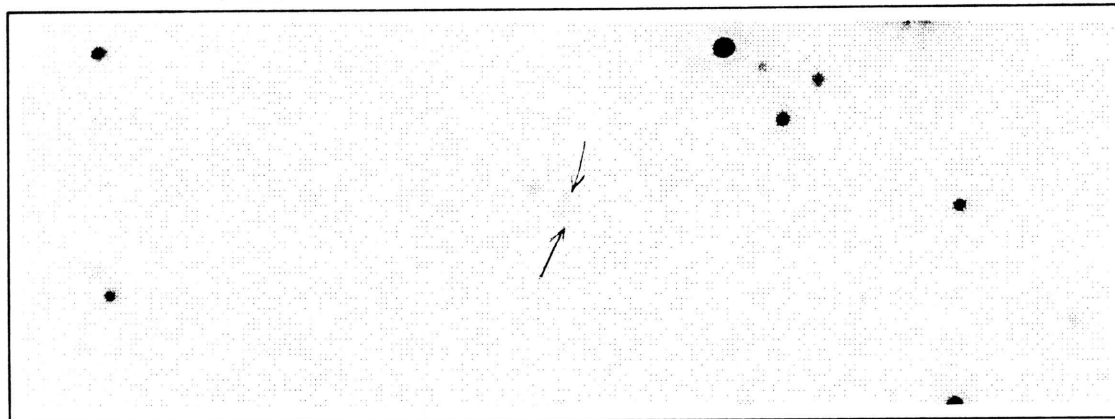


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20
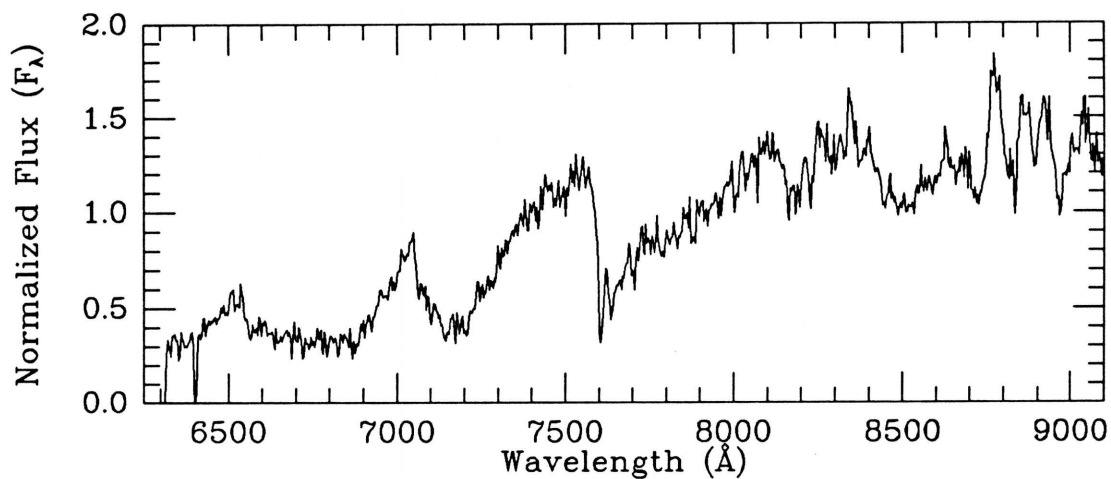
MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1989 Jul 13



Coordinates:  $\alpha$ (1950) = 01:18:18.9      $\delta$ (1950) = +27:51:33

Spectral Type:  M4 V

Photometry:      $I_{KC}$ = 17.25          $R_{CTI}$ = 17.93

 $(V-I)_{KC}$=2.38±.20      $(R-I)_{CTI}$=0.74±.12      $(V-I)_{CTI}$=3.06±.09

Notes: Close double star (see next page).  Photometry is a composite of both stars.

# CTI 012023.2+280320 B
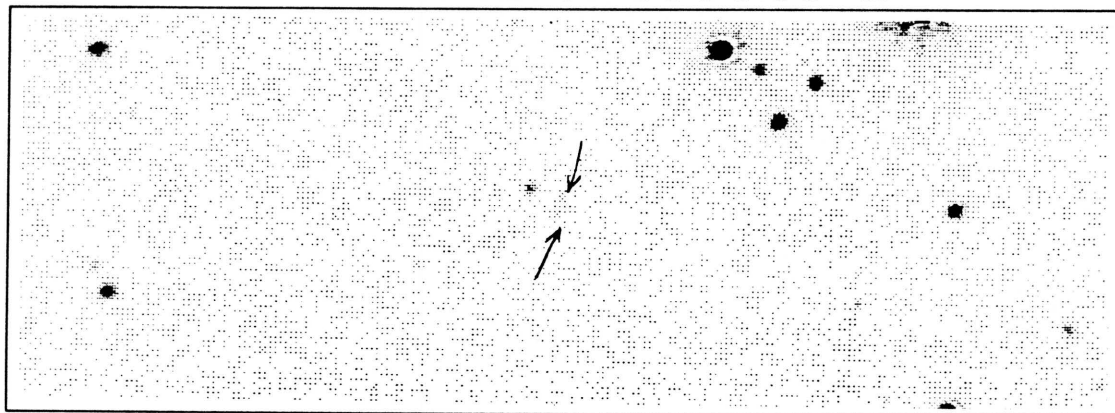


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20
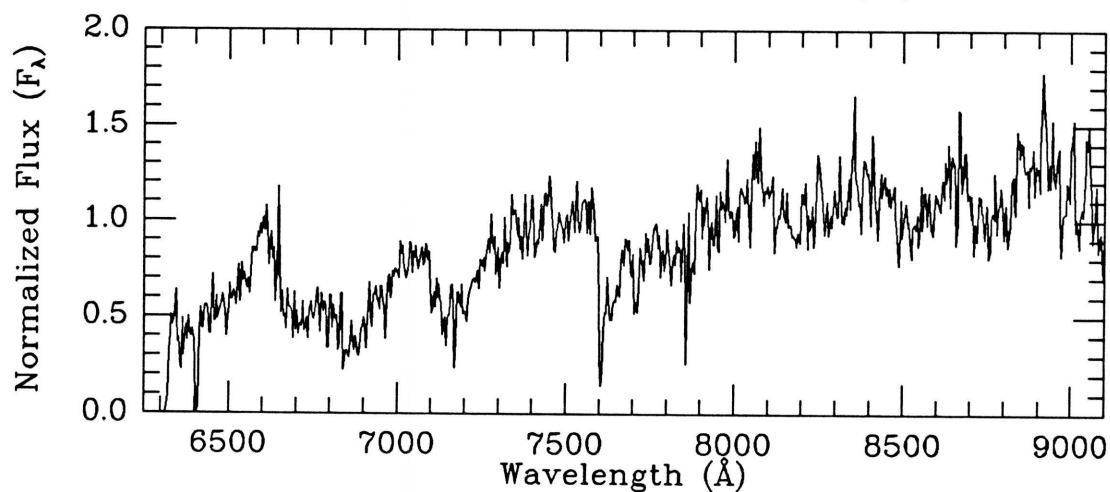
MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1989 Jul 13



Coordinates:  $\alpha$ (1950) = 01:18:18.9     $\delta$ (1950) = +27:51:33

Spectral Type:  M3: V

Photometry:     $I_{KC}$ = 17.25     $R_{CTI}$ = 17.93

$(V-I)_{KC}$=2.38±.20     $(R-I)_{CTI}$=0.74±.12     $(V-I)_{CTI}$=3.06±.09

Notes: Close double star (see previous page).  Photometry is a composite of both stars.

# CTI 012303.4+280449
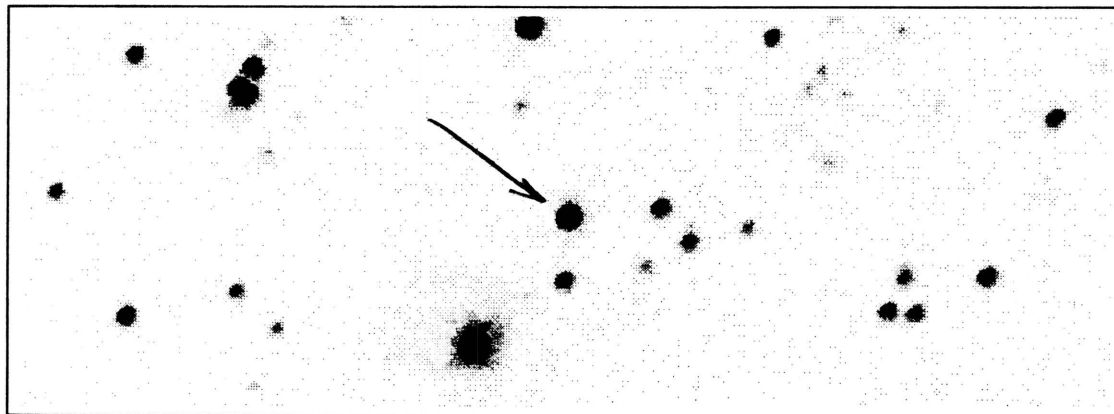


CTI FINDER CHART · · · · · · I filter · · · · · · Obs. (UT) 1989 Nov 03

MMT SPECTRUM · · · · · · Exposure: 600 sec · · · · · · Obs. (UT) 1990 Nov 23
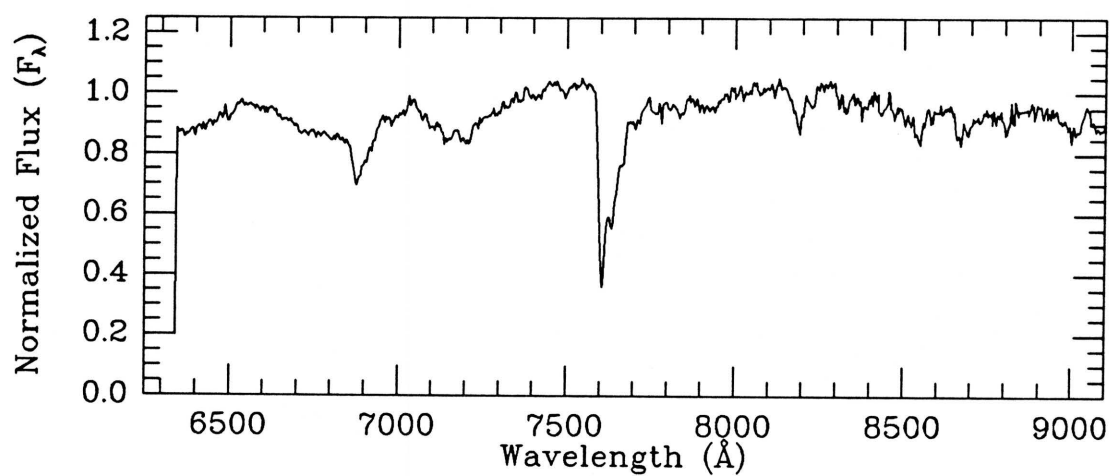


Coordinates: $\alpha$ (1950) = 01:20:58.8 · · · · · · $\delta$ (1950) = +27:53:05

Spectral Type: M0 V

Photometry: · · · · · · $I_{KC}$ = 12.87 · · · · · · $R_{CTI}$ = 13.28

$(V-I)_{KC}$=1.70±.09 · · · · · · $(R-I)_{CTI}$=0.26±.01 · · · · · · $(V-I)_{CTI}$=1.51±.01

Notes:

# CTI 012517.7+280101
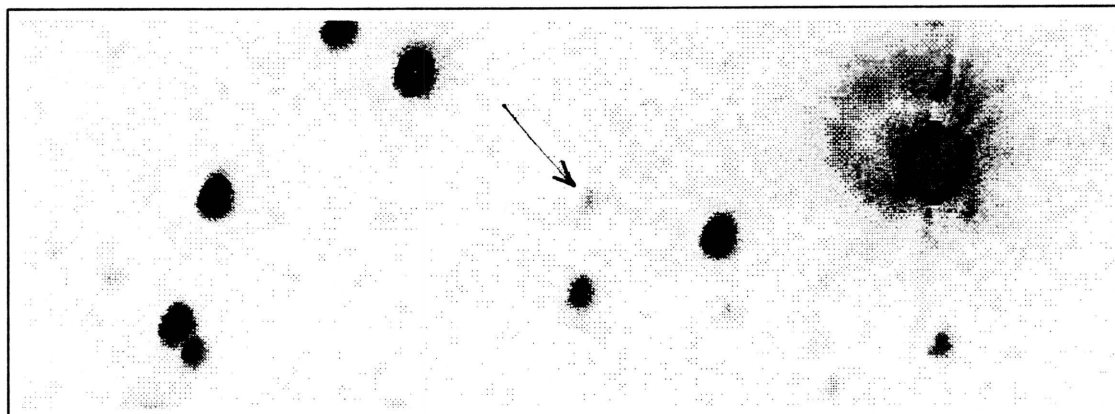


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 3000 sec          Obs. (UT) 1991 Oct 17
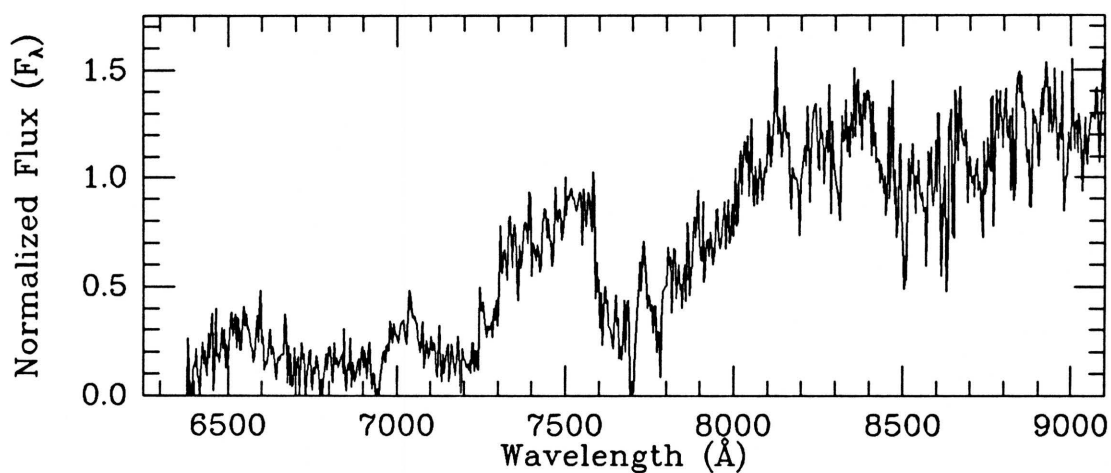


Coordinates:  $\alpha$ (1950) = 01:23:12.9          $\delta$ (1950) = +27:49:20

Spectral Type:  M6 V

Photometry:          $I_{KC}$ = unknown          $R_{CTI}$ = unknown

  $(V-I)_{KC}$=unknown          $(R-I)_{CTI}$=unknown          $(V-I)_{CTI}$=3.88:

Notes:

# CTI 012517.7+280245
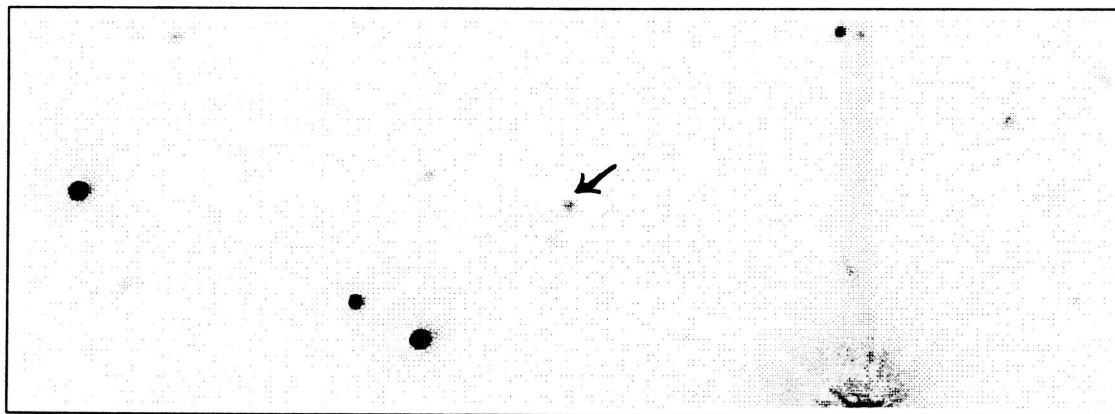


CTI FINDER CHART          V filter          Coadded frame

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1989 Jul 13
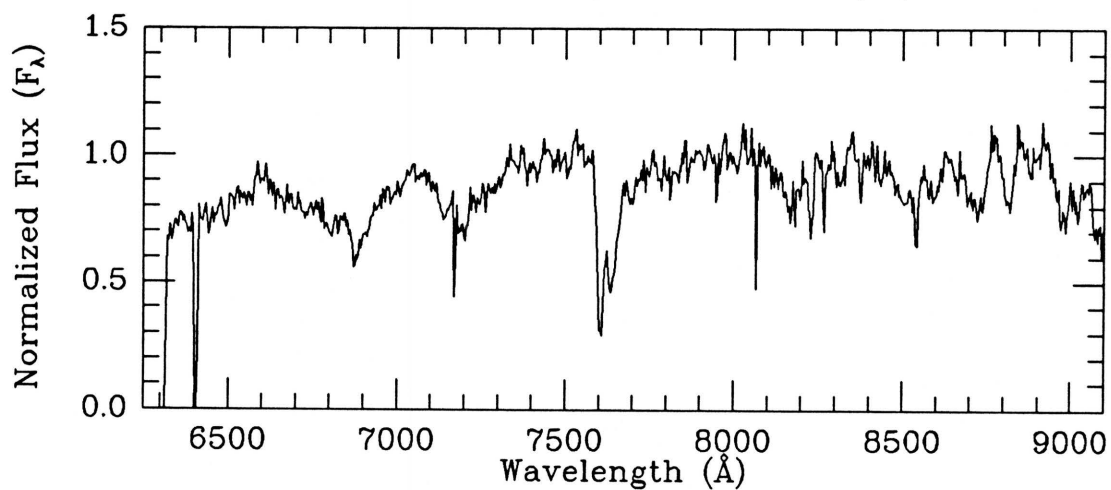


Coordinates: $\alpha$ (1950) = 01:23:12.9          $\delta$ (1950) = +27:51:04

Spectral Type: M0 V

Photometry:          $I_{KC}$ = 17.50          $R_{CTI}$ = 17.78

$(V-I)_{KC}$=1.82±.11          $(R-I)_{CTI}$=0.35±.04          $(V-I)_{CTI}$=1.75±.02

Notes:

# CTI 012657.5+280202
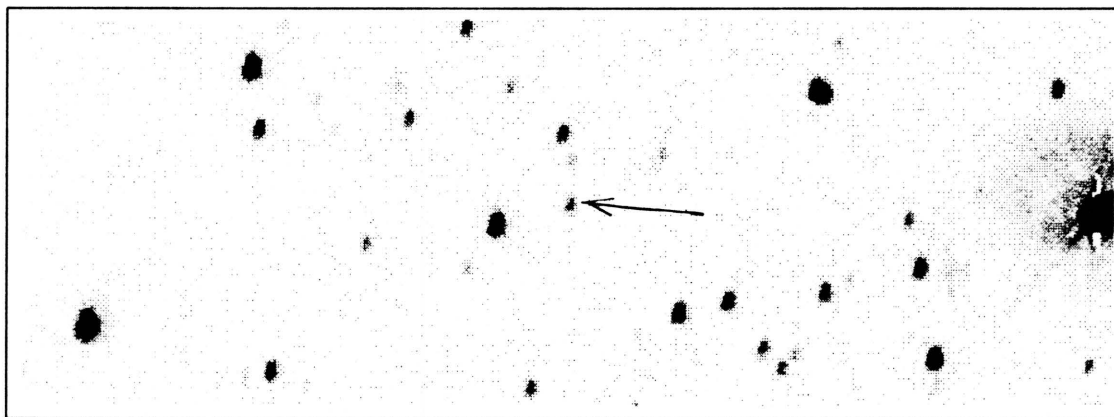


CTI FINDER CHART             I filter             Obs. (UT) 1988 Nov 01

MMT SPECTRUM         Exposure: 3900 sec        Obs. (UT) 1990 Sep 13
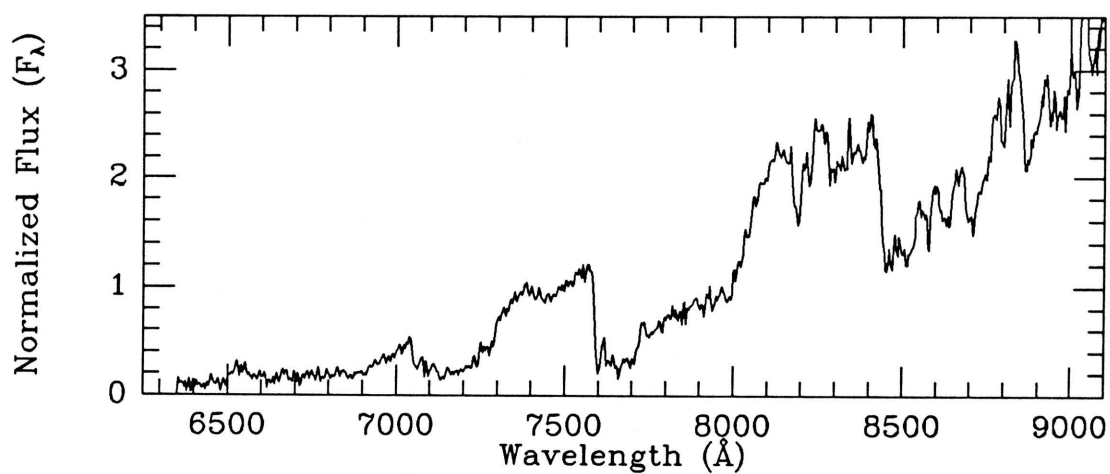


Coordinates:  $\alpha$ (1950) = 01:24:52.5       $\delta$ (1950) = +27:50:23

Spectral Type:  M8.5 V

Photometry:        $I_{KC}$ = 17.10          $R_{CTI}$ = 19.35

$(V-I)_{KC}$=4.61±.38      $(R-I)_{CTI}$=2.30±0.24     $(V-I)_{CTI}$=unknown

Notes: Not seen on POSS E, either because of large motion
or because of faintness.  Latest dwarf found in CTI strip.

# CTI 013743.0+280553:
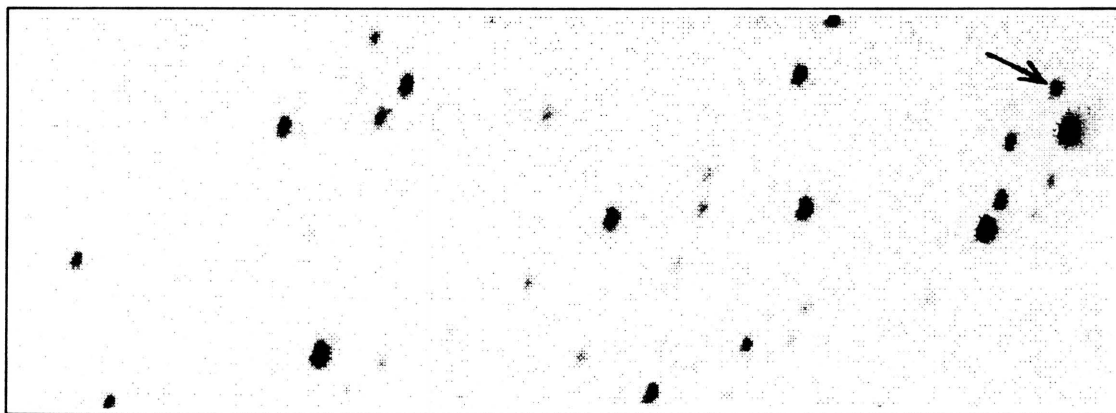


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 Nov 22
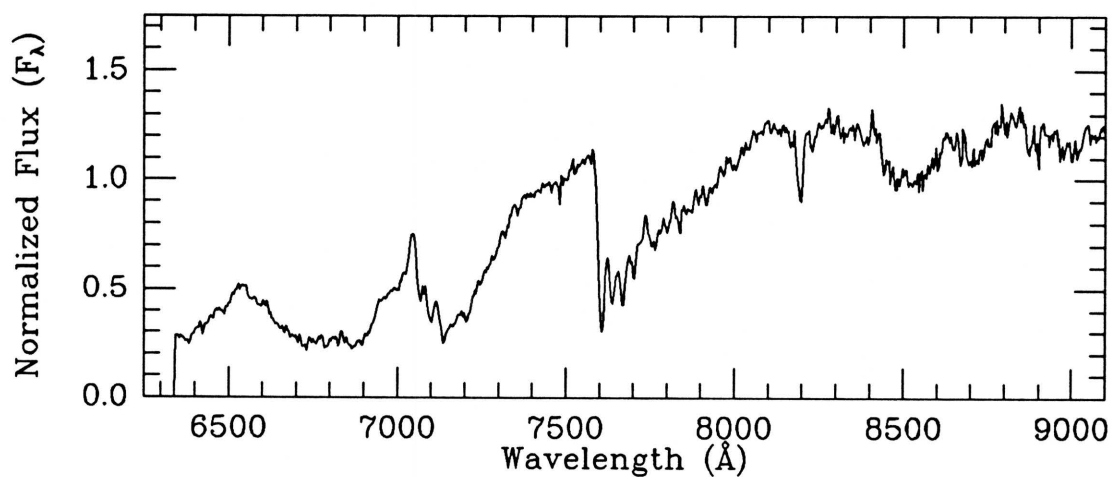


Coordinates:  $\alpha$ (1950) = 01:37:37:     $\delta$ (1950) = +27:54:28:

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = unknown          $R_{CTI}$ = unknown

$(V-I)_{KC}$=unknown     $(R-I)_{CTI}$=unknown     $(V-I)_{CTI}$=unknown

Notes: Proper motion of ~0.4 arcsec/yr E evident when chart compared to POSS E.  Not a color-selected object. Position measured from nearby reference star and is thus uncertain.

# CTI 014716.6+280142
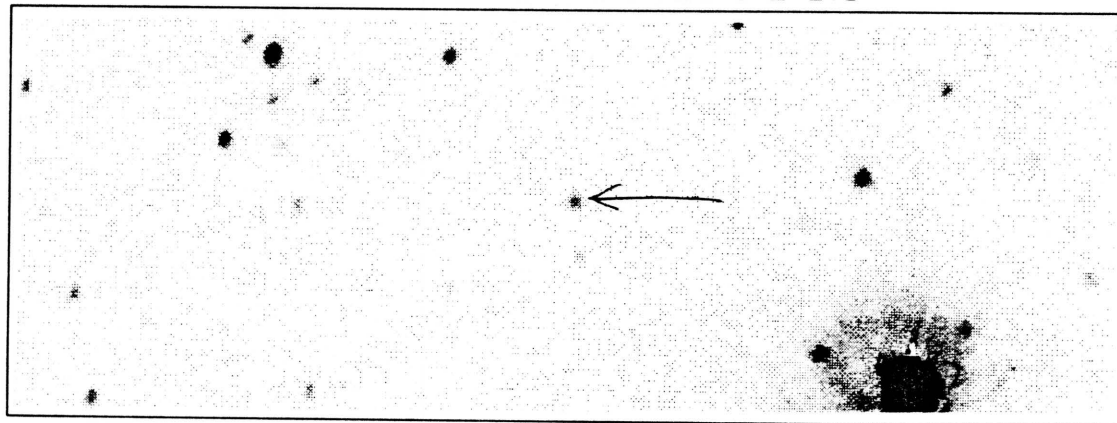


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Nov 22
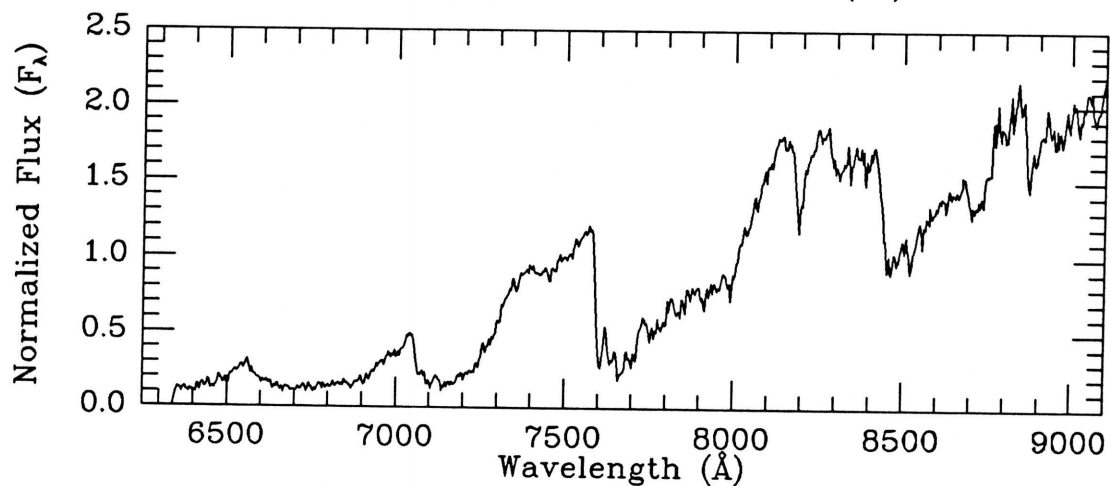


Coordinates:  $\alpha$ (1950) = 01:45.09.4      $\delta$ (1950) = +27:50:30

Spectral Type:  M6 V

Photometry:      $I_{KC}$ = 17.23          $R_{CTI}$ = 19.12

$(V-I)_{KC}$=4.11±.35      $(R-I)_{CTI}$=1.95±.22      $(V-I)_{CTI}$=unknown

Notes: POSS E shows star ~1 arcmin ESE of arrowed position, but no object corresponding to CTI star. If this is the same star at different epochs, proper motion is ~2 arcsec/yr.

# CTI 015115.8+280458
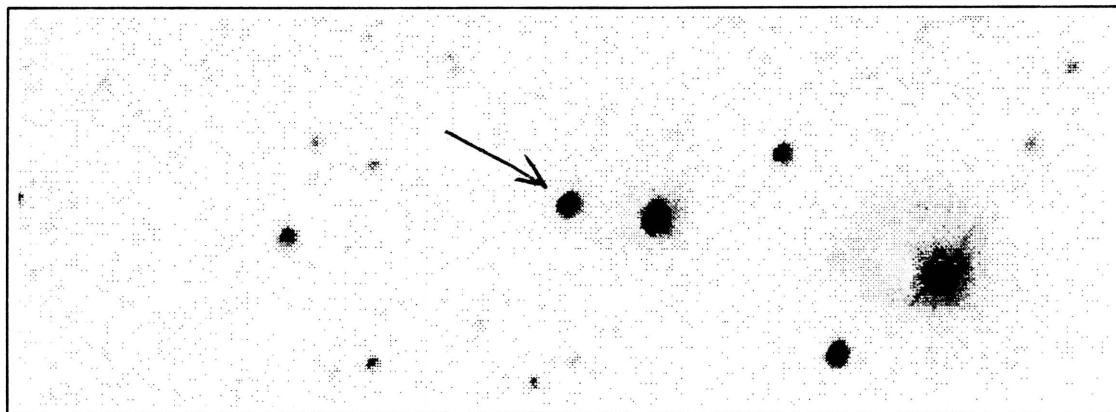


CTI FINDER CHART          I filter          Obs. (UT) 1989 Nov 03

MMT SPECTRUM          Exposure: 1200 sec          Obs. (UT) 1990 Nov 23
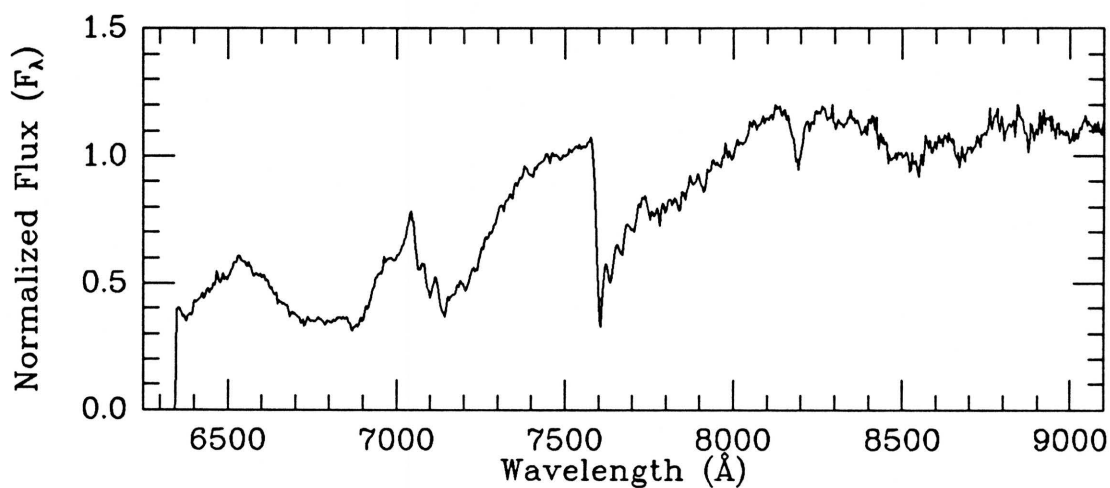


Coordinates:  $\alpha$ (1950) = 01:49:08.2          $\delta$ (1950) = +27:53:52

Spectral Type:  M3.5 V

Photometry:          $I_{KC}$ = 13.97          $R_{CTI}$ = 15.05

(V–I)$_{KC}$=2.74±.11          (R–I)$_{CTI}$=0.99±.01          (V–I)$_{CTI}$=2.57±.01

Notes:

# CTI 015338.5+280036
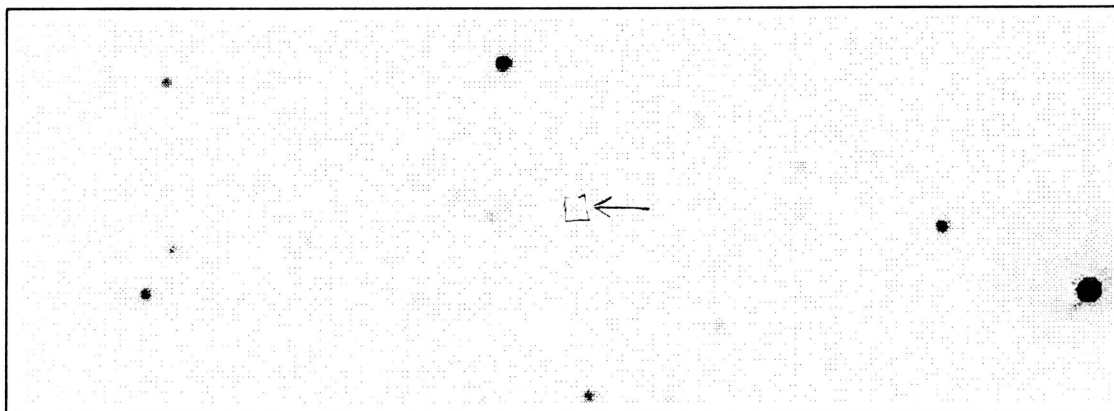


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1989 Jul 14
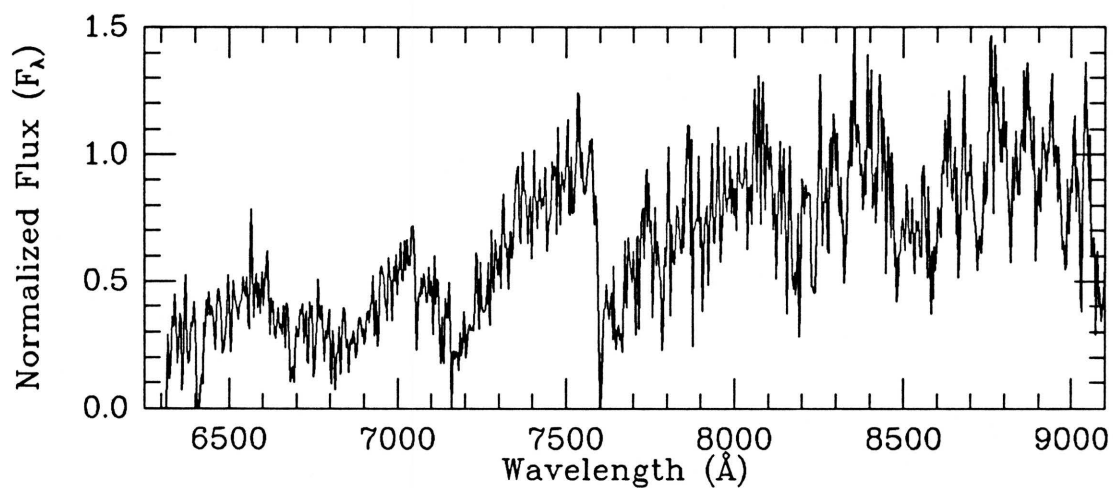


Coordinates: $\alpha$ (1950) = 01:51:30.7          $\delta$ (1950) = +27:49:33

Spectral Type: M3.5 V

Photometry:          $I_{KC}$ = 17.20          $R_{CTI}$ = 18.32

$(V-I)_{KC}$=3.01±.23          $(R-I)_{CTI}$=1.18±.14          $(V-I)_{CTI}$=3.03±.11

Notes:

# CTI 015607.7+280241
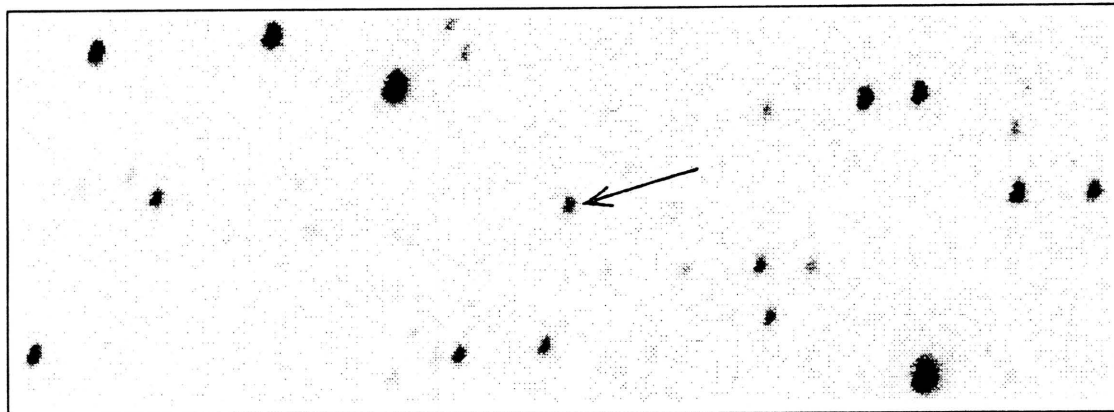


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 Sep 13
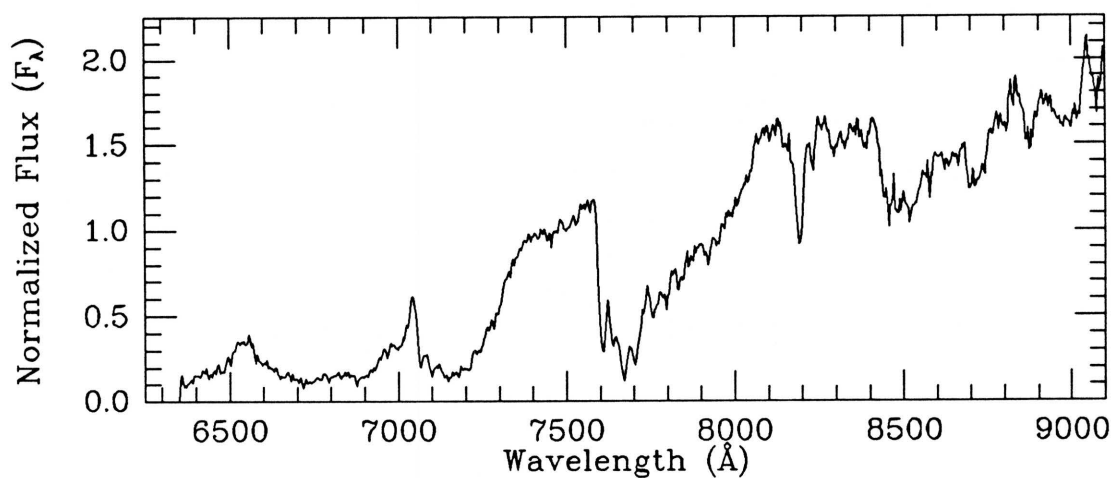


Coordinates:  $\alpha$ (1950) = 01:53:59.6        $\delta$ (1950) = +27:51:42

Spectral Type:  M6.5 V

Photometry:        $I_{KC}$ = 16.53          $R_{CTI}$ = 18.33

  $(V-I)_{KC}$=3.94±.22        $(R-I)_{CTI}$=1.83±.12        $(V-I)_{CTI}$=3.89±.12

Notes:

# CTI 015625.5+280135
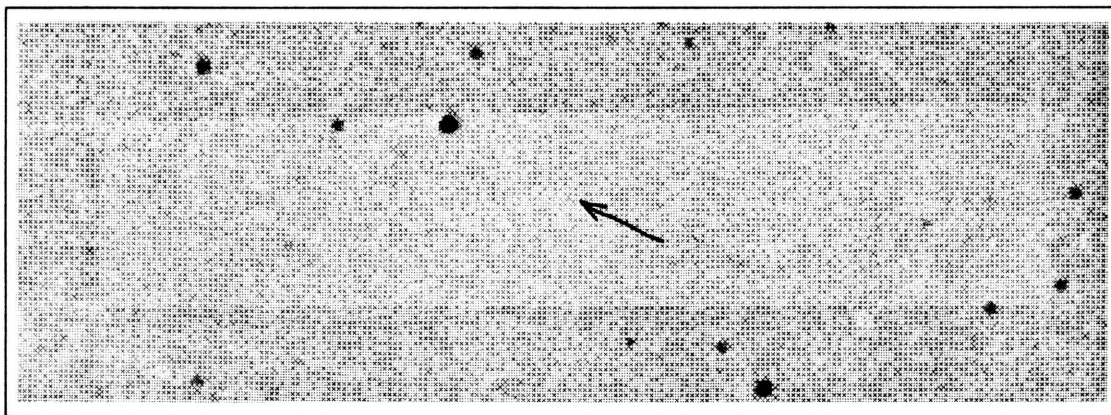


CTI FINDER CHART · V filter · Obs. (UT) 1987 Oct 20

MMT SPECTRUM · Exposure: 1800 sec · Obs. (UT) 1989 Jul 10
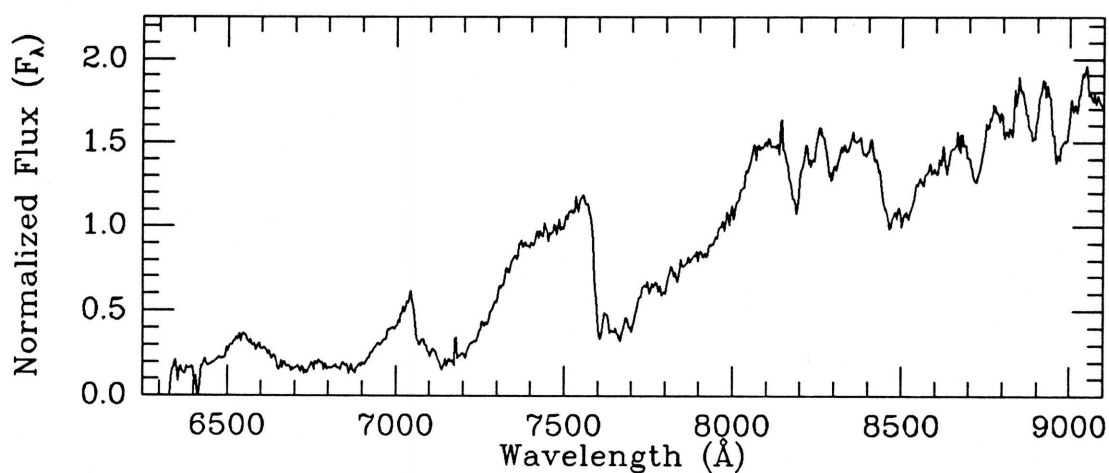


Coordinates: $\alpha$ (1950) = 01:54:17.4 $\delta$ (1950) = +27:50:37
Spectral Type: M6 V
Photometry: $I_{KC}$ = 16.04 $R_{CTI}$ = 17.69
$(V-I)_{KC}$=3.68±.17 $(R-I)_{CTI}$=1.65±.07 $(V-I)_{CTI}$=3.61±.06
Notes:

# CTI 015706.0+280519
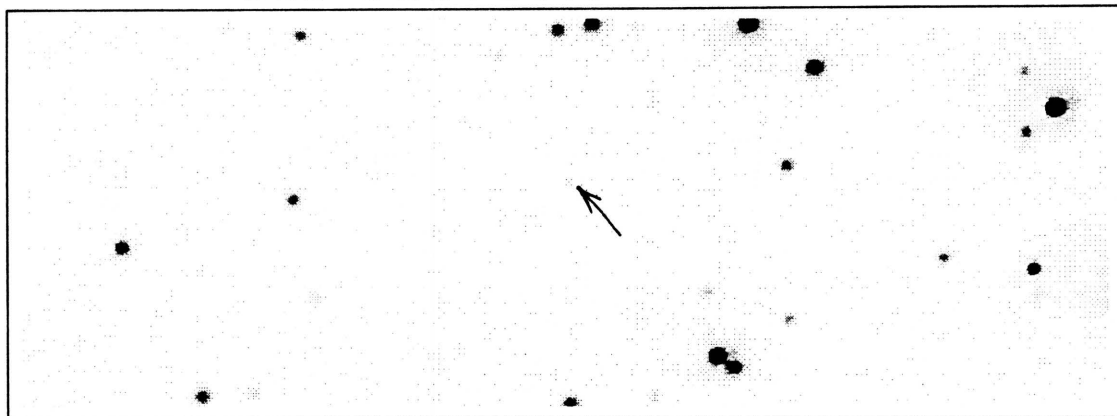


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 2361 sec          Obs. (UT) 1990 Jan 22
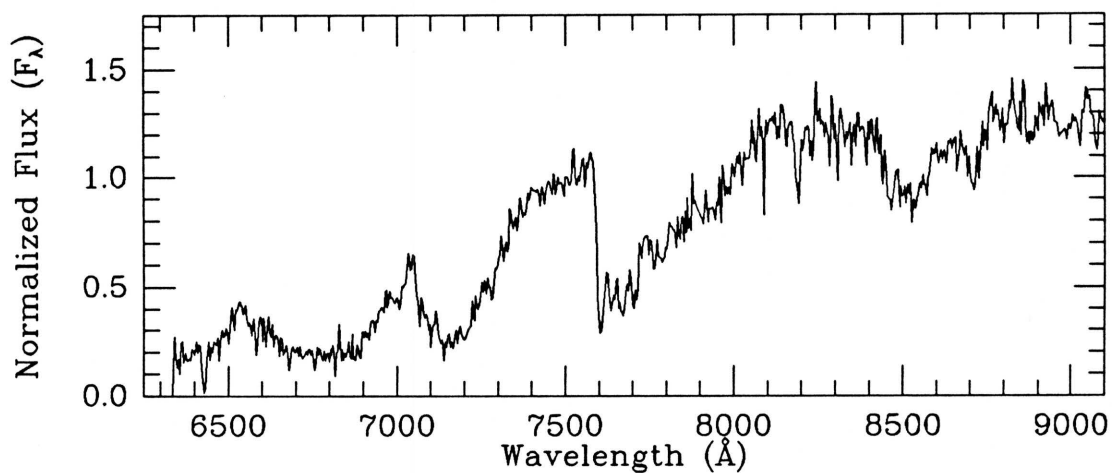


Coordinates:  $\alpha$ (1950) = 01:54:57.8          $\delta$ (1950) = +27:54:22

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = 17.01          $R_{CTI}$ = 18.55

$(V-I)_{KC}$=3.60±.24          $(R-I)_{CTI}$=1.59±.14          $(V-I)_{CTI}$=3.37±.12

Notes:

# CTI 015812.8+280439
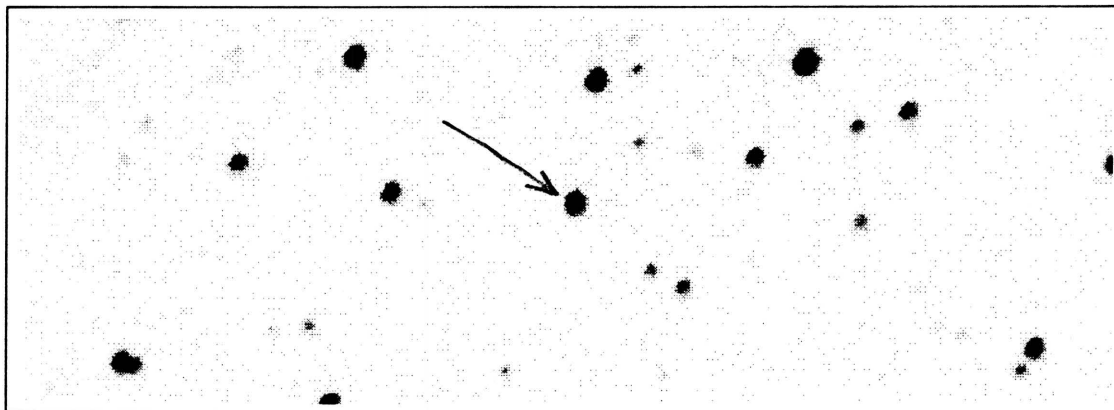


CTI FINDER CHART          I filter          Obs. (UT) 1989 Nov 03

MMT SPECTRUM          Exposure: 900 sec          Obs. (UT) 1990 Nov 23
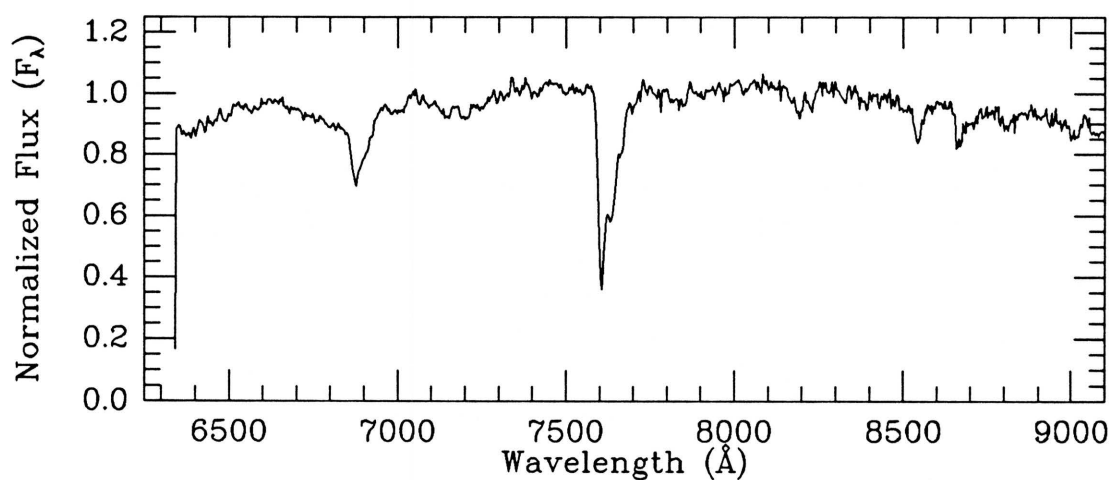


Coordinates:  $\alpha$ (1950) = 01:56:04.5      $\delta$ (1950) = +27:53:43

Spectral Type:  K7 V

Photometry:        $I_{KC}$ = 14.18          $R_{CTI}$ = 14.46

  $(V-I)_{KC}$=1.61±.13      $(R-I)_{CTI}$=0.20±.06      $(V-I)_{CTI}$=1.50±.01

Notes:

# CTI 015825.4+280120
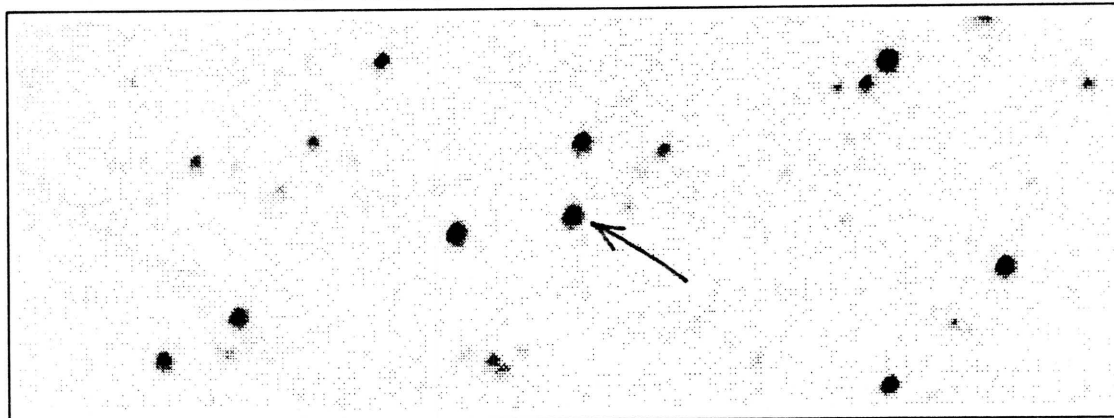


**CTI FINDER CHART**  I filter  Obs. (UT) 1989 Nov 03

MMT SPECTRUM  Exposure: 1200 sec  Obs. (UT) 1990 Nov 23
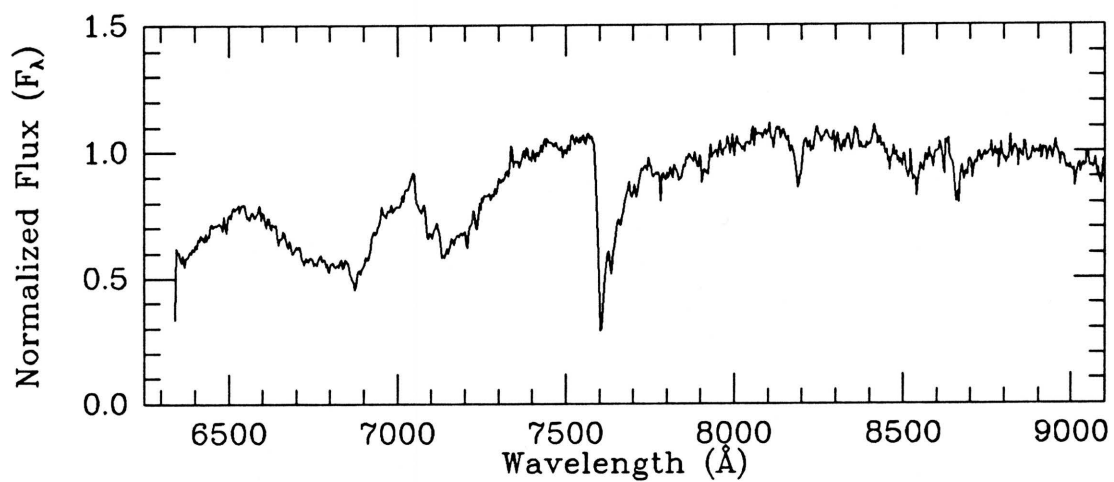


Coordinates: $\alpha$ (1950) = 01:56:17.1  $\delta$ (1950) = +27:50:25

Spectral Type: M1.5 V

Photometry:  $I_{KC}$ = 14.85  $R_{CTI}$ = 15.45

$(V-I)_{KC}$=2.11±.11  $(R-I)_{CTI}$=0.55±.02  $(V-I)_{CTI}$=1.99±.01

Notes:

# CTI 021845.9+280047
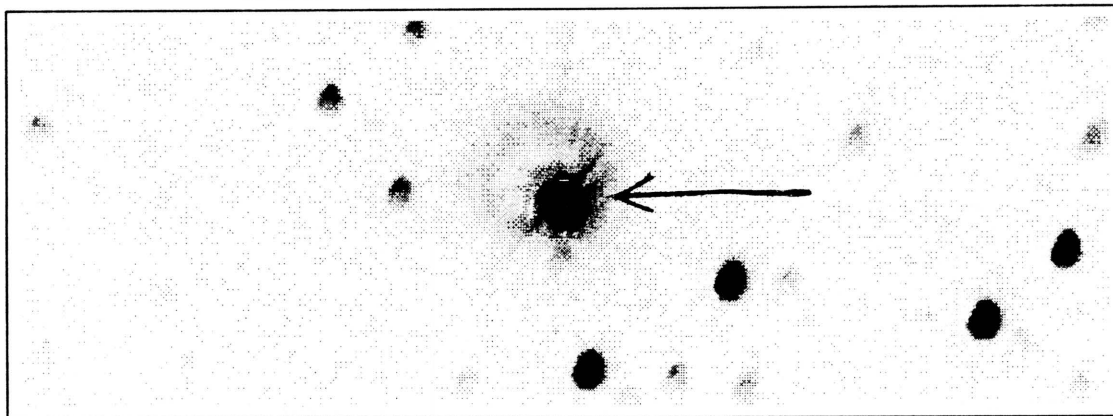


CTI FINDER CHART        I filter        Obs. (UT) 1988 Sep 13

MMT SPECTRUM        Exposure: 390 sec        Obs. (UT) 1990 Nov 23
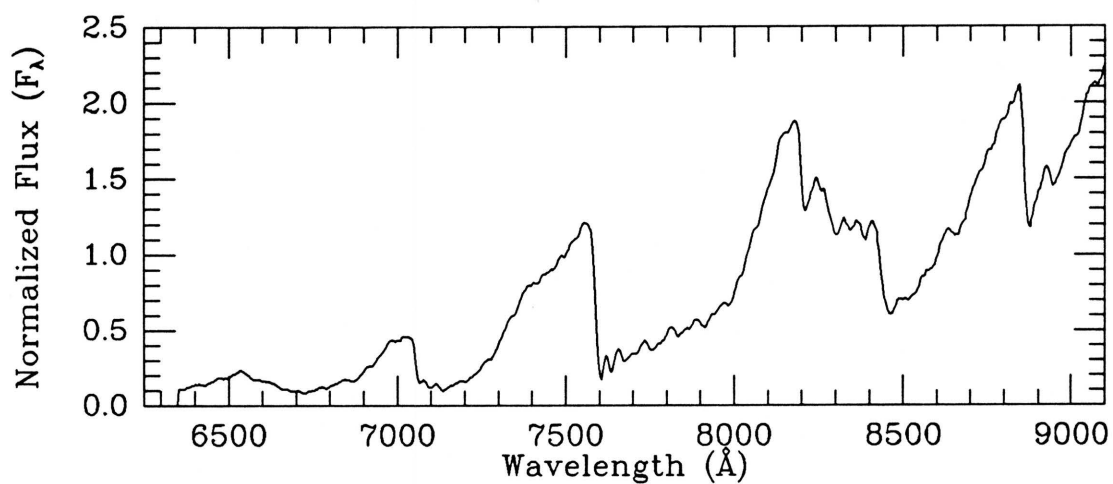


Coordinates:  $\alpha$ (1950) = 02:16:35.6        $\delta$ (1950) = +27:50:27

Spectral Type:  M7 III

Photometry:        $I_{KC}$ = unknown        $R_{CTI}$ = 11.12

 $(V-I)_{KC}$=unknown        $(R-I)_{CTI}$=1.75±.01        $(V-I)_{CTI}$=4.08±.01

Notes: CTI measurement of I, and possibly R, saturated. A Mira
 variable whose 19 CTI V measures range from 12.8 to 13.9.
 Not listed in General Cat. of Variable Stars (Kholopov 1985).

# CTI 023210.0+280313
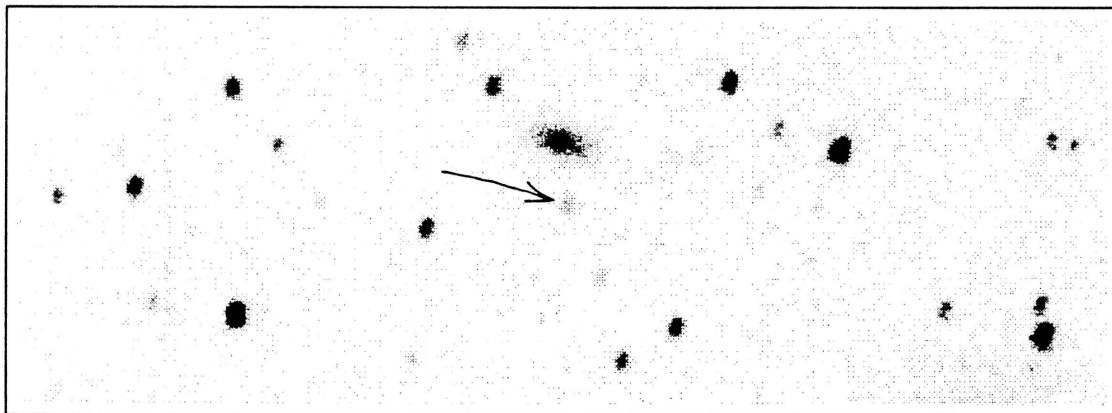


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 2100 sec          Obs. (UT) 1990 Sep 13
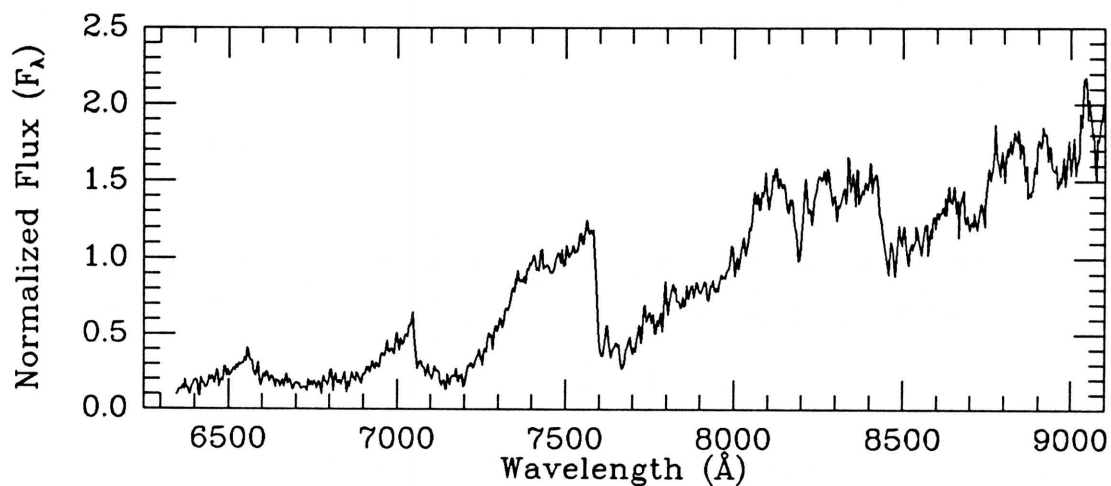


Coordinates:  $\alpha$ (1950) = 02:29:58.4          $\delta$ (1950) = +27:53:19

Spectral Type:  M6 V

Photometry:          $I_{KC}$ = 17.58          $R_{CTI}$ = 19.30

$(V-I)_{KC}$=3.90±.37          $(R-I)_{CTI}$=1.80±.24          $(V-I)_{CTI}$=2.89±.86

Notes: Comparison to the POSS E print suggests that this object may have a proper motion of ~1.5 arcsec/yr to the north.

# CTI 031502.6+280315
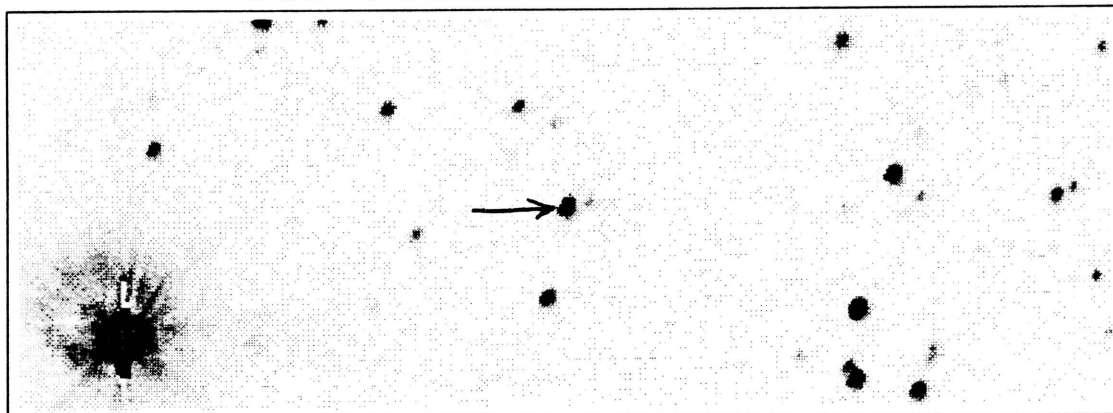


CTI FINDER CHART             I filter             Obs. (UT) 1989 Nov 03

MMT SPECTRUM         Exposure: 300 sec         Obs. (UT) 1991 Oct 17
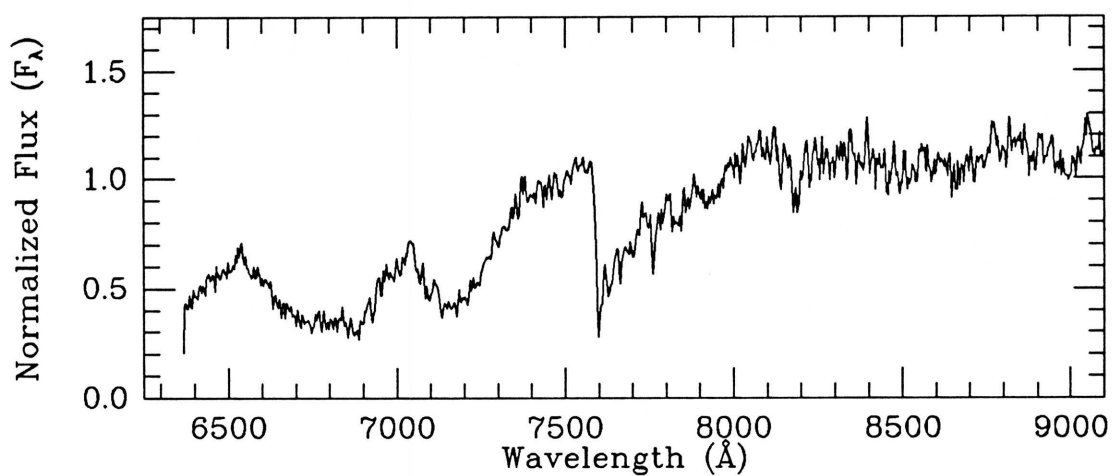


Coordinates:  $\alpha$ (1950) = 03:12:47.4      $\delta$ (1950) = +27:54:57

Spectral Type:  M3.5 V

Photometry:      $I_{KC}$ = 14.84         $R_{CTI}$ = 15.95

  $(V-I)_{KC}$=2.84±.12      $(R-I)_{CTI}$=1.06±.03      $(V-I)_{CTI}$=2.68±.02

Notes:

# CTI 032442.5+280400
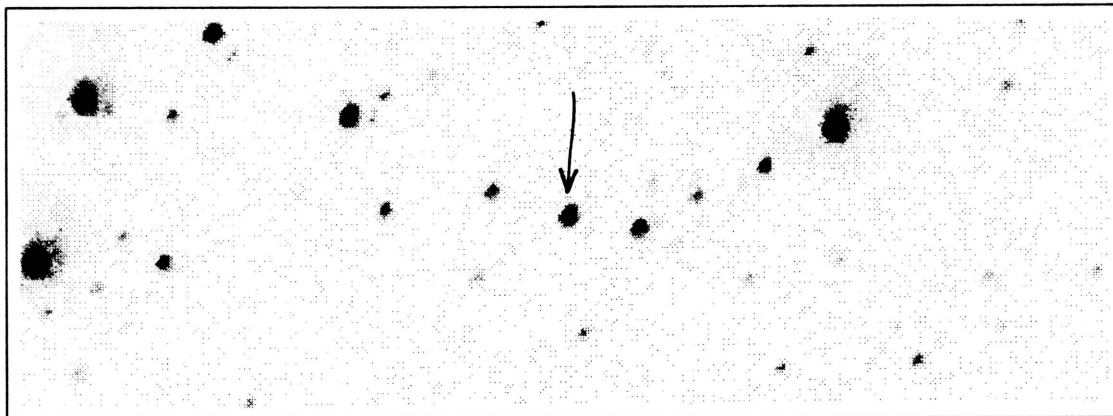


CTI FINDER CHART                    I filter                    Obs. (UT) 1989 Nov 03

MMT SPECTRUM            Exposure: 300 sec            Obs. (UT) 1991 Oct 17
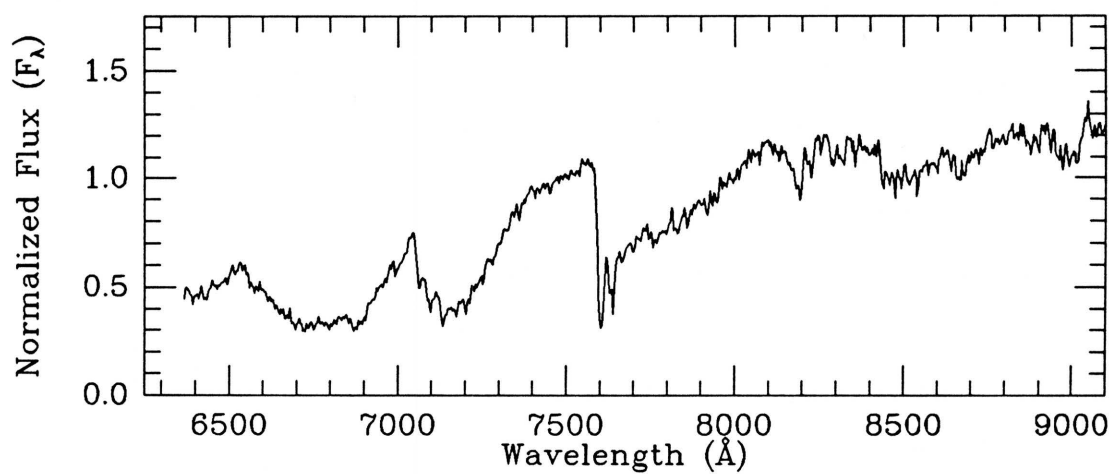


Coordinates:   $\alpha$ (1950) = 03:22:26.5        $\delta$ (1950) = +27:56:06

Spectral Type:   M4 V

Photometry:        $I_{KC}$ = 14.77          $R_{CTI}$ = 15.95

   $(V-I)_{KC}$=2.92±.13        $(R-I)_{CTI}$=1.12±.03        $(V-I)_{CTI}$=2.81±.02

Notes:

# CTI 032659.6+275912
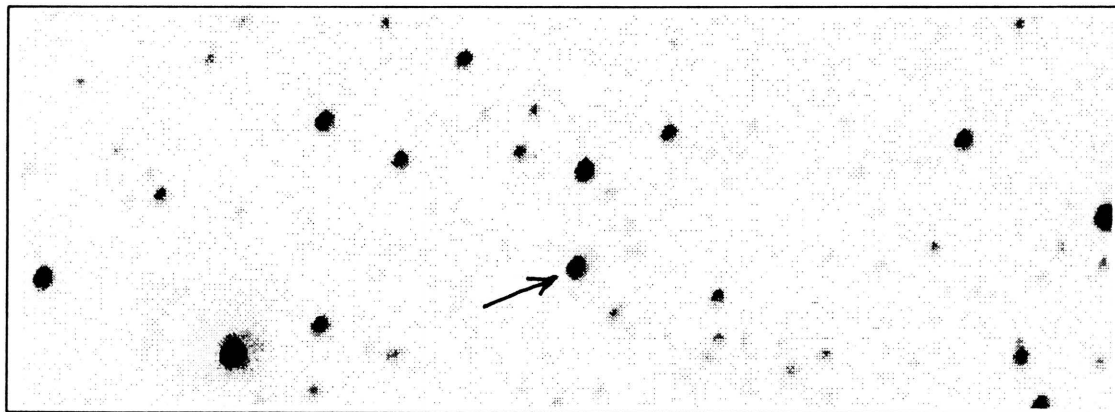


CTI FINDER CHART      I filter      Obs. (UT) 1989 Nov 03

MMT SPECTRUM      Exposure: 300 sec      Obs. (UT) 1991 Oct 17
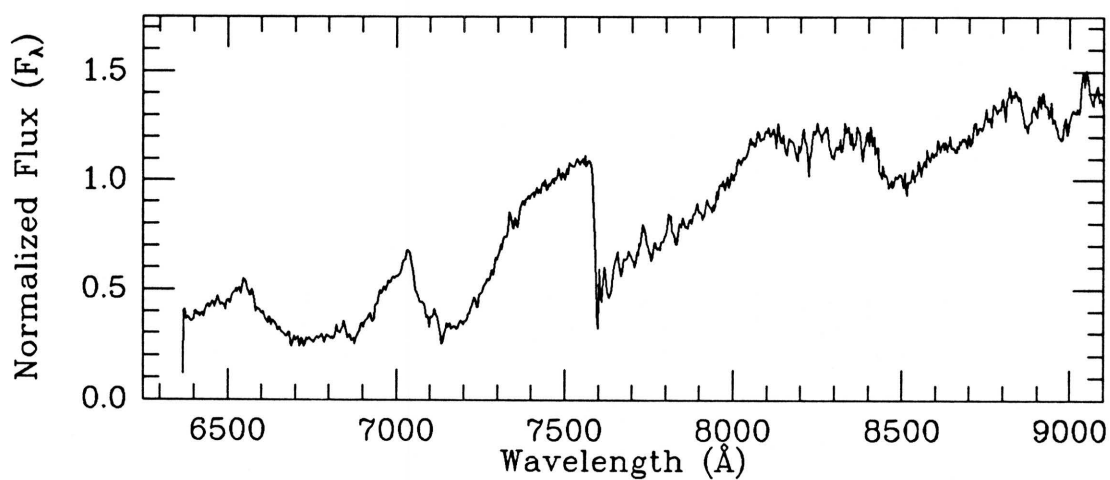


Coordinates:  $\alpha$ (1950) = 03:24:43.5      $\delta$ (1950) = +27:51:24

Spectral Type:  M4.5 V

Photometry:      $I_{KC}$ = 14.25      $R_{CTI}$ = 15.67

$(V-I)_{KC}$=3.24±.13      $(R-I)_{CTI}$=1.34±.03      $(V-I)_{CTI}$=3.19±.02

Notes:

# CTI 034036.8+280248

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Nov 22



Coordinates:  $\alpha$ (1950) = 03:38:19.7          $\delta$ (1950) = +27:55:35

Spectral Type:  M6 V

Photometry:          $I_{KC}$ = 17.88          $R_{CTI}$ = 19.96

 $(V-I)_{KC}$=4.43±.61          $(R-I)_{CTI}$=2.17±.41          $(V-I)_{CTI}$=unknown

Notes:

# CTI 034607.4+280109
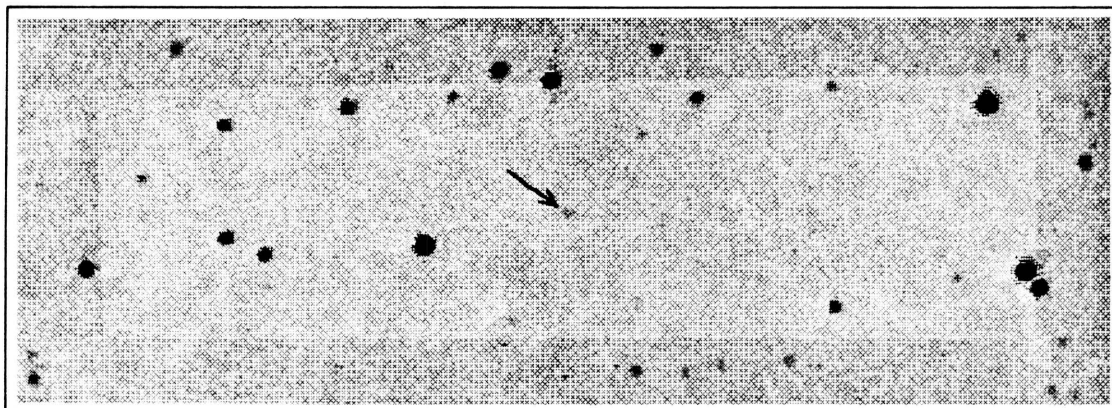


CTI FINDER CHART          V filter          Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 2400 sec          Obs. (UT) 1990 Jan 20
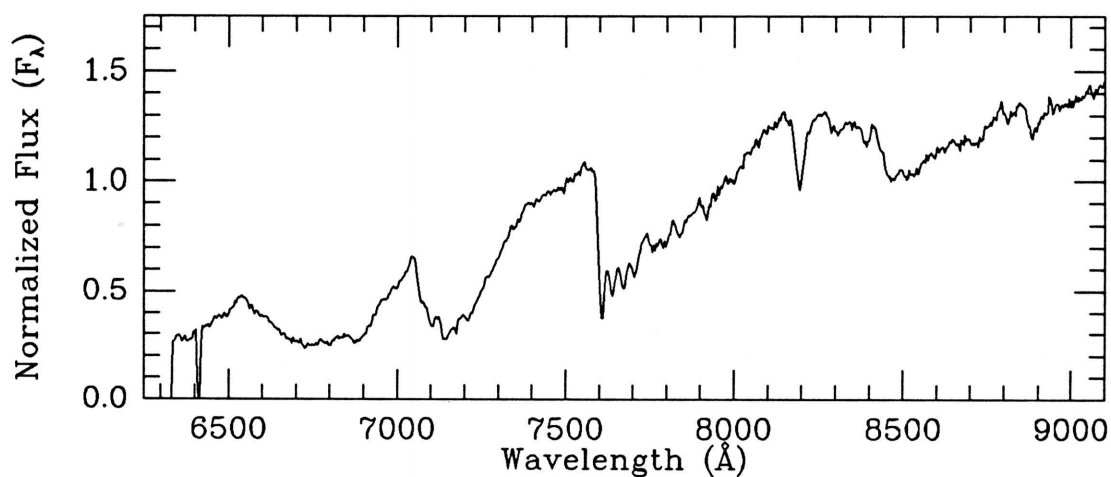


Coordinates:  $\alpha$ (1950) = 03:43:50.0          $\delta$ (1950) = +27:54:11

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = 15.71          $R_{CTI}$ = 16.97

  $(V-I)_{KC}$=3.11±.15          $(R-I)_{CTI}$=1.25±.06          $(V-I)_{CTI}$=3.03±.04

Notes:

# CTI 035750.4+280105
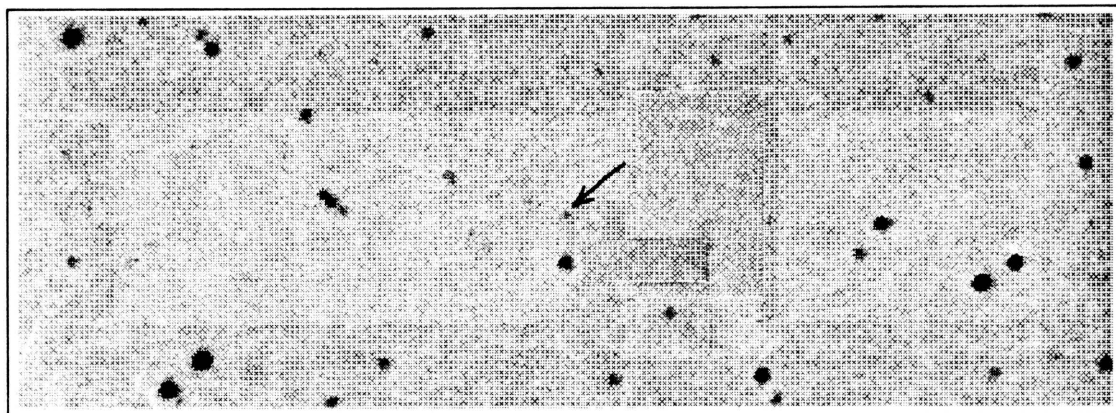


CTI FINDER CHART                    V filter              Obs. (UT) 1987 Oct 20

MMT SPECTRUM          Exposure: 2700 sec        Obs. (UT) 1990 Jan 21
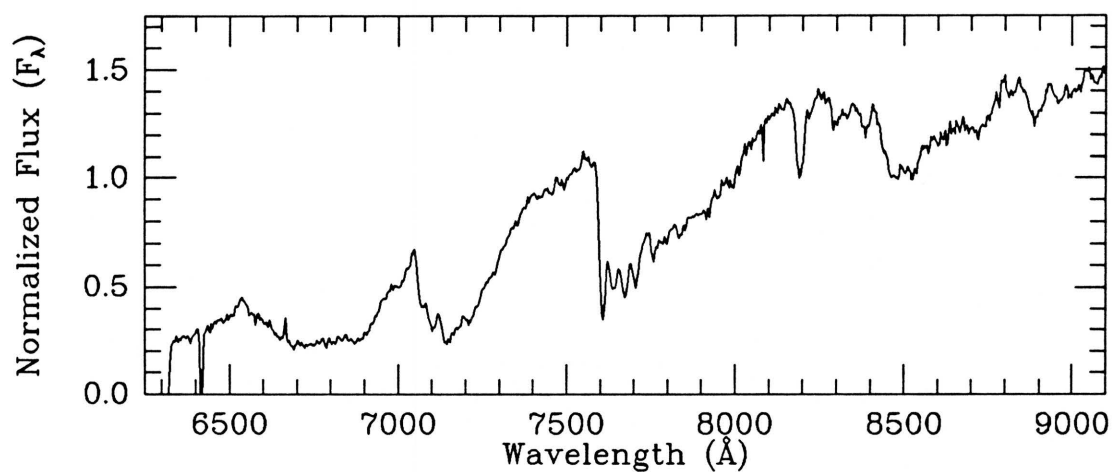


Coordinates:  $\alpha$ (1950) = 03:55:32.3        $\delta$ (1950) = +27:54:40

Spectral Type:  M5 V

Photometry:        $I_{KC}$ = 16.06        $R_{CTI}$ = 17.47

  $(V-I)_{KC}$=3.34±.17        $(R-I)_{CTI}$=1.41±.08        $(V-I)_{CTI}$=3.26±.05

Notes:

# CTI 064951.4+280442
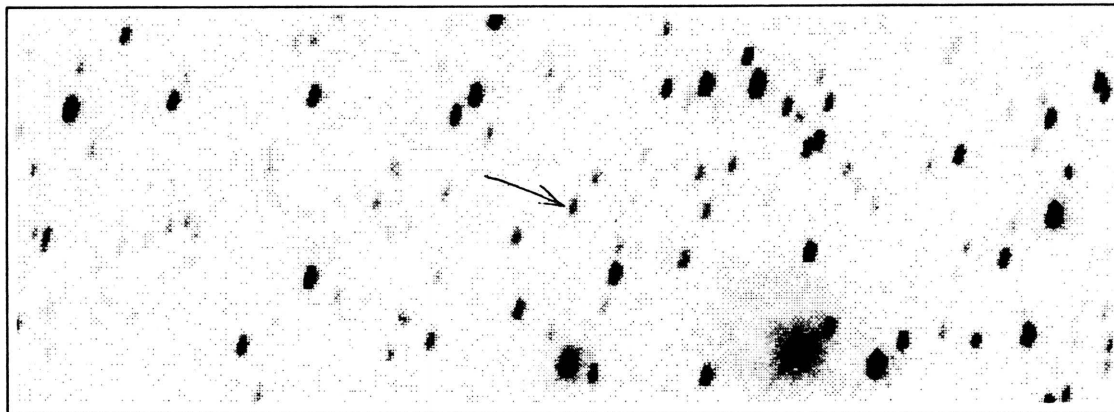


CTI FINDER CHART     I filter     Obs. (UT) 1989 Mar 07

MMT SPECTRUM     Exposure: 2700 sec     Obs. (UT) 1990 Jan 21
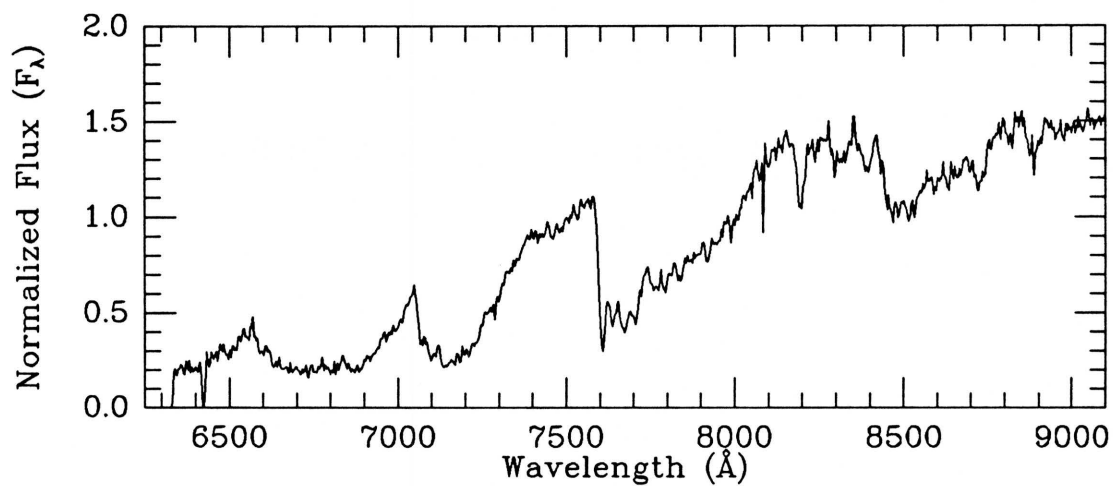


Coordinates:  $\alpha$ (1950) = 06:47:29.9     $\delta$ (1950) = +28:07:21

Spectral Type:  M5.5 V

Photometry:     $I_{KC}$ = 17.22     $R_{CTI}$ = 18.99

 $(V-I)_{KC}$=3.94±.59     $(R-I)_{CTI}$=1.83±.40     $(V-I)_{CTI}$=3.29±.40

Notes:

# CTI 065150.8+280311
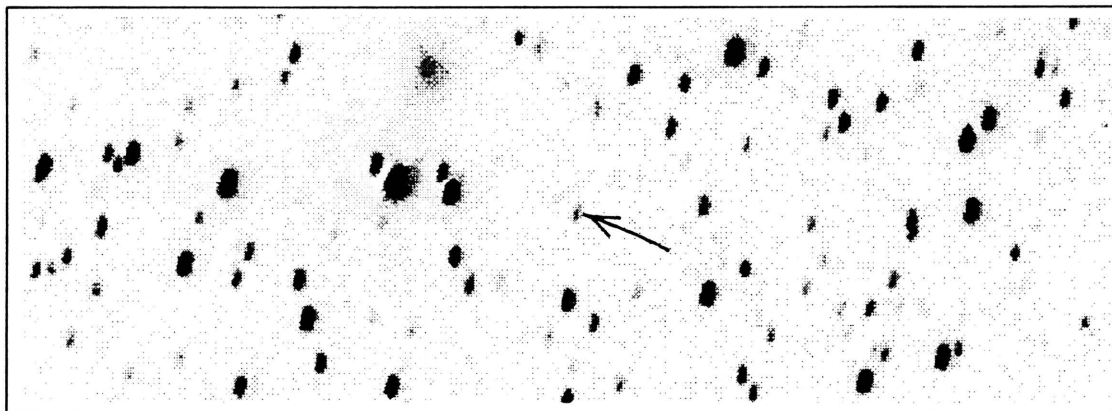


CTI FINDER CHART            I filter            Obs. (UT) 1989 Mar 07

MMT SPECTRUM        Exposure: 2700 sec        Obs. (UT) 1990 Jan 21
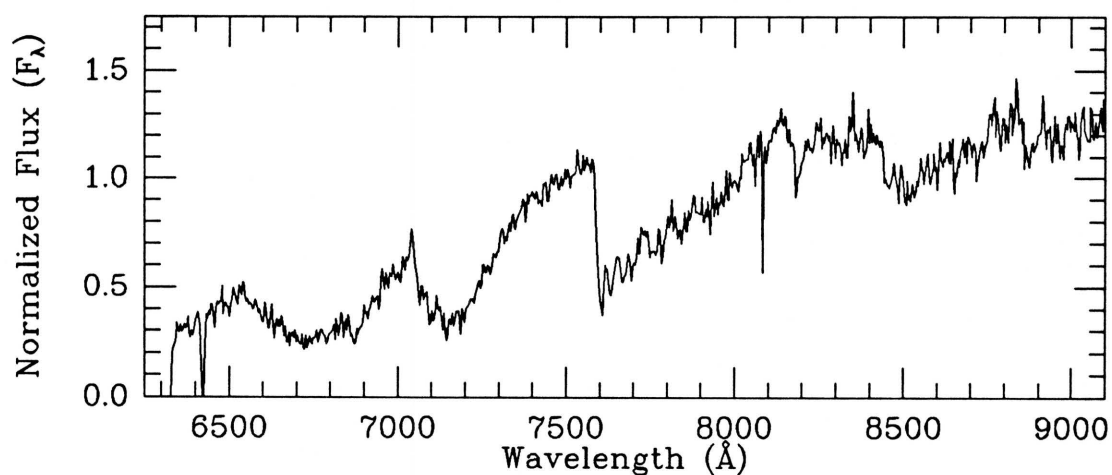


Coordinates:  $\alpha$ (1950) = 06:49:29.4        $\delta$ (1950) = +28:05:56

Spectral Type:  M5.5 V

Photometry:        $I_{KC}$ = unknown            $R_{CTI}$ = unknown

$(V-I)_{KC}$=unknown        $(R-I)_{CTI}$>1.93:        $(V-I)_{CTI}$=3.04±.07

Notes:

# CTI 065950.5+280228
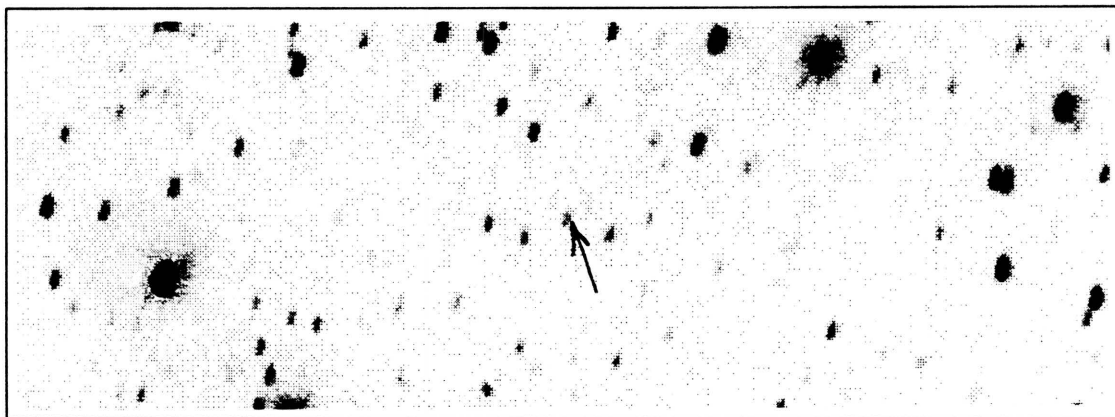


CTI FINDER CHART          I filter          Obs. (UT) 1989 Mar 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 20
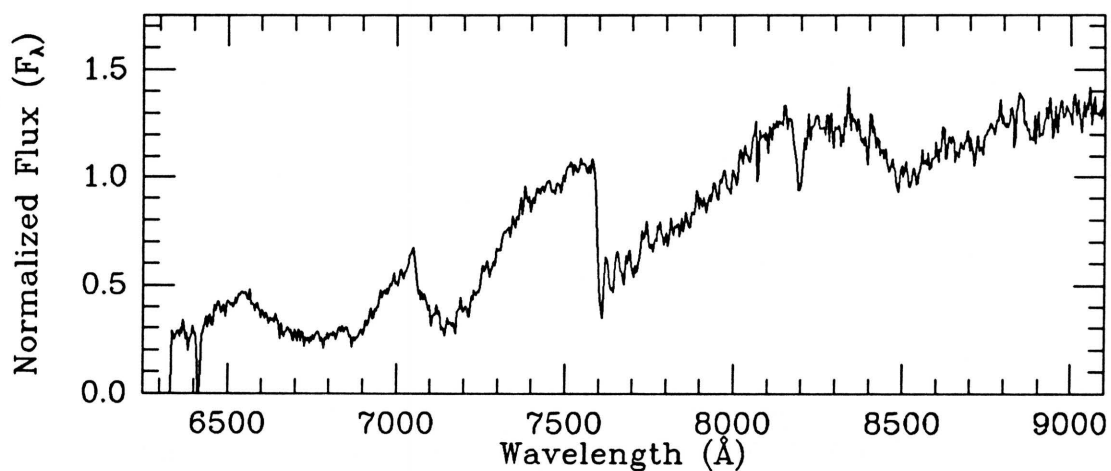


Coordinates:   $\alpha$ (1950) = 06:57:29.4      $\delta$ (1950) = +28:05:38

Spectral Type:   M4.5 V

Photometry:      $I_{KC}$ = 17.47          $R_{CTI}$ = unknown

   $(V-I)_{KC}$=unknown      $(R-I)_{CTI}$=unknown      $(V-I)_{CTI}$=2.98±.07

Notes:

# CTI 072401.3+280238
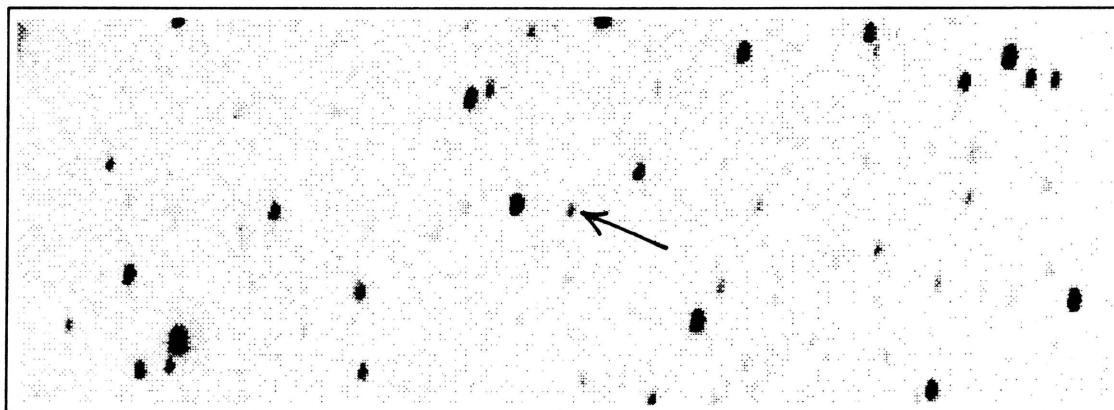


CTI FINDER CHART          I filter          Obs. (UT) 1989 Mar 07

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 Jan 21
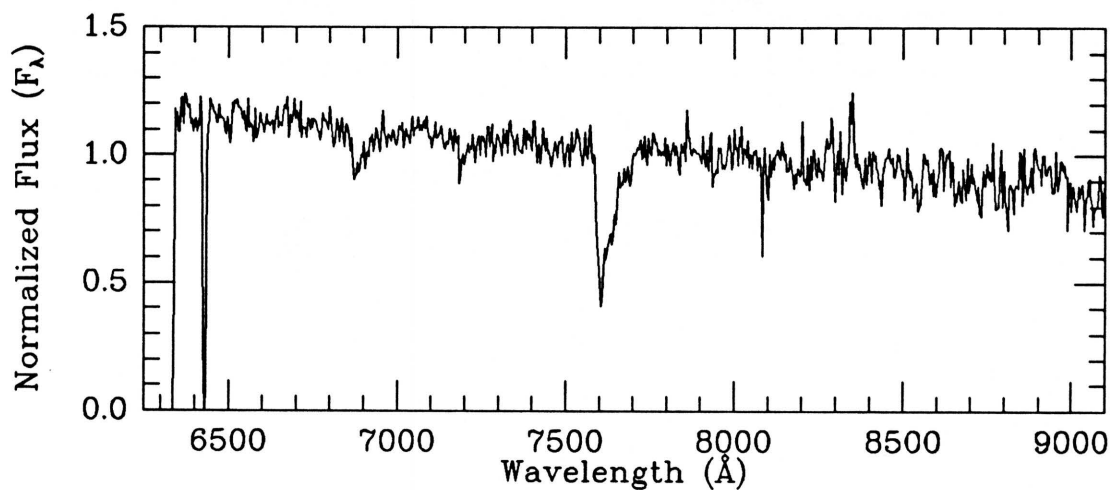


Coordinates:  α (1950) = 07:21:41.0     δ (1950) = +28:07:04
Spectral Type:  <K5 V
Photometry:     $I_{KC}$ = unknown          $R_{CTI}$ = unknown
  $(V-I)_{KC}$=unknown     $(R-I)_{CTI}$>2.12:     $(V-I)_{CTI}$=0.82±.02
Notes:

# CTI 075013.2+280613
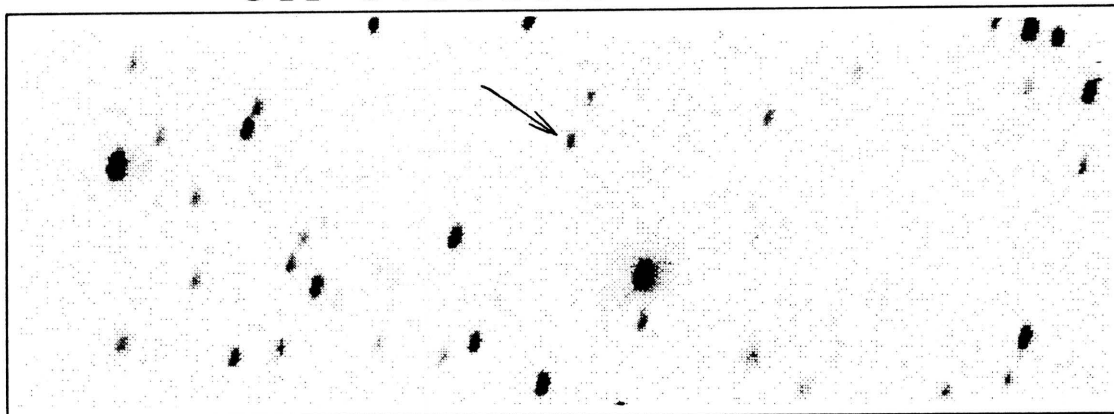


CTI FINDER CHART          I filter          Obs. (UT) 1989 Mar 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 21
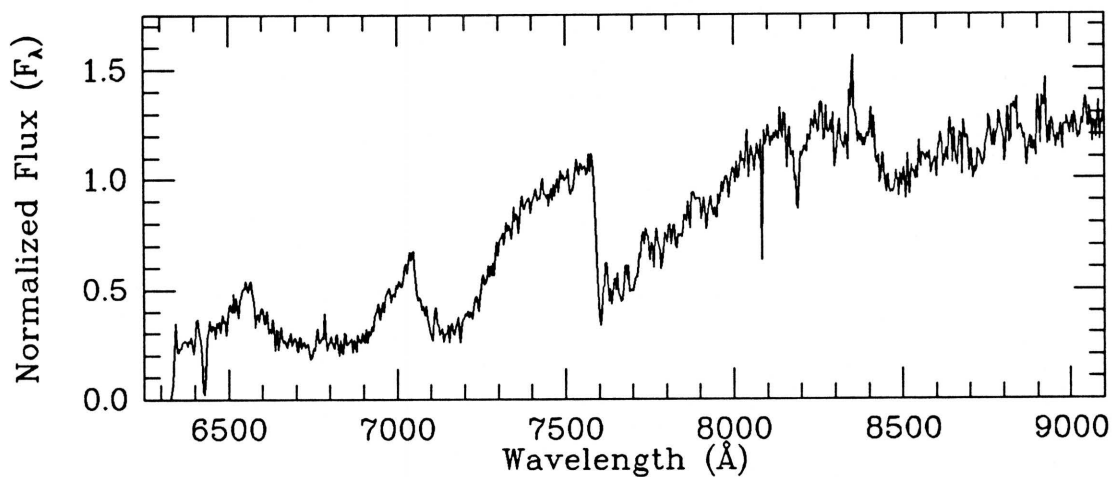


Coordinates:  $\alpha$ (1950) = 07:47:54.1          $\delta$ (1950) = +28:11:57

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = 17.32          $R_{CTI}$ = 19.00

  $(V-I)_{KC}$=3.81±.40          $(R-I)_{CTI}$=1.74±.26          $(V-I)_{CTI}$=2.96±.20

Notes:

# CTI 075723.2+280533
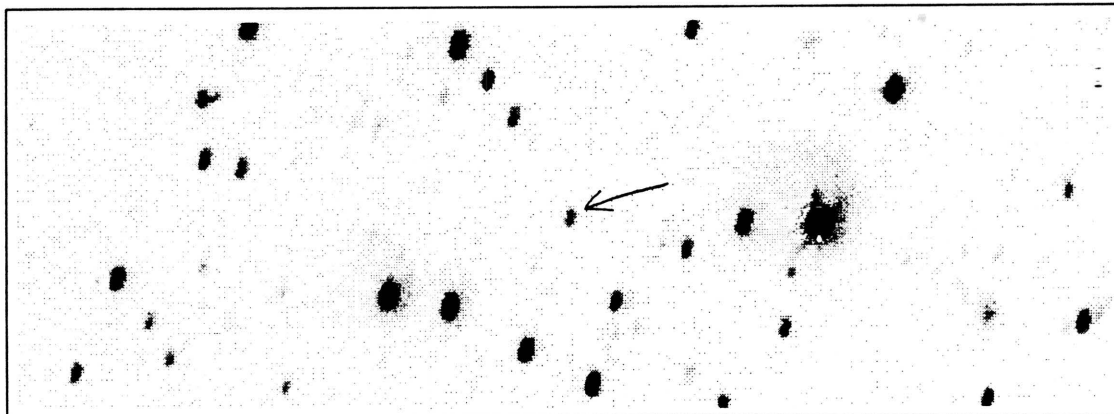


CTI FINDER CHART          I filter          Obs. (UT) 1989 Mar 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 20
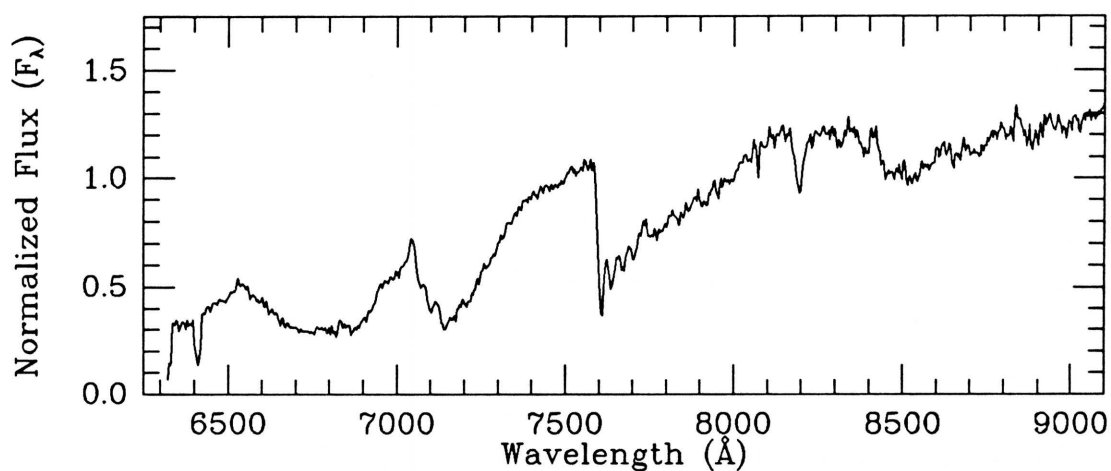


Coordinates:  $\alpha$ (1950) = 07:55:04.5          $\delta$ (1950) = +28:11:38

Spectral Type:  M4 V

Photometry:          $I_{KC}$ = 16.66          $R_{CTI}$ = 18.98

  $(V-I)_{KC}$=4.68±.28          $(R-I)_{CTI}$=2.35±.16          $(V-I)_{CTI}$=3.01±.16

Notes:

# CTI 081722.3+280138
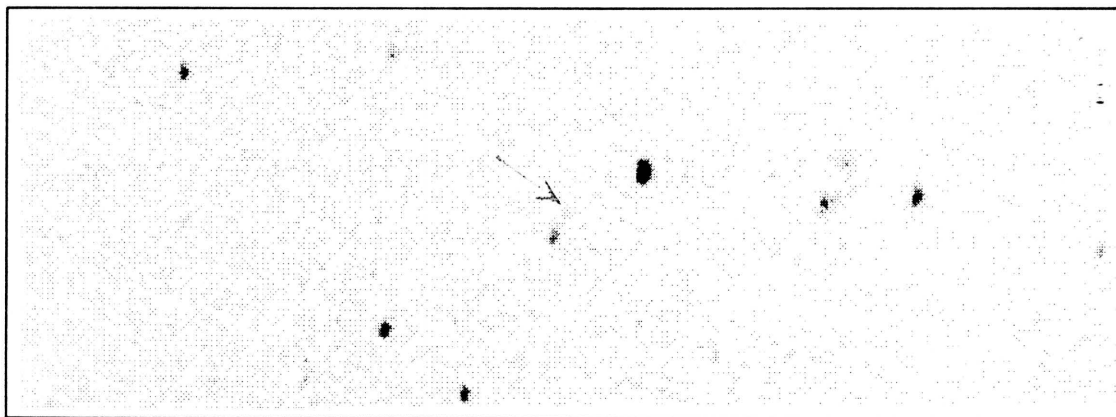


CTI FINDER CHART          I filter          Obs. (UT) 1989 Jan 31

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Nov 22
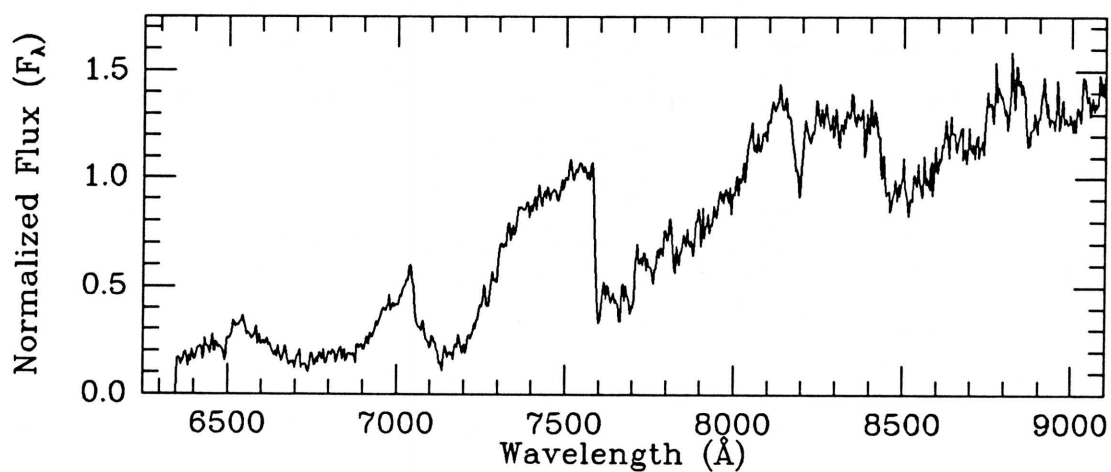


Coordinates:  $\alpha$ (1950) = 08:15:04.9          $\delta$ (1950) = +28:08:39

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 17.25          $R_{CTI}$ = 18.97

$(V-I)_{KC}$=3.87±.24          $(R-I)_{CTI}$=1.78±.14          $(V-I)_{CTI}$=3.18±.14

Notes: Comparison to POSS E print suggests small (~0.2 arcsec/yr) proper motion to the SE.

# CTI 084106.0+280016
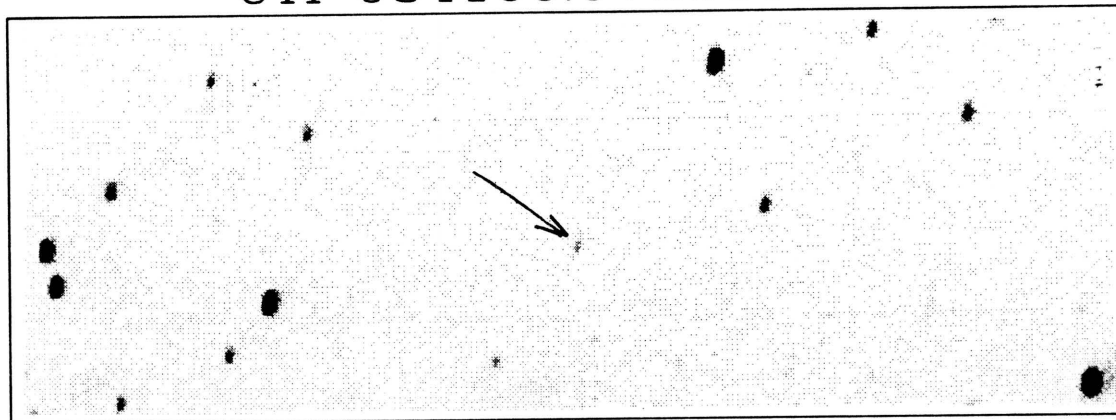


CTI FINDER CHART          I filter          Obs. (UT) 1989 Jan 31

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Nov 22
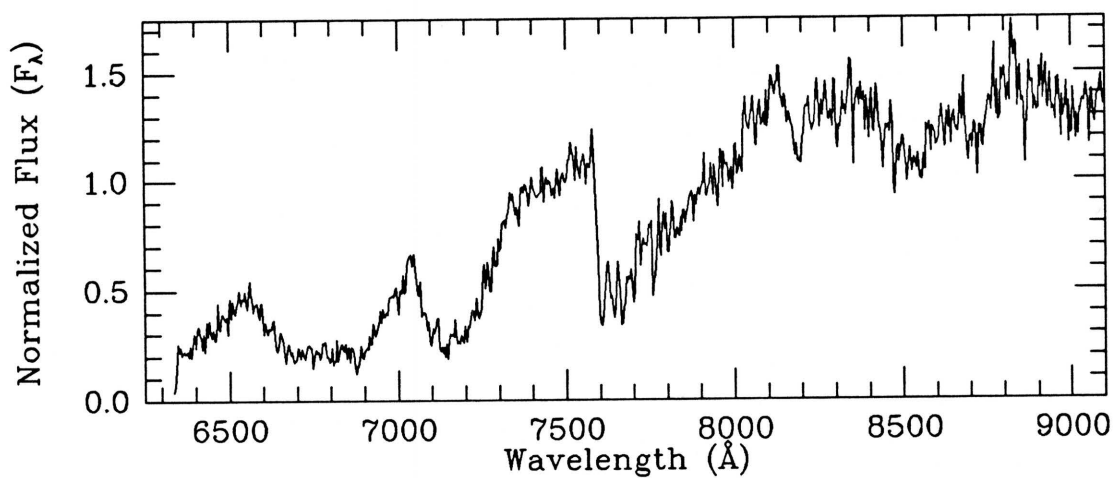


Coordinates:  $\alpha$ (1950) = 08:38:50.2      $\delta$ (1950) = +28:08:19

Spectral Type:  M5.5 V

Photometry:      $I_{KC}$ = 17.88          $R_{CTI}$ = 19.61

  $(V-I)_{KC}$=3.93±.41      $(R-I)_{CTI}$=1.82±.27      $(V-I)_{CTI}$=2.79±.29

Notes:

# CTI 090120.6+280439
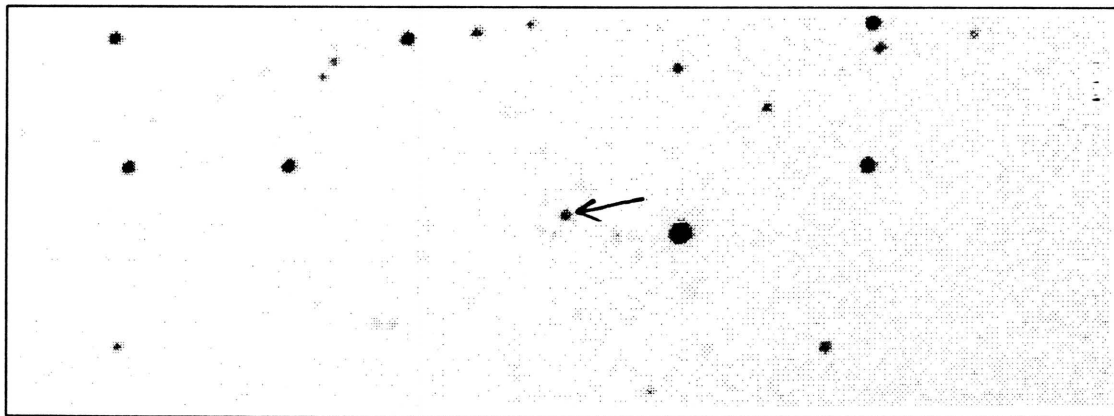


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

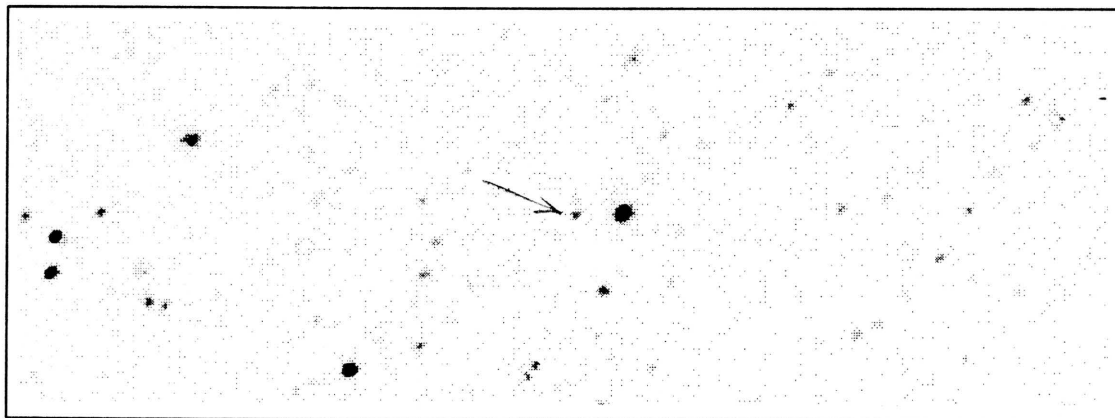MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 May 04
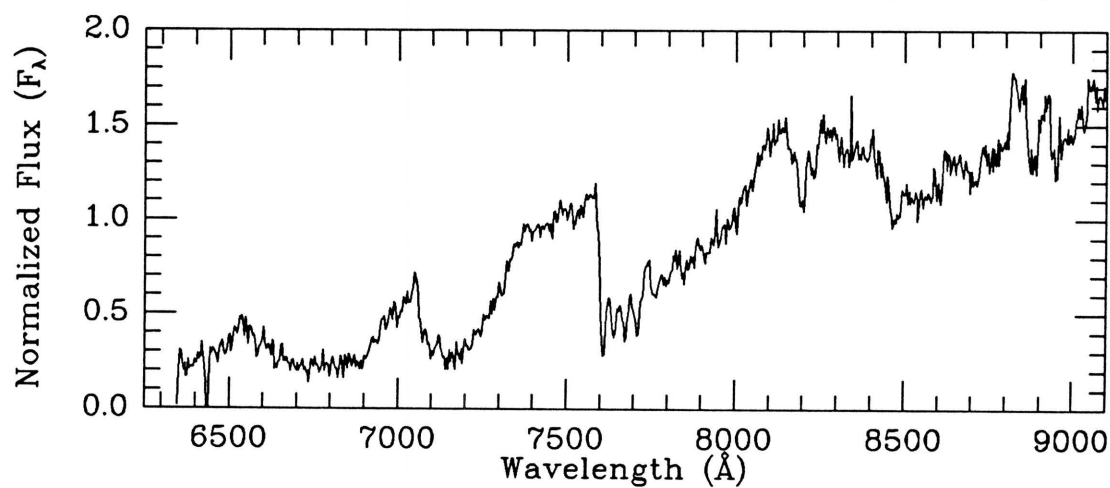


Coordinates:  $\alpha$ (1950) = 08:59:06.4          $\delta$ (1950) = +28:13:31

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 16.86          $R_{CTI}$ = 18.50

   $(V-I)_{KC}$=3.73±.16          $(R-I)_{CTI}$=1.68±.06          $(V-I)_{CTI}$=3.51±.07

Notes:

# CTI 090928.9+280323
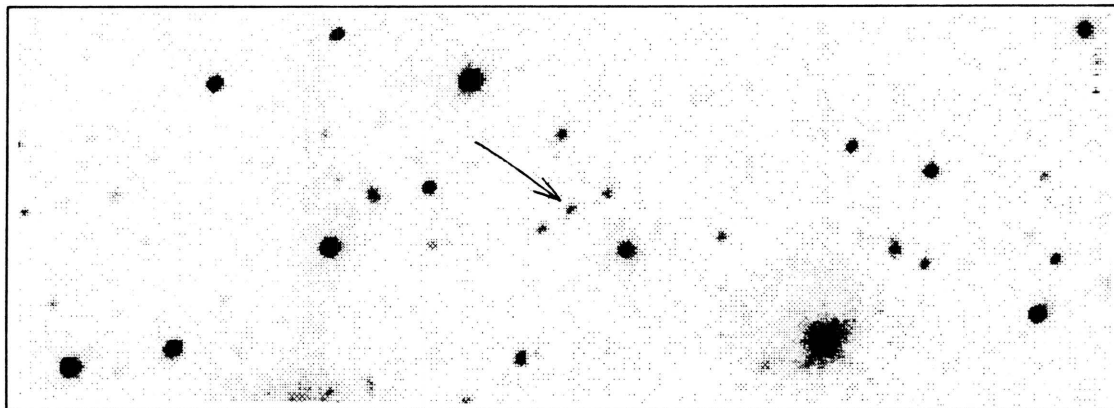


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 20
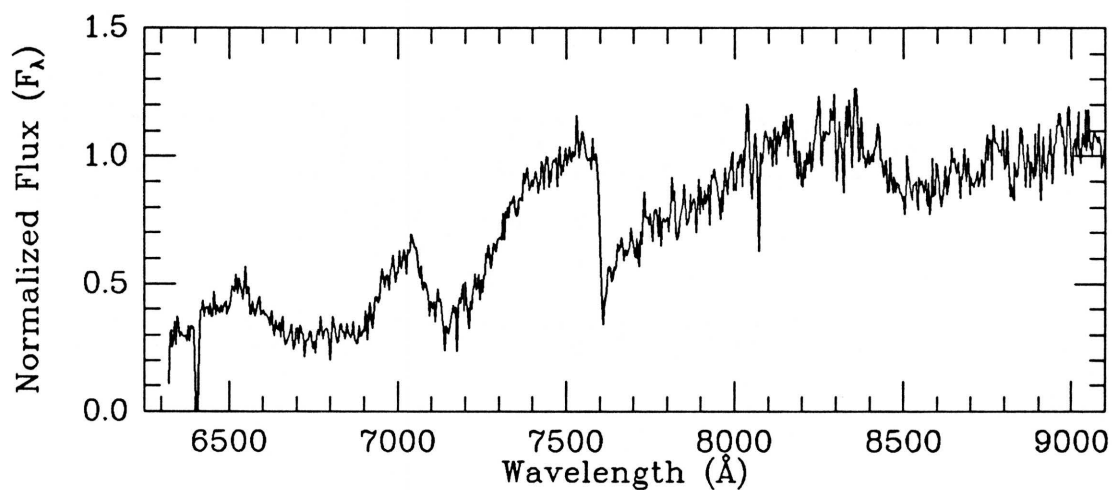


Coordinates:  $\alpha$ (1950) = 09:07:15.4          $\delta$ (1950) = +28:12:34

Spectral Type:  M3.5 V

Photometry:          $I_{KC}$ = 18.20          $R_{CTI}$ = 19.74

(V−I)$_{KC}$=3.67±.84          (R−I)$_{CTI}$=1.64±.58          (V−I)$_{CTI}$=2.39±.09

Notes:

# CTI 091716.8+280532
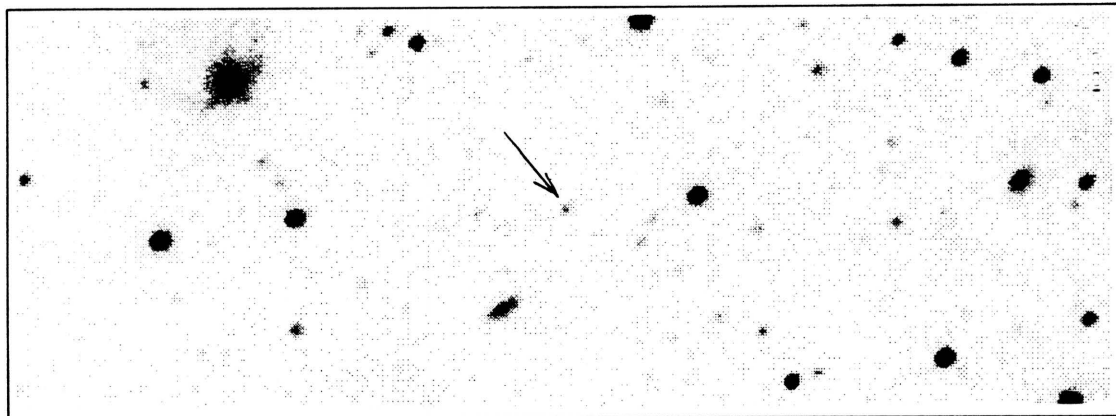


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Jan 21
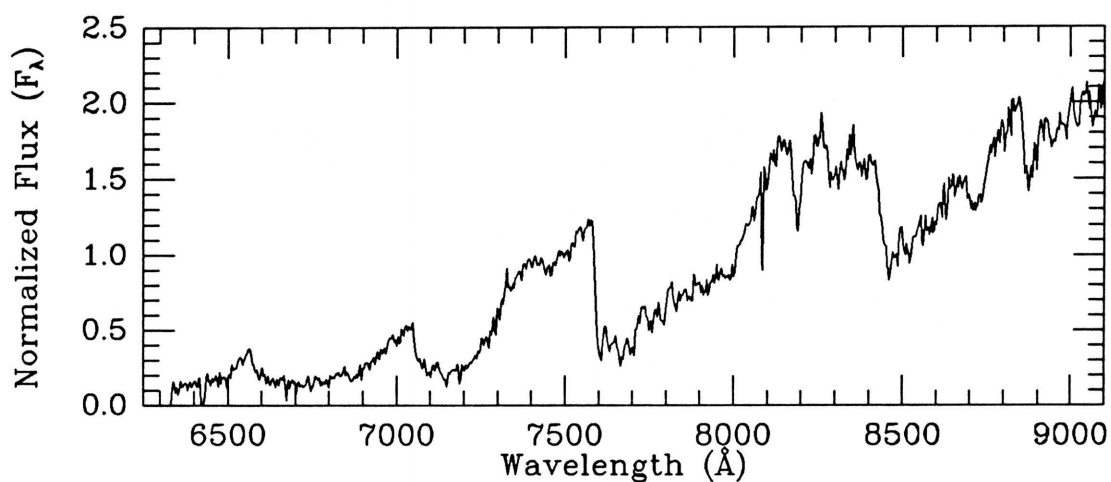


Coordinates:  $\alpha$ (1950) = 09:15:03.9      $\delta$ (1950) = +28:15:00

Spectral Type:  M6 V

Photometry:      $I_{KC}$ = 17.79          $R_{CTI}$ = 19.37

$(V-I)_{KC}$=3.71±1.04      $(R-I)_{CTI}$=1.67±.72      $(V-I)_{CTI}$=2.58±1.01

Notes: Comparison to POSS E prints suggests small (~0.2 arcsec/yr) proper motion to the north.

# CTI 092053.7+280101
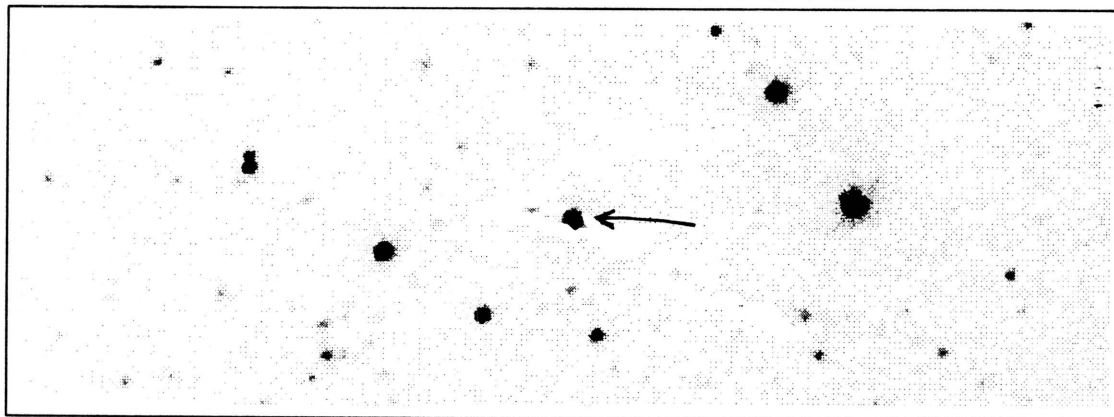


CTI FINDER CHART         Clear filter         Obs. (UT) 1989 Apr 07

MMT SPECTRUM         Exposure: 600 sec         Obs. (UT) 1991 Mar 14
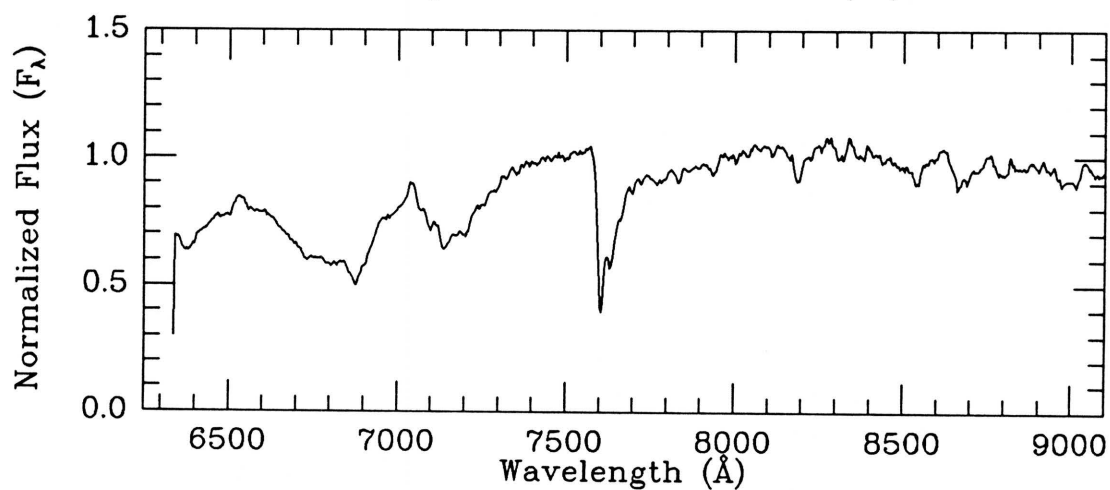


Coordinates:  $\alpha$ (1950) = 09:18:41.2     $\delta$ (1950) = +28:10:36

Spectral Type:  M1.5 V

Photometry:     $I_{KC}$ = 13.60         $R_{CTI}$ = 14.22

  $(V-I)_{KC}$=2.05±.10     $(R-I)_{CTI}$=0.51±.01     $(V-I)_{CTI}$=1.94±.01

Notes:

# CTI 092423.0+280044
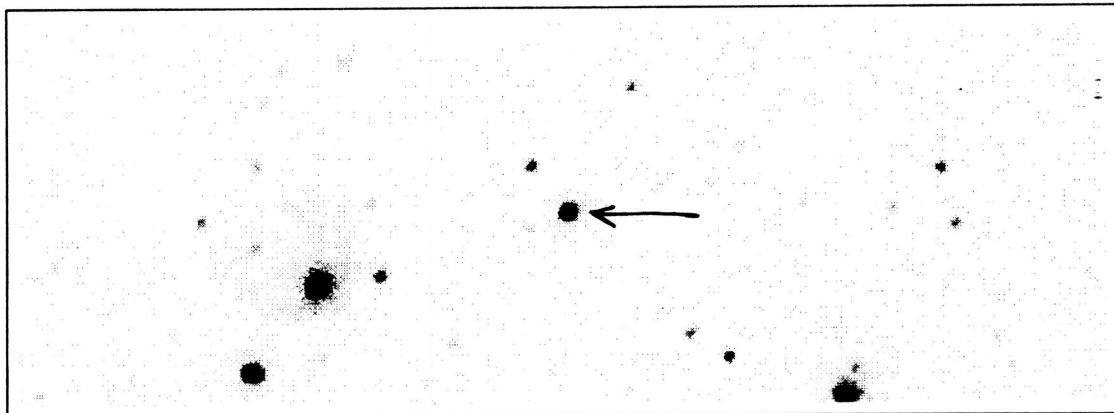


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1991 Mar 14
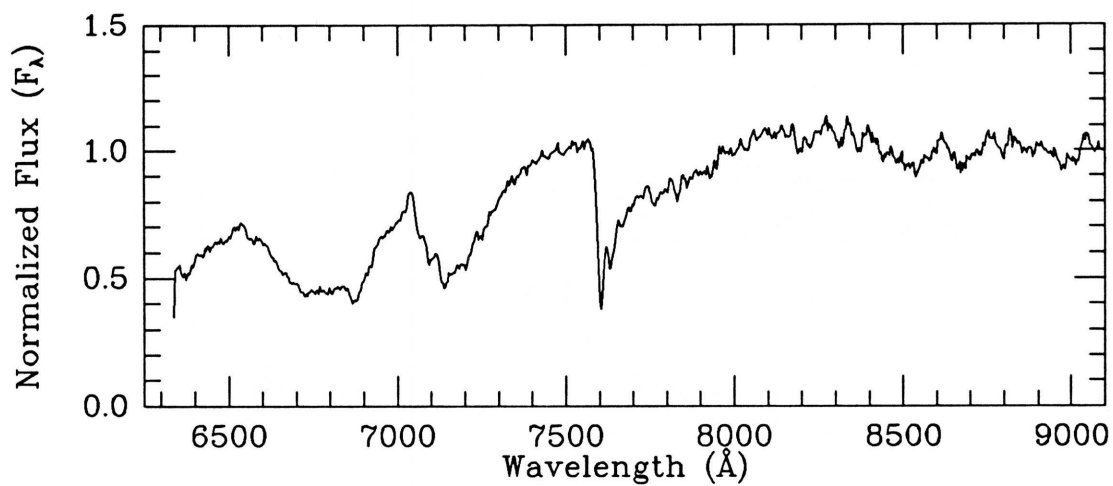


Coordinates:  $\alpha$ (1950) = 09:22:10.8        $\delta$ (1950) = +28:10:27

Spectral Type:  M3 V

Photometry:        $I_{KC}$ = 13.93          $R_{CTI}$ = 14.78

 $(V-I)_{KC}$=2.40±.11        $(R-I)_{CTI}$=0.75±.01        $(V-I)_{CTI}$=2.21±.01

Notes:

# CTI 092539.9+280018
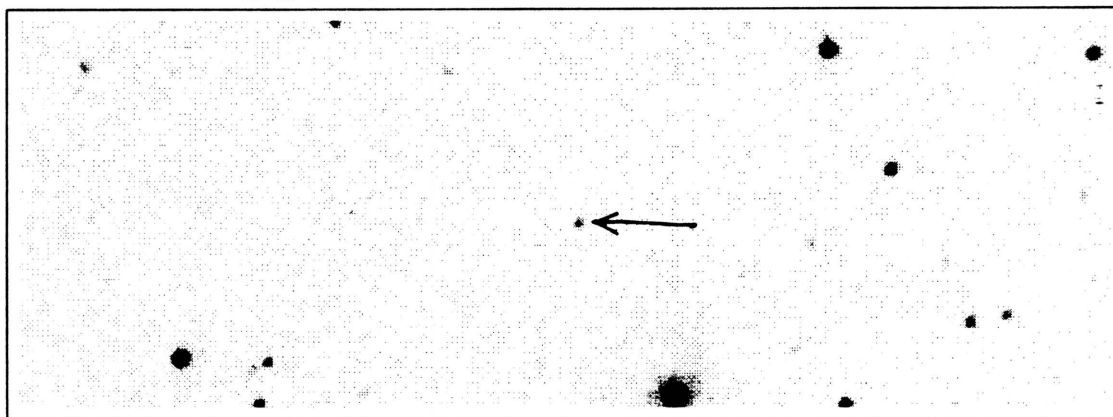


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 20
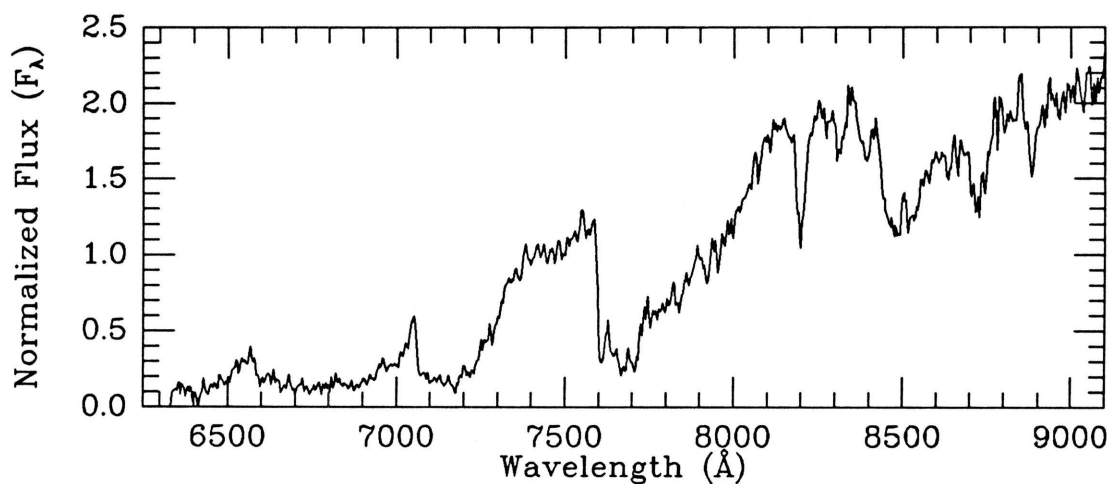


Coordinates:  $\alpha$ (1950) = 09:23:27.8      $\delta$ (1950) = +28:10:03

Spectral Type:  M6.5 V

Photometry:      $I_{KC}$ = 17.47          $R_{CTI}$ = 19.45

  $(V-I)_{KC}$=4.25±.79      $(R-I)_{CTI}$=2.05±.54      $(V-I)_{CTI}$=unknown

Notes: Object not found on POSS E plate, either because of large proper motion or because of faintness.

# CTI 093631.3+280237
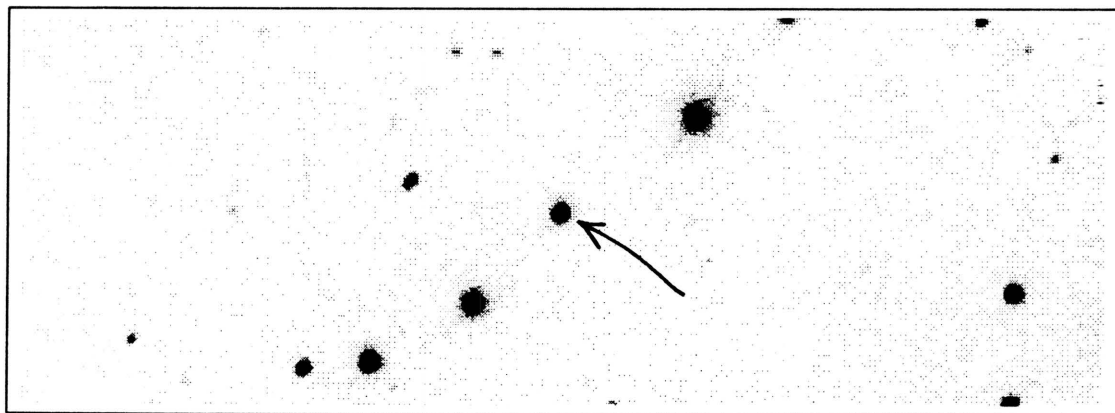


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 600 sec          Obs. (UT) 1991 Mar 14
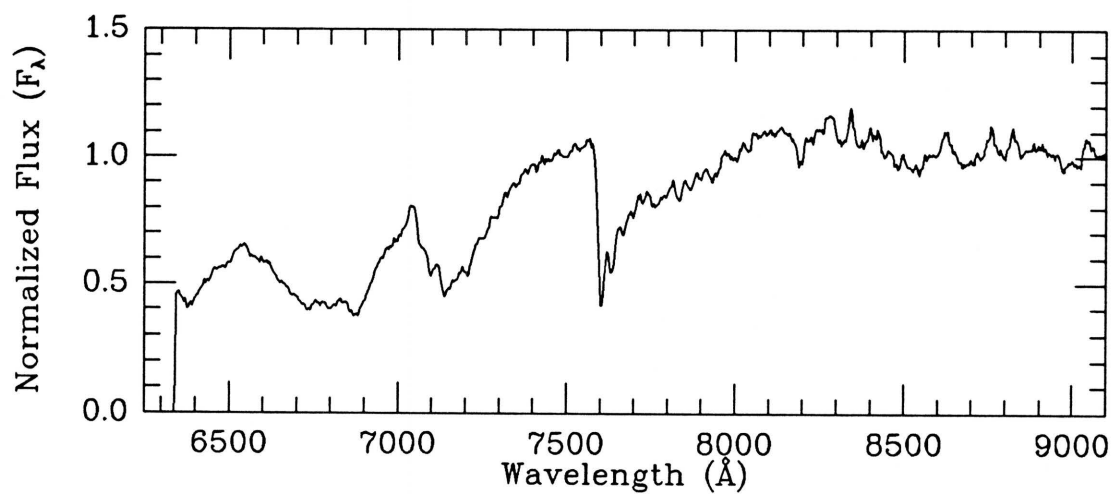


Coordinates:  $\alpha$ (1950) = 09:34:20.2          $\delta$ (1950) = +28:12:44

Spectral Type:  M3 V

Photometry:          $I_{KC}$ = 13.53          $R_{CTI}$ = 14.49

 $(V-I)_{KC}$=2.52±.11          $(R-I)_{CTI}$=0.84±.01          $(V-I)_{CTI}$=2.37±0.01

Notes:

# CTI 100219.5+280036
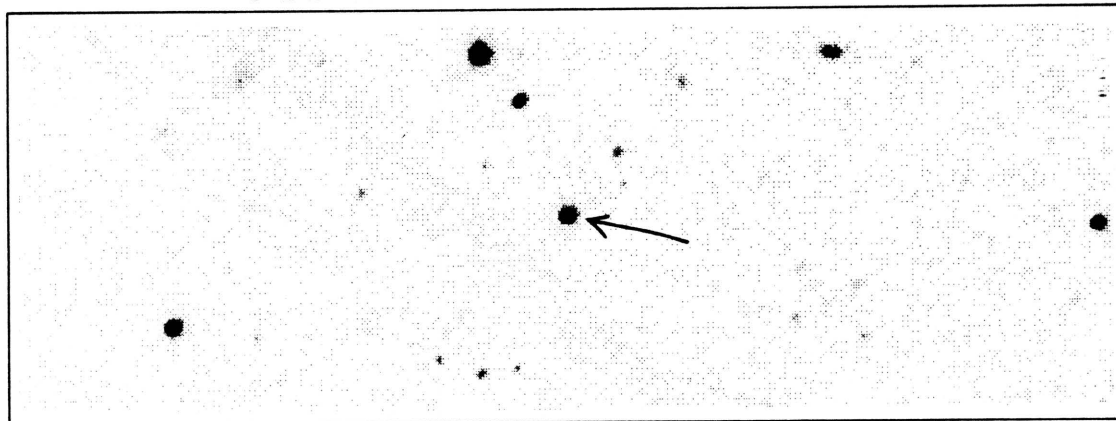


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 600 sec          Obs. (UT) 1991 Mar 14
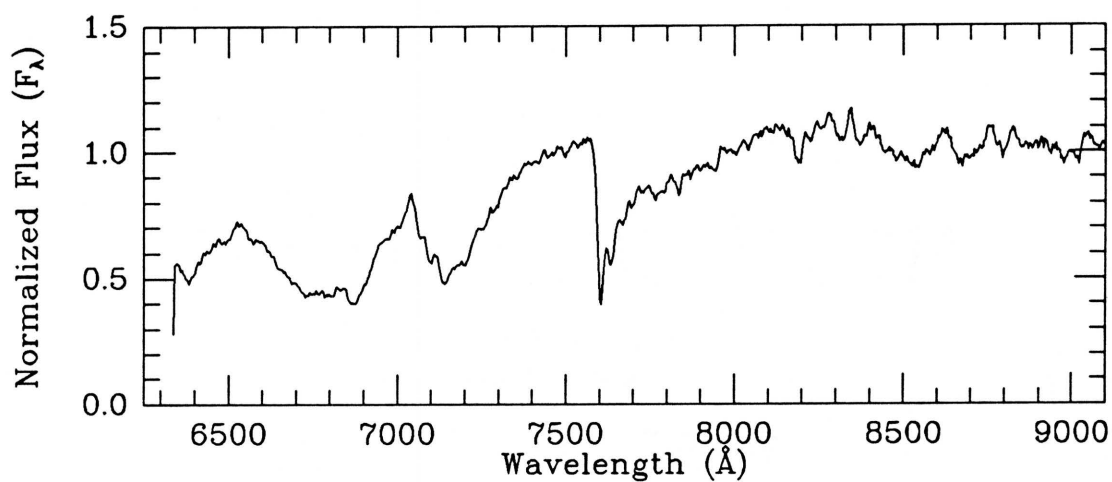


Coordinates:  $\alpha$ (1950) = 10:00:11.0          $\delta$ (1950) = +28:11:29

Spectral Type:  M3 V

Photometry:          $I_{KC}$ = 14.04          $R_{CTI}$ = 14.91

$(V-I)_{KC}$=2.44±.11          $(R-I)_{CTI}$=0.78±.01          $(V-I)_{CTI}$=2.28±.01

Notes:

# CTI 102840.0+280331
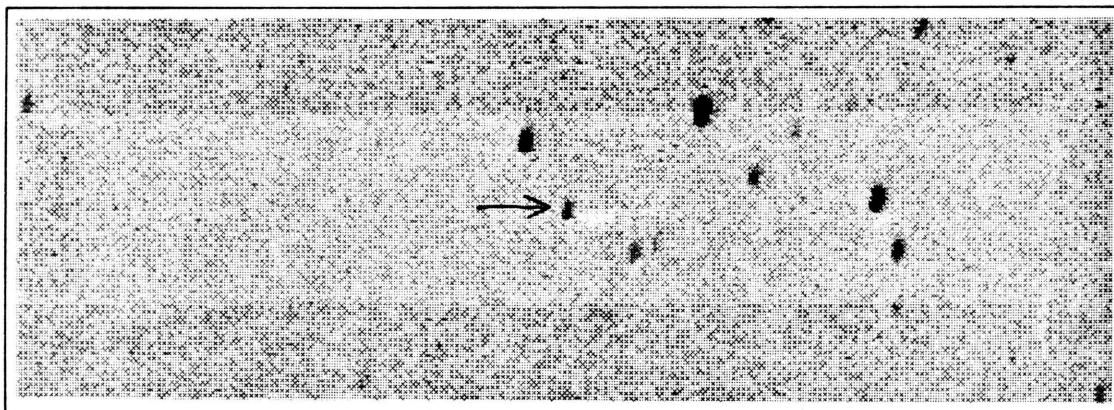


CTI FINDER CHART             I filter          Obs. (UT) 1988 Mar 18

MMT SPECTRUM        Exposure: 2700 sec       Obs. (UT) 1990 Jan 21
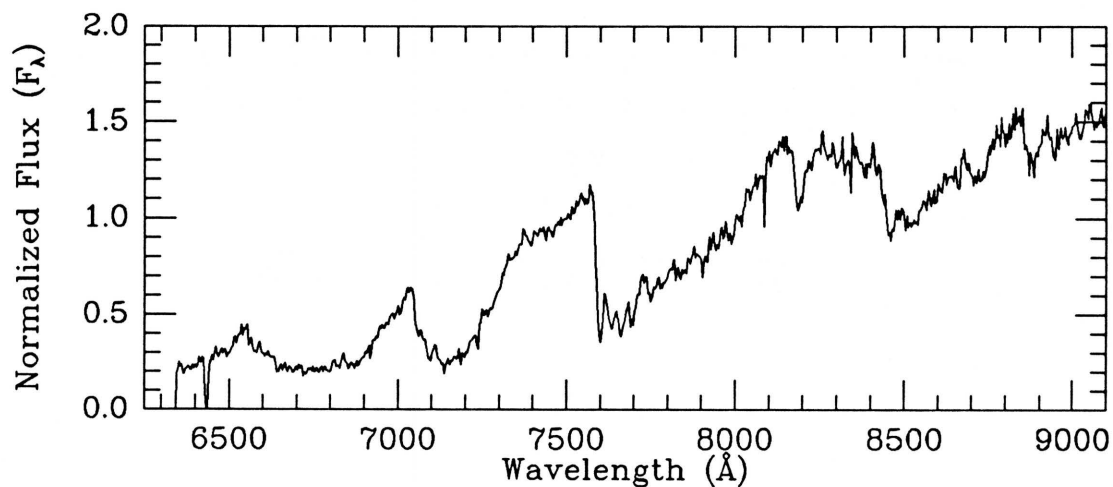


Coordinates:  $\alpha$ (1950) = 10:26:34.2      $\delta$ (1950) = +28:15:03

Spectral Type:  M5.5 V

Photometry:        $I_{KC}$ = 17.03          $R_{CTI}$ = 18.50

   $(V-I)_{KC}$=3.50±.20      $(R-I)_{CTI}$=1.52±.11       $(V-I)_{CTI}$=3.24±.10

Notes: Comparison to POSS E print suggests a proper motion of ~0.2 arcsec/yr to the west.

# CTI 103000.3+280432
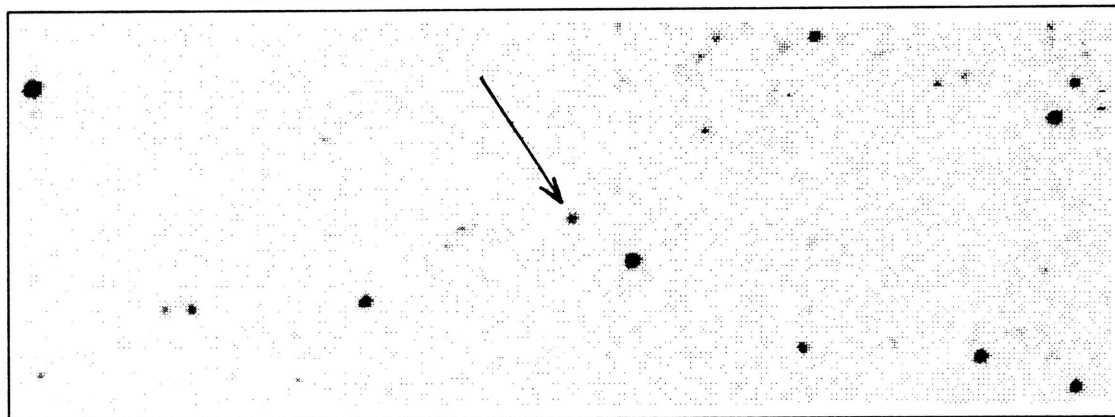
MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1991 Mar 14
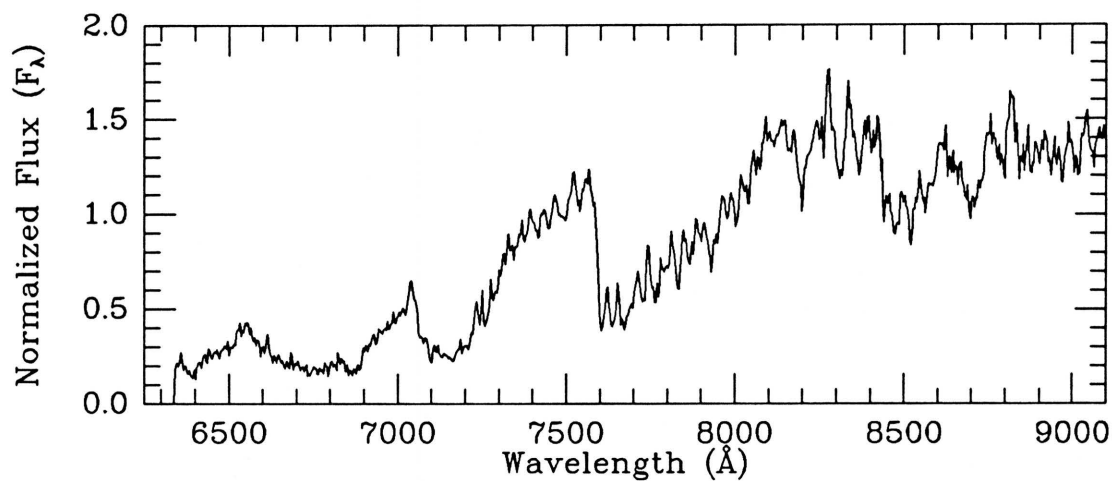


Coordinates:  $\alpha$ (1950) = 10:27:54.6          $\delta$ (1950) = +28:16:05

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 17.14          $R_{CTI}$ = 18.51

  $(V-I)_{KC}$=3.35±.18          $(R-I)_{CTI}$=1.42±.09          $(V-I)_{CTI}$=3.52±.07

Notes:

# CTI 105201.6+280448
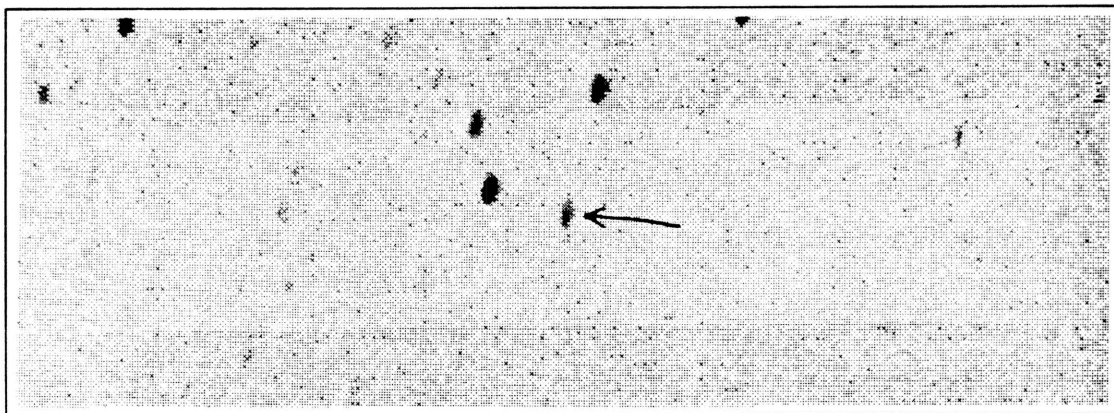


CTI FINDER CHART              I filter              Obs. (UT) 1988 Mar 18

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Jan 21
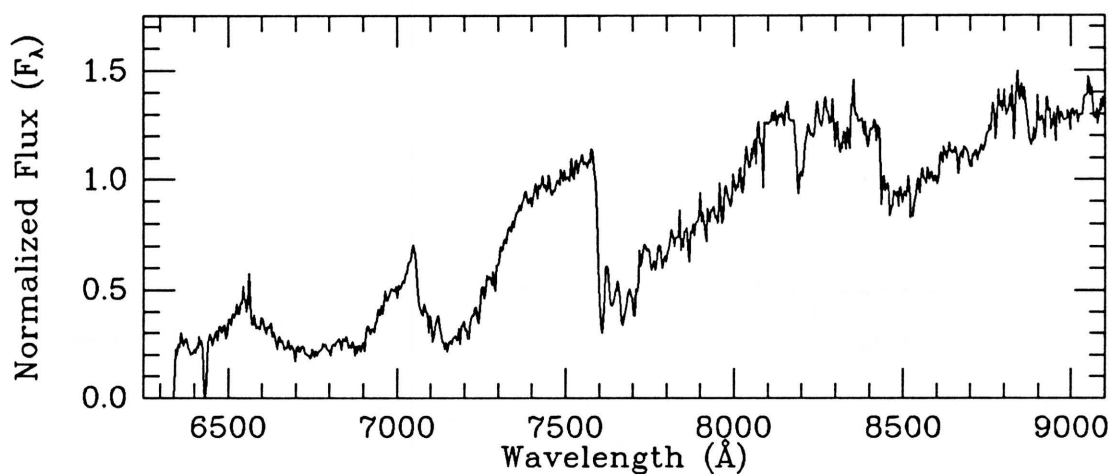


Coordinates:  $\alpha$ (1950) = 10:49:58.4        $\delta$ (1950) = +28:16:46

Spectral Type:  M5 V

Photometry:       $I_{KC}$ = 16.96          $R_{CTI}$ = 18.47

  $(V-I)_{KC}$=3.55±.21        $(R-I)_{CTI}$=1.56±.11        $(V-I)_{CTI}$=3.28±.10

Notes: On the POSS E print there are two objects near the position of the CTI star, neither of which appears on the POSS O print. A third epoch image is needed for $\mu$ determination.

# CTI 105707.5+280223
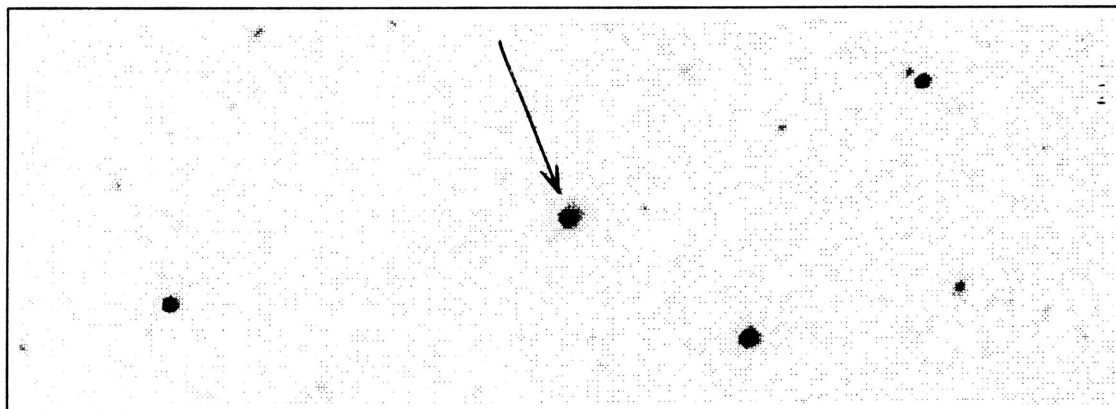


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 600 sec          Obs. (UT) 1991 Mar 14
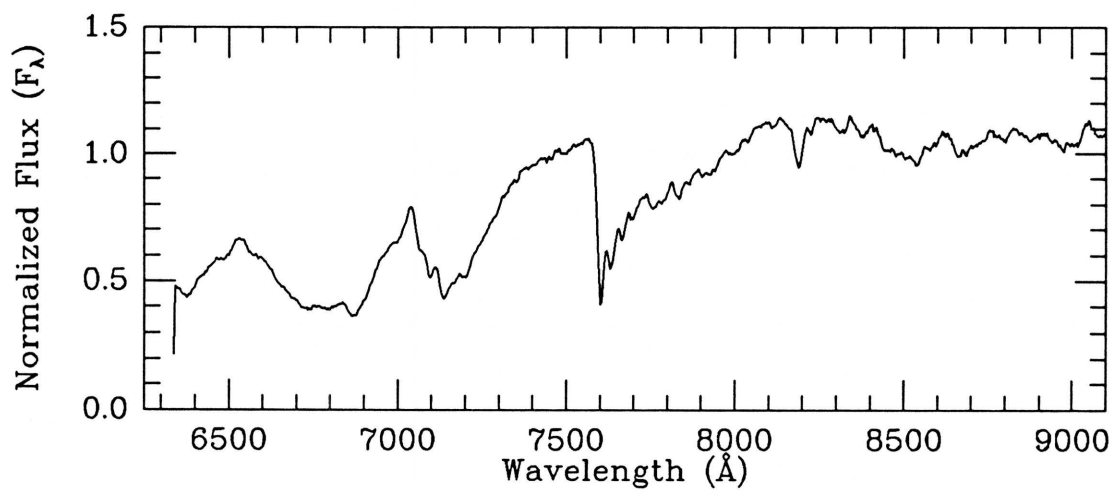


Coordinates:   $\alpha$ (1950) = 10:55:04.8        $\delta$ (1950) = +28:14:26

Spectral Type:   M3 V

Photometry:        $I_{KC}$ = 13.16          $R_{CTI}$ = 14.17

   $(V-I)_{KC}$=2.58±.11        $(R-I)_{CTI}$=0.88±.01        $(V-I)_{CTI}$=2.45±.01

Notes:

# CTI 105802.4+280251
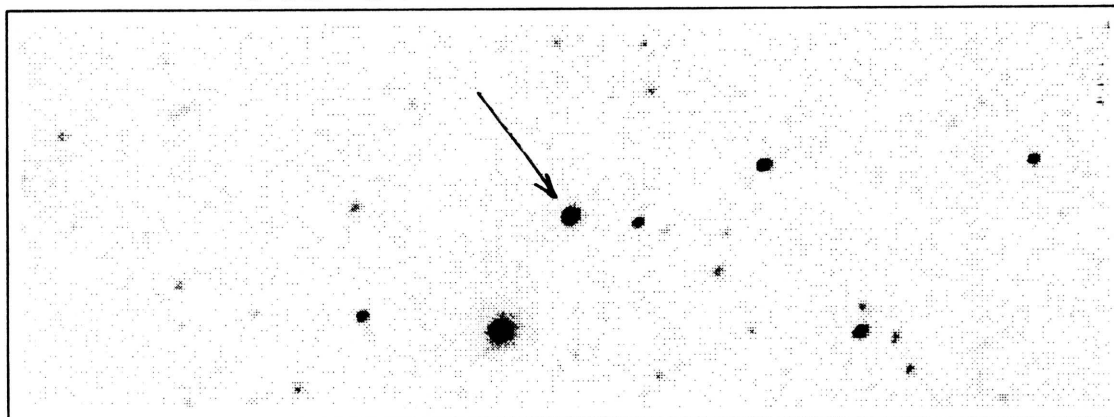


CTI FINDER CHART                Clear filter              Obs. (UT) 1989 Apr 07

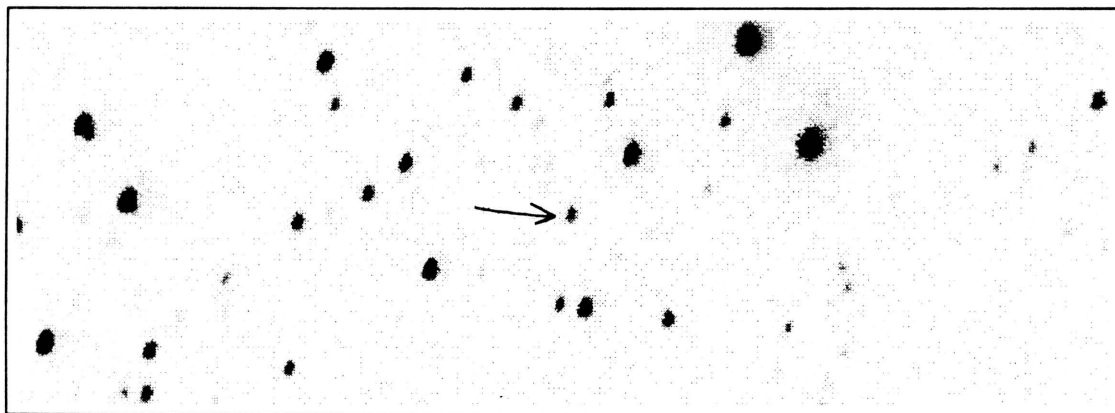MMT SPECTRUM           Exposure: 600 sec           Obs. (UT) 1991 Mar 14
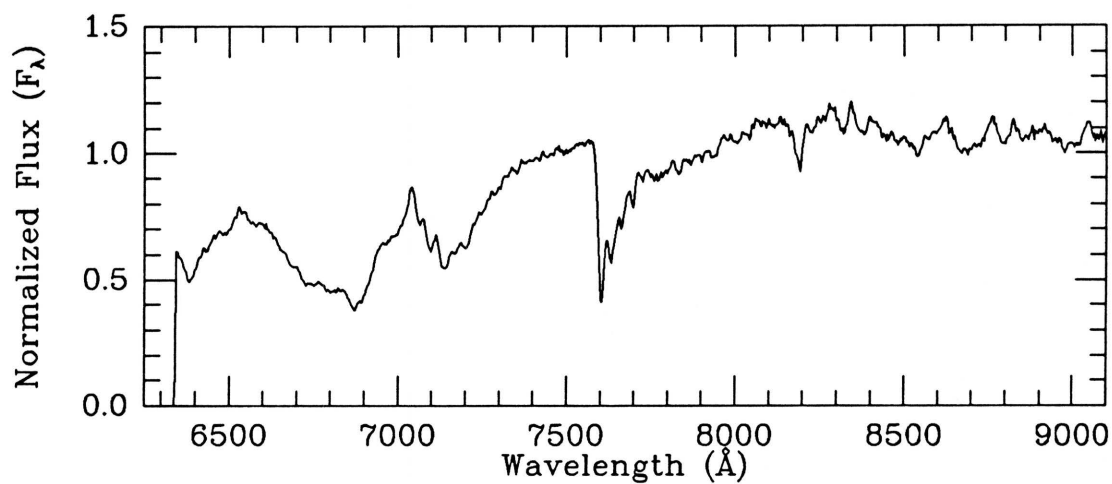


Coordinates:  $\alpha$ (1950) = 10:55:59.8        $\delta$ (1950) = +28:14:54

Spectral Type:  M2.5 V

Photometry:        $I_{KC}$ = 13.84          $R_{CTI}$ = 14.69

  $(V-I)_{KC}$=2.40±.11        $(R-I)_{CTI}$=0.75±.01        $(V-I)_{CTI}$=2.28±.01

Notes:

# CTI 111035.6+275951
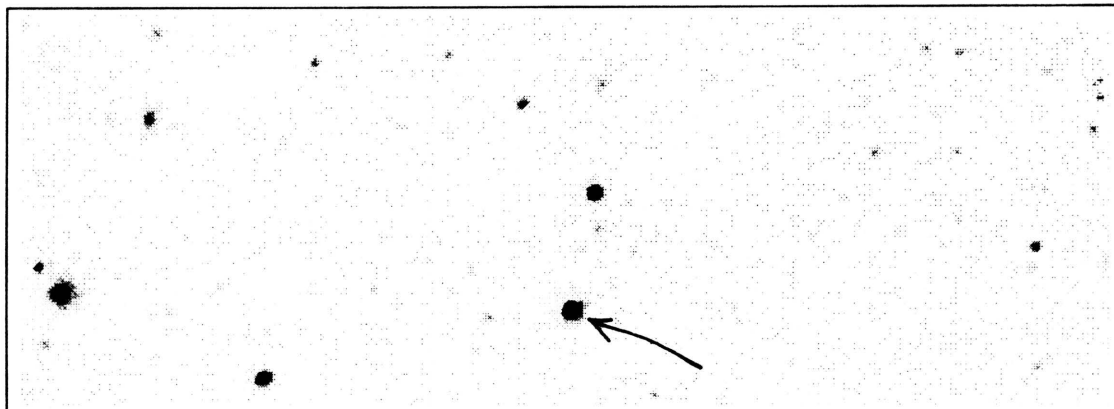


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 900 sec          Obs. (UT) 1991 May 07
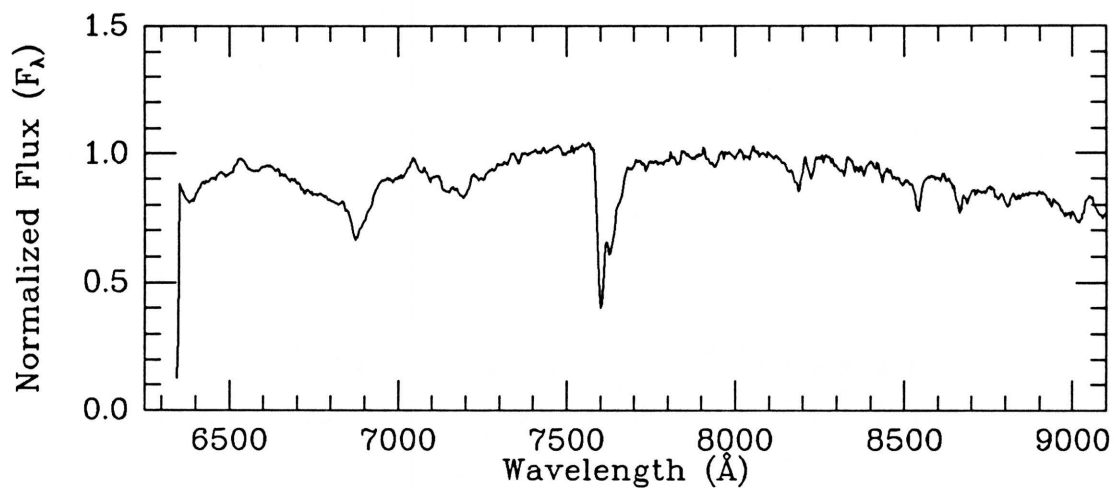


Coordinates:  $\alpha$ (1950) = 11:08:34.5      $\delta$ (1950) = +28:12:05

Spectral Type:  K7 V

Photometry:       $I_{KC}$ = 13.93          $R_{CTI}$ = 14.29

  $(V-I)_{KC}$=1.70±.09      $(R-I)_{CTI}$=0.26±.01      $(V-I)_{CTI}$=1.59±.01

Notes:

# CTI 112443.6+280426
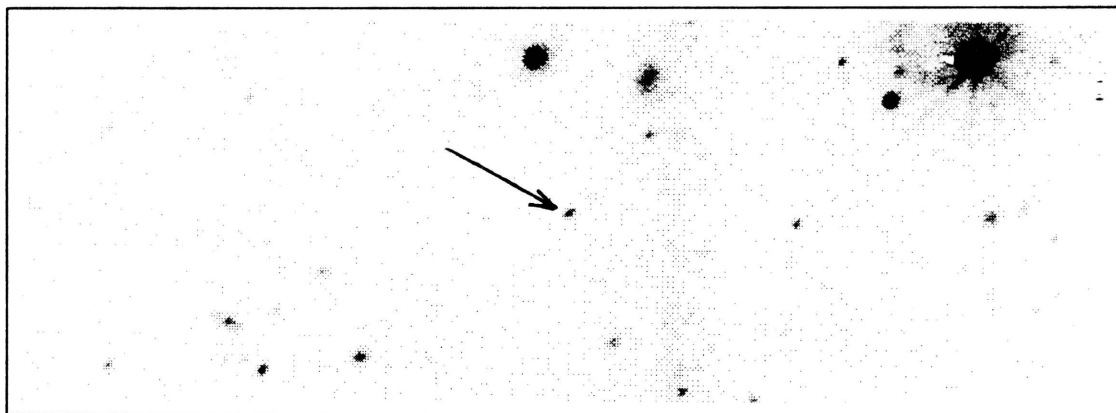


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 May 04
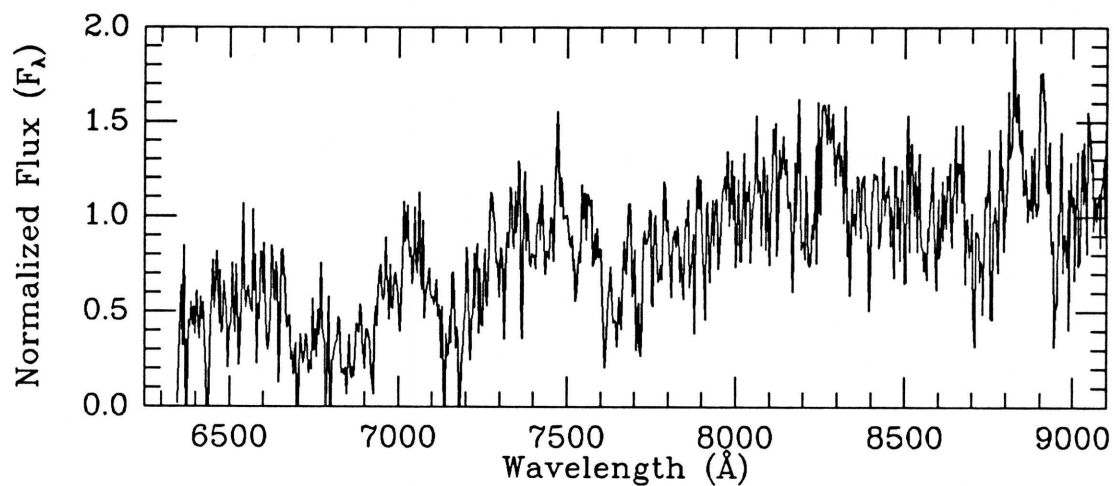


Coordinates:  $\alpha$ (1950) = 11:22:44.1          $\delta$ (1950) = +28:16:48

Spectral Type:  M3: V

Photometry:          $I_{KC}$ = 17.24          $R_{CTI}$ = 18.95

$(V-I)_{KC}$=3.85±.22          $(R-I)_{CTI}$=1.77±.12          $(V-I)_{CTI}$=3.23±.12

Notes:

# CTI 112750.0+280406
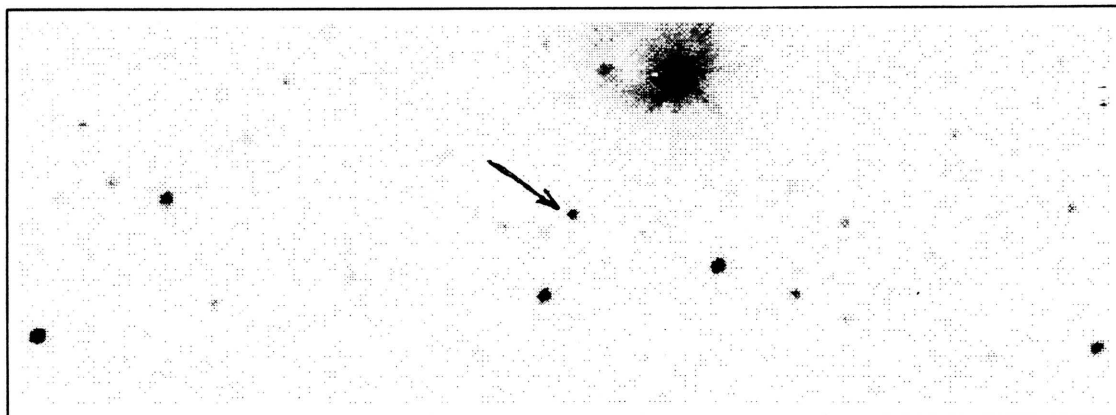


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 May 04
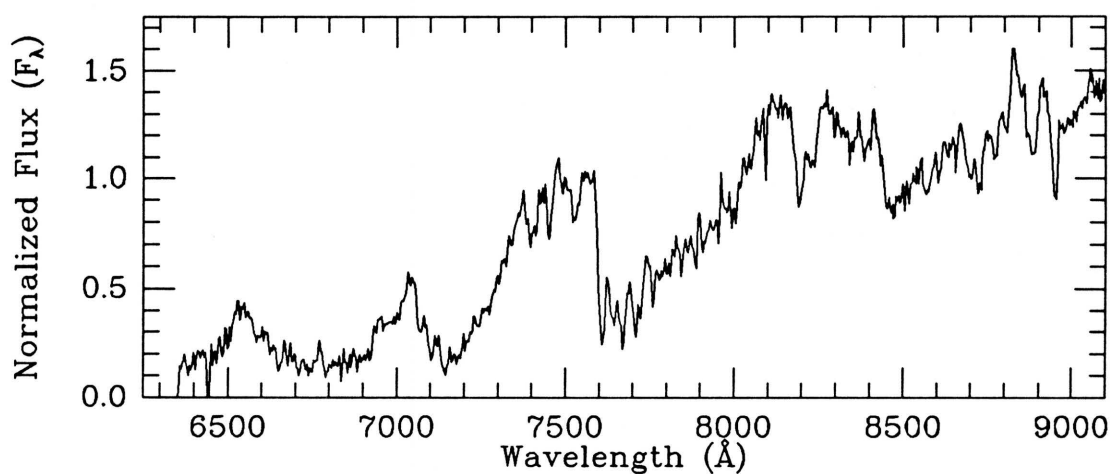


Coordinates:  $\alpha$ (1950) = 11:25:50.8          $\delta$ (1950) = +28:16:30

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 16.91          $R_{CTI}$ = 18.47

$(V-I)_{KC}$=3.61±.24          $(R-I)_{CTI}$=1.60±.14          $(V-I)_{CTI}$=3.56±.11

Notes:

# CTI 113104.5+280201
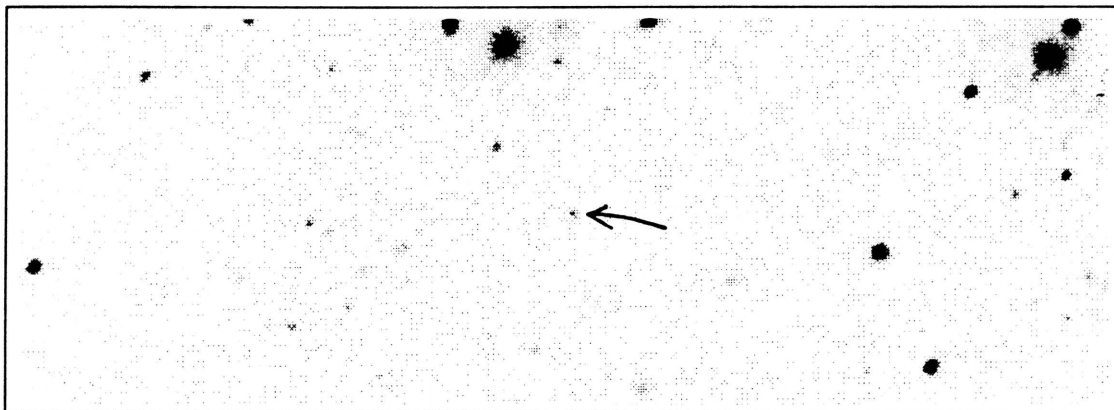


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 20
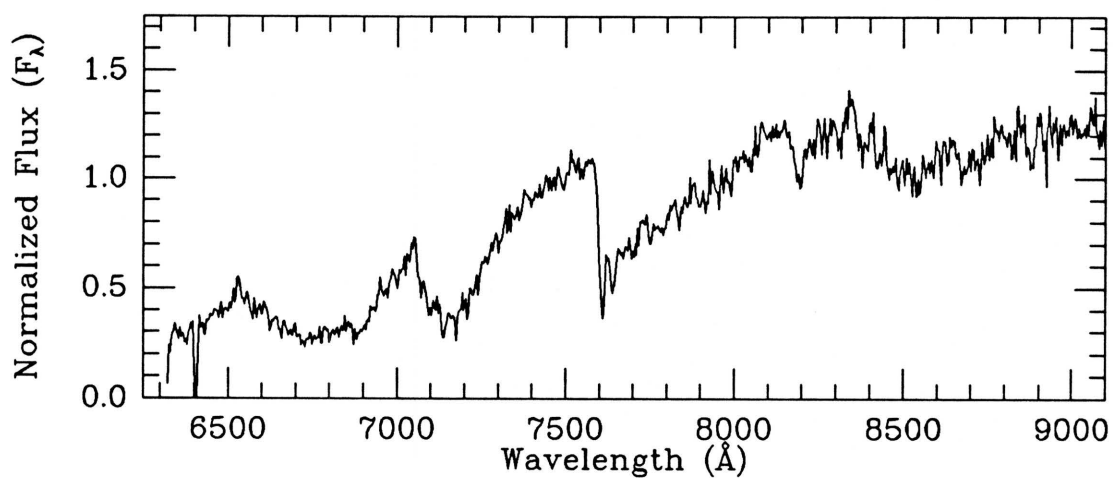


Coordinates:  $\alpha$ (1950) = 11:29:05.7      $\delta$ (1950) = +28:14:26

Spectral Type:  M4 V

Photometry:      $I_{KC}$ = 17.99          $R_{CTI}$ = 20.10

  $(V-I)_{KC}$=4.46±.90      $(R-I)_{CTI}$=2.20±.62      $(V-I)_{CTI}$=2.42±.12

Notes:

# CTI 115638.5+280002
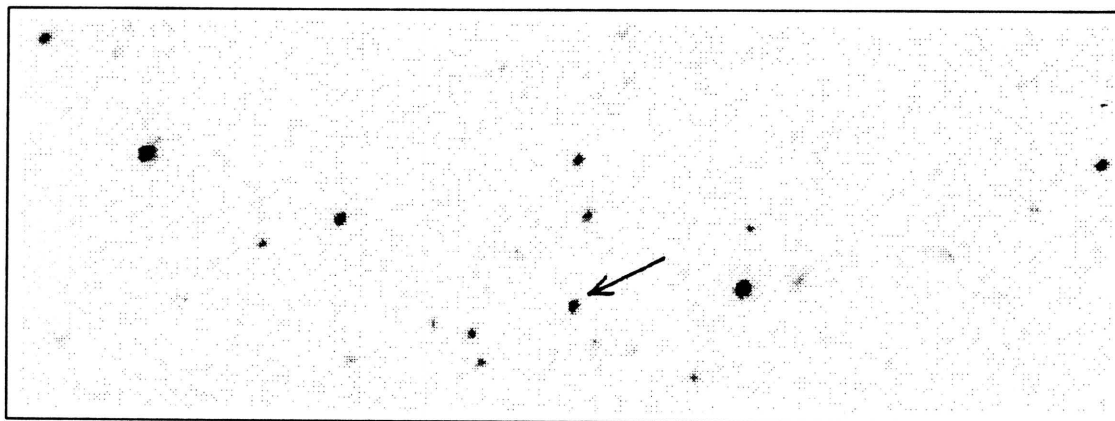


**CTI FINDER CHART**          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 20
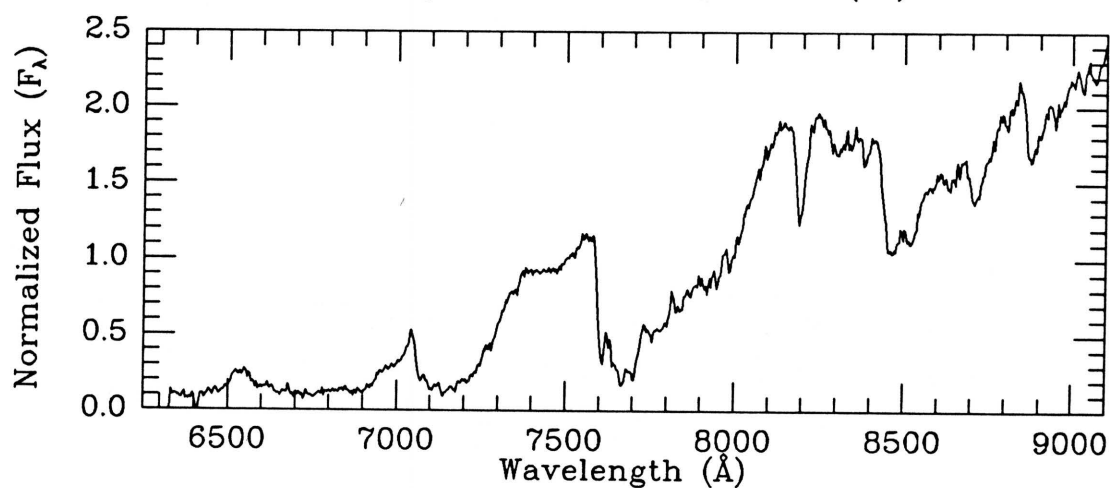


Coordinates:  $\alpha$ (1950) = 11:54:42.7      $\delta$ (1950) = +28:12:34

Spectral Type:  M7 V

Photometry:      $I_{KC}$ = 16.74          $R_{CTI}$ = 18.61

$(V-I)_{KC}$=4.05±.45      $(R-I)_{CTI}$=1.91±.30      $(V-I)_{CTI}$=3.76±.19

Notes: This object is not found on the POSS E plate, probably because of a large proper motion, since the R magnitude is well above the plate limit.

# CTI 120144.1+280527
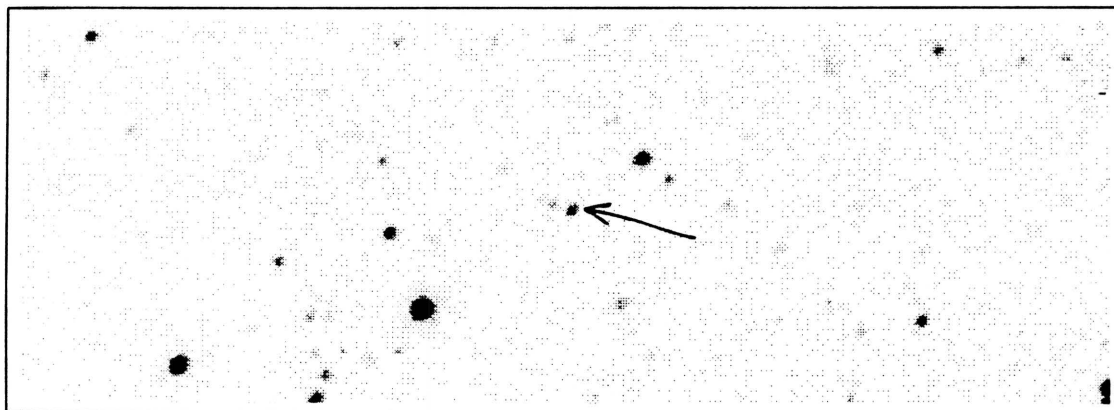


CTI FINDER CHART  Clear filter  Obs. (UT) 1989 Apr 07

MMT SPECTRUM  Exposure: 3660 sec  Obs. (UT) 1990 May 04
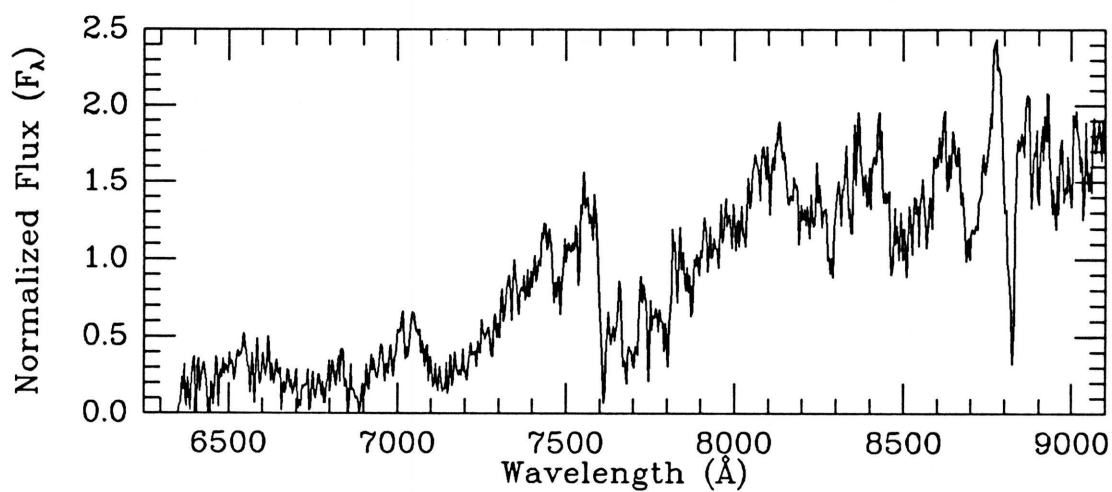


Coordinates:  $\alpha$ (1950) = 11:59:48.9  $\delta$ (1950) = +28:17:59

Spectral Type:  M6: V

Photometry:  $I_{KC}$ = 16.80  $R_{CTI}$ = 18.27

$(V-I)_{KC}$=3.48±.18  $(R-I)_{CTI}$=1.51±.09  $(V-I)_{CTI}$=3.58±.13

Notes:

# CTI 120237.0+275949
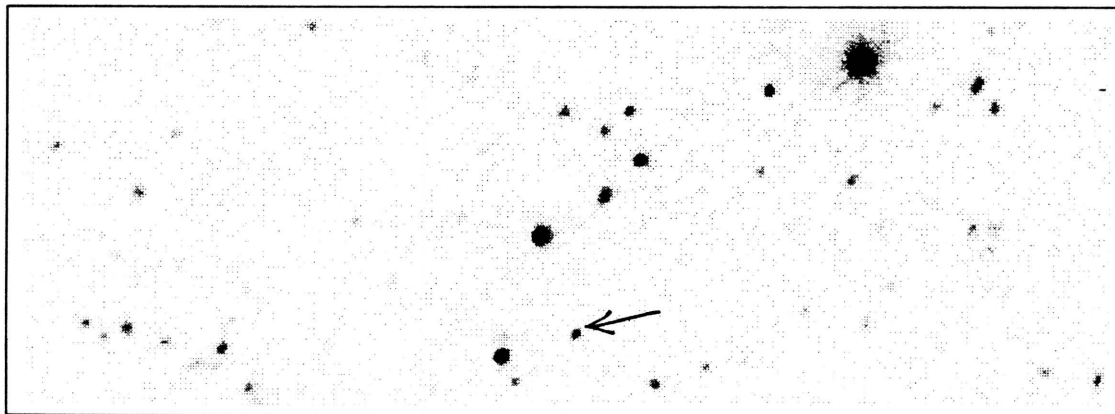


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Jan 20
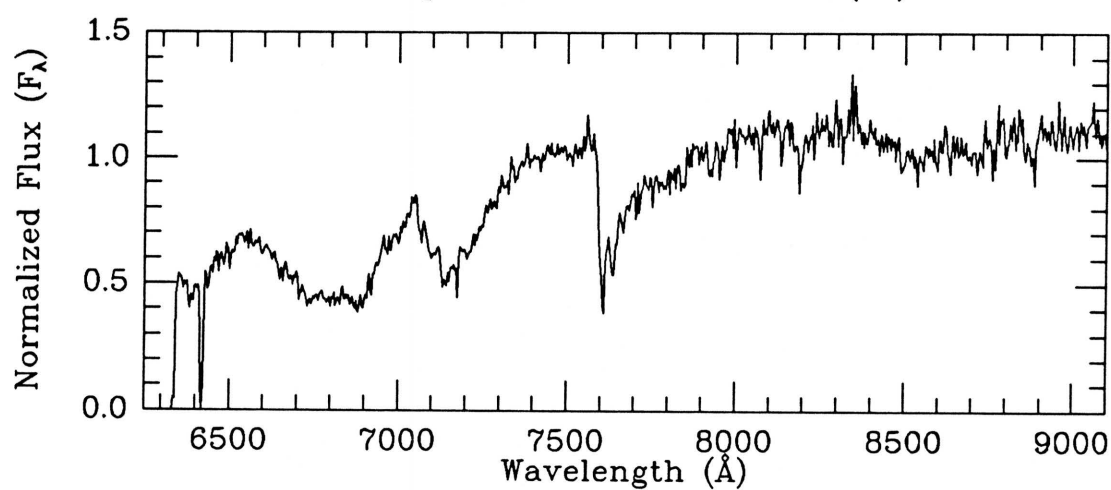


Coordinates:  $\alpha$ (1950) = 12:00:41.9          $\delta$ (1950) = +28:12:21

Spectral Type:  M2.5 V

Photometry:          $I_{KC}$ = unknown          $R_{CTI}$ = unknown

  $(V-I)_{KC}$=unknown          $(R-I)_{CTI}$>1.94:          $(V-I)_{CTI}$=2.76±.12

Notes:

# CTI 124450.0+280024
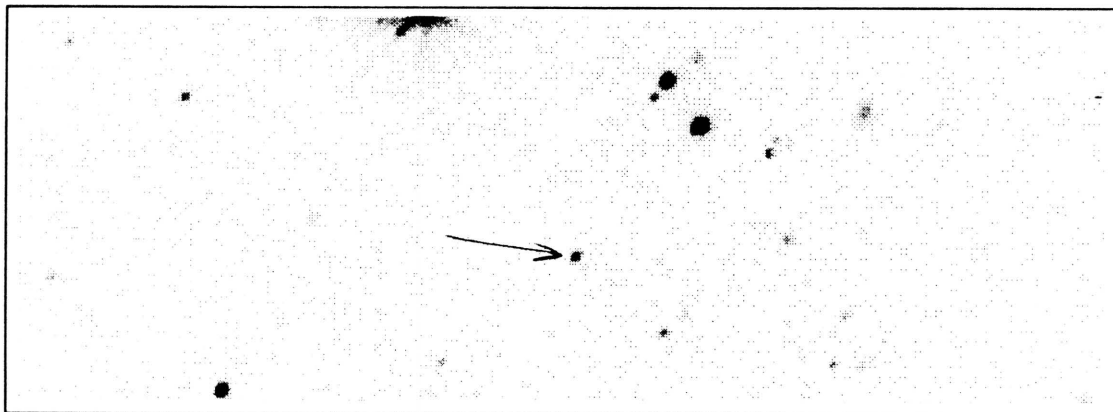


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1991 Mar 14
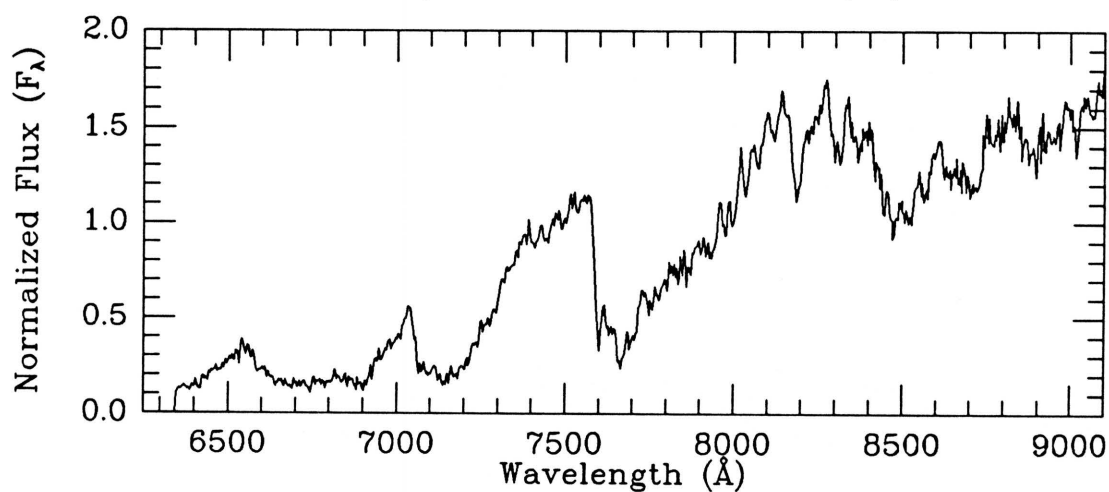


Coordinates:   $\alpha$ (1950) = 12:42:59.8          $\delta$ (1950) = +28:12:42

Spectral Type:   M5.5 V

Photometry:          $I_{KC}$ = unknown          $R_{CTI}$ = unknown

  $(V-I)_{KC}$=unknown          $(R-I)_{CTI}$=unknown          $(V-I)_{CTI}$=4.10±1.00

Notes:

# CTI 124832.6+280502
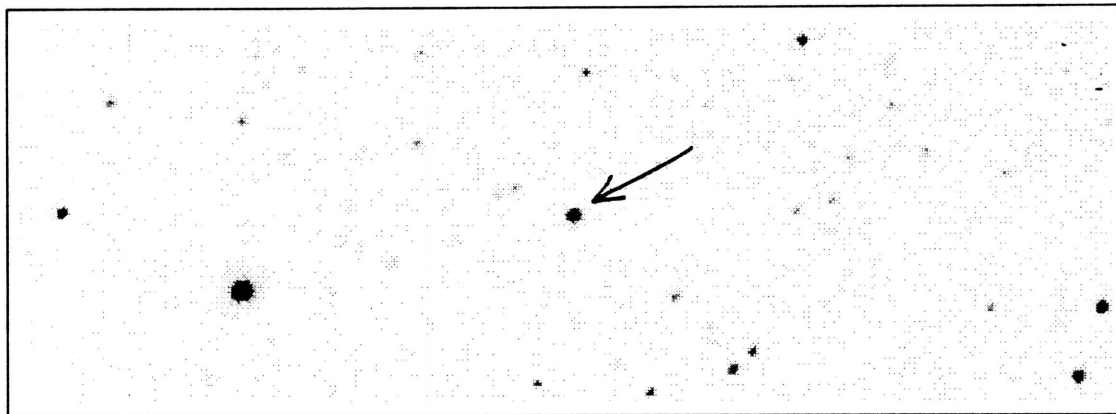


| CTI FINDER CHART | Clear filter | Obs. (UT) 1989 Apr 07 |

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 May 04
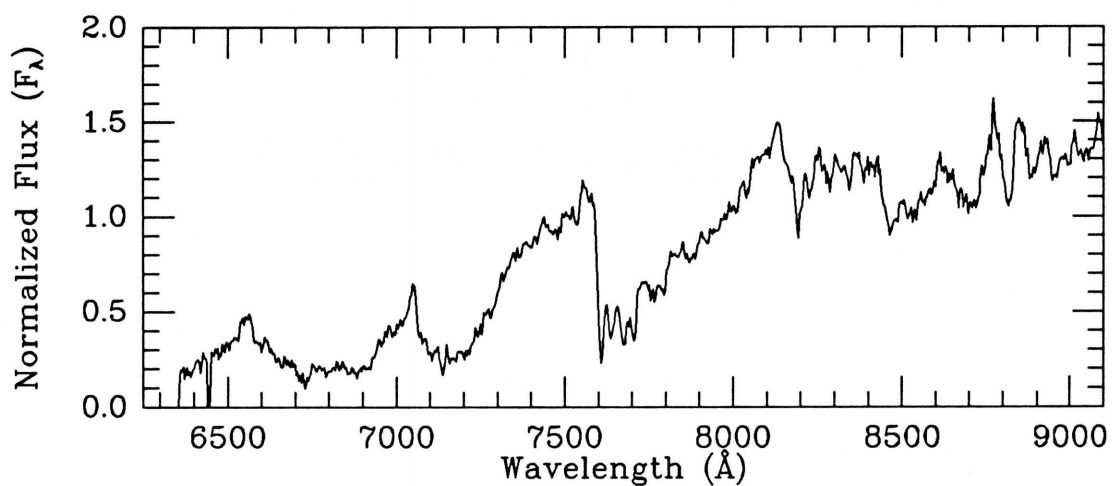


Coordinates:  $\alpha$ (1950) = 12:46:42.9        $\delta$ (1950) = +28:17:18

Spectral Type:  M5.5 V

Photometry:        $I_{KC}$ = 15.36          $R_{CTI}$ = 16.92

  $(V-I)_{KC}$=3.51±.14        $(R-I)_{CTI}$=1.53±.03        $(V-I)_{CTI}$=3.50±.03

Notes:

# CTI 131541.4+280227
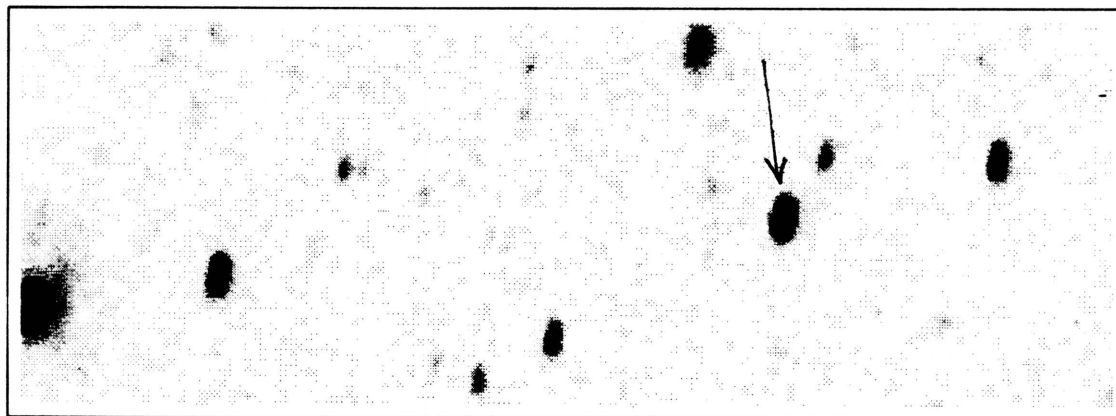


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 600 sec          Obs. (UT) 1991 Jun 22
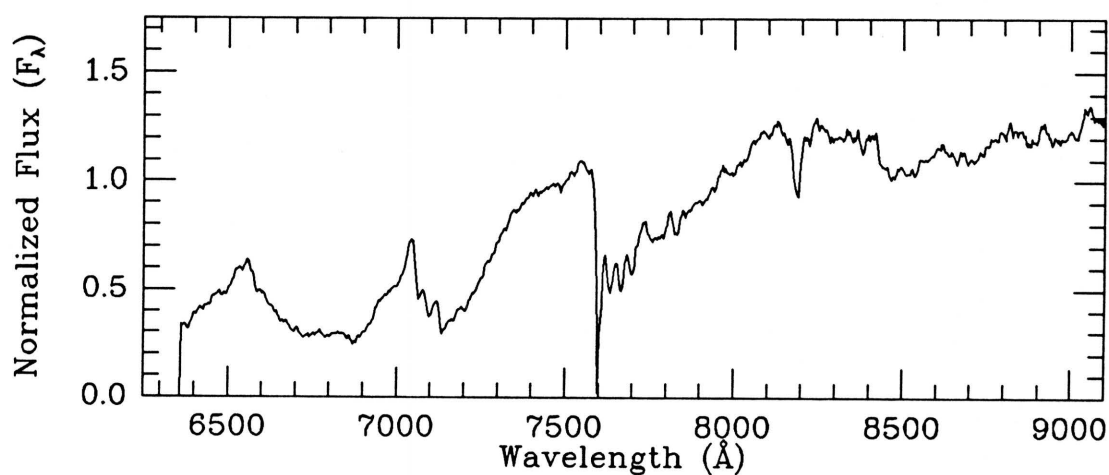


Coordinates:  $\alpha$ (1950) = 13:13:54.7          $\delta$ (1950) = +28:14:19

Spectral Type:  M4 V

Photometry:          $I_{KC}$ = 14.10          $R_{CTI}$ = 15.35

$(V-I)_{KC}$=2.98±.04          $(R-I)_{CTI}$=1.21±.01          $(V-I)_{CTI}$=2.93±.01

Notes: Actual USNO VI photometry.

# CTI 131631.5+280542
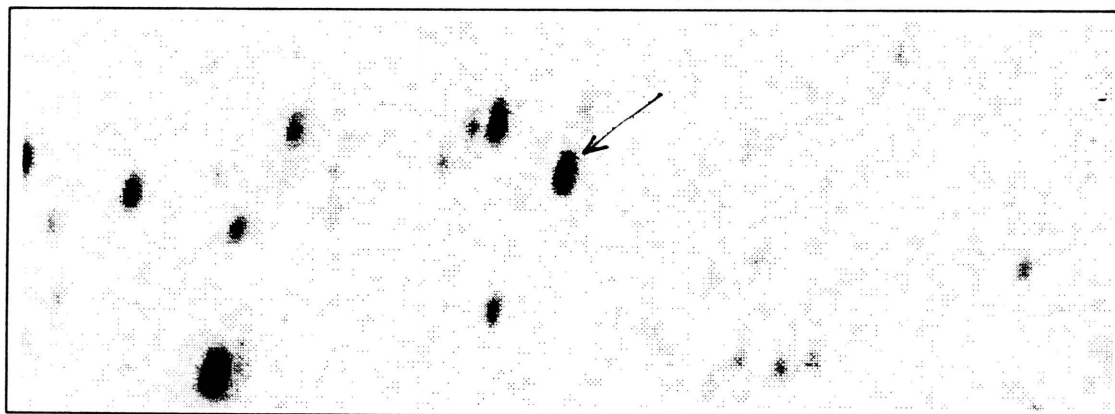


**CTI FINDER CHART**  **I filter**  **Coadded frame**

MMT SPECTRUM  Exposure: 600 sec  Obs. (UT) 1991 Jun 22
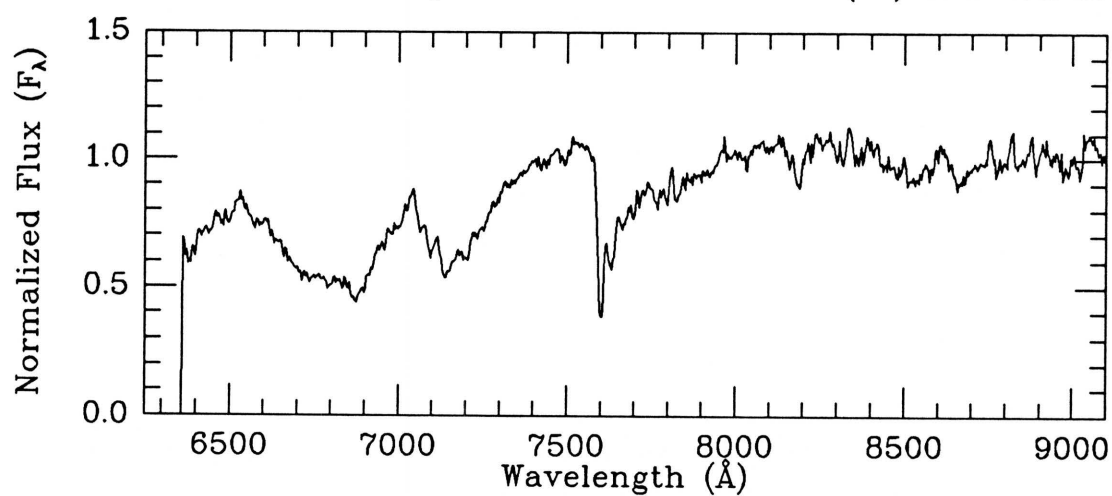


Coordinates: $\alpha$ (1950) = 13:14:44.9  $\delta$ (1950) = +28:17:33

Spectral Type: M2 V

Photometry:  $I_{KC}$ = 15.27  $R_{CTI}$ = 15.92

$(V-I)_{KC}$=2.21±.11  $(R-I)_{CTI}$=0.62±.03  $(V-I)_{CTI}$=unknown

Notes:

# CTI 133827.9+280633
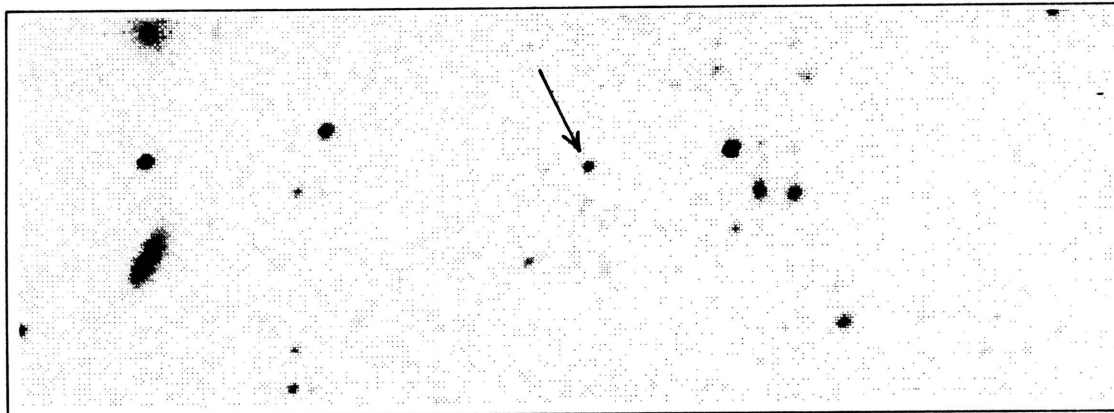


CTI FINDER CHART          Clear filter          Ob. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1991 Mar 14
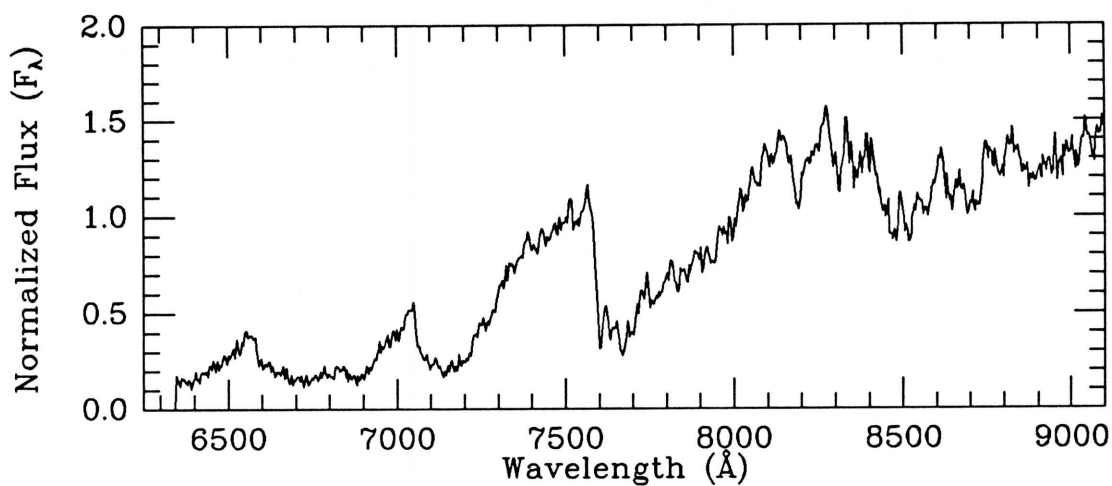


Coordinates:  $\alpha$ (1950) = 13:36:43.7          $\delta$ (1950) = +28:17:58

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 17.21          $R_{CTI}$ = 18.96

$(V-I)_{KC}$=3.91±.63          $(R-I)_{CTI}$=1.81±.43          $(V-I)_{CTI}$=3.23±.40

Notes:

# CTI 133857.8+280437
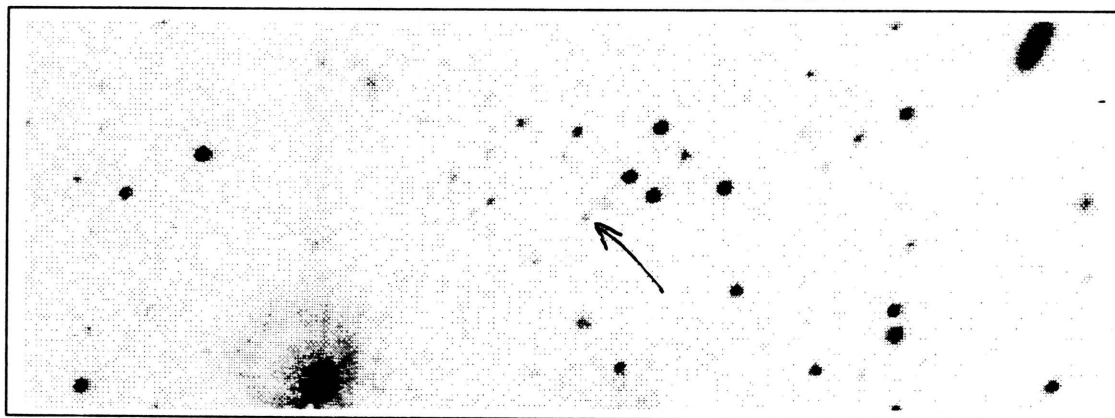
CTI FINDER CHART          Clear filter          Ob. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 May 23
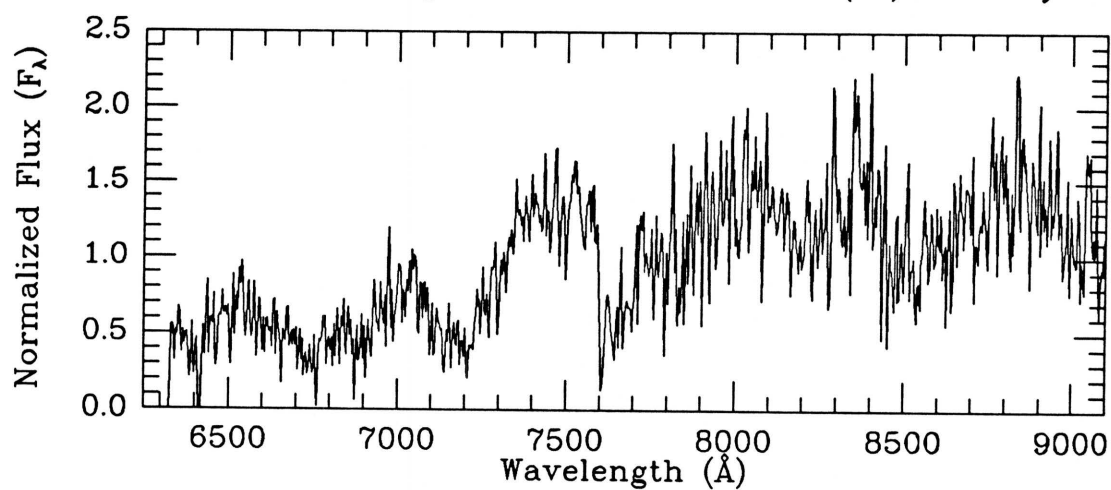
Coordinates:  $\alpha$ (1950) = 13:37:13.7      $\delta$ (1950) = +28:16:01

Spectral Type:  M3.5: V

Photometry:      $I_{KC}$ = 18.41          $R_{CTI}$ = 20.32

$(V-I)_{KC}$=4.21±1.41      $(R-I)_{CTI}$=2.02±.98      $(V-I)_{CTI}$=unknown

Notes:

# CTI 134402.9+280522
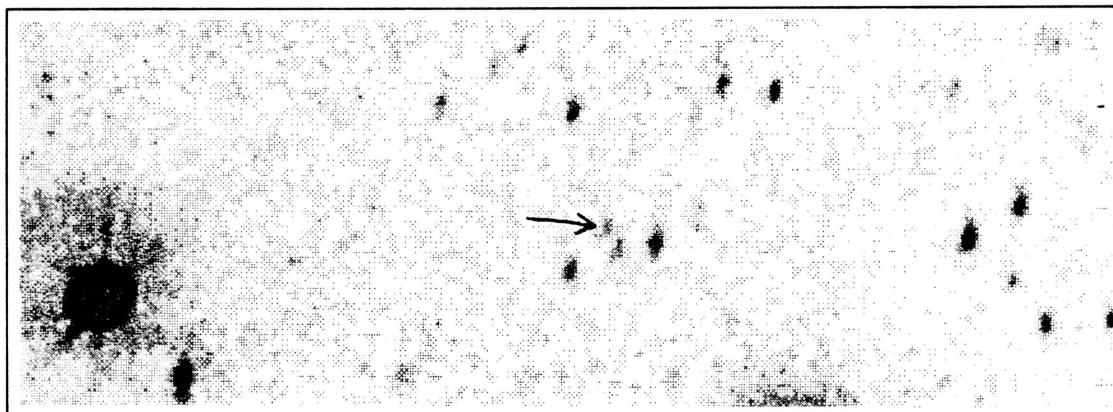


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1991 Jun 24
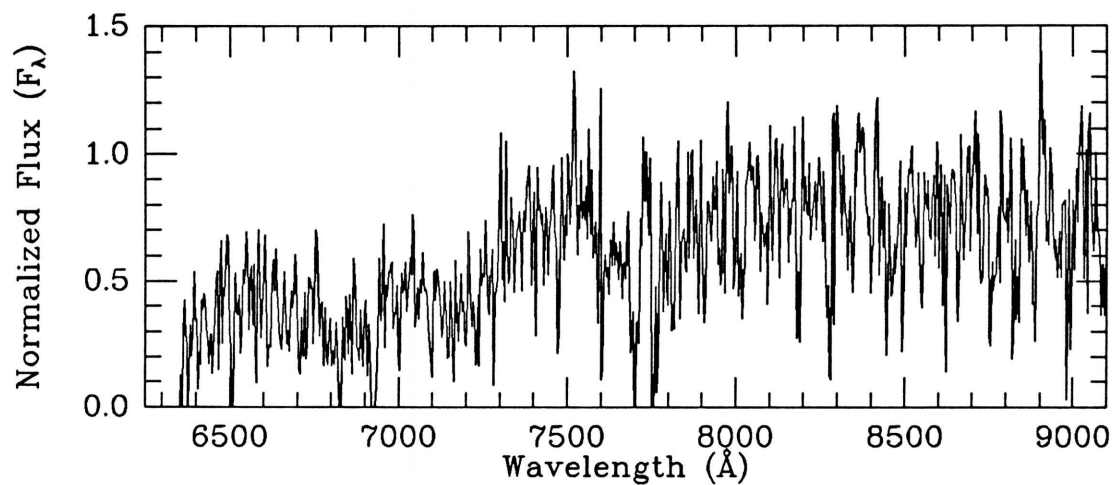


Coordinates:   $\alpha$ (1950) = 13:42:19.3          $\delta$ (1950) = +28:16:39

Spectral Type:   M3: V

Photometry:          $I_{KC}$ = 19.31          $R_{CTI}$ = 21.2

   $(V-I)_{KC}$=4.25±1.45          $(R-I)_{CTI}$=2.05±1.01          $(V-I)_{CTI}$=unknown

Notes:

# CTI 135347.7+280418
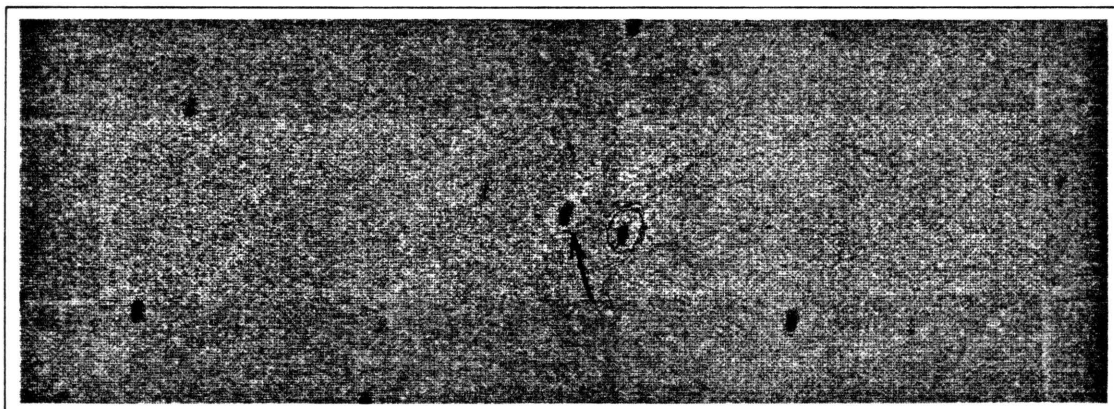


CTI FINDER CHART           I filter           Obs. (UT) 1988 Mar 18

MMT SPECTRUM           Exposure: 3900 sec           Obs. (UT) 1989 Jul 13
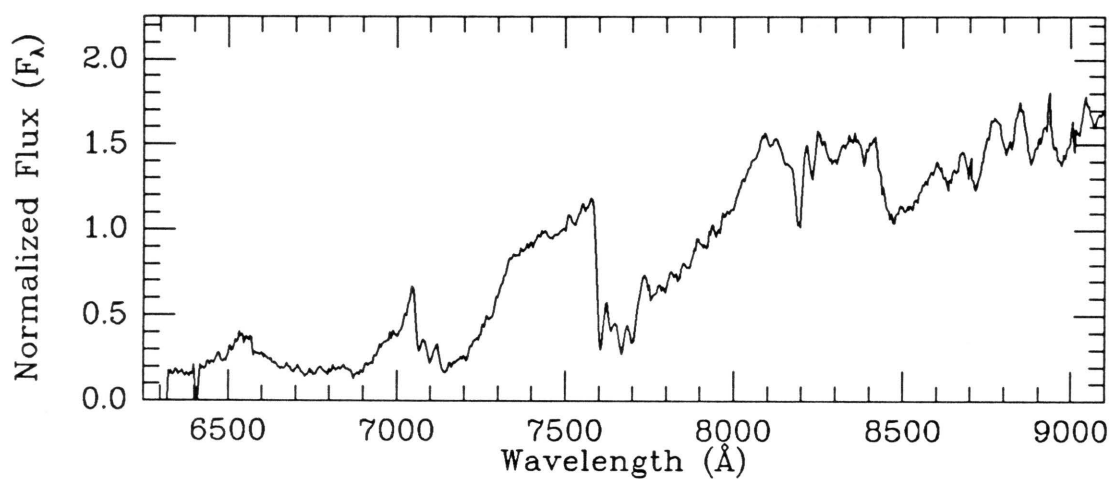


Coordinates:  $\alpha$ (1950) = 13:52:05.1        $\delta$ (1950) = +28:15:20

Spectral Type:  M6 V

Photometry:        $I_{KC}$ = 15.76           $R_{CTI}$ = 17.35

 $(V-I)_{KC}$=3.69±.05        $(R-I)_{CTI}$=1.60±.06        $(V-I)_{CTI}$=3.47±.06

Notes: Actual USNO VI photometry. Comparison to POSS E print suggests proper motion of ~0.2 arcsec/yr to the north.

# CTI 135752.7+275958
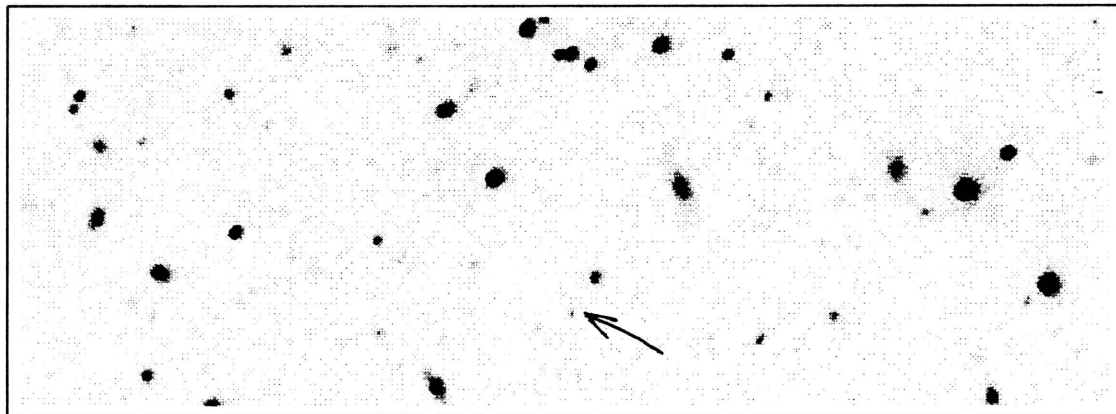


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 1494 sec          Obs. (UT) 1990 May 22
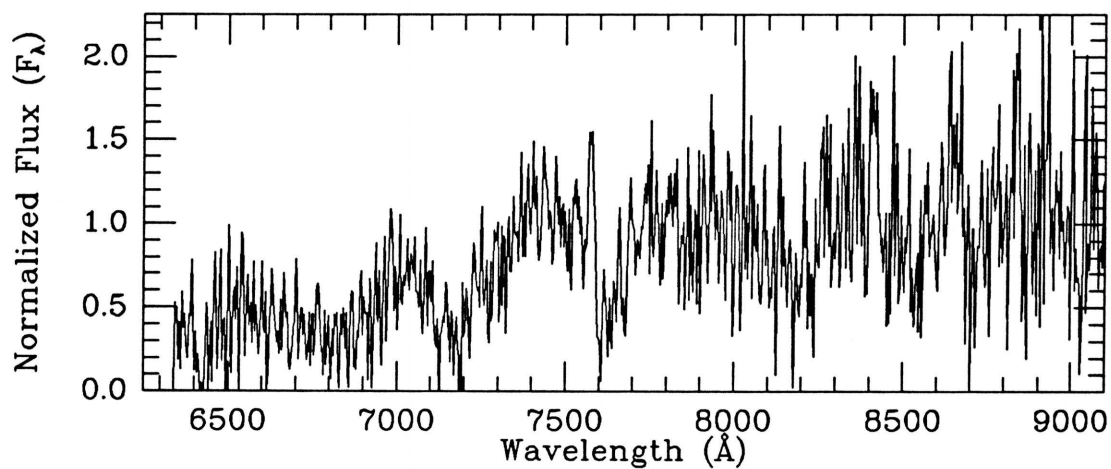


Coordinates:   $\alpha$ (1950) = 13:56:10.5          $\delta$ (1950) = +28:10:54

Spectral Type:   M3: V

Photometry:          $I_{KC}$ = 18.86          $R_{CTI}$ = 19.57

   $(V-I)_{KC}$=2.54±.98          $(R-I)_{CTI}$=0.85±.68          $(V-I)_{CTI}$=1.63±.71

Notes:

# CTI 141034.3+280158
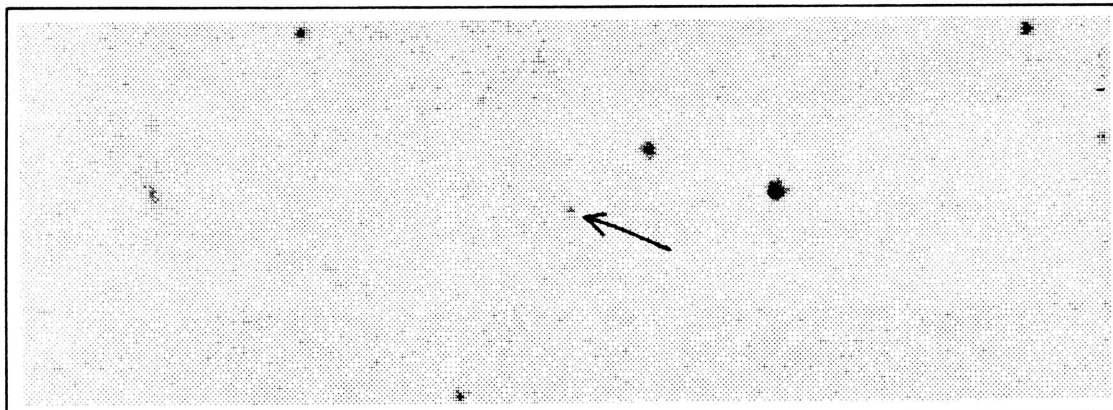


CTI FINDER CHART          V filter          Obs. (UT) 1986 Apr 04

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1989 Jul 14
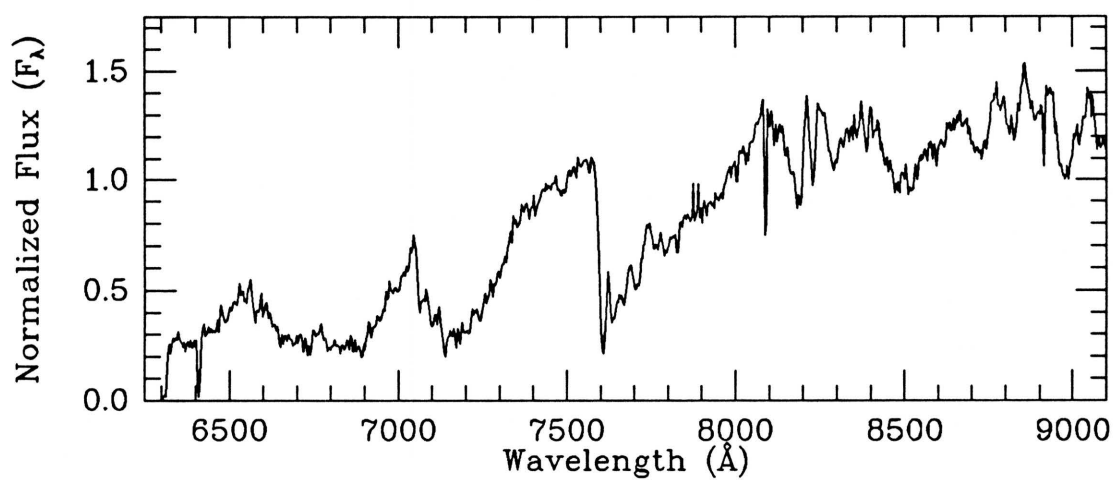


Coordinates:  $\alpha$ (1950) = 14:08:53.4          $\delta$ (1950) = +28:12:32

Spectral Type:  M4.5 V

Photometry:          $I_{KC}$ = 15.01          $R_{CTI}$ = 16.39

  $(V-I)_{KC}$=3.23±.13          $(R-I)_{CTI}$=1.33±.03          $(V-I)_{CTI}$=3.12±.03

Notes:

# CTI 141111.3+280141
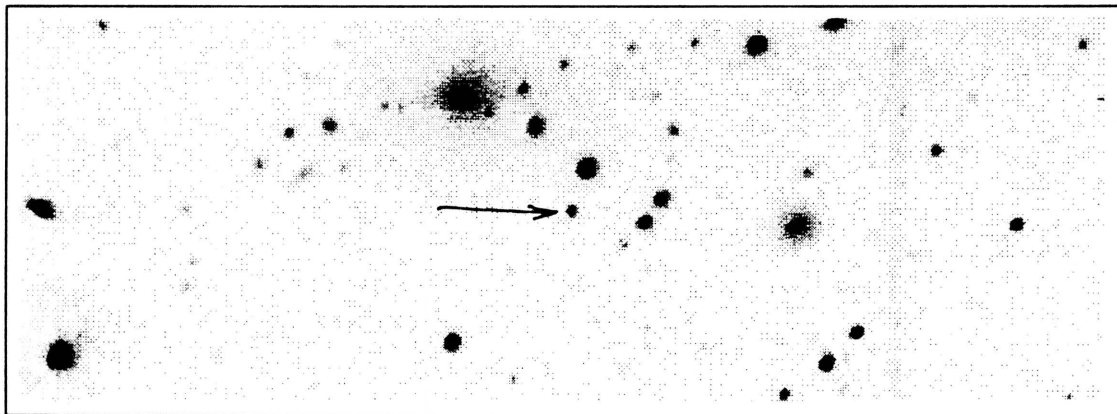


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 May 04
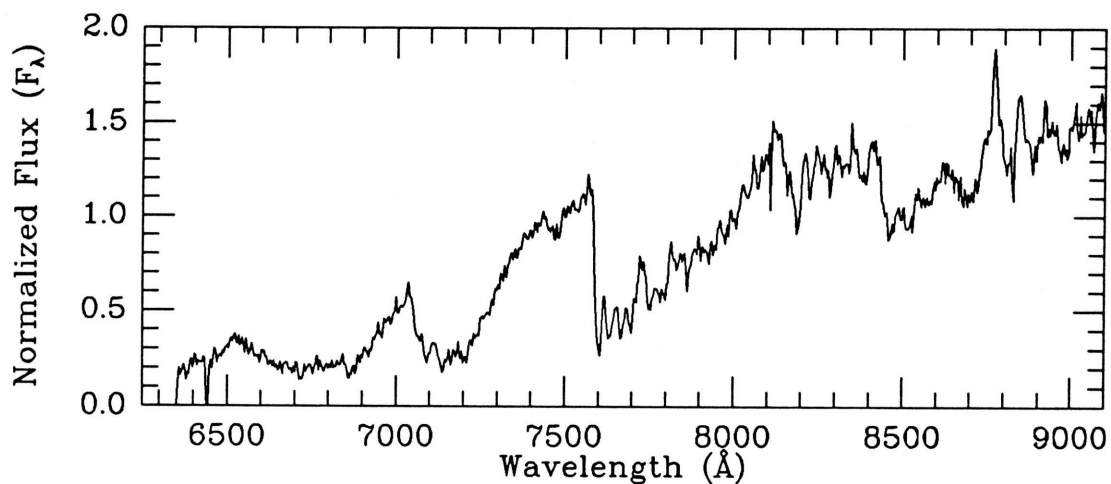


Coordinates:  $\alpha$ (1950) = 14:09:30.4          $\delta$ (1950) = +28:12:14

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 16.40          $R_{CTI}$ = 17.84

$(V-I)_{KC}$=3.54±.06          $(R-I)_{CTI}$=1.43±.09          $(V-I)_{CTI}$=3.51±.08

Notes: Actual USNO VI photometry.  Comparison to POSS E print suggests proper motion of ~0.2 arcsec/yr to the south.

# CTI 141237.7+280559
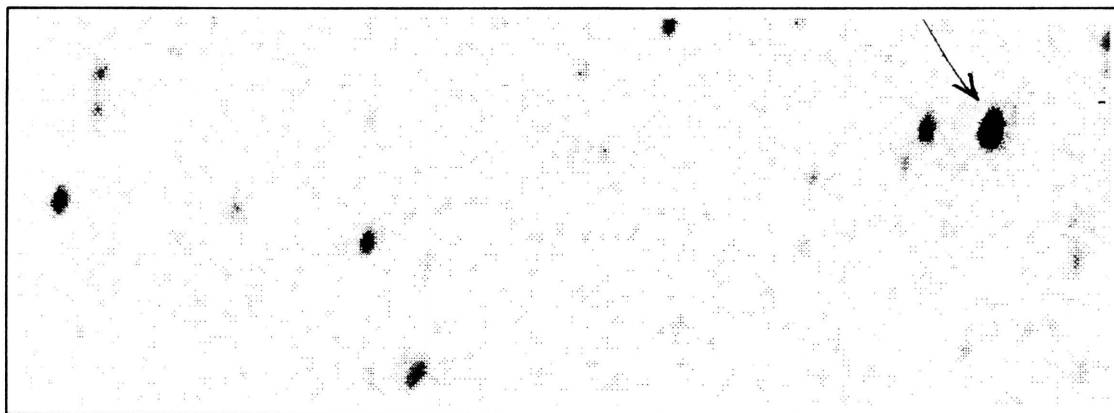


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1991 Jun 23
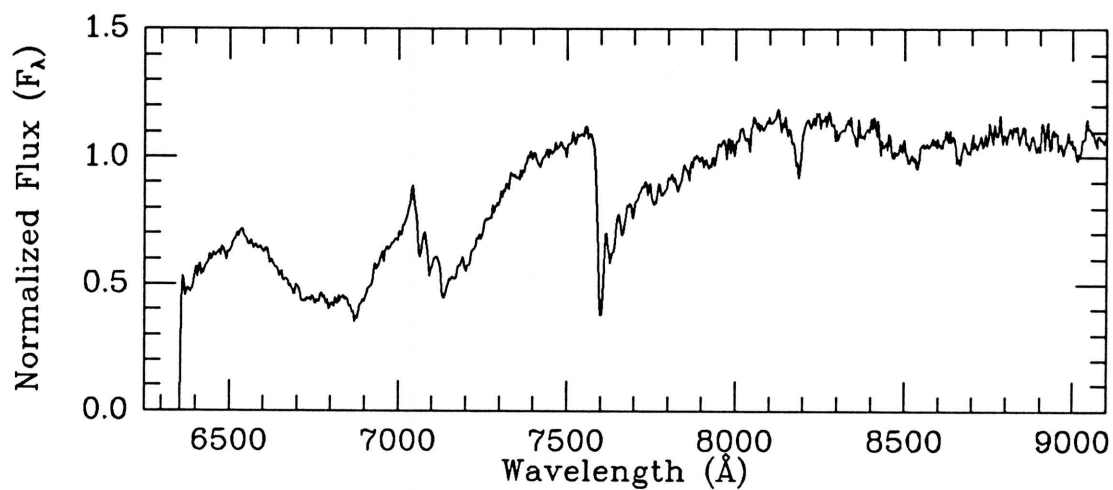


Coordinates:  $\alpha$ (1950) = 14:10:57.0          $\delta$ (1950) = +28:16:30
Spectral Type:  M3 V
Photometry:          $I_{KC}$ = 14.58          $R_{CTI}$ = 15.44
   $(V-I)_{KC}$=2.46±.04          $(R-I)_{CTI}$=0.78±.02          $(V-I)_{CTI}$=unknown
Notes: Actual USNO VI photometry.

# CTI 141329.8+280131
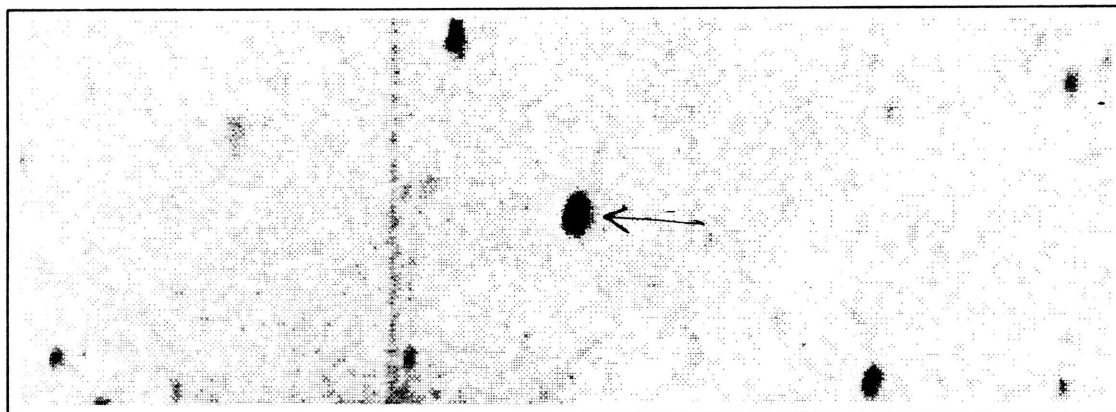


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1991 Jun 24
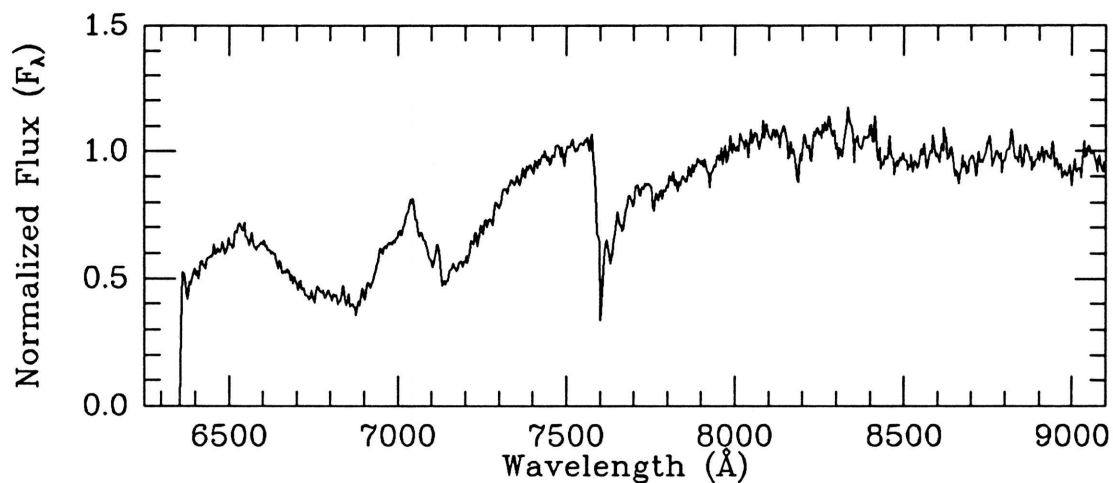


Coordinates:   $\alpha$ (1950) = 14:11:49.2      $\delta$ (1950) = +28:12:00

Spectral Type:   M2.5 V

Photometry:       $I_{KC}$ = 14.58          $R_{CTI}$ = 15.37

  $(V-I)_{KC}$=2.36±.03      $(R-I)_{CTI}$=0.73±.02      $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 150225.7+280231
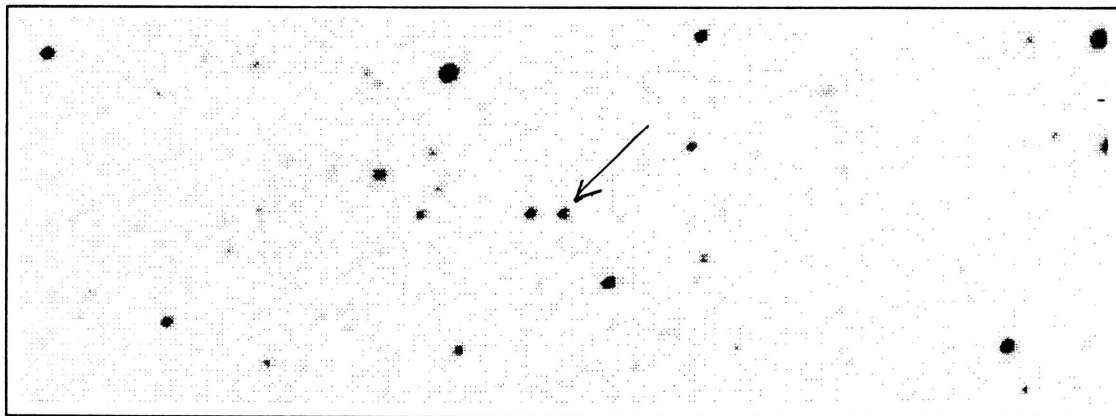


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 May 22
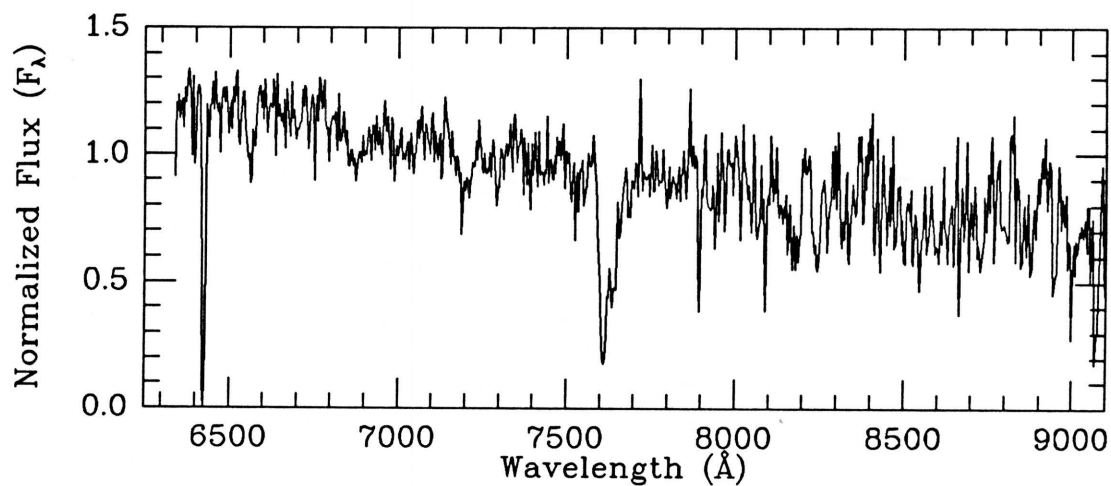


Coordinates:  $\alpha$ (1950) = 15:00:49.5          $\delta$ (1950) = +28:11:19

Spectral Type:  <K5 V

Photometry:          $I_{KC}$ = 18.01          $R_{CTI}$ = 18.74

$(V-I)_{KC}$=2.51±.23          $(R-I)_{CTI}$=0.83±.14          $(V-I)_{CTI}$=0.67±.12

Notes: Average CTI R magnitude may be incorrect due to the inclusion of an erroneous measurement of R=20.6.

# CTI 150546.7+280116
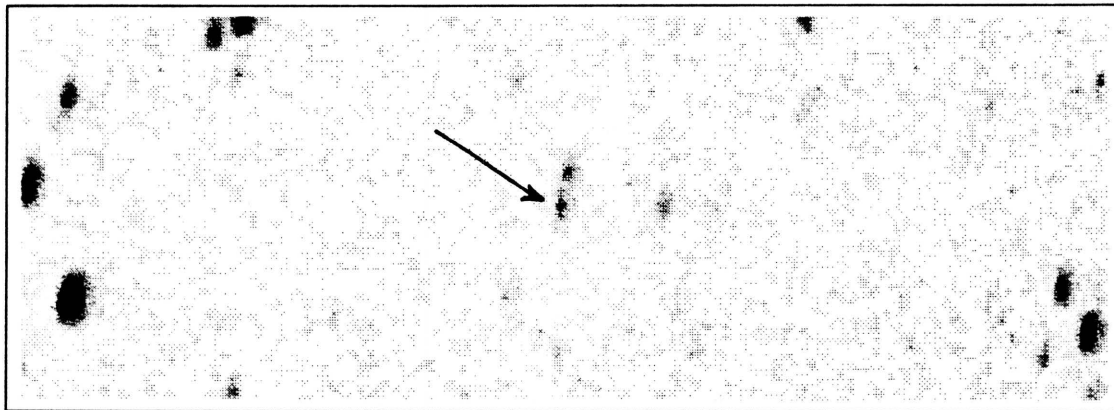


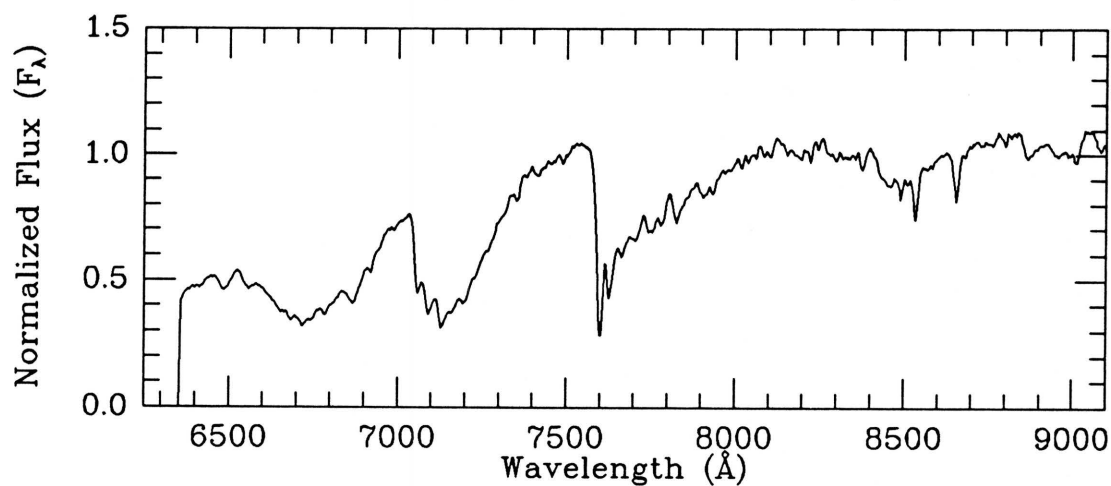CTI FINDER CHART                    I filter                    Coadded frame

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1991 Jun 23
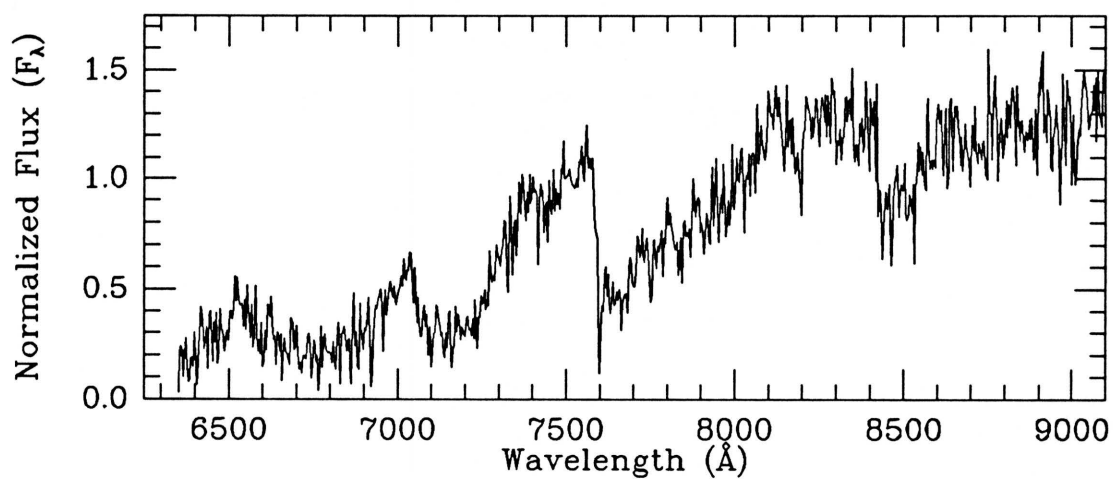


Coordinates:   $\alpha$ (1950) = 15:04:10.7      $\delta$ (1950) = +28:09:56

Spectral Type:   M5.5 V

Photometry:        $I_{KC}$ = 18.55          $R_{CTI}$ = unknown

 $(V-I)_{KC}$=unknown      $(R-I)_{CTI}$=unknown      $(V-I)_{CTI}$=unknown

Notes:

# CTI 153729.8+280454
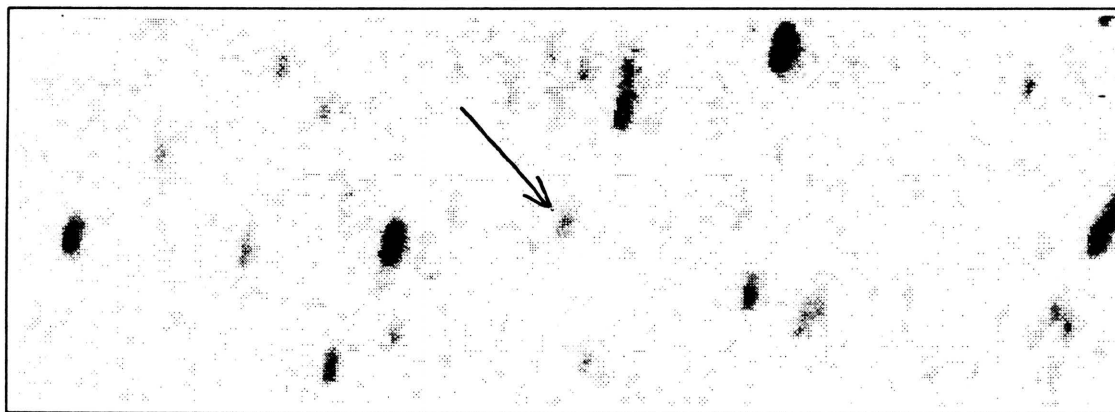


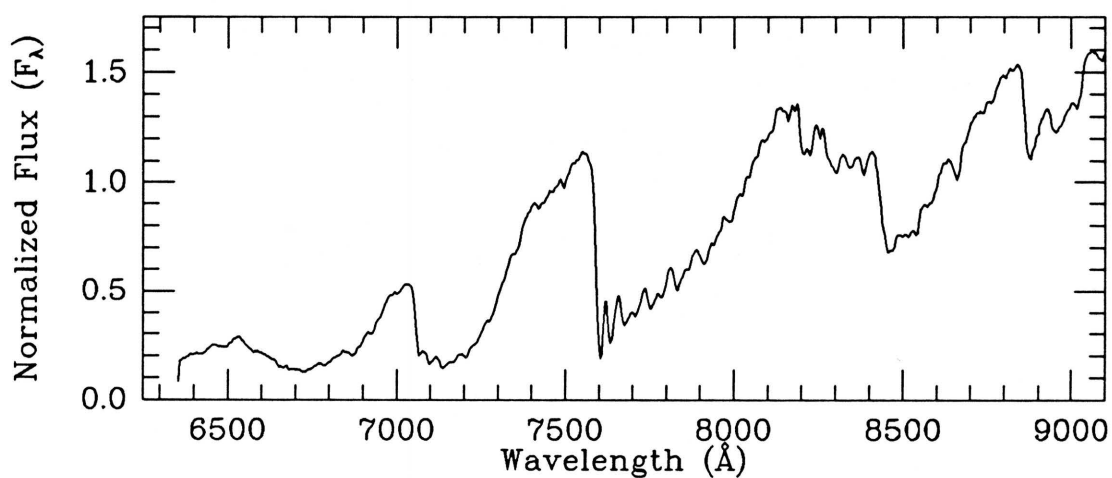CTI FINDER CHART                    I filter                    Coadded frame

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1991 Jun 23
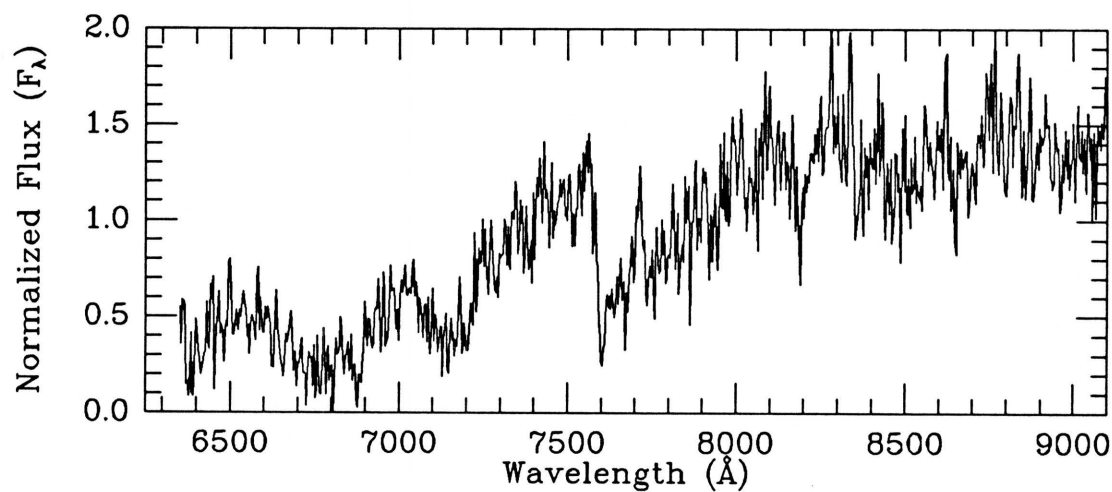


Coordinates:  $\alpha$ (1950) = 15:35:56.3      $\delta$ (1950) = +28:12:14

Spectral Type:  M4.5 V

Photometry:      $I_{KC}$ = 18.80          $R_{CTI}$ = 21.6

$(V-I)_{KC}$=5.51±1.88      $(R-I)_{CTI}$=2.93±1.31      $(V-I)_{CTI}$=unknown

Notes:

# CTI 153915.6+280214
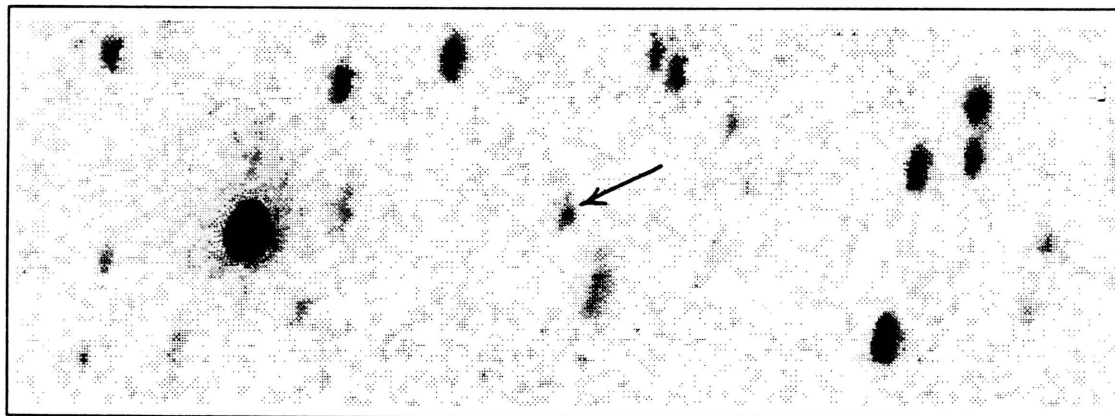


**CTI FINDER CHART**        **I filter**        **Coadded frame**

MMT SPECTRUM        Exposure: 3000 sec        Obs. (UT) 1991 Jun 22
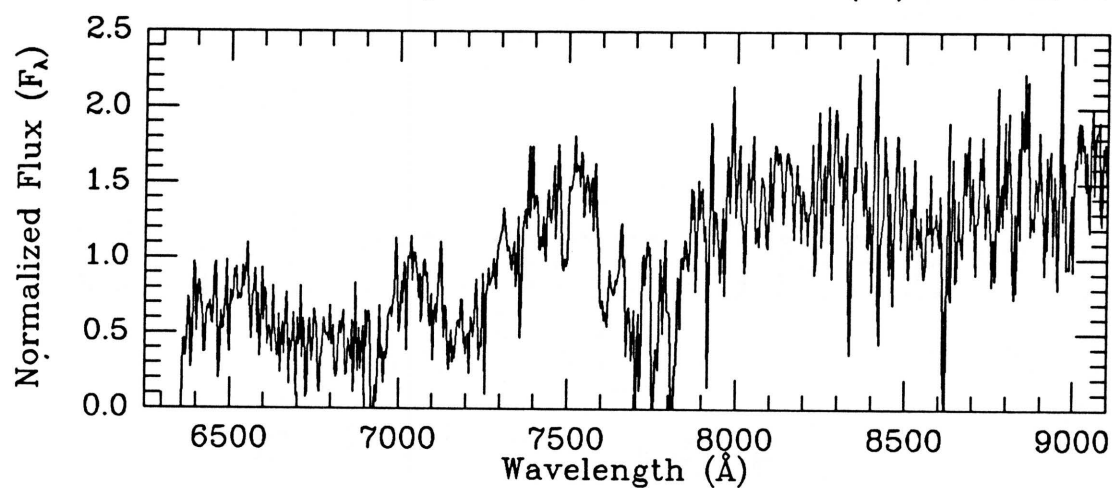


Coordinates:  $\alpha$ (1950) = 15:37:42.1        $\delta$ (1950) = +28:09:29

Spectral Type:  M4: V

Photometry:        $I_{KC}$ = 18.44        $R_{CTI}$ = 20.96

  $(V-I)_{KC}$=2.82±.06        $(R-I)_{CTI}$=2.33±.79        $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 153915.6+280446
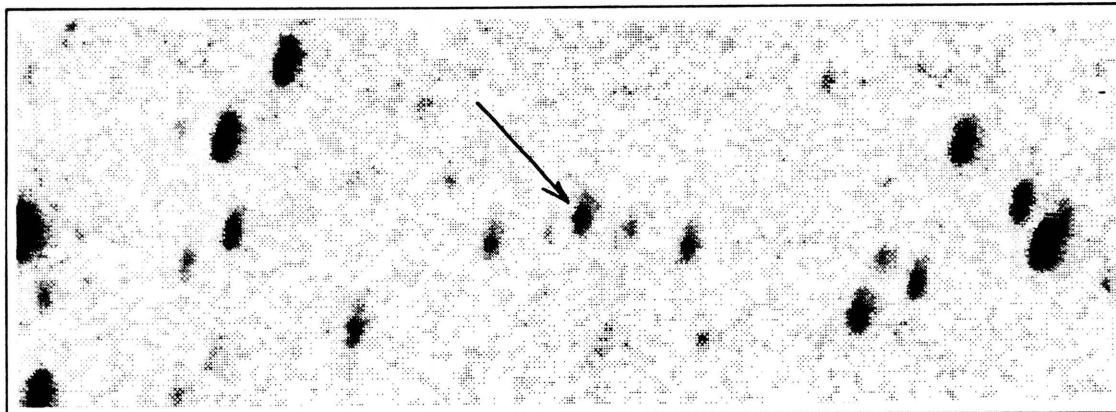


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1991 Jun 22
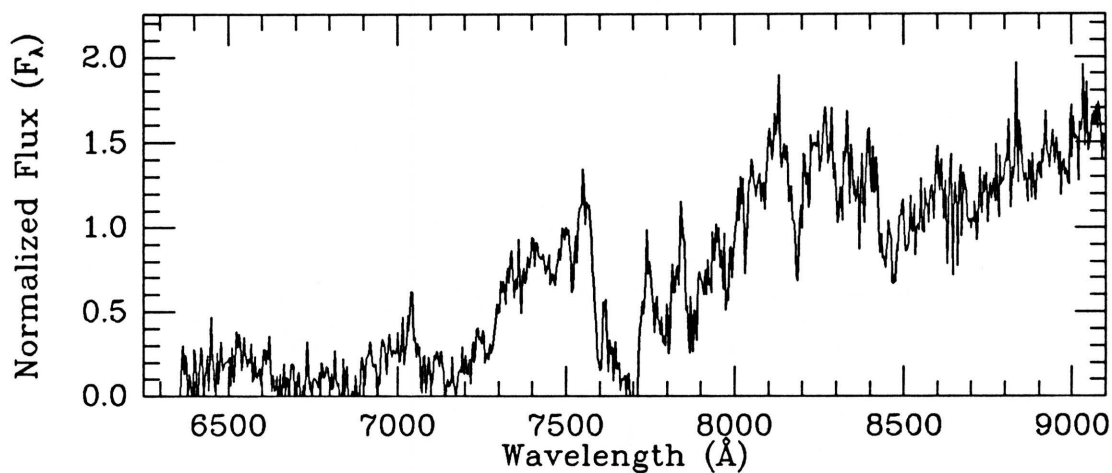


Coordinates:  $\alpha$ (1950) = 15:37:42.2      $\delta$ (1950) = +28:12:01

Spectral Type:  M6.5 V

Photometry:      $I_{KC}$ = 17.90          $R_{CTI}$ = 19.69

 $(V-I)_{KC}$=4.43±.12      $(R-I)_{CTI}$=1.92±.49      $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 153945.1+280234
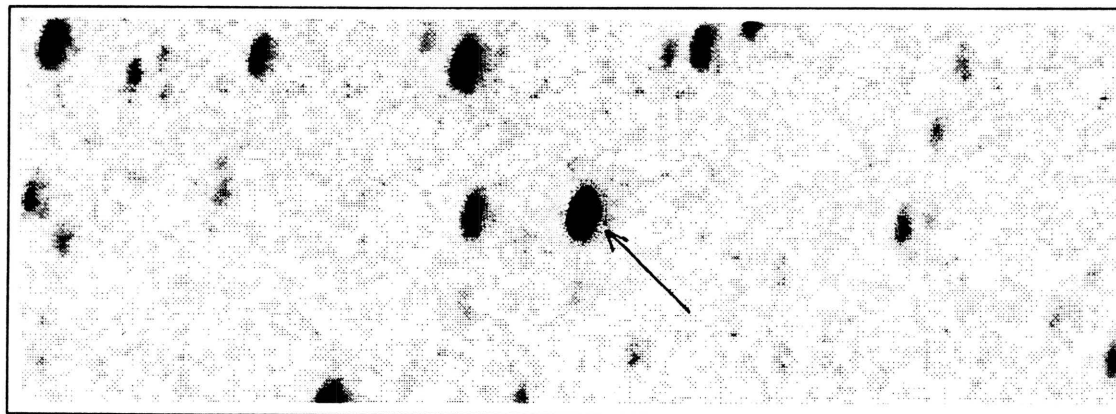


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1991 Jun 24
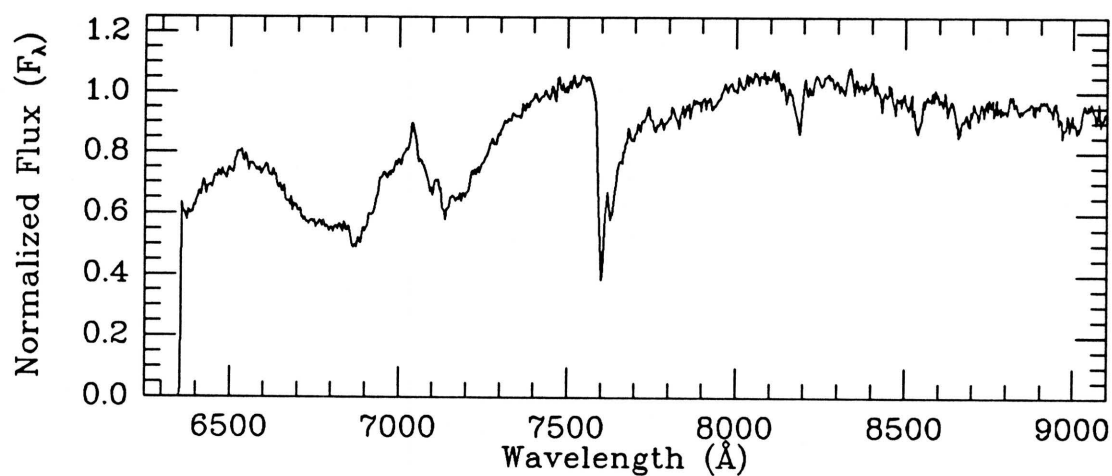


Coordinates:  $\alpha$ (1950) = 15:38:11.7          $\delta$ (1950) = +28:09:48

Spectral Type: M1.5 V

Photometry:          $I_{KC}$ = 14.04          $R_{CTI}$ = 14.70

  $(V-I)_{KC}$=2.12±.06          $(R-I)_{CTI}$=0.56±.01          $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 153948.1+280322
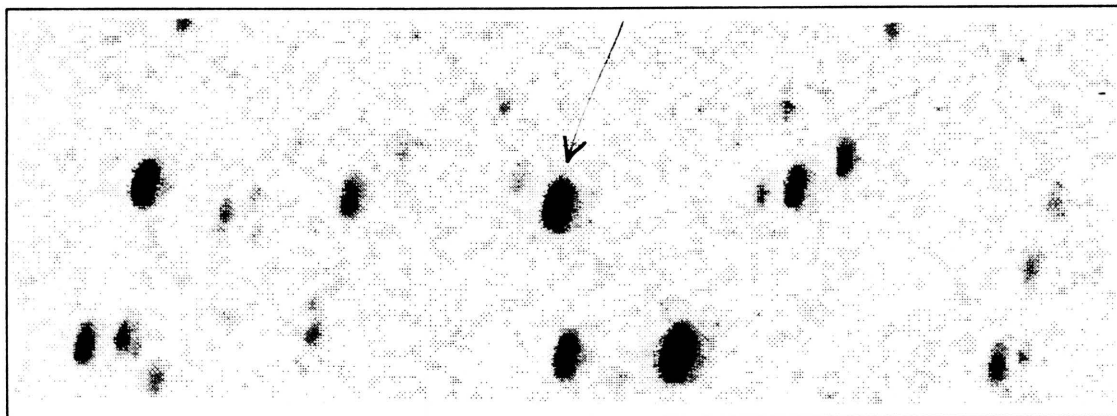


CTI FINDER CHART        I filter        Coadded frame

MMT SPECTRUM      Exposure: 600 sec      Obs. (UT) 1991 Jun 24
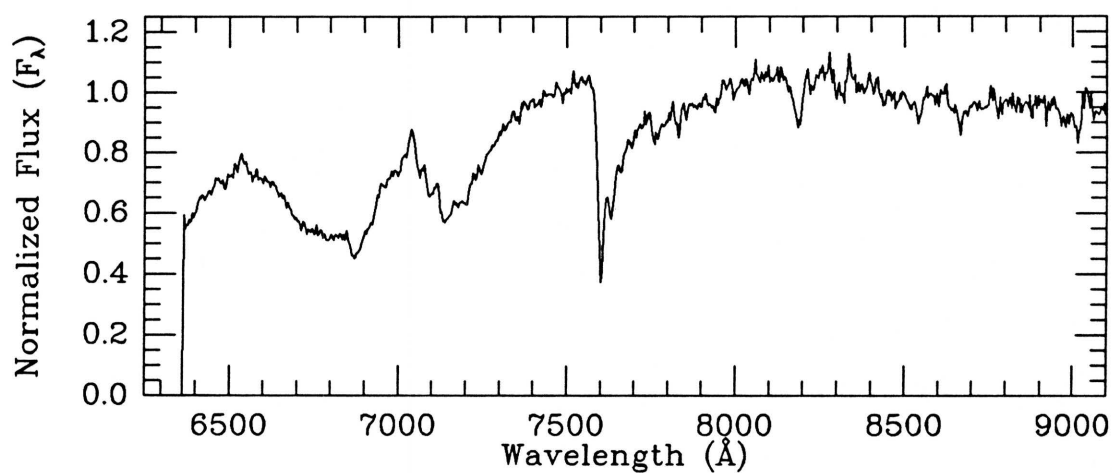


Coordinates: $\alpha$ (1950) = 15:38:14.7      $\delta$ (1950) = +28:10:36

Spectral Type: M2 V

Photometry:      $I_{KC}$ = 14.74      $R_{CTI}$ = 15.48

$(V-I)_{KC}$=2.21±.03      $(R-I)_{CTI}$=0.65±.02      $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 154231.3+280401
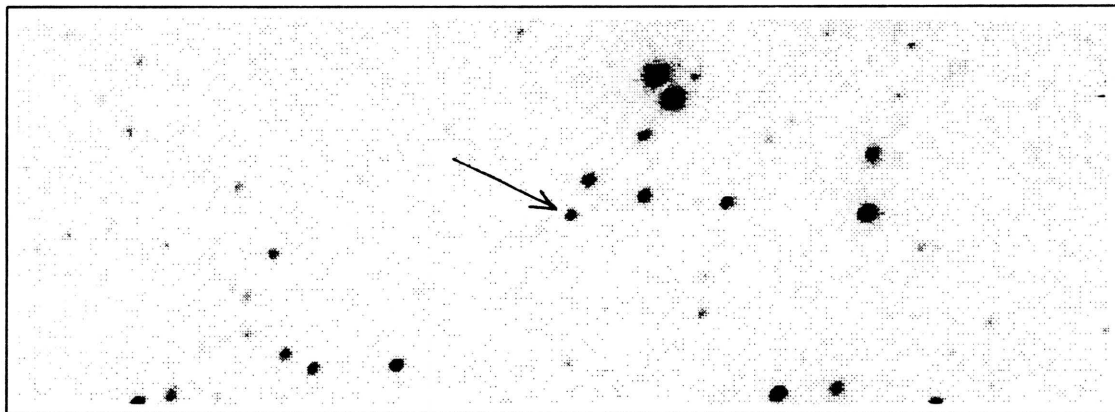


CTI FINDER CHART      Clear filter      Obs. (UT) 1989 Apr 07

MMT SPECTRUM      Exposure: 2700 sec      Obs. (UT) 1990 May 04
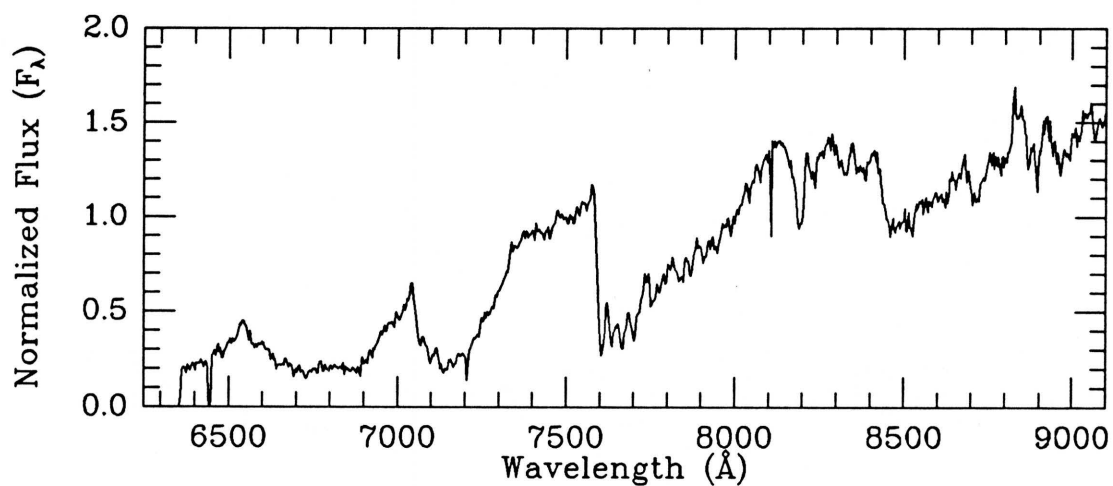


Coordinates: $\alpha$ (1950) = 15:40:58.1      $\delta$ (1950) = +28:11:07

Spectral Type: M5.5 V

Photometry:      $I_{KC}$ = 16.71      $R_{CTI}$ = 18.31

$(V-I)_{KC}$=3.62±.06      $(R-I)_{CTI}$=1.57±.12      $(V-I)_{CTI}$=3.44±.12

Notes: Actual USNO VI photometry. Comparison to POSS E print suggests proper motion of ~0.2 arcsec/yr to the SW.

# CTI 160557.4+280437



**CTI FINDER CHART**     **Clear filter**     **Obs. (UT) 1989 Apr 07**

MMT SPECTRUM     Exposure: 3304 sec     Obs. (UT) 1990 May 23
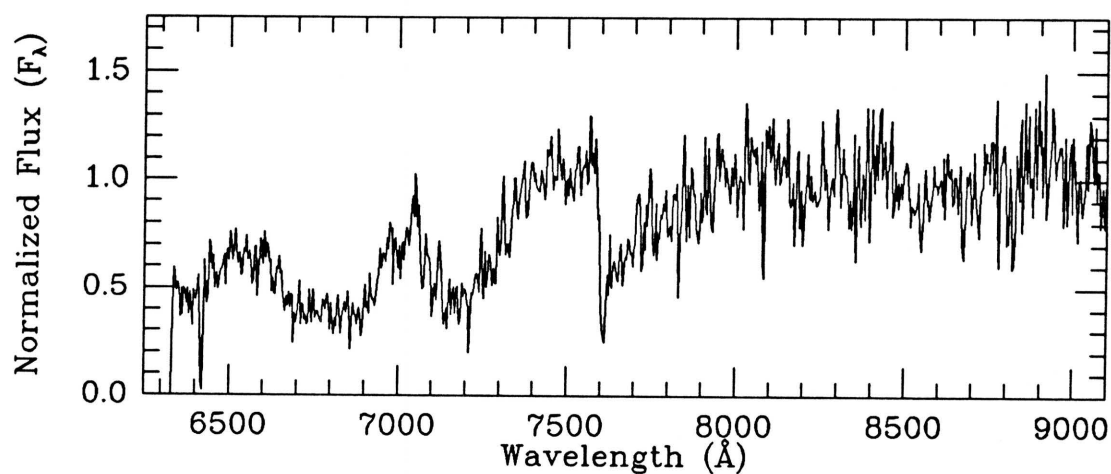


Coordinates:  $\alpha$ (1950) = 16:04:25.6     $\delta$ (1950) = +28:10:38

Spectral Type:  M3 V

Photometry:     $I_{KC}$ = 18.19     $R_{CTI}$ = 19.51

 $(V-I)_{KC}$=2.50±.10     $(R-I)_{CTI}$=1.55±.28     $(V-I)_{CTI}$=2.42±.28

Notes: Actual USNO VI photometry.

# CTI 161340.2+280011
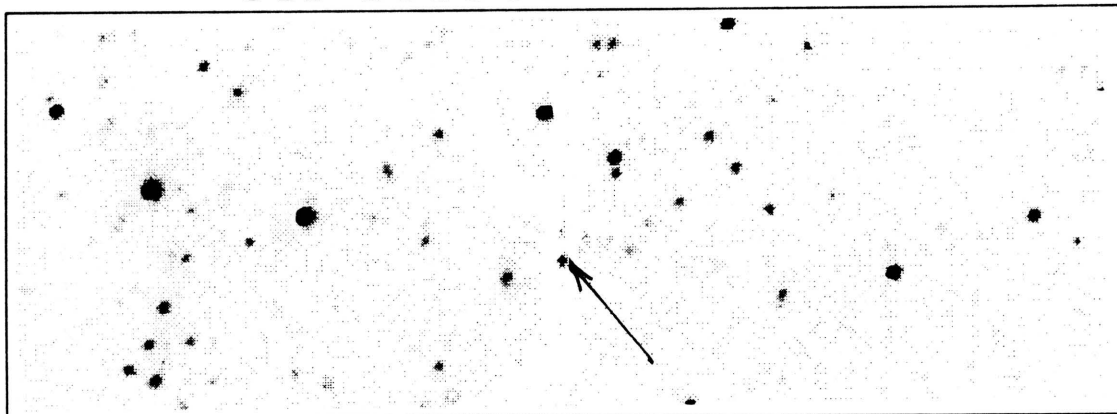


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 3600 sec          Obs. (UT) 1991 May 07
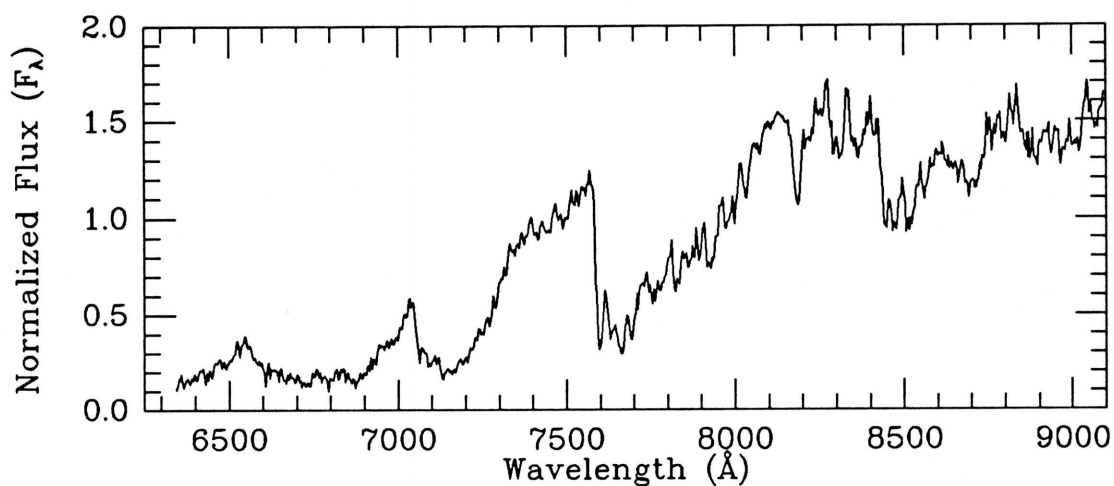


Coordinates:  $\alpha$ (1950) = 16:12:08.8       $\delta$ (1950) = +28:05:50

Spectral Type:  M5.5 V

Photometry:       $I_{KC}$ = 17.31          $R_{CTI}$ = 19.09

  $(V-I)_{KC}$=3.92±.06       $(R-I)_{CTI}$=1.77±.41       $(V-I)_{CTI}$=3.02±.40

Notes: Actual USNO VI photometry.

# CTI 161340.2+280024
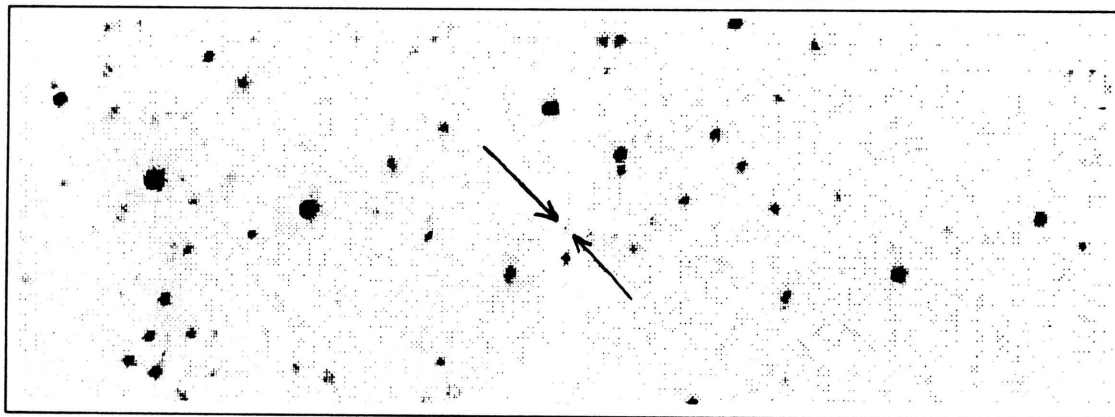


CTI FINDER CHART      Clear filter      Obs. (UT) 1989 Apr 07

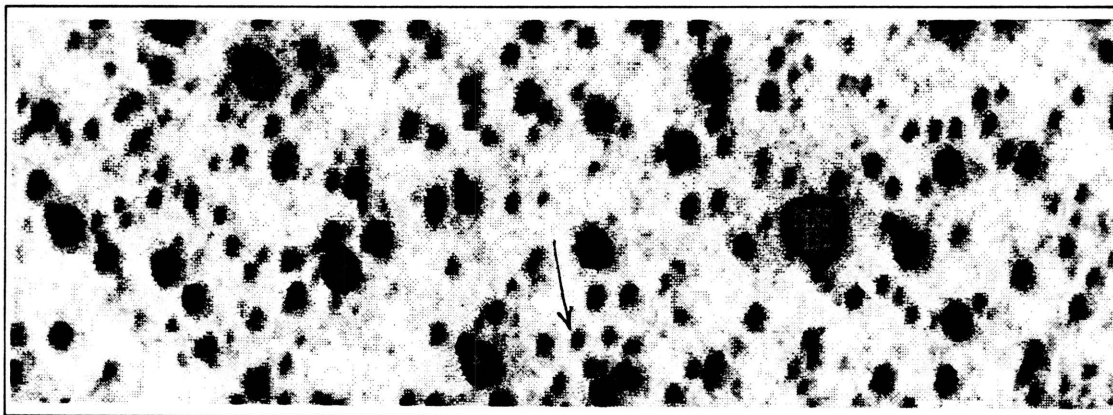MMT SPECTRUM      Exposure: 3600 sec      Obs. (UT) 1991 May 07
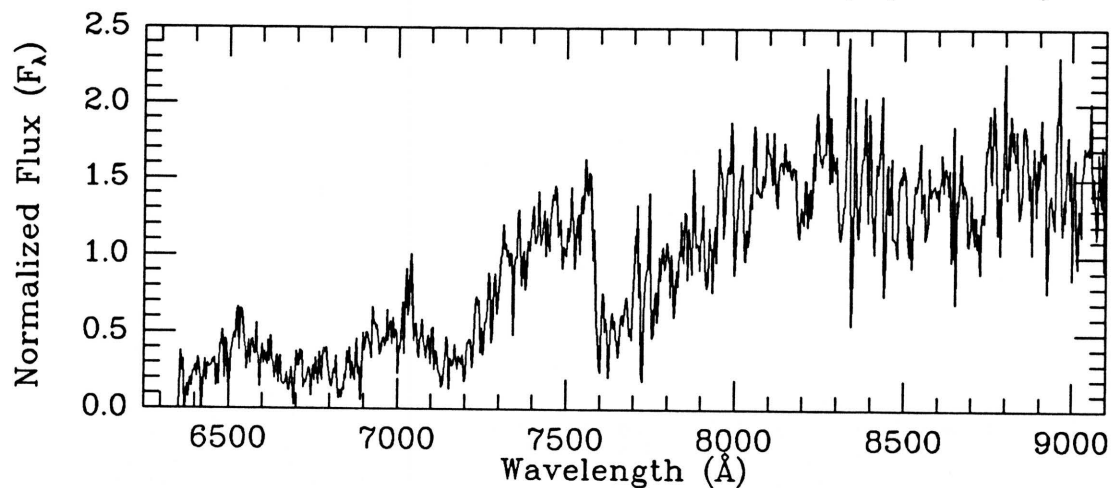


Coordinates: $\alpha$ (1950) = 16:12:08.8      $\delta$ (1950) = +28:06:03

Spectral Type: M4.5: V

Photometry:      $I_{KC}$ = 19.18      $R_{CTI}$ = unknown

$(V-I)_{KC}$=3.55±.16      $(R-I)_{CTI}$=unknown      $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry. The spectrum of this object was obtained simultaneously with that of the object on the last page.

# CTI 162342.9+280305
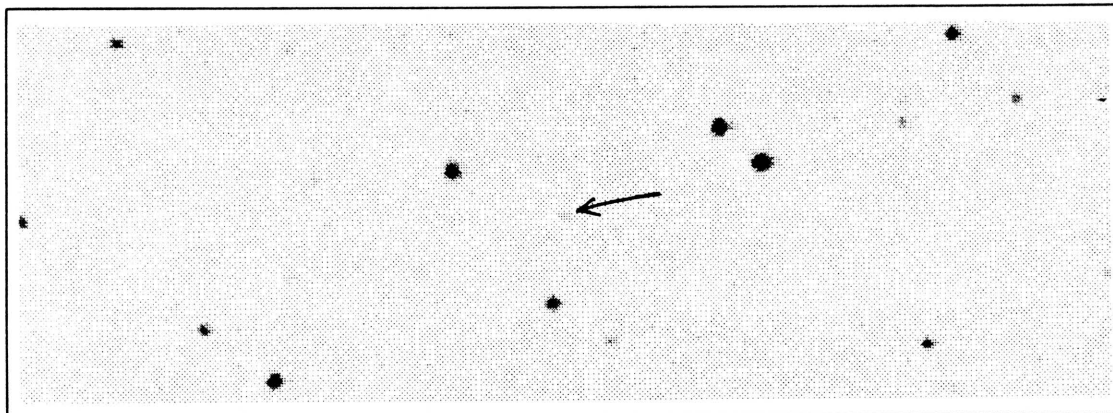


CTI FINDER CHART          V filter          Obs. (UT) 1986 Apr 04

MMT SPECTRUM       Exposure: 2700 sec       Obs. (UT) 1989 Jul 10
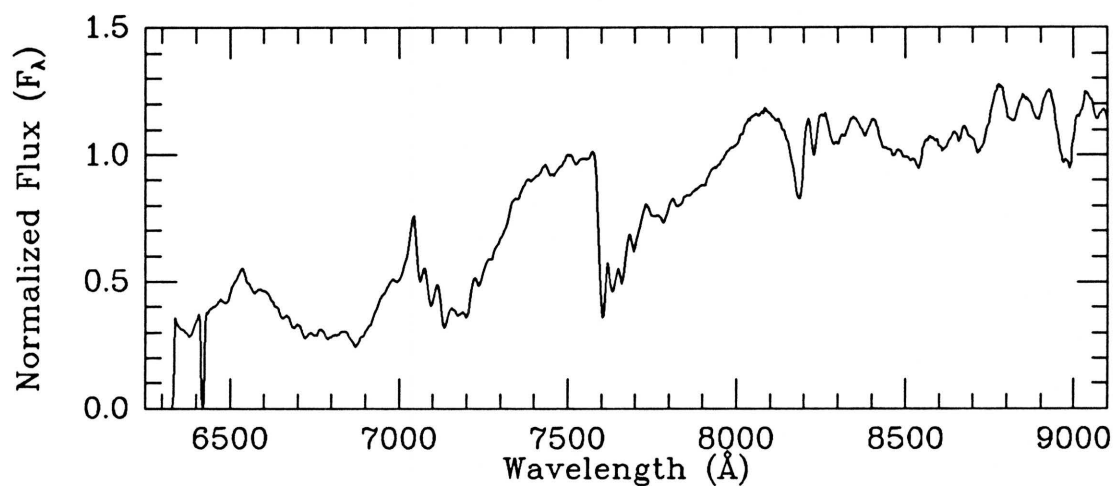


Coordinates: $\alpha$ (1950) = 16:22:12.0      $\delta$ (1950) = +28:08:14

Spectral Type: M4 V

Photometry:      $I_{KC}$ = 15.82      $R_{CTI}$ = 17.02

$(V-I)_{KC}$=3.03±.14      $(R-I)_{CTI}$=1.19±.05      $(V-I)_{CTI}$=2.85±.04

Notes:

# CTI 162356.1+275942
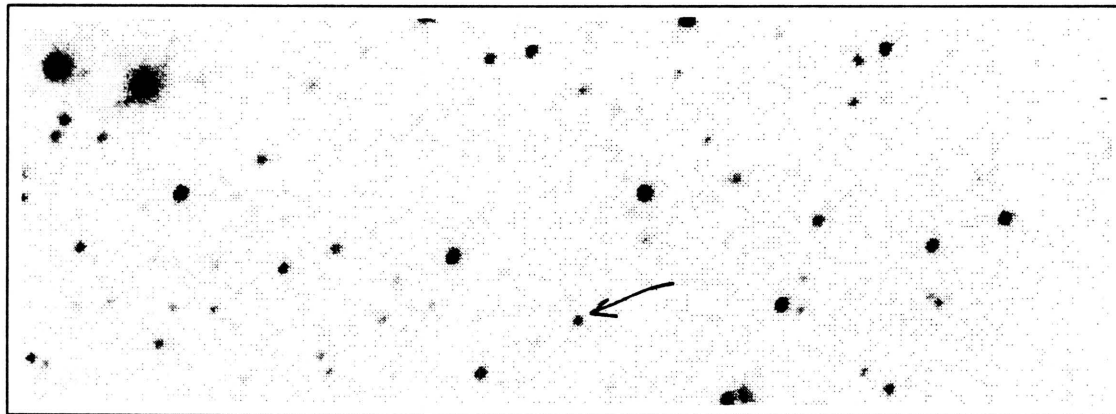


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1990 May 23
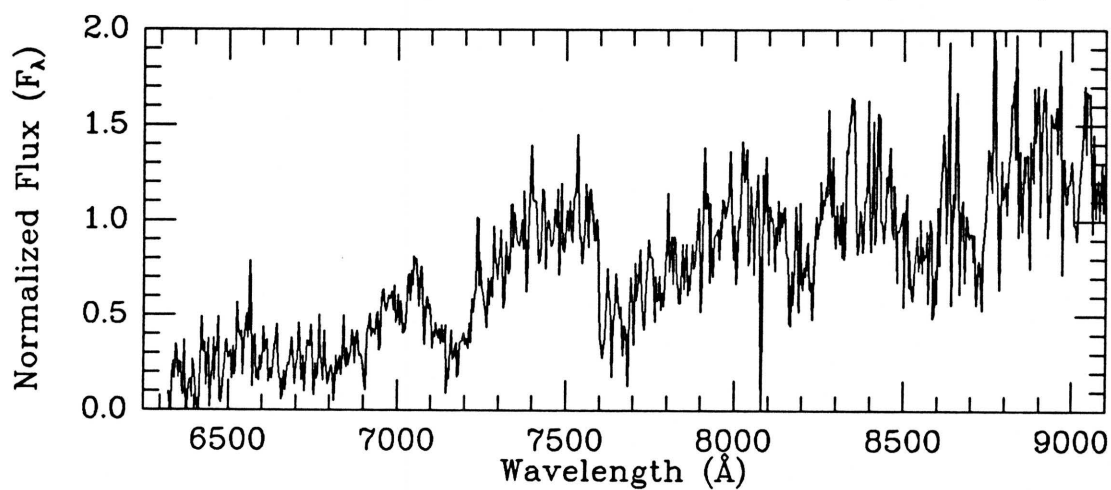


Coordinates:  $\alpha$ (1950) = 16:22:25.2          $\delta$ (1950) = +28:04:50

Spectral Type:  M3 V

Photometry:          $I_{KC}$ = 17.29          $R_{CTI}$ = 18.52

 $(V-I)_{KC}$=3.17±.24          $(R-I)_{CTI}$=1.29±.14          $(V-I)_{CTI}$=2.98±.14

Notes:

# CTI 162920.4+280238
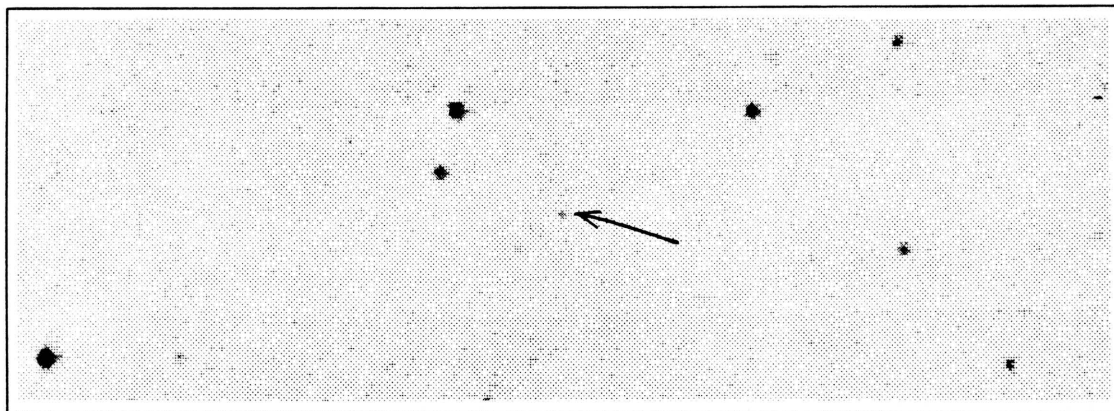


CTI FINDER CHART            V filter            Obs. (UT) 1986 Apr 04

MMT SPECTRUM        Exposure: 1800 sec        Obs. (UT) 1989 Jul 10
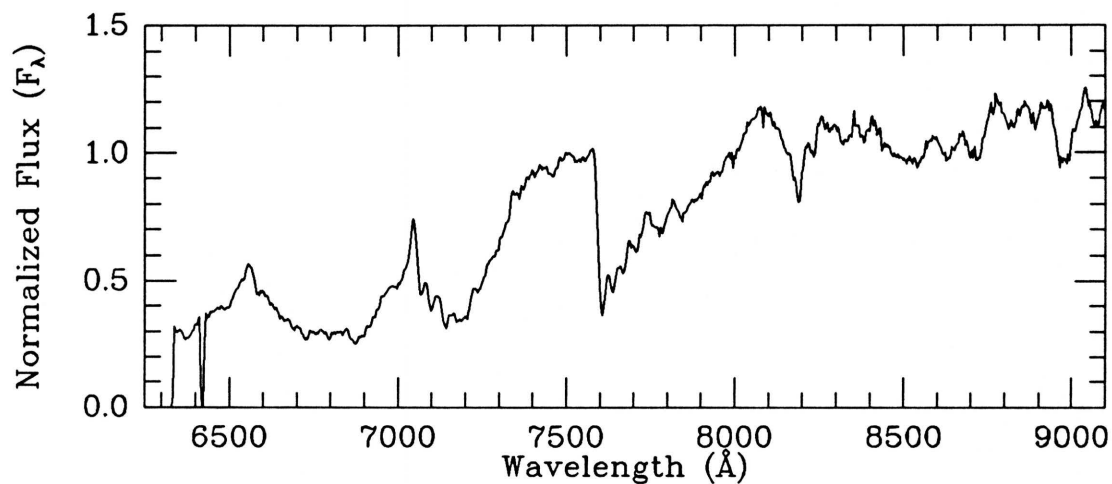


Coordinates:  $\alpha$ (1950) = 16:27:49.8      $\delta$ (1950) = +28:07:30

Spectral Type:  M4 V

Photometry:      $I_{KC}$ = 15.59        $R_{CTI}$ = 16.55

 $(V-I)_{KC}$=2.67±.15      $(R-I)_{CTI}$=0.94±.07      $(V-I)_{CTI}$=2.63±.07

Notes:

# CTI 170958.5+275905
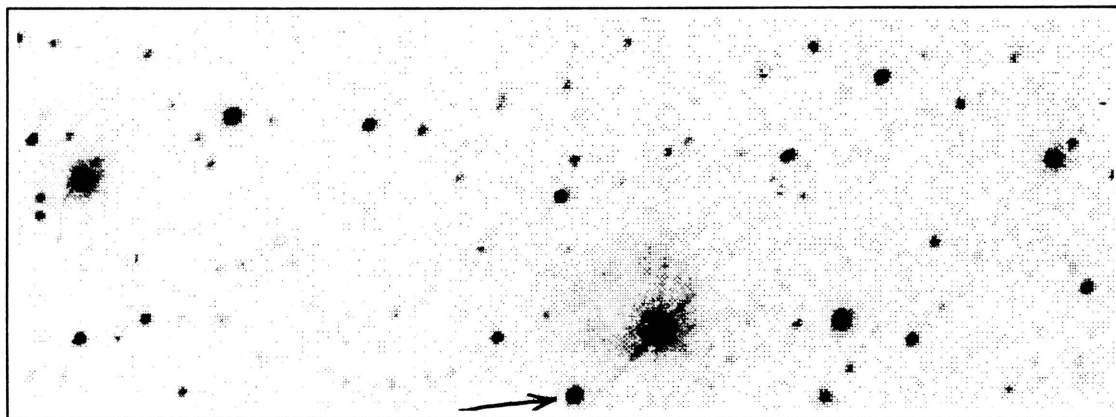


CTI FINDER CHART          Clear filter          Obs. (UT) 1989 Apr 07

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1991 May 07
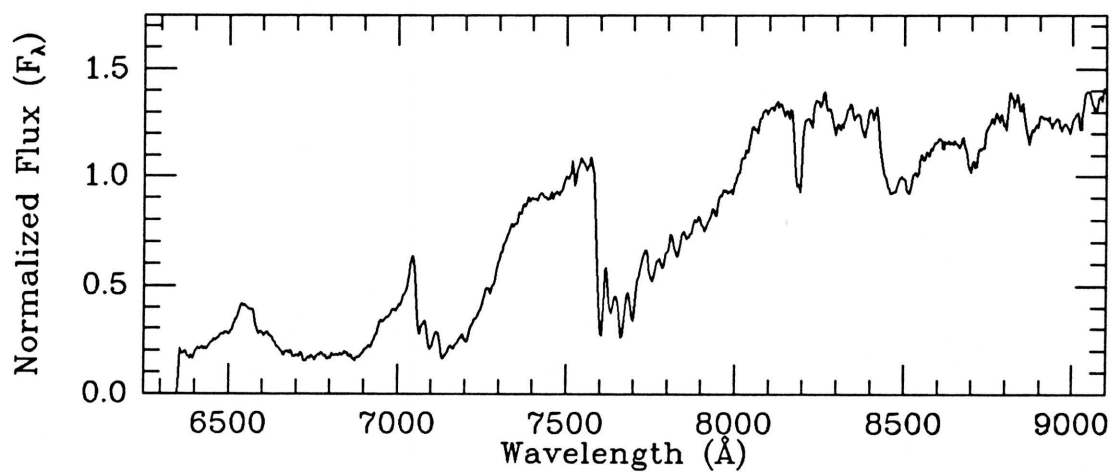


Coordinates:  $\alpha$ (1950) = 17:08:29.2          $\delta$ (1950) = +28:01:50

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 13.90          $R_{CTI}$ = 15.46

$(V-I)_{KC}$=3.67±.03          $(R-I)_{CTI}$=1.58±.03          $(V-I)_{CTI}$=3.65±.02

Notes: Actual USNO VI photometry.

# CTI 171818.0+280512



CTI FINDER CHART          I filter          Obs. (UT) 1990 Jun 20

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Sep 13
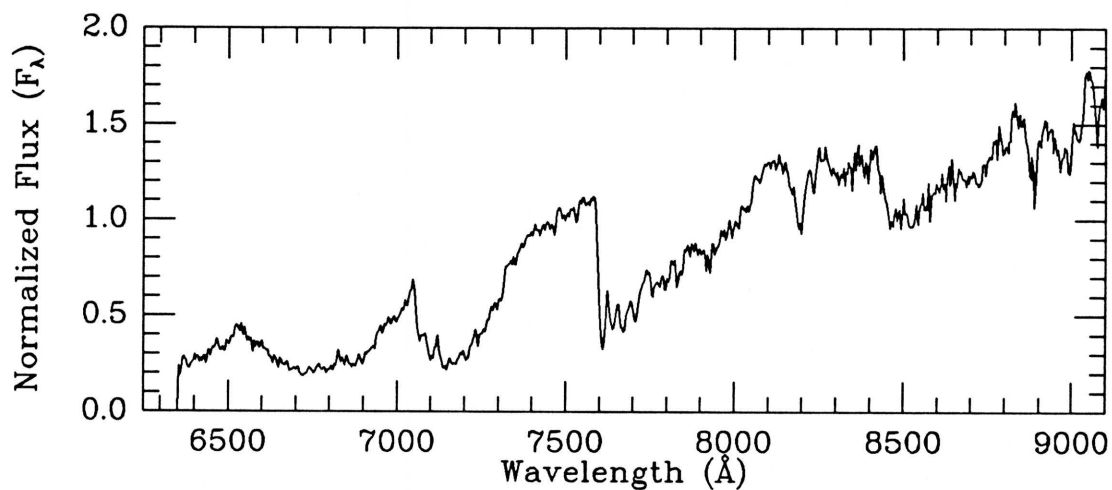


Coordinates:  $\alpha$ (1950) = 17:16:49.0          $\delta$ (1950) = +28:07:30

Spectral Type:  M5 V

Photometry:          $I_{KC}$ = 16.83          $R_{CTI}$ = 18.50

  $(V-I)_{KC}$=3.37±.12          $(R-I)_{CTI}$=1.57±.18          $(V-I)_{CTI}$=3.57±.18

Notes: Actual USNO VI photometry.

# CTI 174729.0+280322
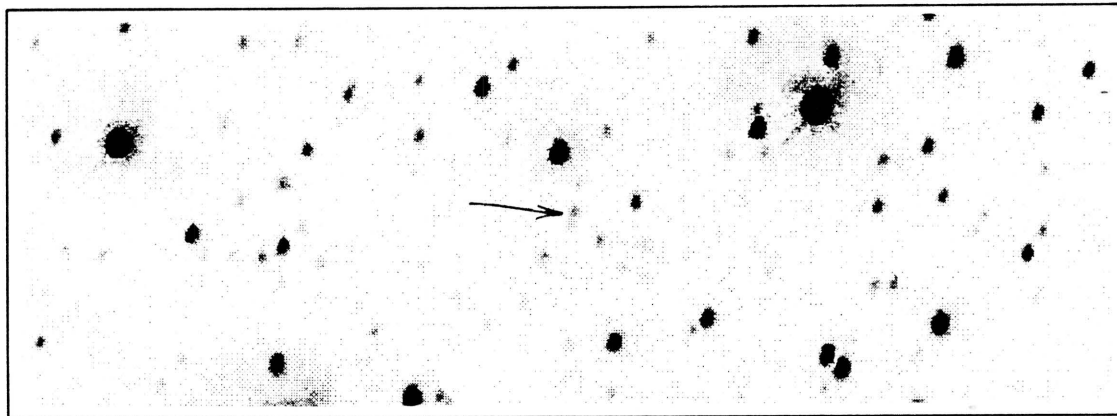


CTI FINDER CHART                    I filter                    Obs. (UT) 1990 Jun 20

MMT SPECTRUM            Exposure: 5400 sec    Obs. (UT) 1990 Sep 13/14
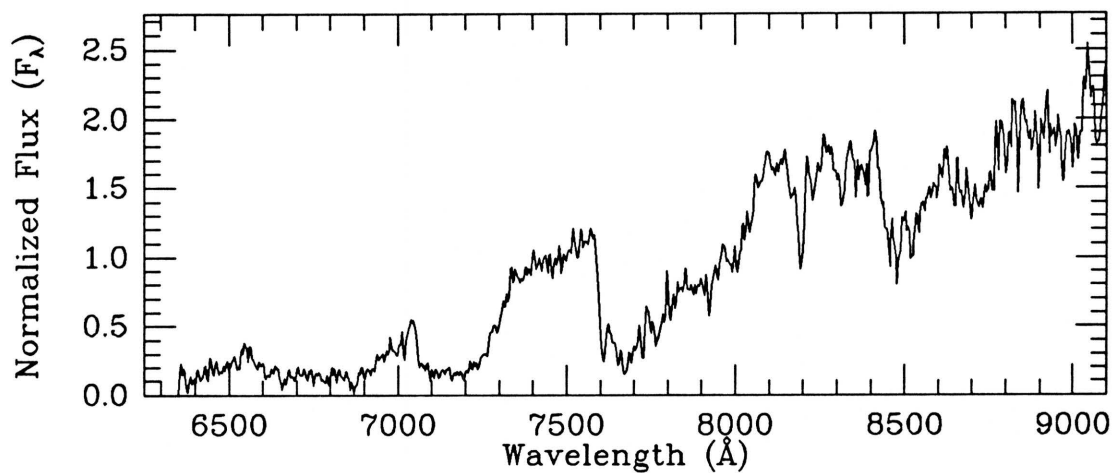


Coordinates:  $\alpha$ (1950) = 17:46:00.4        $\delta$ (1950) = +28:04:05

Spectral Type:  M6.5 V

Photometry:        $I_{KC}$ = 17.87            $R_{CTI}$ = 19.78

  $(V-I)_{KC}$=4.27±.20        $(R-I)_{CTI}$=2.21±.42        $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 180120.1+280410
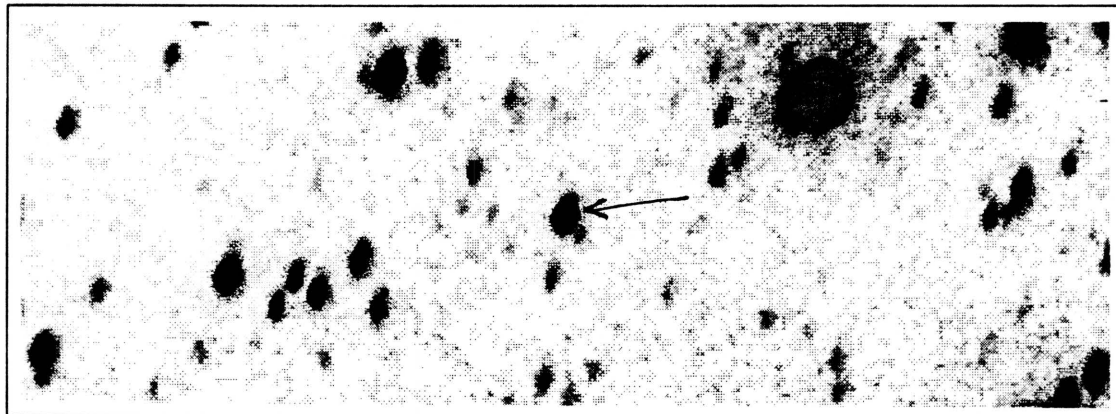


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM        Exposure: 600 sec        Obs. (UT) 1991 Jun 23
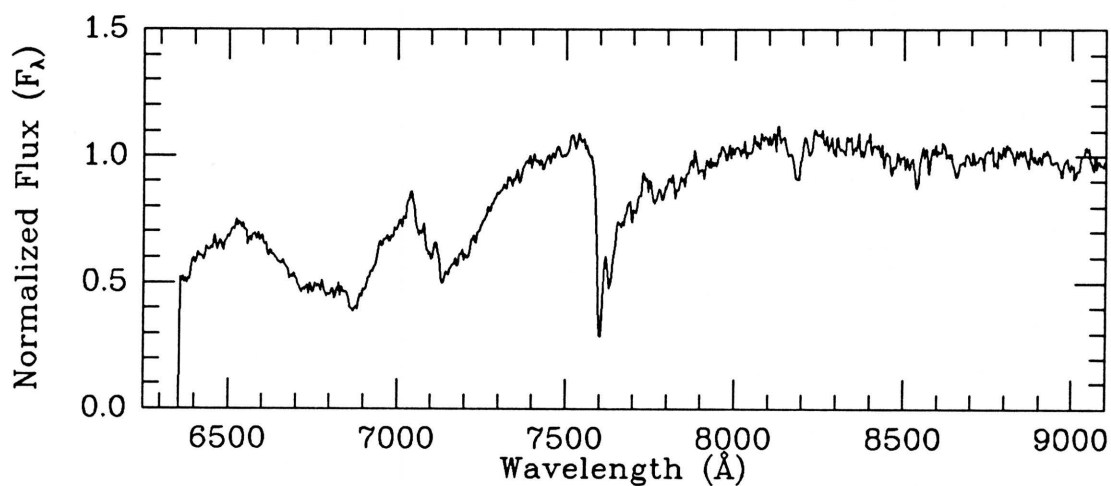


Coordinates:   $\alpha$ (1950) = 17:59:51.5       $\delta$ (1950) = +28:04:08

Spectral Type:   M2.5 V

Photometry:        $I_{KC}$ = 14.70        $R_{CTI}$ = 15.39

  $(V-I)_{KC}$=2.27±.03        $(R-I)_{CTI}$=0.60±.02        $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 180142.2+275924
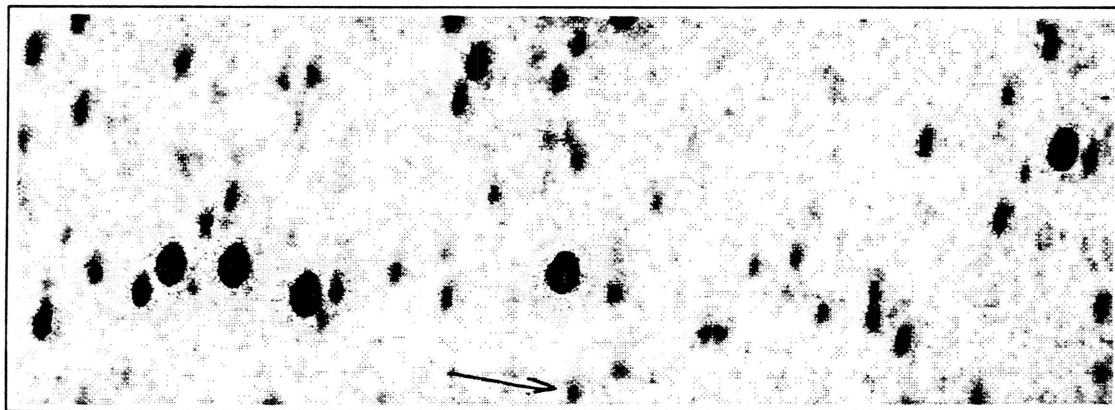


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1991 Jun 24
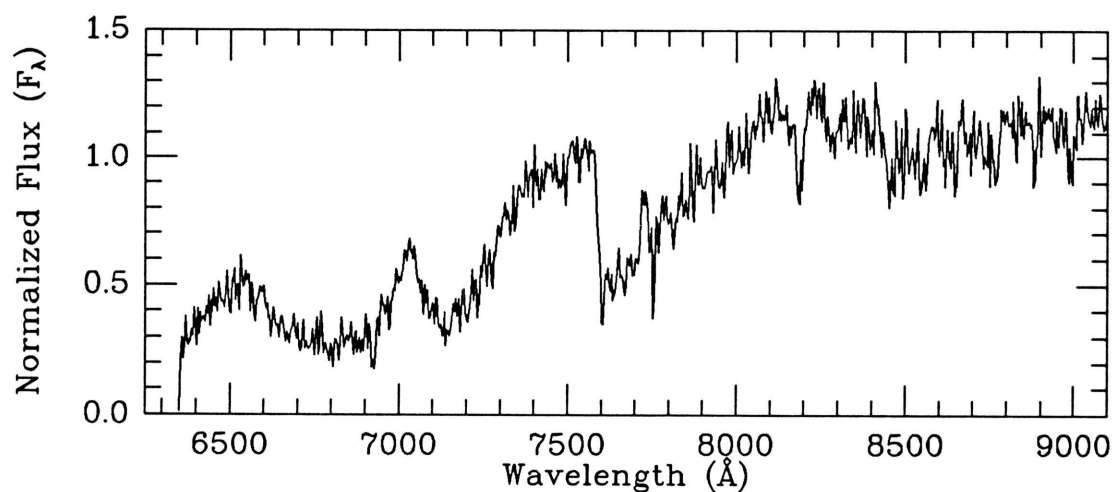


Coordinates:  $\alpha$ (1950) = 18:00:13.6          $\delta$ (1950) = +27:59:21

Spectral Type:  M4 V

Photometry:          $I_{KC}$ = 17.89          $R_{CTI}$ = unknown

$(V-I)_{KC}$=unknown          $(R-I)_{CTI}$=unknown          $(V-I)_{CTI}$=unknown

Notes:

# CTI 180216.7+280458
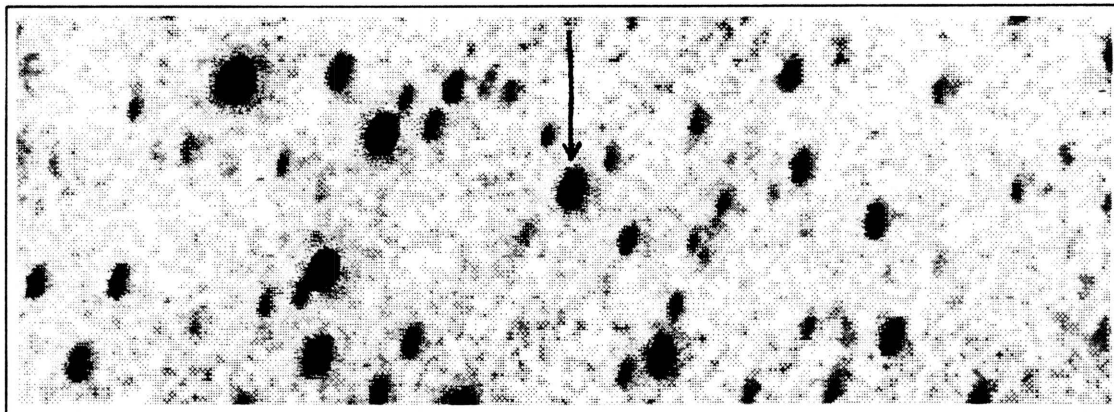


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 600 sec          Obs. (UT) 1991 Jun 23
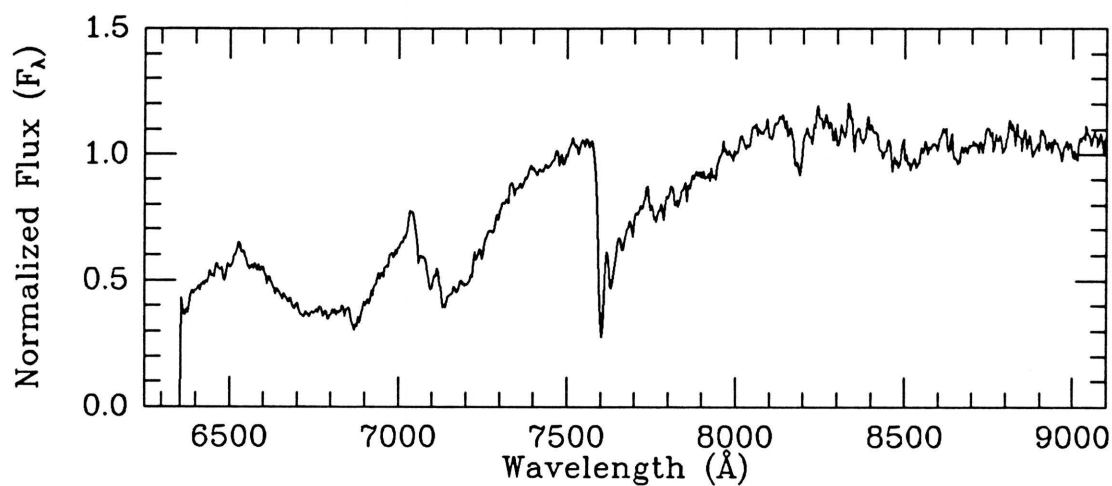


Coordinates:  $\alpha$ (1950) = 18:00:48.2          $\delta$ (1950) = +28:04:53

Spectral Type:  M3 V

Photometry:          $I_{KC}$ = 15.09          $R_{CTI}$ = 15.90

   $(V-I)_{KC}$=2.42±.12          $(R-I)_{CTI}$=0.77±.03          $(V-I)_{CTI}$=unknown

Notes:

# CTI 180257.0+280454
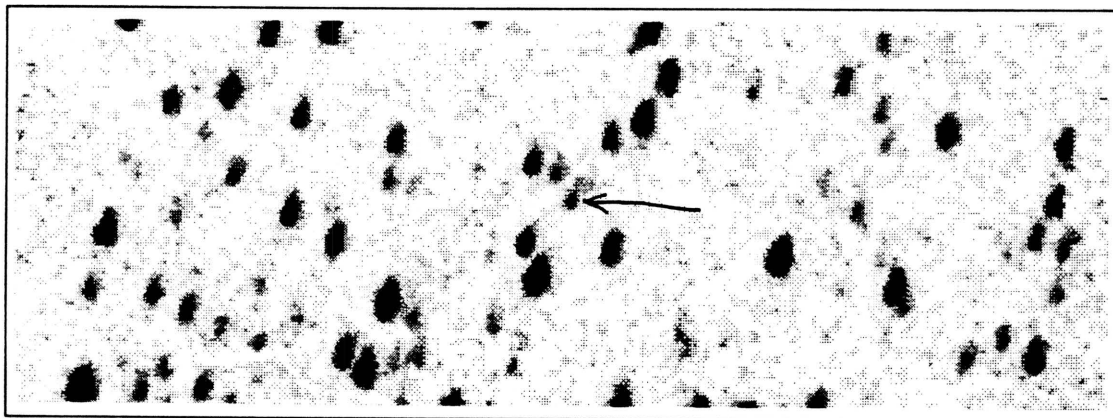


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1991 Jun 22
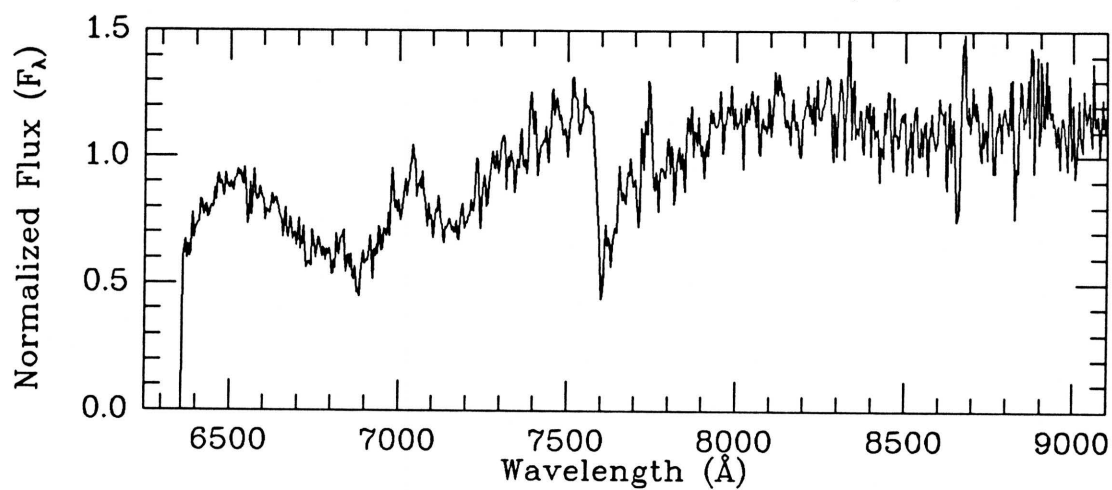


Coordinates:  $\alpha$ (1950) = 18:01:28.5          $\delta$ (1950) = +28:04:47

Spectral Type:  M2: V

Photometry:          $I_{KC}$ = 17.95          $R_{CTI}$ = 19.97

$(V-I)_{KC}$=4.34±.63          $(R-I)_{CTI}$=2.11±.43          $(V-I)_{CTI}$=unknown

Notes:

# CTI 180304.9+280256
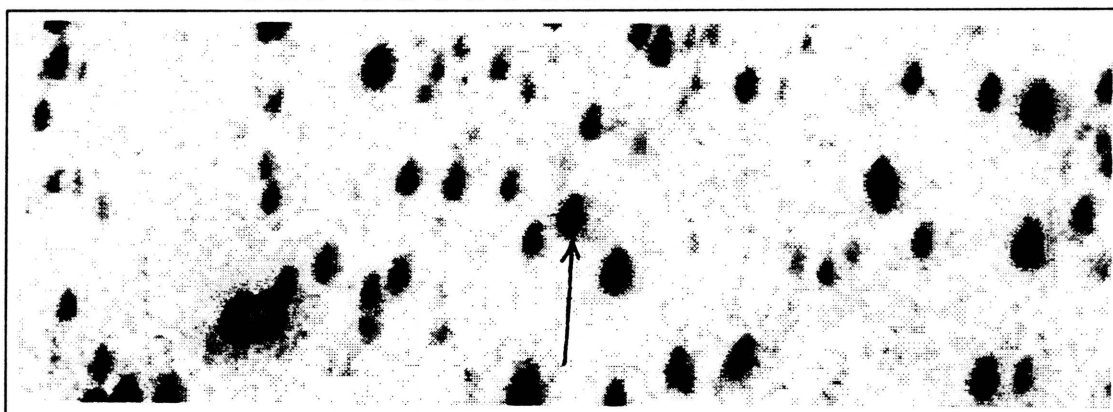


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1991 Jun 23
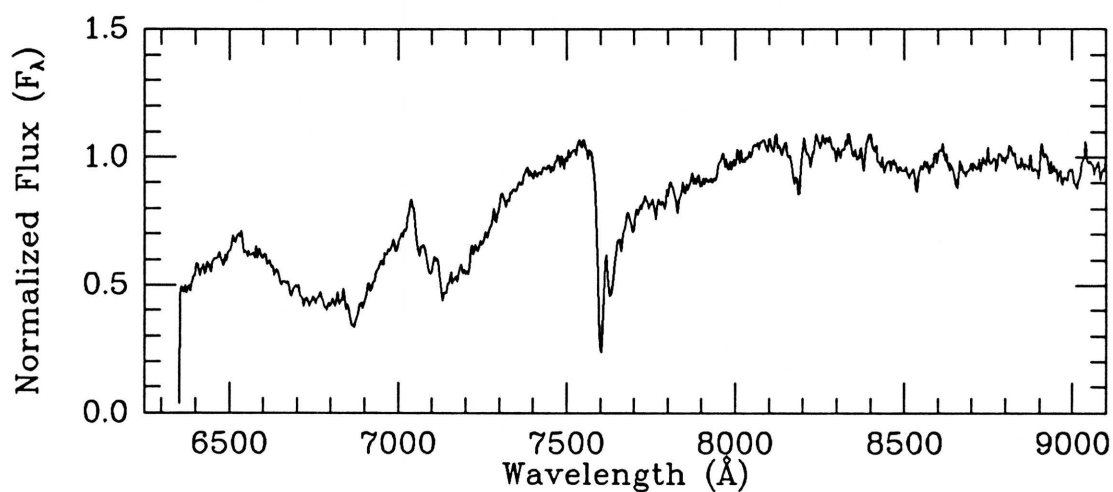


Coordinates:  $\alpha$ (1950) = 18:01:36.3     $\delta$ (1950) = +28:02:48

Spectral Type:  M2.5 V

Photometry:     $I_{KC}$ = 14.88     $R_{CTI}$ = 15.77

  $(V-I)_{KC}$=2.37±.04     $(R-I)_{CTI}$=0.76±.03     $(V-I)_{CTI}$=unknown

Notes: Actual USNO VI photometry.

# CTI 180350.7+280133
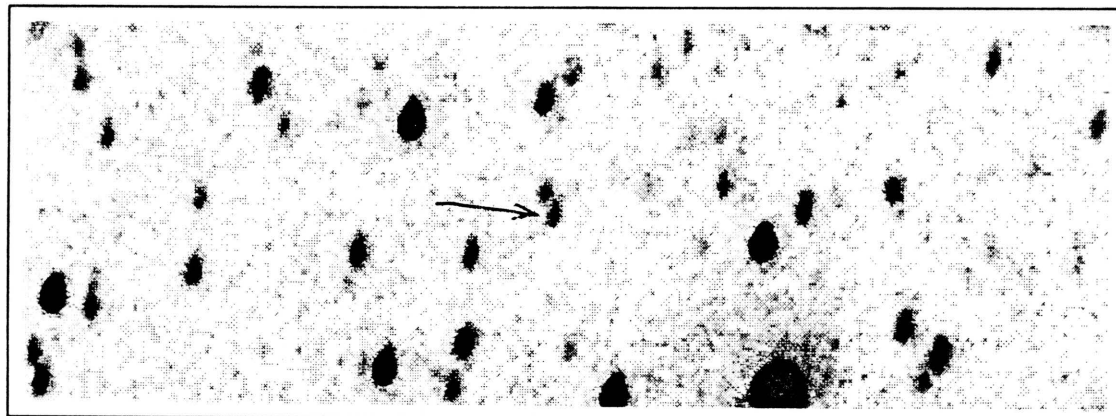


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1991 Jun 23
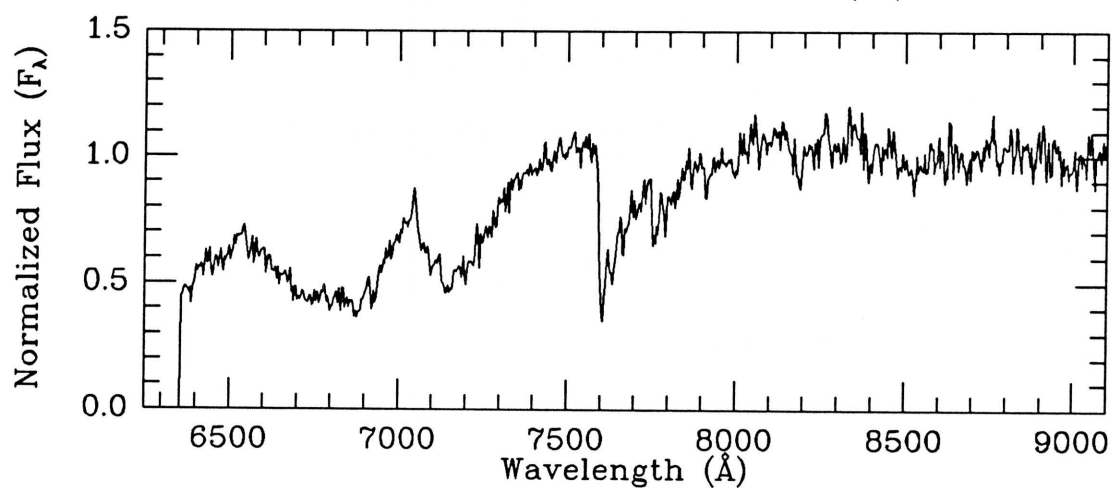


Coordinates:  $\alpha$ (1950) = 18:02:22.1     $\delta$ (1950) = +28:01:23

Spectral Type:  M3 V

Photometry:     $I_{KC}$ = 18.08          $R_{CTI}$ = unknown

  $(V-I)_{KC}$=unknown     $(R-I)_{CTI}$=unknown     $(V-I)_{CTI}$=unknown

Notes:

# CTI 180408.2+280353
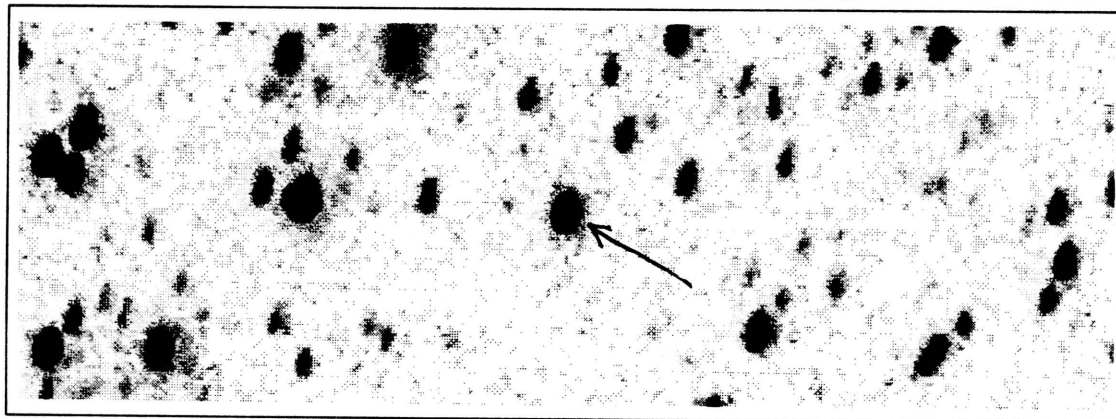


CTI FINDER CHART             I filter             Coadded frame

MMT SPECTRUM        Exposure: 300 sec        Obs. (UT) 1991 Jun 23
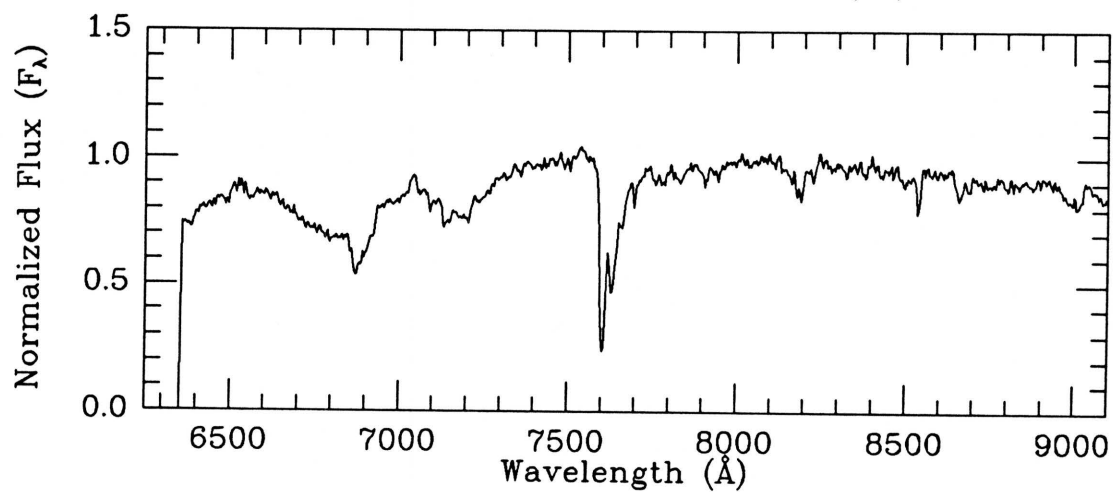


Coordinates:  $\alpha$ (1950) = 18:02:39.6      $\delta$ (1950) = +28:03:42

Spectral Type:  M0 V

Photometry:      $I_{KC}$ = 14.09          $R_{CTI}$ = 14.49

 $(V-I)_{KC}$=1.77±.10      $(R-I)_{CTI}$=0.31±.01      $(V-I)_{CTI}$=unknown

Notes:

# CTI 180456.5+280048
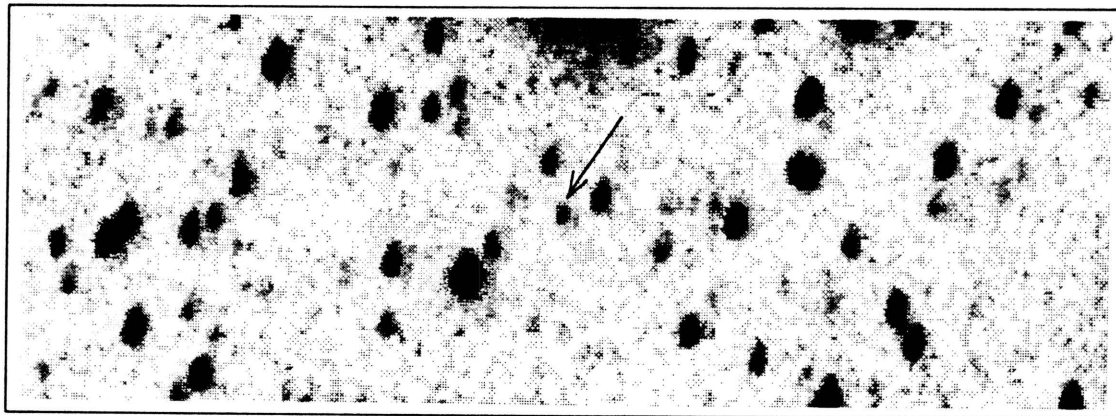


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1991 Jun 23
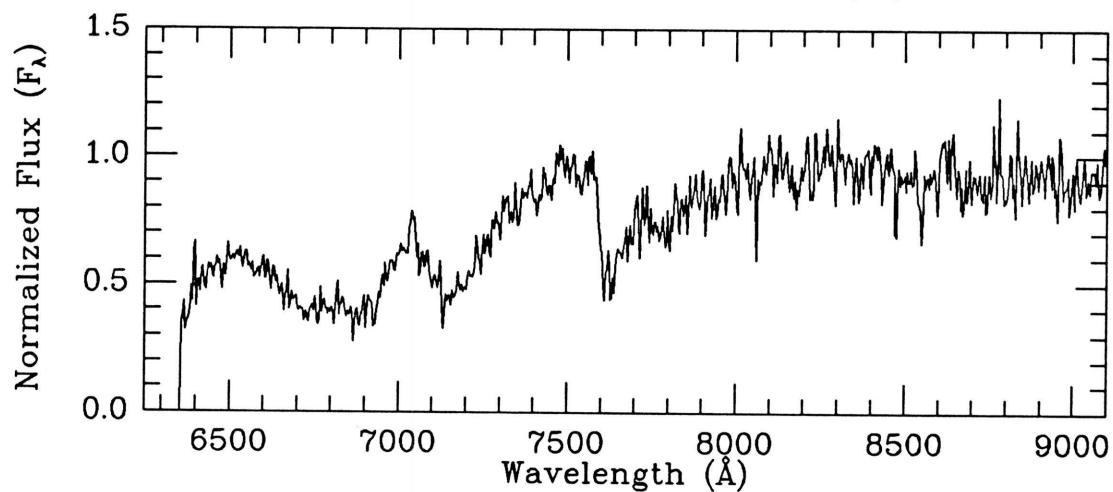


Coordinates:  $\alpha$ (1950) = 18:03:28.0          $\delta$ (1950) = +28:00:34

Spectral Type:  M3 V

Photometry:          $I_{KC}$ = 18.27          $R_{CTI}$ = 19.88

 $(V-I)_{KC}$=3.78±.76          $(R-I)_{CTI}$=1.72±.52          $(V-I)_{CTI}$=unknown

Notes:

# CTI 180516.3+280447
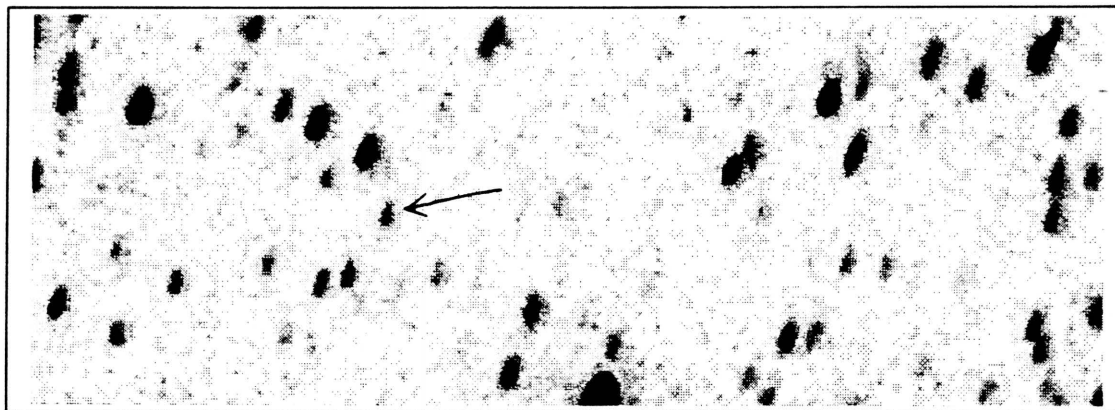


CTI FINDER CHART  I filter  Coadded frame

MMT SPECTRUM  Exposure: 2700 sec  Obs. (UT) 1991 Jun 22
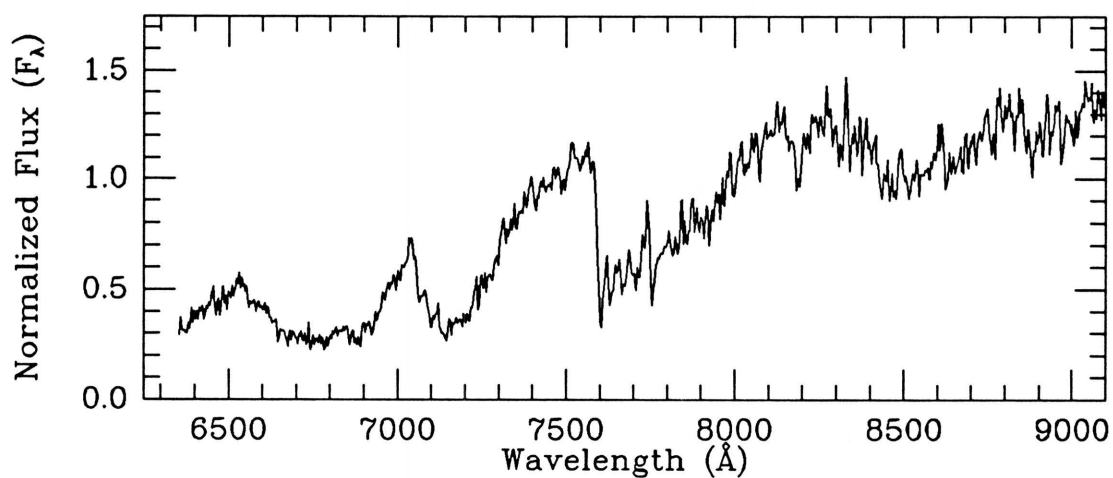


Coordinates:  $\alpha$ (1950) = 18:03:47.7  $\delta$ (1950) = +28:04:32

Spectral Type:  M4.5 V

Photometry:  $I_{KC}$ = 17.94  $R_{CTI}$ = unknown

$(V-I)_{KC}$=unknown  $(R-I)_{CTI}$=unknown  $(V-I)_{CTI}$=unknown

Notes:

# CTI 185818.3+280045
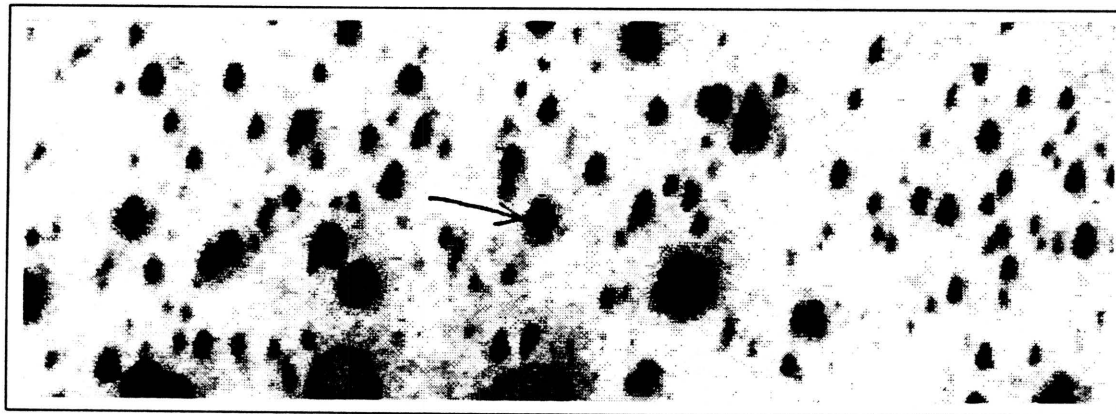


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1991 Jun 23
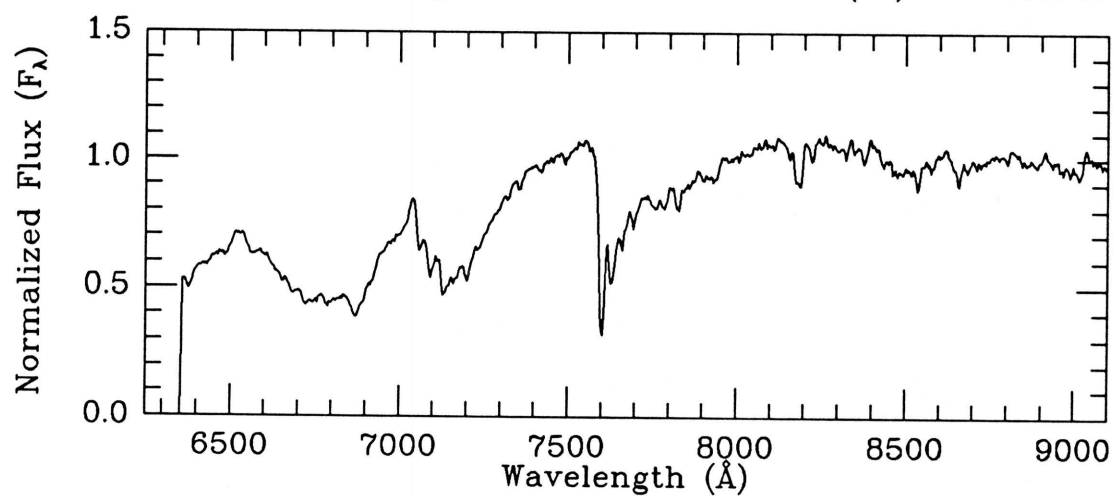


Coordinates:  $\alpha$ (1950) = 18:56:48.8          $\delta$ (1950) = +27:57:38

Spectral Type:  M2.5 V

Photometry:          $I_{KC}$ = 14.06          $R_{CTI}$ = 14.82

   $(V-I)_{KC}$=2.28±.11          $(R-I)_{CTI}$=0.67±.01          $(V-I)_{CTI}$=unknown

Notes:

# CTI 185818.4+275940
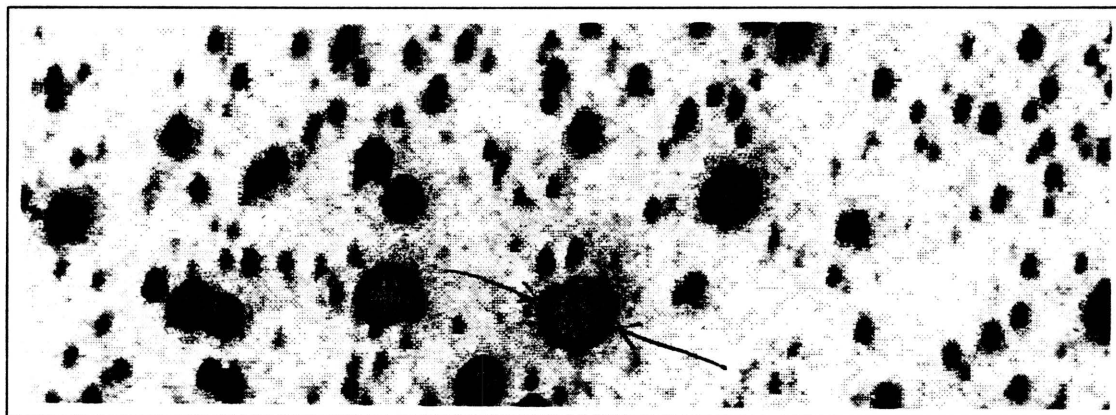


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 30 sec          Obs. (UT) 1991 Jun 23



Coordinates:  $\alpha$ (1950) = 18:56:48.9          $\delta$ (1950) = +27:56:33

Spectral Type:  M3 III

Photometry:          $I_{KC}$ = unknown          $R_{CTI}$ = 11.81

$(V-I)_{KC}$=unknown          $(R-I)_{CTI}$=0.36±.01          $(V-I)_{CTI}$=1.24±.01

Notes: CTI R and I measures probably saturated. A Mira
variable whose 14 CTI V measures range from 12.6 to 12.8.
Not listed in General Cat. of Variable Stars (Kholopov 1985).

# CTI 190006.7+280451
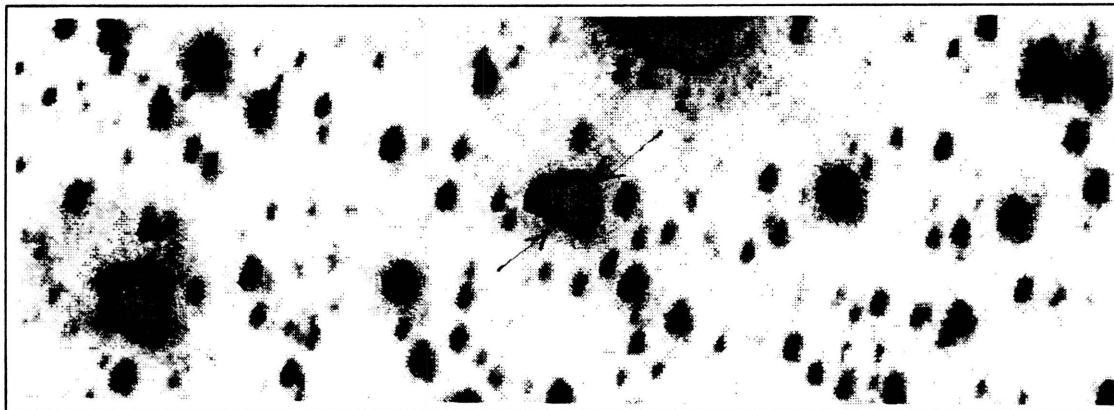


CTI FINDER CHART       I filter       Coadded frame

MMT SPECTRUM      Exposure: 300 sec      Obs. (UT) 1991 Jun 22



Coordinates: $\alpha$ (1950) = 18:58:37.2      $\delta$ (1950) = +28:01:38

Spectral Type: M5.5 III

Photometry:     $I_{KC}$ = unknown      $R_{CTI}$ = 12.72

   $(V-I)_{KC}$=unknown     $(R-I)_{CTI}$=1.48±.01     $(V-I)_{CTI}$=3.78±.01

Notes: A Mira variable whose 13 CTI V measures range from 14.8 to 15.2. Not listed in General Cat. of Variable Stars (Kholopov 1985).

# CTI 190016.9+280539
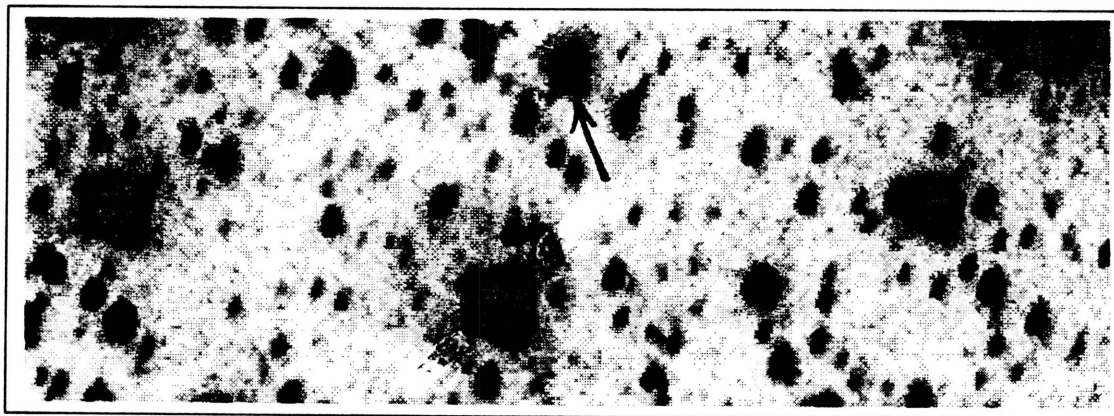


CTI FINDER CHART       I filter       Coadded frame

MMT SPECTRUM     Exposure: 300 sec     Obs. (UT) 1991 Jun 24
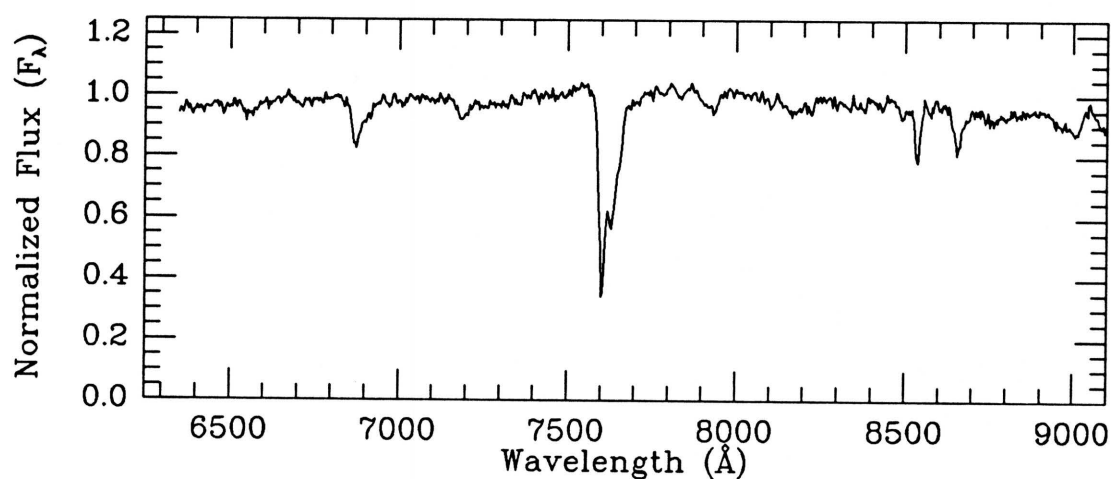


Coordinates: $\alpha$ (1950) = 18:58:47.4      $\delta$ (1950) = +28:02:26

Spectral Type: K7 III

Photometry:     $I_{KC}$ = unknown      $R_{CTI}$ = 13.45

   $(V-I)_{KC}$=unknown     $(R-I)_{CTI}$=0.34±.01     $(V-I)_{CTI}$=1.24±.01

Notes: Possible Mira variable whose 12 CTI V measures range from 14.27 to 14.37. Not listed in General Cat. of Variable Stars (Kholopov 1985).

# CTI 190917.7+280305
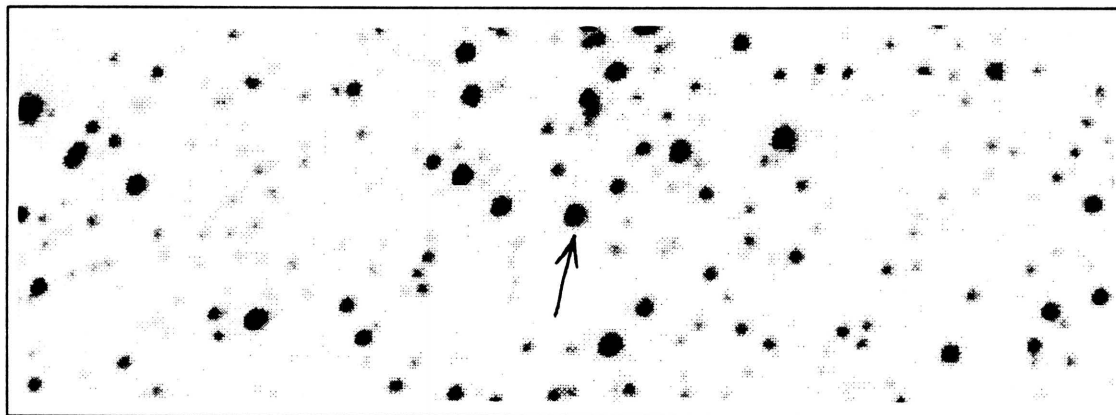


CTI FINDER CHART                    V filter?                    Obs. (UT) not known

MMT SPECTRUM          Exposure: 3 sec          Obs. (UT) 1989 Jul 10
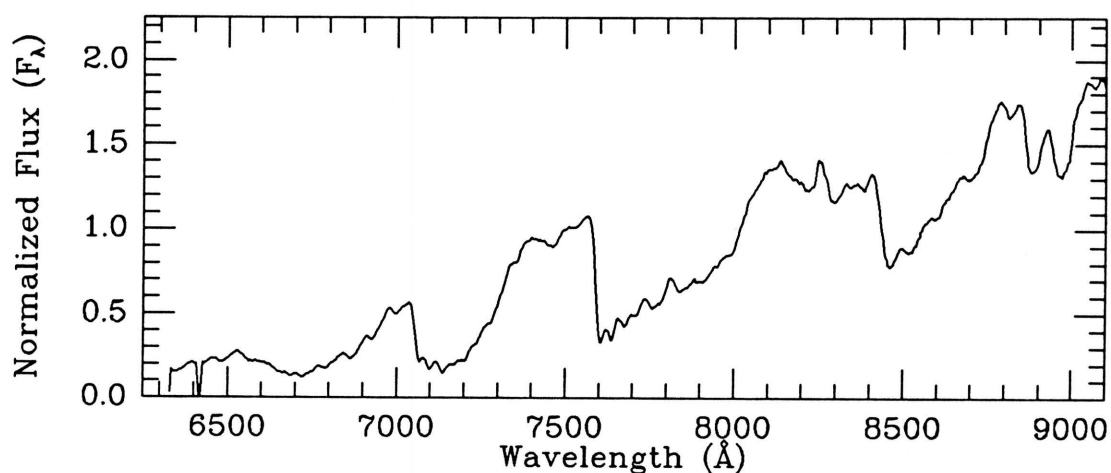


Coordinates:  $\alpha$ (1950) = 19:07:47.9      $\delta$ (1950) = +27:59:24

Spectral Type:  M6 III

Photometry:        $I_{KC}$ = unknown            $R_{CTI}$ = 9.99

$(V-I)_{KC}$=unknown      $(R-I)_{CTI}$=2.61:          $(V-I)_{CTI}$=6.00:

Notes: CTI R value is saturated.  A Mira variable having 6 CTI
V measures ranging from 11.3 to 14.2 over 100 days. Given
as TY Lyrae in General Cat. of Variable Stars (Kholopov 1985).

# CTI 191216.8+280229
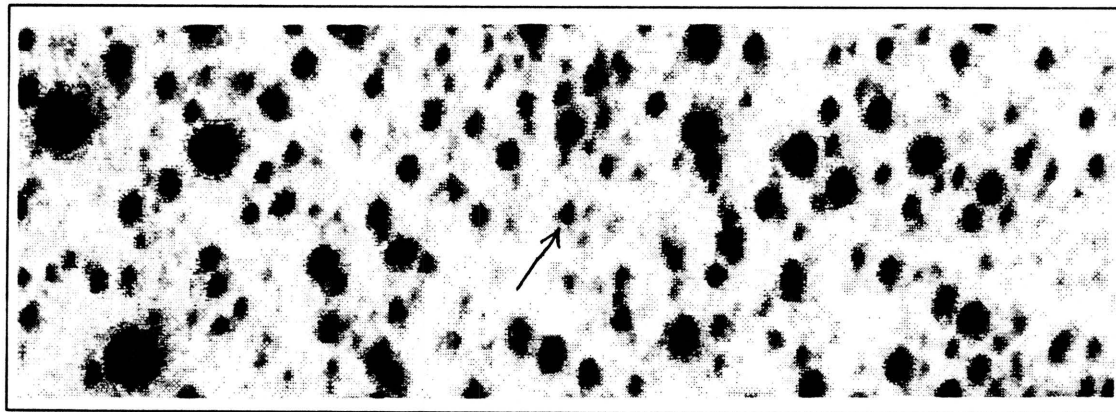


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1991 Oct 17
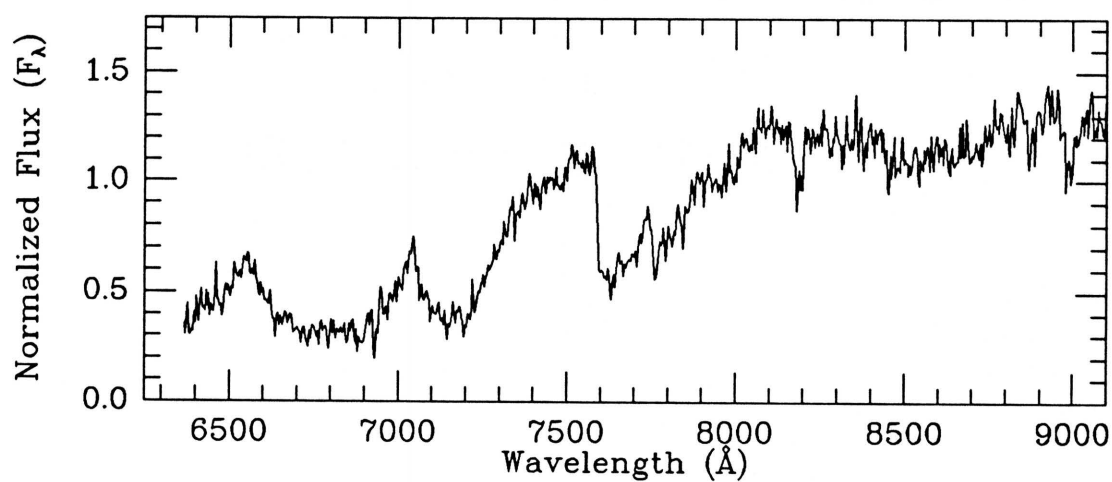


Coordinates:   $\alpha$ (1950) = 19:10:46.9          $\delta$ (1950) = +27:58:38

Spectral Type:   M4 V

Photometry:          $I_{KC}$ = 17.17          $R_{CTI}$ = 19.61

  $(V-I)_{KC}$=2.95±.06          $(R-I)_{CTI}$=2.11±.4          $(V-I)_{CTI}$=4.45±.4

Notes: Actual USNO VI photometry.

# CTI 191258.9+280352
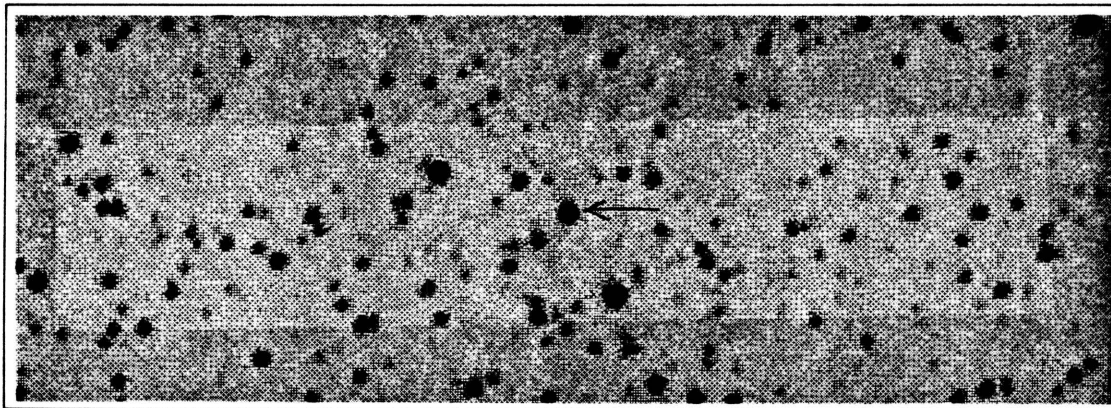


CTI FINDER CHART                    V filter                    Obs. (UT) 1988 Jun 08

MMT SPECTRUM          Exposure: 135 sec          Obs. (UT) 1989 Jul 10
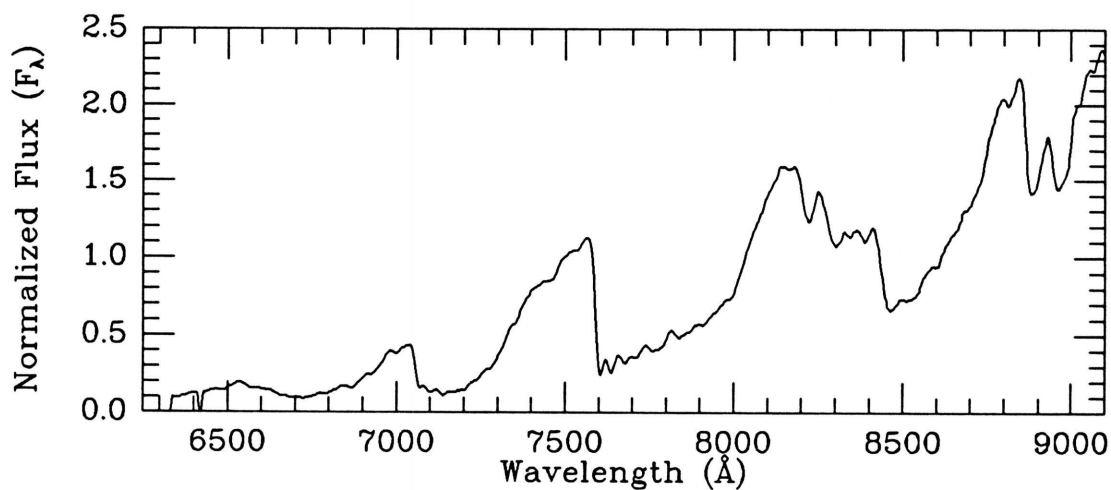


Coordinates:  $\alpha$ (1950) = 19:11:29.0        $\delta$ (1950) = +27:59:59

Spectral Type:  M7 III

Photometry:        $I_{KC}$ = unknown            $R_{CTI}$ = 11.56

$(V-I)_{KC}$=unknown        $(R-I)_{CTI}$=1.46±.01        $(V-I)_{CTI}$=3.75±.01

Notes: CTI I, and possibly R, saturated.  A Mira variable whose 14 CTI V measures range from 13.5 to 14.2.  Not listed in the General Catalogue of Variable Stars (Kholopov 1985).

# CTI 191326.8+275930



CTI FINDER CHART                    I filter                    Coadded frame

MMT SPECTRUM          Exposure: 1500 sec          Obs. (UT) 1991 Sep 15
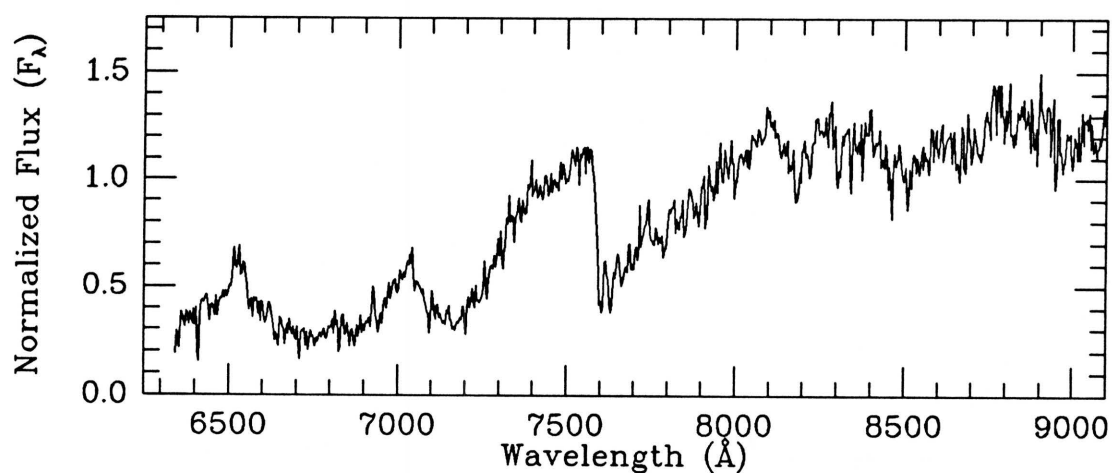


Coordinates:   $\alpha$ (1950) = 19:11:56.8        $\delta$ (1950) = +27:55:36

Spectral Type:   M4.5 V

Photometry:         $I_{KC}$ = 17.76            $R_{CTI}$ = 20.17

   $(V-I)_{KC}$=4.88±1.06        $(R-I)_{CTI}$=2.49±.73        $(V-I)_{CTI}$=unknown

Notes:

# CTI 192121.7+280100
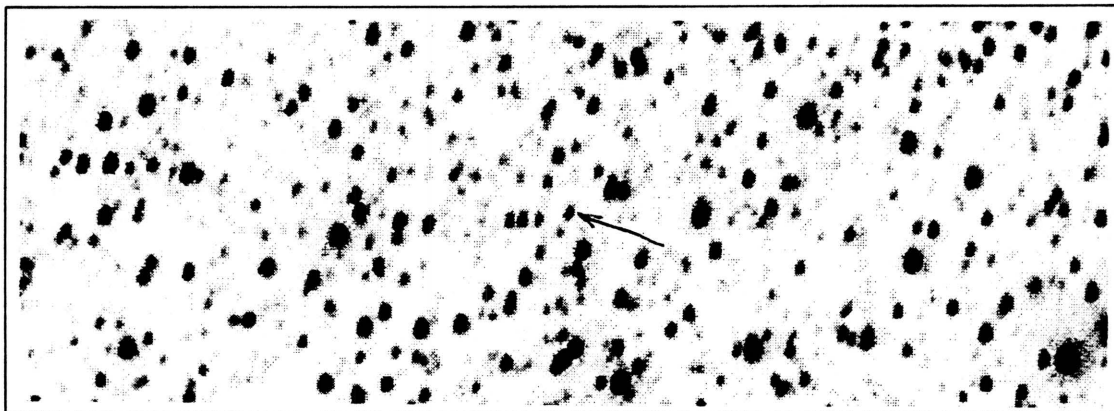


CTI FINDER CHART      I filter      Obs. (UT) 1990 Jun 20

MMT SPECTRUM      Exposure: 300 sec      Obs. (UT) 1990 Sep 14
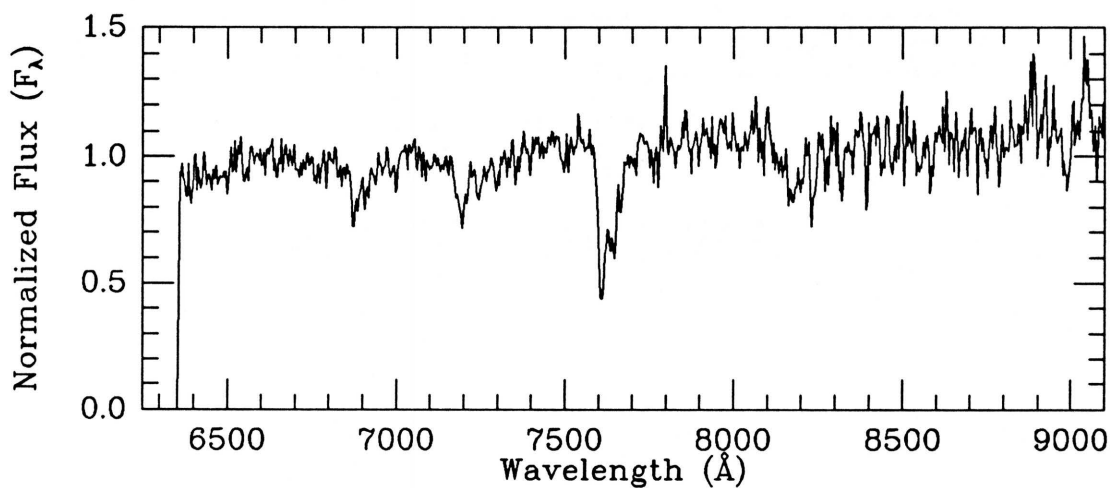


Coordinates: $\alpha$ (1950) = 19:19:51.4      $\delta$ (1950) = +27:56:41

Spectral Type: M0 V

Photometry:      $I_{KC}$ = 14.26      $R_{CTI}$ = 16.62

$(V-I)_{KC}$=4.58±.18      $(R-I)_{CTI}$=2.28±.06      $(V-I)_{CTI}$=3.56±.06

Notes:

# CTI 192853.3+280415
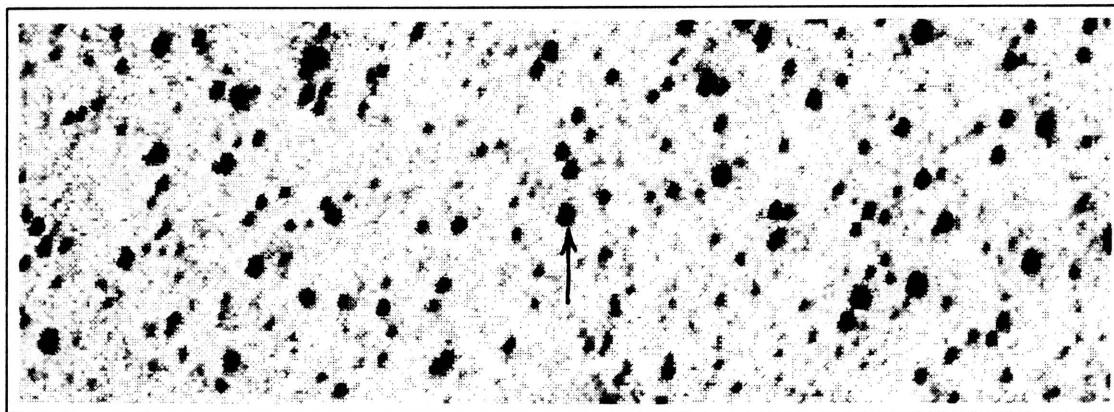


CTI FINDER CHART　　　　　I filter　　　　Obs. (UT) 1990 Aug 24

MMT SPECTRUM　　　Exposure: 600 sec　　　Obs. (UT) 1991 Sep 15
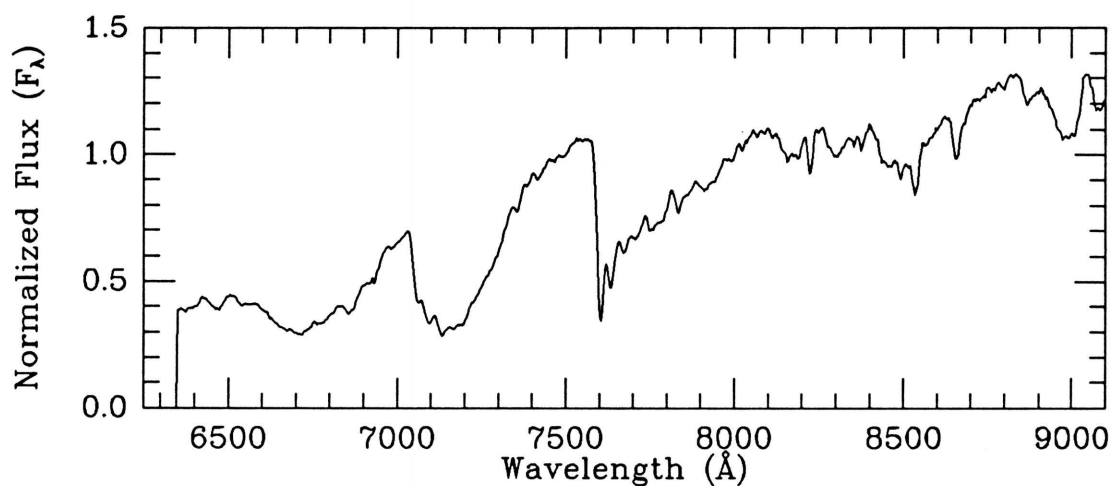


Coordinates:　$\alpha$ (1950) = 19:27:22.8　　　$\delta$ (1950) = +27:59:33

Spectral Type:　M4 III

Photometry:　　$I_{KC}$ = 12.89　　　$R_{CTI}$ = 14.08

$(V-I)_{KC}$=2.90±.04　　　$(R-I)_{CTI}$=1.08±.01　　　$(V-I)_{CTI}$=2.84±.01

Notes: Actual USNO VI photometry.　A possible Mira variable. Not listed in the General Catalogue of Variable Stars (Kholopov 1985).

# CTI 202636.9+275934
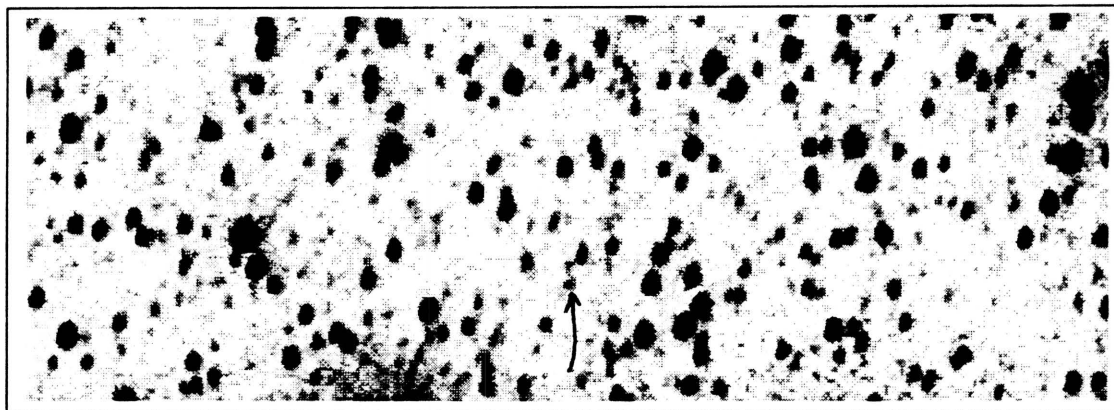


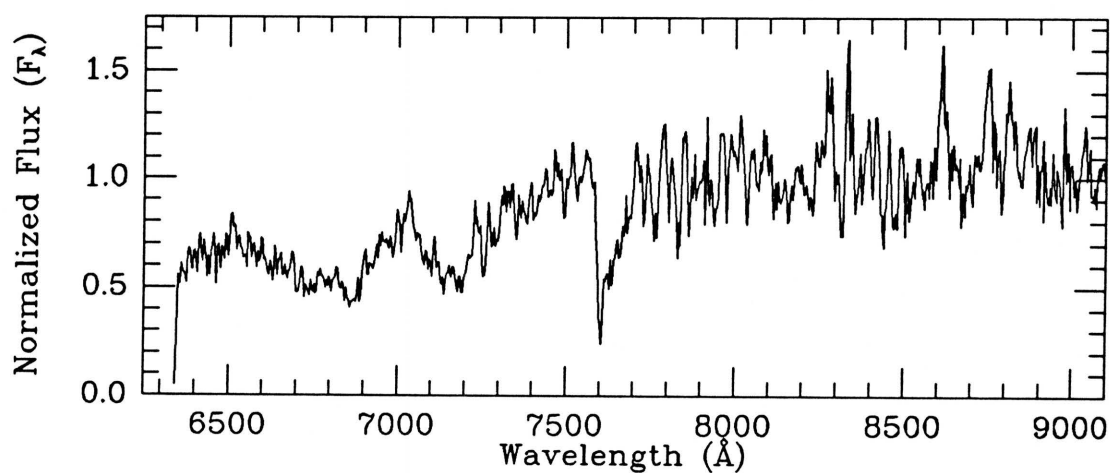CTI FINDER CHART              I filter                    Coadded image

MMT SPECTRUM          Exposure: 2700 sec        Obs. (UT) 1991 Sep 15
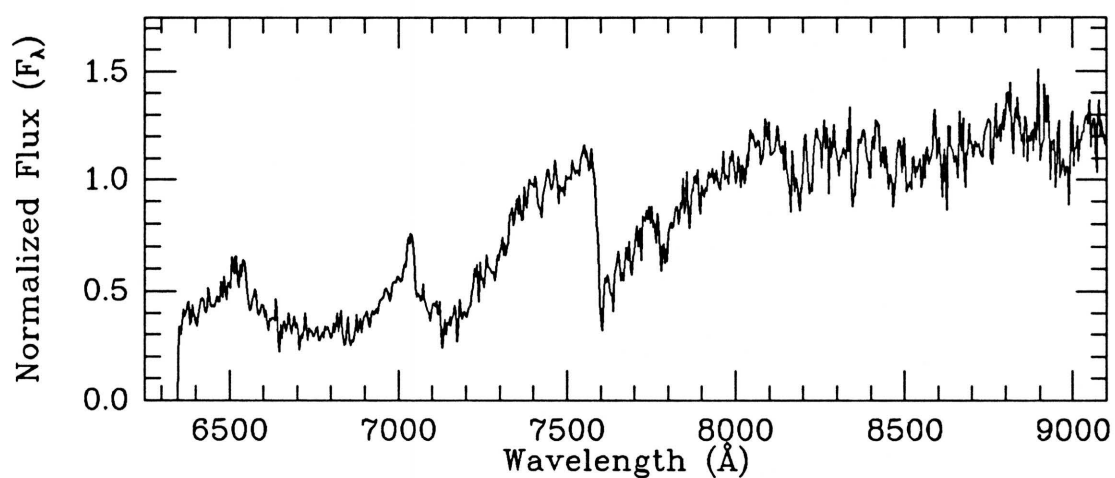


Coordinates:  $\alpha$ (1950) = 20:25:03.0        $\delta$ (1950) = +27:52:07

Spectral Type:  M4 V

Photometry:        $I_{KC}$ = unknown            $R_{CTI}$ = unknown

  $(V-I)_{KC}$=unknown      $(R-I)_{CTI}$=unknown        $(V-I)_{CTI}$=4.44:

Notes:

# CTI 202738.5+280227
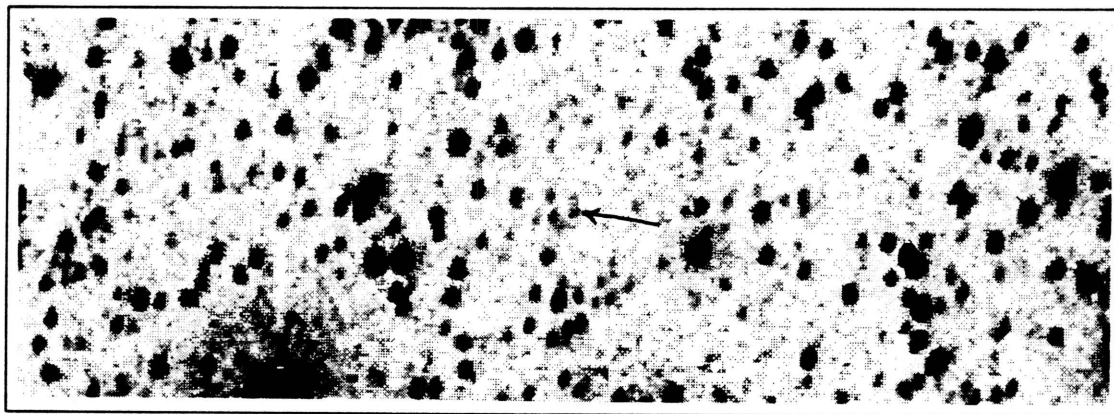


CTI FINDER CHART          I filter          Coadded image

MMT SPECTRUM          Exposure: 2400 sec          Obs. (UT) 1991 Sep 15
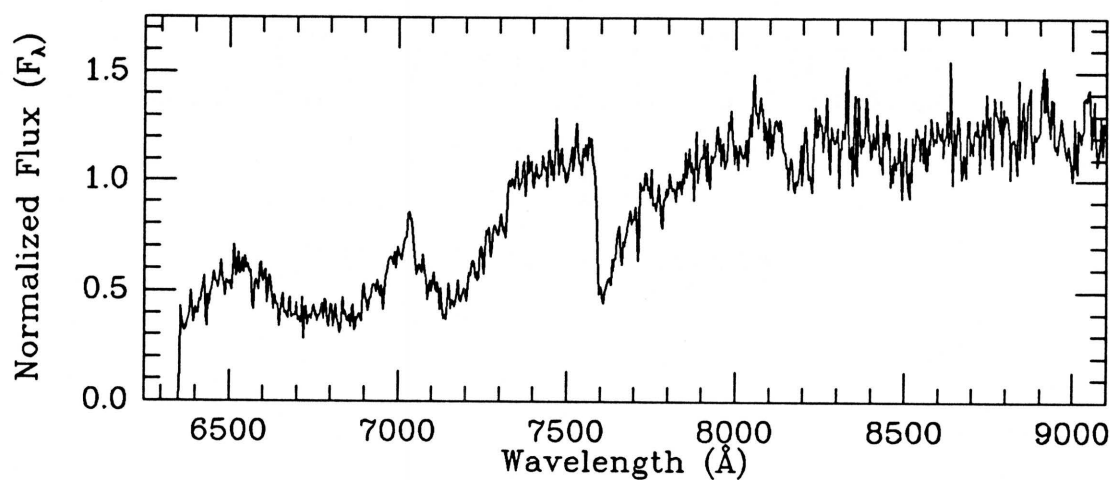


Coordinates:  $\alpha$ (1950) = 20:26:04.6          $\delta$ (1950) = +27:54:58

Spectral Type:  M3 V

Photometry:          $I_{KC}$ = 18.45          $R_{CTI}$ = 20.89

 $(V-I)_{KC}$=2.53±0.13          $(R-I)_{CTI}$=2.86±.5          $(V-I)_{CTI}$=4.16±.5

Notes: Actual USNO VI photometry. Comparison to POSS E print
  suggests possible small proper motion (~0.3 arcsec/yr) to
  the NNE.

# CTI 202928.1+280152
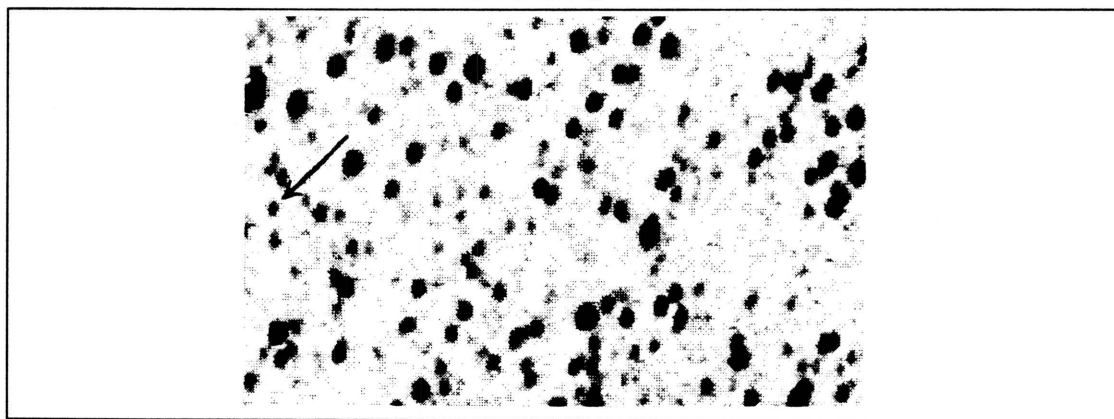


CTI FINDER CHART          I filter          Coadded image

MMT SPECTRUM          Exposure: 2400 sec          Obs. (UT) 1991 Oct 17
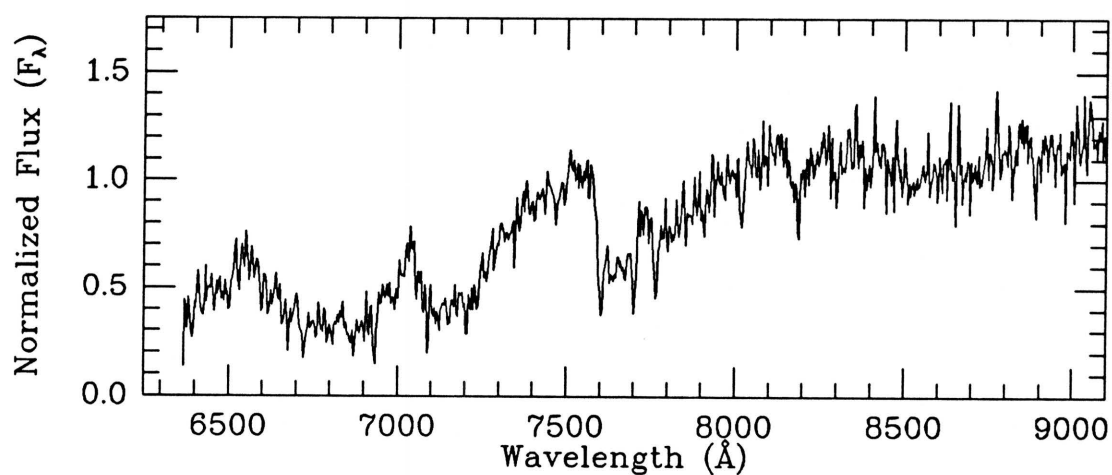


Coordinates:   $\alpha$ (1950) = 20:27:54.0          $\delta$ (1950) = +27:54:18

Spectral Type:   M4 V

Photometry:          $I_{KC}$ = 17.84          $R_{CTI}$ = 20.46

   $(V-I)_{KC}$=5.20±0.74          $(R-I)_{CTI}$=2.71±.5          $(V-I)_{CTI}$=3.62±.5

Notes:

# CTI 223752.5+275918
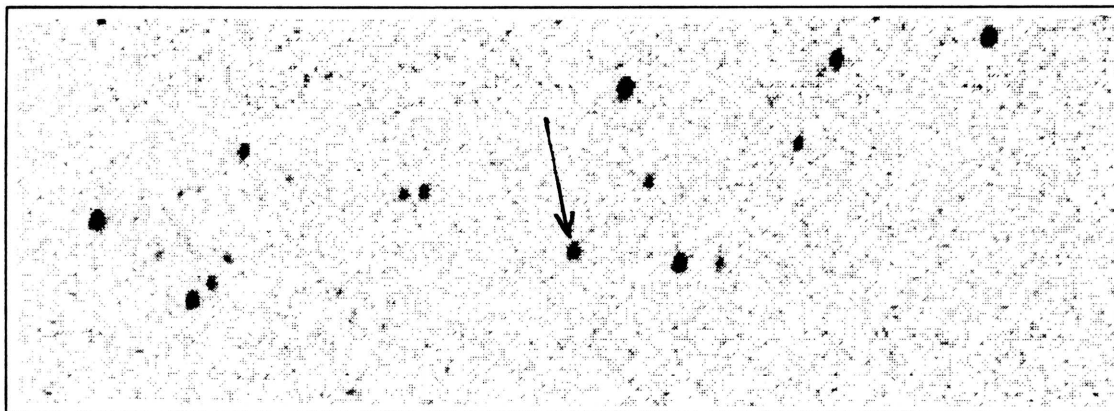


CTI FINDER CHART                    I filter              Obs. (UT) 1990 Aug 24

MMT SPECTRUM            Exposure: 300 sec           Obs. (UT) 1991 Oct 17
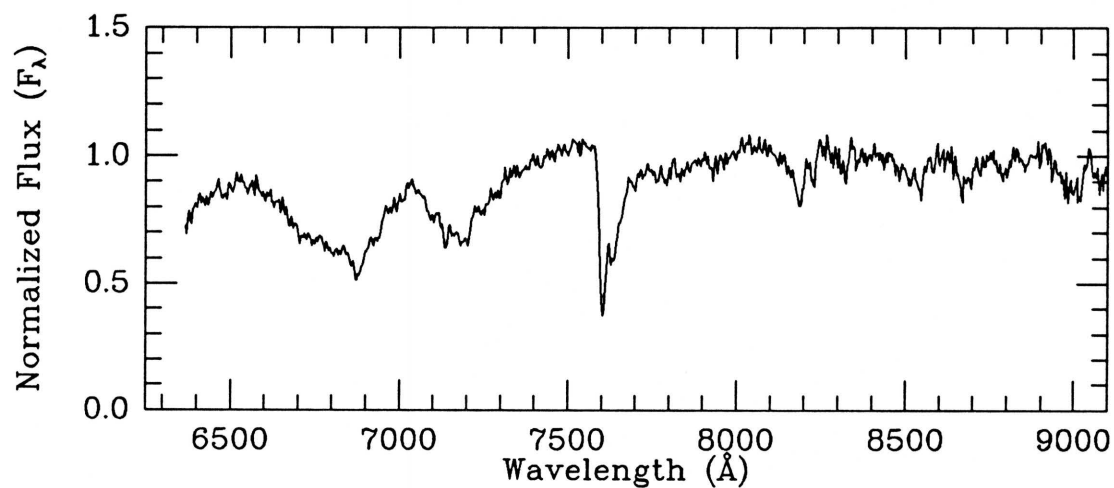


Coordinates:  $\alpha$ (1950) = 22:36:06.6        $\delta$ (1950) = +27:47:35

Spectral Type:  M1 V

Photometry:        $I_{KC}$ = 14.76            $R_{CTI}$ = 15.32

  $(V-I)_{KC}$=2.06±.06        $(R-I)_{CTI}$=0.48±.03        $(V-I)_{CTI}$=1.89±.01

Notes: Actual USNO VI photometry.

# CTI 224056.1+280052
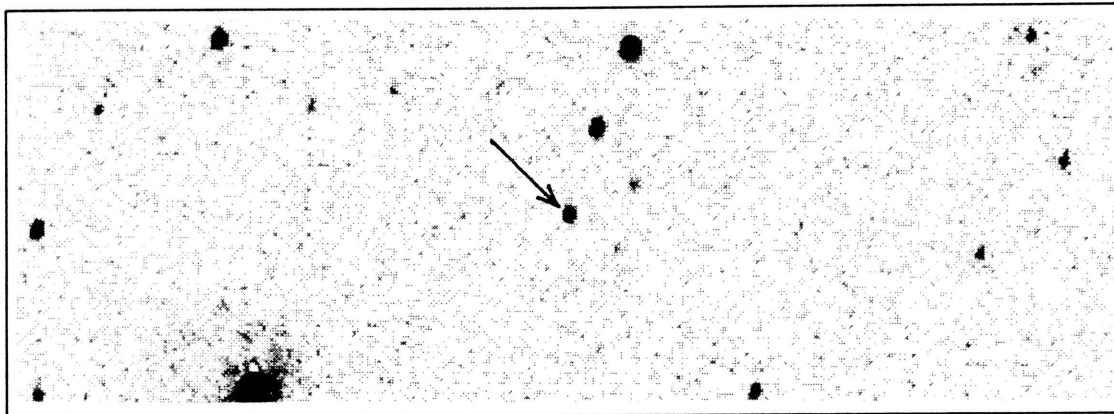


CTI FINDER CHART      I filter      Obs. (UT) 1990 Aug 24

MMT SPECTRUM      Exposure: 600 sec      Obs. (UT) 1991 Oct 17
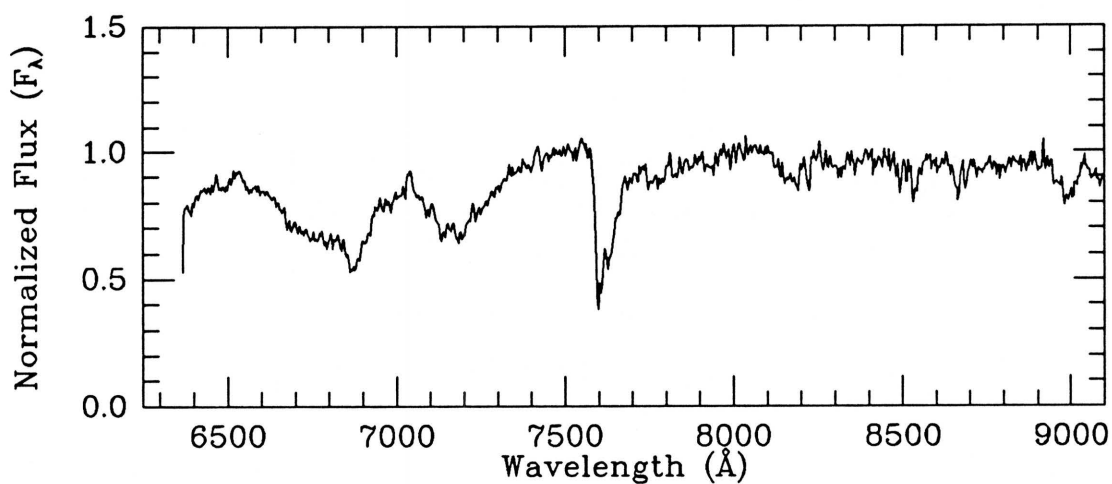


Coordinates:   $\alpha$ (1950) = 22:39:09.9      $\delta$ (1950) = +27:49:06

Spectral Type:   M1 V

Photometry:      $I_{KC}$ = 14.67      $R_{CTI}$ = 15.18

   $(V-I)_{KC}$=1.97±.11      $(R-I)_{CTI}$=0.45±.03      $(V-I)_{CTI}$=1.82±.01

Notes:

# CTI 225024.0+275956
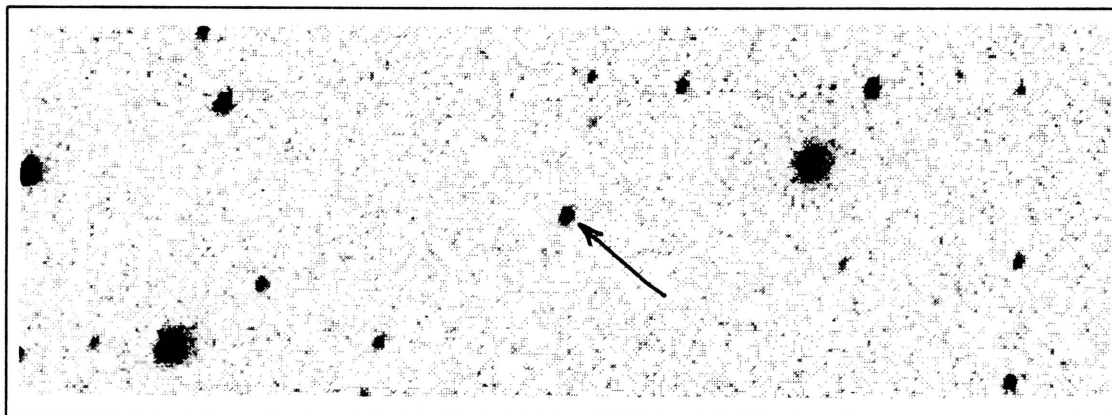


CTI FINDER CHART          I filter          Obs. (UT) 1990 Aug 24

MMT SPECTRUM          Exposure: 300 sec          Obs. (UT) 1991 Oct 17
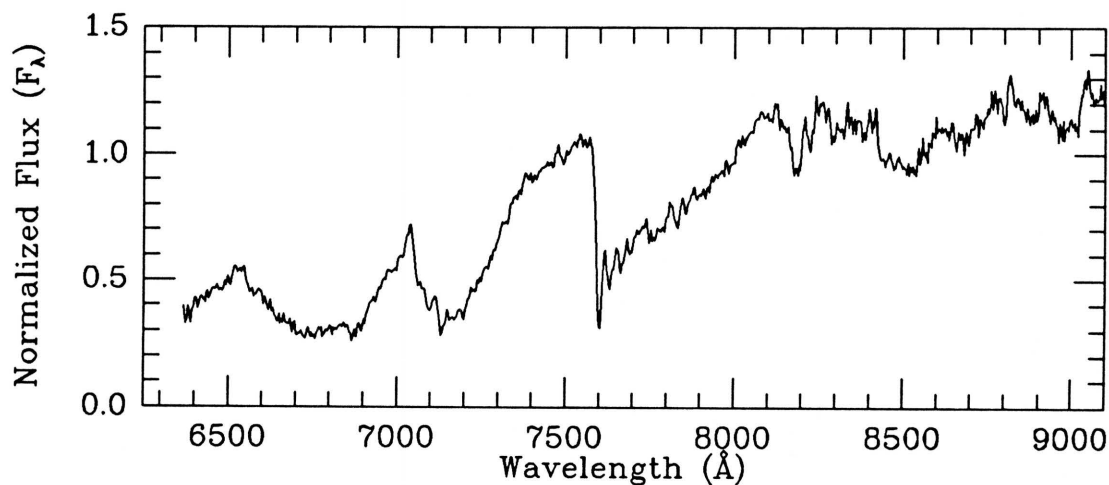


Coordinates:  $\alpha$ (1950) = 22:48:36.8          $\delta$ (1950) = +27:48:00

Spectral Type:  M4 V

Photometry:          $I_{KC}$ = 14.43          $R_{CTI}$ = 15.64

   $(V-I)_{KC}$=2.95±.13          $(R-I)_{CTI}$=1.14±.03          $(V-I)_{CTI}$=2.86±.01

Notes:

# CTI 225431.2+280046
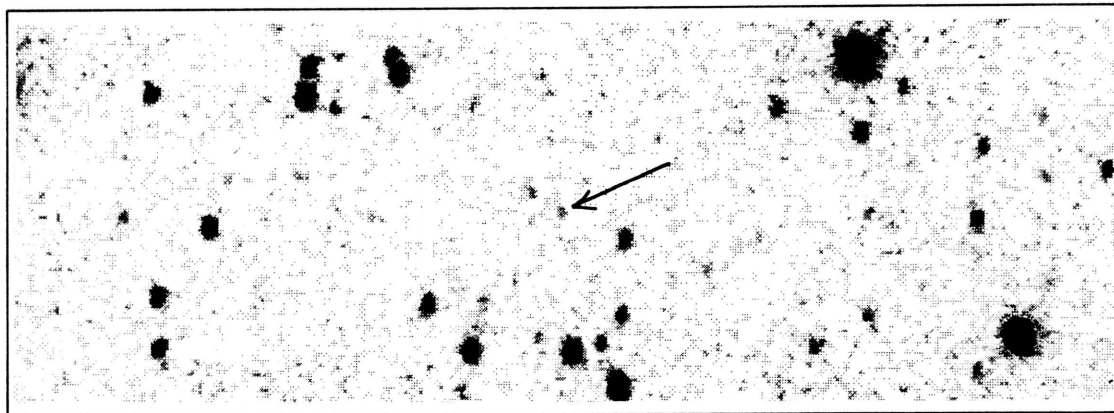


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 2400 sec          Obs. (UT) 1991 Jun 24
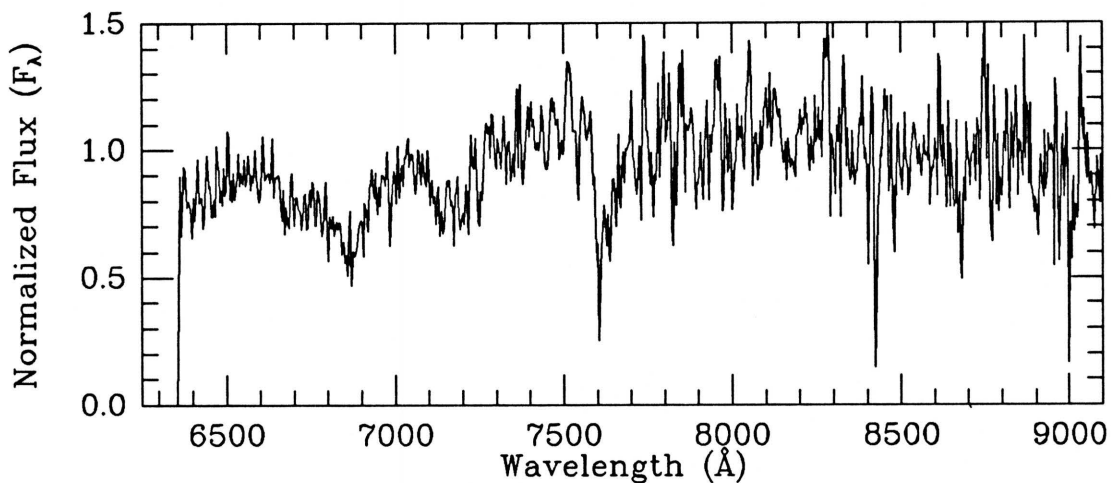


Coordinates:  $\alpha$ (1950) = 22:52:43.5          $\delta$ (1950) = +27:48:46

Spectral Type:  sdM0:

Photometry:          $I_{KC}$ = unknown          $R_{CTI}$ = 20.59

   $(V-I)_{KC}$=unknown          $(R-I)_{CTI}$=2.15±.60          $(V-I)_{CTI}$=unknown

Notes:

# CTI 225508.5+280234
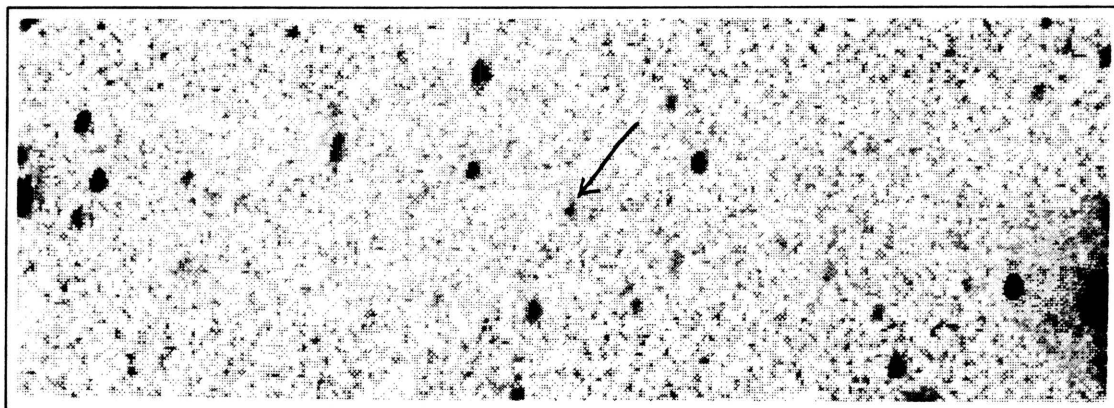


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 2400 sec          Obs. (UT) 1991 Jun 22
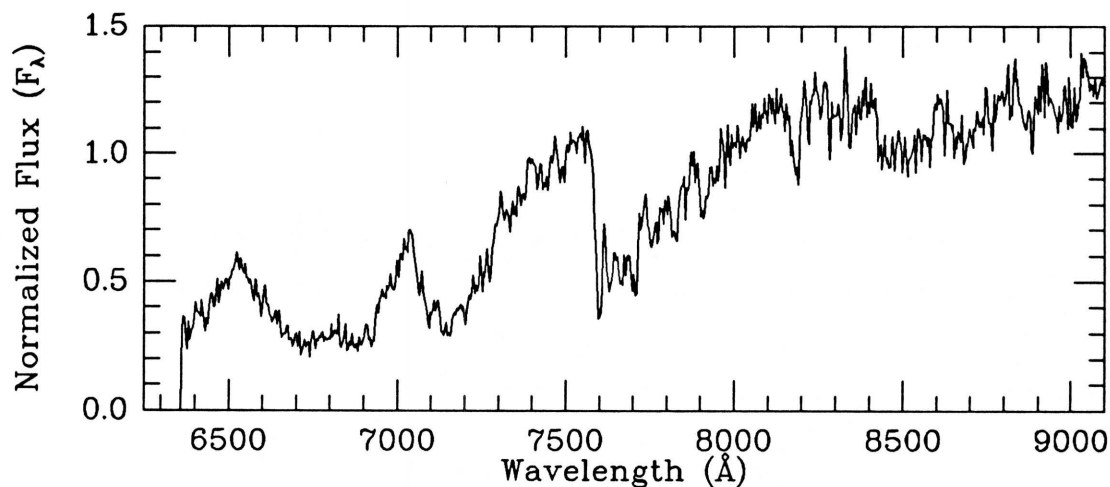


Coordinates:  $\alpha$ (1950) = 22:53:20.7          $\delta$ (1950) = +27:50:33

Spectral Type:  M4 V

Photometry:          $I_{KC}$ = 17.76          $R_{CTI}$ = 19.67

$(V-I)_{KC}$=4.17±.55          $(R-I)_{CTI}$=1.99±.37          $(V-I)_{CTI}$=unknown

Notes:

# CTI 230047.6+280216
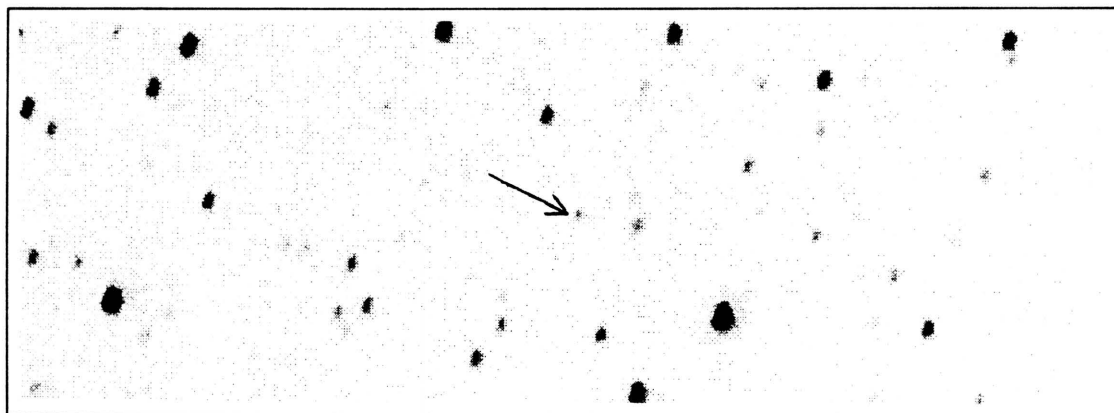


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Sep 14
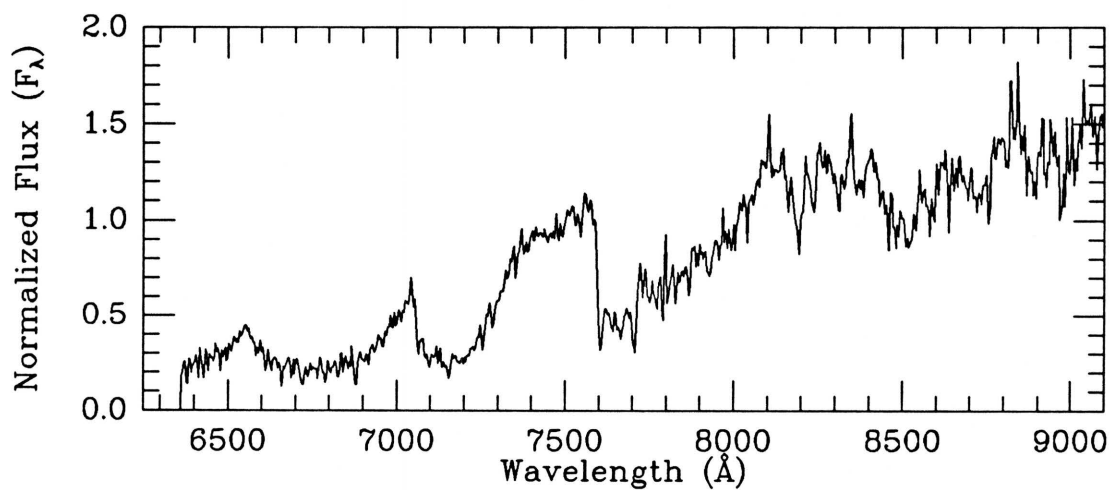


Coordinates:  $\alpha$ (1950) = 22:58:59.2        $\delta$ (1950) = +27:50:10

Spectral Type:  M5 V

Photometry:        $I_{KC}$ = 17.76        $R_{CTI}$ = 19.50

  $(V-I)_{KC}$=3.93±.55        $(R-I)_{CTI}$=1.82±.37        $(V-I)_{CTI}$=unknown

Notes: Comparison to POSS E print suggests possible small
  proper motion (~0.15 arcsec/yr) to the ESE.

# CTI 232425.5+275949
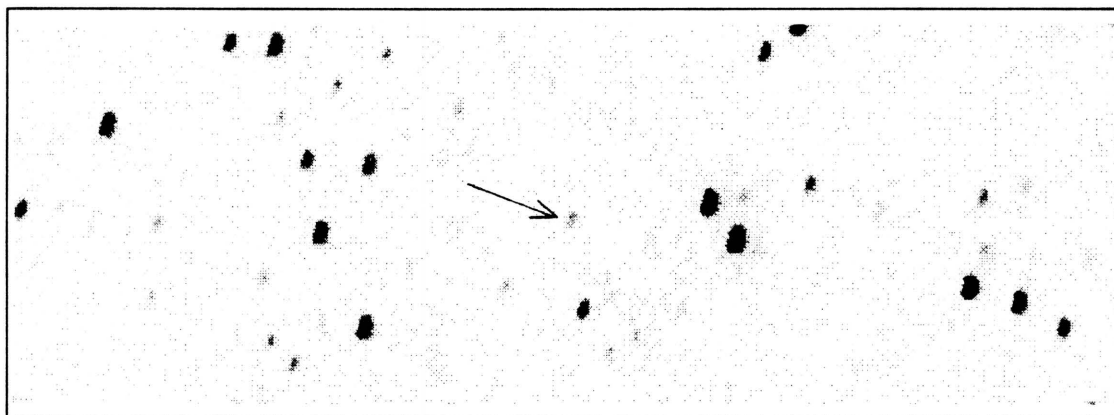


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Nov 23
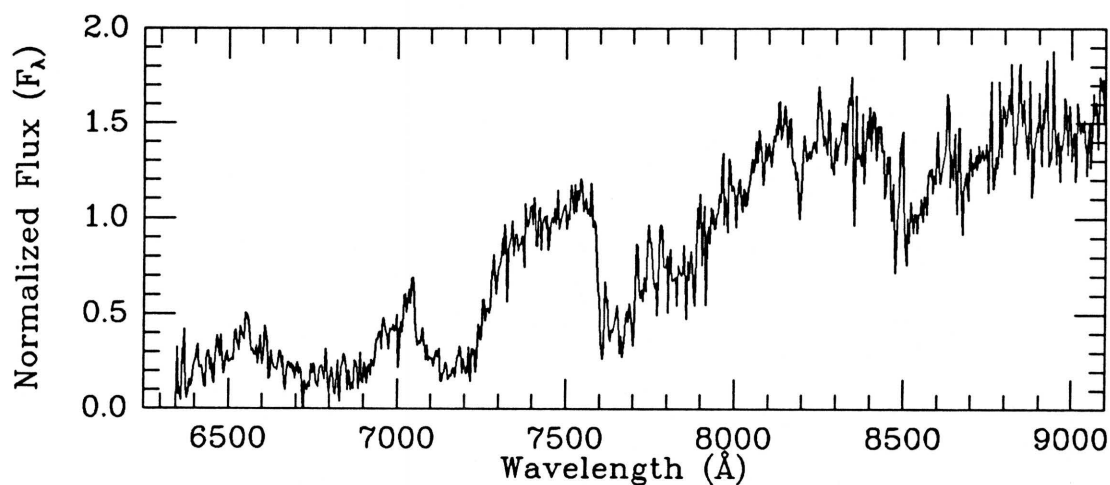


Coordinates:  $\alpha$ (1950) = 23:22:34.4          $\delta$ (1950) = +27:47:27

Spectral Type:  M5.5 V

Photometry:          $I_{KC}$ = 17.94          $R_{CTI}$ = 19.79

$(V-I)_{KC}$=4.10±.56          $(R-I)_{CTI}$=1.94±.38          $(V-I)_{CTI}$=unknown

Notes:

# CTI 233201.1+275943
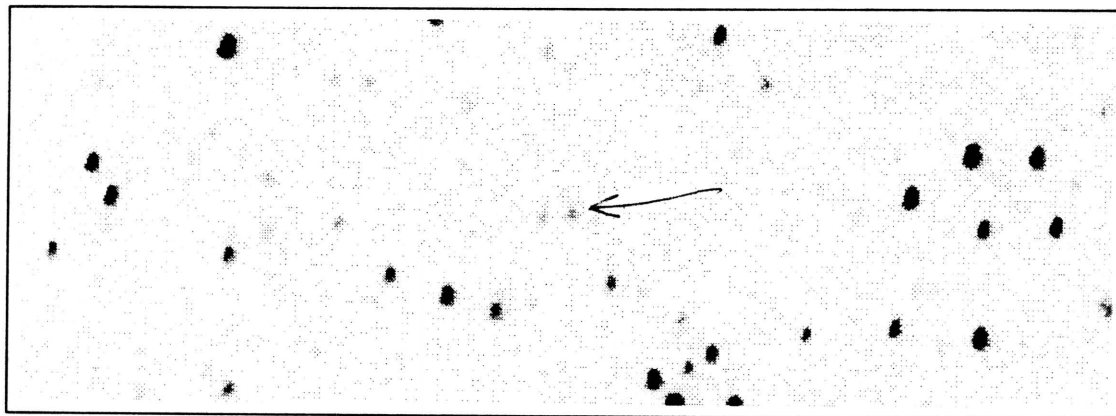


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 3900 sec          Obs. (UT) 1990 Nov 22
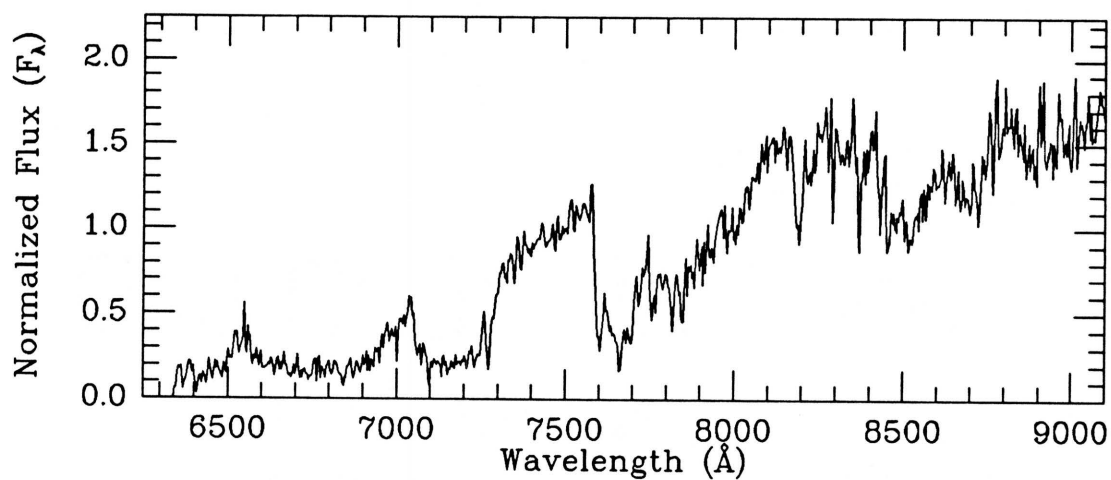


Coordinates:  $\alpha$ (1950) = 23:30:09.2          $\delta$ (1950) = +27:47:17

Spectral Type:  M6 V

Photometry:          $I_{KC}$ = 17.90          $R_{CTI}$ = 20.02

   $(V-I)_{KC}$=4.48±.62          $(R-I)_{CTI}$=2.21±.42          $(V-I)_{CTI}$=unknown

Notes:

# CTI 233828.2+275817
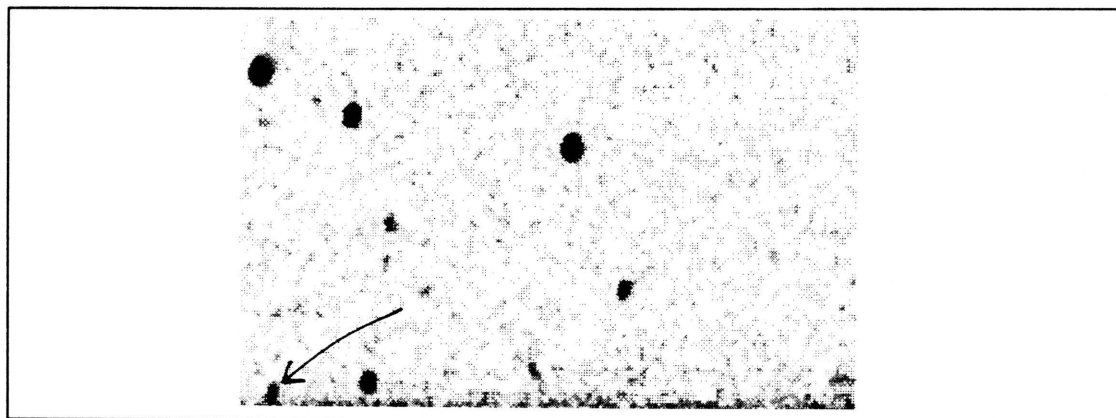


CTI FINDER CHART          I filter          Coadded frame

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1991 Sep 15



Coordinates:  $\alpha$ (1950) = 23:36:35.5          $\delta$ (1950) = +27:45:49

Spectral Type:  M2.5: V

Photometry:          $I_{KC}$ = 17.22          $R_{CTI}$ = 19.14

  $(V-I)_{KC}$=4.15±.45          $(R-I)_{CTI}$=1.98±.3          $(V-I)_{CTI}$=unknown

Notes:

# CTI 234957.0+280136
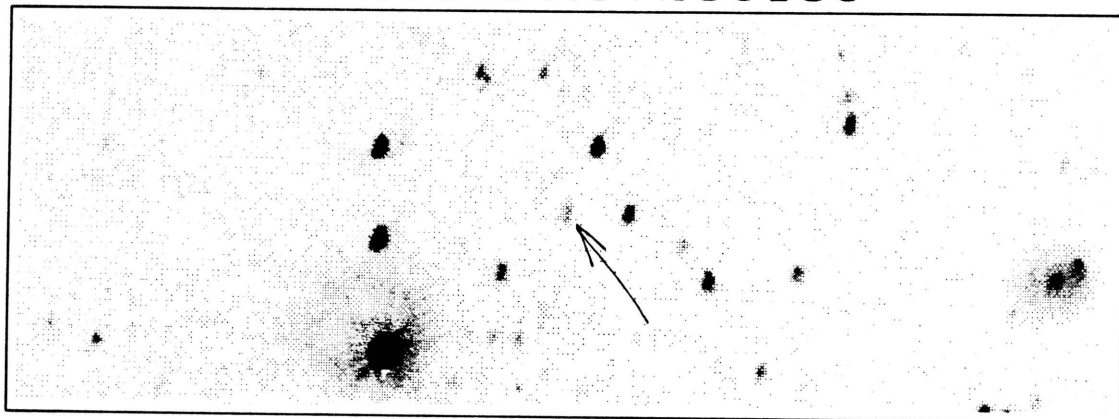


CTI FINDER CHART          I filter          Obs. (UT) 1988 Nov 01

MMT SPECTRUM          Exposure: 2700 sec          Obs. (UT) 1990 Sep 14
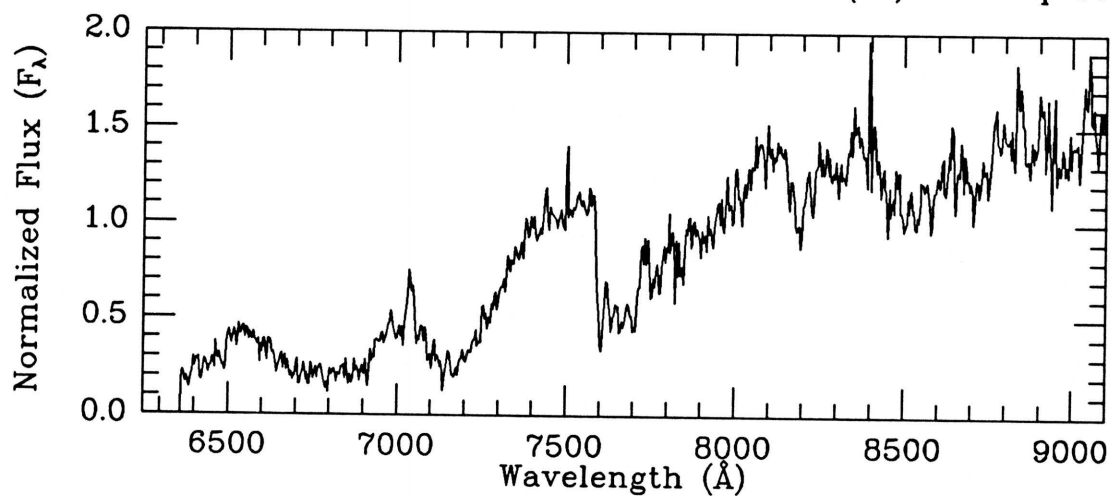


Coordinates:  $\alpha$ (1950) = 23:48:03.0     $\delta$ (1950) = +27:49:05

Spectral Type:  M5 V

Photometry:     $I_{KC}$ = 18.08          $R_{CTI}$ = 19.85

$(V-I)_{KC}$=4.00±.49     $(R-I)_{CTI}$=1.87±.33     $(V-I)_{CTI}$=unknown

Notes: Comparison to the POSS E print suggests a possible proper motion of ~0.8 arcsec/yr to the NNW.

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