A SEARCH FOR ADDITIONAL PARANETERS IN THE INFRARED LUMINOSITY / 21 CM LINE-WIDTH RELATION FOR SPIRAL GALAXIES IN CLUSTERS OF GALAXIES
by
Mark Edward Cornell
A Dissertation Submitted to the Paculty 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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A search for additional parameters in the infrared luminosity/21 cm line-width relation for spiral galaxies in clusters of galaxies

Cornell, Mark Edward, Ph.D.
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## THE UNIVERSI'TY OF ARIZONA GRADUATE COLLEGE

As members of the Final Examination Committee, we cextify that we have read the dissertation prepared by Mark Edward Cornell entitled A SEARCH FOR ADDITIONAL PARAMETERS IN THE INFRARED

LUMINOSITY / 21 CM LINE-WIDTH RELATION FOR SPIRAL
GALAXIES IN CLUSTERS OF GALAXIES
and recomend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy -


Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that $I$ have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.


Dissertation Director Simon D. M. White

$$
\frac{3 / 16 / 89}{\text { Date }}
$$

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SIGNED: $\qquad$

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#### Abstract

The relationship first pointed out by Tully and Fisher between the luminosity of spiral galaxies and their maximum rotation velocity, as measured by the 21 cm line-width, continues to be one of the best methods available to measure relative distances. At infrared wavelengths, the observational scatter about this relation is typically 0.35 to 0.50 magnitudes, permitting relative distance estimates with an accuracy of about 20 percent. The Malmquist bias in a magnitude-limited sample is $1.38 \sigma^{2}$, and while the solution to the general problem is complex, it is clear that reducing the scatter about the Tully-Fisher relation by even a factor of two would make a large difference in our ability to determine the local velocity field from distances and velocities of individual galaxies.

In this dissertation we discuss the scatter in the Tully-Fisher relation at infrared wavelengths, and look for ways to reduce that dispersion through the inclusion of additional observational parameters. The data for this study are derived from a CCD survey of 244 spiral galaxies in twenty clusters falling in the redshift range 3,000 to 11,000 $\mathrm{km} \mathrm{s}^{-1}$. From surface brightness profiles and elliptical aperture photometry, we obtained isophotal and total magnitudes at $B, R$, and $I$, isophotal diameters, mean and nuclear surface brightnesses, and a concentration parameter indicative of the bulge-to-disk ratio. These


quantities were then combined with colors and HI-content measures taken from the literature in a search for correlations with Tully-Fisher residuals. None of the trial second-parameters resulted in a substantial decrease in the scatter about the fiducial Tully-Fisher relation. An examination of the properties of the cluster samples shows that many of the clusters exhibit considerable substructure. While it is possible that the implied depth effects are important to the scatter about the magnitude/line-width relation, calculated lower limits to the dispersion in depth turn out to be rather small.

## CHAPTER 1: INTRODUCTION

The leading method for determining extragalactic distances appears to be the relationship between galaxian luminosity at infrared wavelengths and rotation speed as measured by the velocity width of the neutral hydrogen 21 cm line profile (Aaronson and Mould 1986). This relation was first proposed as a distance indicator by Tully and Fisher (1977), and hence bears t' $\because f$ name, although in fact, a fairly accurate distance determination to M31 was made using similar principles as early as 1922 (Oepik). The magnitude/line-width relation used by Tully and Fisher had a serious deficiency, as first pointed out by Sandage and Tammann (1976), in that it was based on blue magnitudes which are subject to large and uncertain corrections for internal absorption. The problem is that the measured rotation velocities must be reduced to edge-on values in order to be meaningful, and this correction is large unless the objects are nearly edge-on to the line of sight. However, for these highly inclined objects the corrections necessary to reduce the blue magnitudes to faceon values are large and have a considerable random component. Aaronson, Huchra, and Mould (1979) largely solved this problem, by utilizing the relation at infrared (1.6 m or H -band) wavelengths. In the infrared, corrections for internal extinction within the object under study, as well as for Galactic absorption along the line of sight, are greatly reduced.

We have been involved for the past several years in a program to improve various technical aspects of the practical application of the infrared Tully-Fisher relation to the determination of the extragalactic distance scale. To that end, we have conducted a survey of spiral galaxies in clusters of galaxies using charge-coupled devices (CCD's), very sensitive detectors with linear response, in order to obtain twodimensional maps at optical mavelengths of the brightness of each program object on a fine grid of points on the sky. The first application of these data was an improvement of the galaxy diameter system upon which the H-band photometry used in the infrared Tully-Fisher relation is based (Cornell et al. 1987). In this dissertation, we are interested in another potential improvement in the determination of extragalactic distances. We would like to know if we can improve distance estimates by considering other information about the objects under study, in addition to the 21 cm line-width and $H$ magnitude. The interesting question is whether we can improve our ability to predict the absolute magnitude of a spiral galaxy by adding additional parameters to the basic rotation velocity measurement.

The question of the dimensionality of apiral galaxy properties, the extent to which a spiral property such as absolute magnitude can be accurately deduced from a single observable guch as 21 cm line-width, has had a checkered history. On one hand, Aaronson and Mould (1983) found no significant dependence of the infrared Tully-Pisher relation on
morphological type. Furthermore, Tully, Mould and Aaronson (1982) found tight relationships between $\mathrm{B}_{\mathrm{T}^{-H}} \mathbf{H}_{-0.5}$ color and mass or luminosity, independent of type, suggesting that spiral properties are predominantly dependent on a single parameter, which they identify as total mass. On the other hand, Rubin et al. (1982), for example, find strong type dependence in their blue Tully-Fisher relations. Whitmore (1984) has argued that this difference comes mostly from different selection effects in the two samples, but that the two-dimentionality does not disappear at H-band, in conflict with the Tully, Mould, and Aaronson result. Whitmore finds two principal components in his data, one identifiable with a "scale" (blue magnitude and diameter) and the other with a "form", B-H color or bulge/total luminosity ratio.

Thus there is evidence for two dominant dimensions in the space of spiral properties, and there is some hope that considering additional information would improve Tully-Fisher distances by adding knowledge about the other dimension. Aaronson et al. (1982a) explicitly searched for such an improvement using a hybrid surface brightness, type, inclination, and 21 cm flux as trial second-parameters. While they were unsuccessful, Whitmore's (1984) conclusions, plus a recent Principal Component Analysis by Watanabe, Kodaira, and Okamura (1985) which showed that the two dimensions in spiral properties could be identified using optical surface photometry alone, encouraged us to use our new CCD survey data to once more address this issue.

The organization of this dissertation is as follows. The selection and properties of the $C C D$ survey sample, and its extension to the southern hemisphere, as well as the observational techniques, reductions, and the derivation of photometric parameters are discussed in Chapter 2 . In Chapter 3 we examine the scatter about the infrared Tully-Fisher relation on a cluster by cluster basis, and attempt to estimate the importance of dispersion in depth and substructure in the cluster samples themselves to the observed scatter about the magnitude/line-width relation. In Chapter 4 we apply the observational data derived in Chapter 2 to a search for additional parameters in the infrared Tully-Fisher relation, with largely negative results. We present the complete set of our surface brightness profiles and derived parameters in the Appendix.

## CHAPTER 2: OBSERVATIONS AND REDUCTIONS

## THE SAMPLE

The new data presented in this thesis consist of CCD (charge-coupled device) frames of 244 spiral galaxies taken as part of two surveys: one of objects in clusters of galaxies in the northern hemisphere (see Cornell et al. 1987) and one of cluster spirals in the south. The northern survey covers a subset of the galaxies studied by Bothun (1981) and hence follows the selection criteria given in that reference. Bothun's sample is basically a magnitude-limited selection of cluster spirals falling in the redshift range $3,000 \mathrm{~km} \mathrm{~s}$ to $12,000 \mathrm{~km} \mathrm{~s}^{-1}$, with declinations between $0^{\circ}$ and $40^{\circ}$ (i.e. accessible by Arecibo). The southern clusters surveyed for this thesis lie mostly in the Hydra-Centaurus supercluster and the Telescopium-Grus/Pavo-Indus chain of galaxy clusters (see Tully and Fisher 1987). These clusters were chosen for study as part of the Aaronson et al. (1989) study of large-scale motions in the southern hemisphere.

The twenty clusters discussed here provide a variety of environments and exhibit a wide range of spiral fractions, densities, and velocity dispersions. The positions and mean redshifts of each cluster are listed in Table 2.1, together with some of their global properties. Column (1) gives the name of the cluster. Columns (2) and (3) list the position of
the cluster center. The northern positions are taken from Aaronson et al. (1986) and the southern positions are the averages of the coordinates for those objects listed in Sandage (1975). We give the mean cluster redshift in column (4), corrected to the Local Group velocity centroid via $300 \sin 1 \cos b$. Here the northern velocities come from Aaronson et al. (1986) and the southern velocities are taken from the sources listed in the notes. The same is true of the cluster velocity dispersions listed in column (5). The northern velocity dispersions were estimated as the quoted error on the mean velocity, multiplied by the square root of the number of objects that went into the mean. The mean distance modulus for each cluster is given in column (6), with the northern data from Aaronson et al. (1986) and the southern data from Aaronson et al. (1989), unless otherwise noted. For a few clusters it was necessary to estimate the distance modulus from the redshift, after applying the linear bi-infall model of Aaronson et al. (1989) for the large-scale streaming motions in the south. Column (7) contains the relative spiral, so, and elliptical fractions of each cluster. The northern data come from Table 1 of Bothun et al. (1985a) and the sources listed therein. The relative frequency of each type for the southern clusters was derived from the $T$ types listed In the ESO (B) catalog (Lauberts 1982) for normal, non-interacting galaxies within 5 degrees of the cluster center. The ratios for the southern data reflect the subjective bias noted in the introduction to the ESO catalog against classifying galaxies as ellipticals. Column (8) gives the adopted foreground reddening in the direction of each cluster.

Table 2.1. Mean Cluster Properties

| Name | Position (1950) |  | $\left.\mathrm{V}_{\mathrm{o}} \mathrm{~km}^{-1}\right)^{\sigma}$ |  | $\begin{gathered} \mathrm{m}-\mathrm{M} \\ (\mathrm{mag}) \end{gathered}$ | \%Sp:S0:E | $\begin{gathered} \mathrm{A}_{\mathrm{b}} \\ (\operatorname{mag}) \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\alpha$ | $\delta$ |  |  |  |  |  |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pisces | $01^{h_{00}}{ }^{m}$ | $+30^{\circ} 00^{\prime}$ | 5274 | 426 | 33.59 |  | 0.18 |
| A400 | 0255 | +05 50 | 7154 | 649 | 34.55 | 36:53:11 | 0.54 |
| A539 | 0514 | +06 23 | 8561 | 778 | 34.89 | 40:50:10 | 0.95 |
| Cancer | 0818 | +21 14 | 4790 | 830 | 33.82 | 71:18:11 | 0.18 |
| A1367 | 1142 | +20 07 | 6427 | 762 | 34.35 | 43:40:17 | 0.00 |
| Coma | 1257.4 | +28 15 | 6931 | 769 | 34.51 | 18:47:35 | 0.00 |
| 274-23 | 1400 | +09 34 | 6025 | 943 | 34.25 | 62:28:10 | 0.00 |
| Hercules | 1603 | +1756 | 11077 | 1156 | 35.25 | 51:35:14 | 0.09 |
| Pegasus | 2318 | +0755 | 4078 | 614 | 32.97 | 59:29:12 | 0.18 |
| A2634/66 | 2340 | +24 00 | 8783 | 853 | 34.65 |  | 0.18 |
| Virgo | 1228.3 | +1240 | 1073 | 723 | 30.82 | 62:19:18 ${ }^{\text {a }}$ | 0.00 |
| NGC 1209 | 0301 | -15 33 | $2913{ }^{\text {b }}$ | $425{ }^{\text {b }}$ | $32.35{ }^{\text {C }}$ | 91: 9: 0 | 0.18 |
| Antlia | 1027 | -35 35 | 2667 d | $293{ }^{\text {e }}$ | 32.34 | 75:20: 5 | 0.18 |
| Hydra | 1034 | -27 15 | $3455{ }_{\text {f }}^{\text {d }}$ | $1031{ }_{f}^{\text {e }}$ | 33.18 | 74:24: 2 | 0.18 |
| Centaurus 30 | 1247 | -41 03 | 2804 f | 577 f | 32.44 | 62:34: 4 | 0.50 |
| Centaurus 45 | 1247 | -41 03 | 4337 f | $262{ }^{\text {f }}$ | 33.33 | 62:34: 4 | 0.50 |
| Telescopium 27 | 2012 | -46 44 | $2765{ }^{\text {b }}$ | $616{ }^{\text {b }}$ | $32.46{ }^{\text {C }}$ | 78:19: 3 | 0.02 |
| Telescopium 56 | 2012 | -46 44 | $5594{ }^{\text {g }}$ | $611{ }^{\text {g }}$ | $33.93{ }^{\text {c }}$ | 78:19: 3 | 0.02 |
| Pavo | 2012 | -70 54 | 3229 d | $503{ }^{\text {e }}$ | 32.48 | 82:17: 1 | 0.18 |
| Indus | 2104 | -47 43 | $5033{ }^{\text {b }}$ | $346{ }^{\text {b }}$ | $33.68{ }^{\text {C }}$ | 61:34: 5 | 0.18 |

a Sandage, Binggeli, and Tammann (1985), types E-Sm only.
Huchra (1988).
C Distances derived from the linear bi-infall model of Aaronson et al. (1989: Table 9, Model 1).
d Aaronson et al. (1989).
e Mould (1988).
$f$ Lucey, Currie, and Dickens (1986a).
$g$ Mean and standard deviation for those objects within a radius of $4^{\circ}$ of the listed center in a copy of The Center for Astrophysics Redshift Catalogue obtained from the Astronomical Data Center.

The northern extinctions were taken from Bothun et al. (1985a) and are based on H $I$ column densities measured by Heiles (1975) and a calibration given by Bothun et al. Estimates of the absorptions to the southern clusters were made using $H$ I maps given by Cleary, Heiles, and Haslam (1979) and the Bothun et al. calibration.

The original aim of the $C C D$ surveys was to improve the diameter system used to define the $H$ magnitudes necessary in the distance-scale work of Aaronson et al. (1986, 1989 and references therein). Although some effort was made to choose a random subset of spiral galaxies, the final selection of cluster members was biased toward objects appropriate for distance determinations via the $H$-magnitude $/ 21 \mathrm{~cm}$ line-width relation. There are two potential selection effects. The first comes from the tendency to observe objects with previous H I detections, and hence 21 cm line-width measurements. This process selects against galaxies with relatively little neutral hydrogen, i.e. early type spirals. We investigate this potential bias in Figure 2.1a, where we plot the relative frequency of the morphological types of the objects in our sample. The T types are Hubble types taken from the UGC (Nilson 1973) and the ESO catalog, coded according to the prescription given by de Vaucouleurs, de Vaucouleurs, and Corwin (1976, hereafter RC2). For comparison, we plot the morphological types of all of the objects with $T \geq-3$ (SO's and spirals) in the RC2. Also plotted are types for those RC2 galaxies which fall within the search radil on the sky given by Aaronson et al. (1986)


Figure 2.1a. Relative Frequency of Morphological Types Expressed as a Percentage of the Total Number.
for our northern clusters and a search radius of 5 degrees for the southern clusters. Relative frequency is expressed as a percentage of the number in each sample. The number of typed objects in each sample is given in parentheses. At first glance, an $H$ I selection bias is readily apparent in our sample. We have essentially no SO or So/a galaxies ($3 \leq T \leq 0)$ and apparently quite a few more $S c$ 's $(T=6)$ than either of the RC2 samples. However, this interpretation is not obviously correct. The $T=5$ bin in our sample is misleading and probably should be ignored because it consists of objects which are thought to be spirals, but no further information is available. (The ESO or UGC catalogs give them a Hubble type of "S..."). Because 20 percent of the objects are not fully typed, expressing frequency as a percentage of the total is not quite right. Figure 2.1 b contains the same frequency information as Figure 2.1a, but the counts are expressed as a ratio to the number of $\mathrm{Sa}(\mathrm{T}=1)$ galaxies. The number of Sa's in each sample is given in parentheses for reference. Finally, objects classified in the ESO catalog and the UGC as "Sc" galaxies are mapped into $T=6$ by the $R C 2$ prescription, even though the RC2 itself has several bins, $T=5,6$, and 7 , for these late-type spirals. We therefore have to use somewhat coarser binning to make a meaningful comparison of the frequency of these types. If we count up the objects known to fall in the bins $T=5,6$, and 7 for the three samples and compare their frequency to that of Sa 's, we find that the ratios are $2.29 \pm 0.56,3.49 \pm 0.27$, and $1.64 \pm 0.31$ for our sample, the total RC2 sample, and the cluster RC2 sample respectively. The error estimates


Figure 2.1b. Relative Frequency of Morphological Types Expressed as a Ratio to the Number of Sa Galaxies.
assume root-n errors in the counting statistics. Thus our sample actually has relatively fewer Sc's than the total RC2 sample and a similar number to that in the general cluster sample.

The other selection bias in our sample is more straightforward. In order to avoid large and uncertain corrections to the 21 cm line-widths for inclination, objects used for Tully-Fisher distances are constrained to be inclined more than $45^{\circ}$. Although we tried to include face-on objects, Figure 2.2 shows that our sample exhibits this edge-on bias. Figure 2.2 is constructed similarly to Figure 2.1 , but shows histograms of the logarithm of the ratio of the major to minor axis of each object. Thus a face-on spiral has $\log R=0.0$, and an edge-on spiral has a large value of $\log R$.

Our sample overlaps with the infrared Tully-Fisher samples of Aaronson et al. (1986) and Aaronson et al. (1989) such that CCD surface photometry is presented here for about half of their northern spirals and 15 percent of the southern spirals.

THE DATA

The new data discussed here consist of CCD surface photometry obtained with a direct camera operating at the cassegrain focus of the


Pigure 2.2. Relative Prequency of Axis Ratios.
0.9 m telescopes at Kitt Peak and Cerro Tololo. A summary of the seven observing runs allocated for this project is given in Table 2.2. All of the detectors used for the project were RCA CCD's with a $320 \times 512$ pixel format and 30 micron square pixels. The operational parameters of the devices we used are listed in Table 2.3. Briefly, the RCA\#4 chip used at Tololo is a much lower noise device than the ones used at Kitt Peak, but it is subject to a high radiation event rate, make additional steps to deal with the affected pixels necessary in the reductions.

Over the course of seven observing runs, about 250 spirals were observed in the $R$ band, with approximately 200 of these observed in the $B$ band as well. About 40 southern objects were observed at $B, R$, and $I$ bands. The filters used were from the Mould set. As discussed below, the northern data was calibrated to the Johnson filter system (see Johnson et al. 1966), and the southern data to that of Kron-Cousins (see Cousins 1976). Exposures of 450 s at R and 900 s at $B$ were sufficient to reach well below the 25 th $B$ mag $\operatorname{arcsec}^{-2}$ isophote in the Kitt Peak data. The Tololo exposures were somewhat longer, 1200 s at $\mathrm{B}, 600 \mathrm{~s}$ at R , and 600 $s$ at $I$, and went correspondingly deeper.

Table 2.2: Journal of Observations
Weather

a Almost all of the images were poorly focussed.

Table 2.3: Detector Characteristics

| CCD <br> Name | Readout Noise $\left(e^{-}\right)$ | $\begin{gathered} \text { Gain } \\ \left(\mathrm{e}^{-} / \mathrm{ADU}\right) \end{gathered}$ | $\begin{gathered} \text { Dark } \\ \left(\mathrm{e}^{\text {Count }} \mathrm{pix}^{-1}\right) \end{gathered}$ | Radiation Event Rate (min ${ }^{-1}$ ) | $\begin{gathered} \text { Image } \\ \text { Scale } \\ \left(\operatorname{arcsec} p i x^{-1}\right) \end{gathered}$ | $\begin{aligned} & \text { Field } \\ & \text { Size } \\ & \text { (arcmin) } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| RCA*1 | 80 | 10.5 | 40 | low | 0.86 | 7.3x4.6 |
| RCA\#2 | 80 | 13.4 | 40 | low | 0.86 | $7.3 \times 4.6{ }^{\text {a }}$ |
| RCA\#4 | 42 | 1.2/1.8 ${ }^{\text {b }}$ | 6 | 6 | 0.495 | $4.2 \times 2.6{ }^{\text {c }}$ |

${ }^{2}$ RCA\#2 has a three-column region of low sensitivity at column 187.
b August 1986/January 1987.
c Column 265 is bad in RCA*4.

## BASIC REDUCTIONS

The preliminary reduction and flattening of the raw data was carried out at the telescope using the standard NOAO mountain reduction software. The electrical DC offset in each frame was removed by subtracting the average value in the overscan region from the data on a row by row basis. Once this operation is complete, each frame is trimmed to a 320 by 512 (or slightly smaller) pixel format. Next, the remaining low spatial frequency variation in each frame is removed with the two-dimensional subtraction of an averaged bias frame. Finally, pixel-to-pixel variations in sensitivity are removed by dividing a high signal-to-noise dome flat taken through the appropriate filter at the beginning of the night into each bias-corrected data frame. There was little or no residual fringing left after performing the above steps for almost all of the frames, so sky flattening was not done. Because the dark current was small and subtracting it would just add noise, no explicit dark subtraction was performed. Note that the mean value of the dark current gets subtracted out automatically when the sky subtraction is done. In the Kitt Peak data the cosmic ray and/or radiation event rate was low and no attempt was made to correct for these events or other one- or two-pixel problems in the data. However, the Tololo data were subject to a high radiation event rate and each event of ten involved more than one pixel. An IRAF script was designed to replace these corrupted pixels with the median value of the pixels in the 3 by 3 pixel box centered on the radiation event. Bad
pixels were defined as having a value greater than 1.5 times the median value in the neighboring pixels. This procedure selected out and replaced fewer than 0.3 percent of the pixels in a typical 1200 exposure. Most of these replaced pixels were along the bad column in RCA\#4.

After the above reduction steps, the only serious defect remaining in the data is the group of three or so bad columns near column 187 of RCA\#2. This region is a problem because it is near the middle of the chip and it is difficult to avoid it when placing large objects on the frame. Row-averaged plots of the data in a typical frame show that in addition to the dead column 187, columns 188 and 190 are systematically low and high respectively. Therefore in all frames obtained with RCA\#2, columns 187, 188, and 190 were interpolated across linearly on a row by row basis. The purpose of the interpolation was to provide an estimate of pixel values for the photometry programs, rather than improve the surface brightness profiles as the profile-fitter is capable of ignoring bad data.

## SURFACE PAOTONETRY

Surface brightness profiles were extracted from the flattened data using a set of FORTRAN programs known as the "GAlaxy Surface Photometry" (GASP) package. GASP was written by M. Cawsor to run on a VAX/VNS system and was subsequently modified by $M$. E. Cornell to run on a Steward

Observatory MV/10000 under the AOS operating system. The principal features and algorithms of GASP were summarized quite well by Davis et al. (1985, section IV), so the discussion here will be kept short. The theory behind the algorithms was discussed in some detail by Cawson (1983). The surface photometry for the first four of our observing runs was obtained using GASP on an NOAO VMS VAX 11/750, the fifth run was processed with GASP running on a VAX $11 / 780$ at Caltech and reductions for the sixth and seventh runs and all subsequent processing were done at Steward.

The ultimate limit to surface photometry accuracy is the uncertainty in the sky background measurement. We measured the sky background by taking the average of the pixel values within a box of user-specifed size positioned in the frame using a cursor on an interactive display device. Pixel values more than three standard deviations from the mean were rejected and the mean and standard deviation were recomputed. The adopted background for each frame was the average of the sky values found in four 31 by 31 pixel boxes located near the galaxy of interest, with care taken to avoid both extended galaxy light and stars. The uncertainty of the sky value was estimated as the standard deviation of the various box values, divided by the square root of the number of different measurements. Sky values found in this way during dark time at Kitt Peak were typically about 22.2 mag $\operatorname{arcsec}^{-2}$ in the blue and $20.4 \mathrm{mag} \operatorname{arcsec}^{-2}$ in the Johnson $R$ bandpass, with errors of about 0.5 percent at both $B$ and $R$. The background at Cerro Tololo was somewhat fainter and bluer at about 22.4,
21.1, and 19.3 mag $\operatorname{arcsec}^{-2}$ at $B$, Kron-Cousins $R$, and $I$ bands respectively. Our Tololo measurements are brighter and bluer than those quoted for the mountain by Geisler (1988), perhaps affected by some moonlight.

Images can be specified for subsequent analysis by GASP in one of two ways. For most of the data frames, it was sufficient to use a cursor and display device to manually mark the centers of the galaxies to be analyzed. Then a file of images is created, containing for each object the $x-y$ position and starting values of zero for the object's ellipticity and position angle. One of the virtues of GASP is its ability to ignore specified regions of the data, such as bad pixels, columns with poor charge transfer or low sensitivity, or regions containing an overlapping object such as a star or galaxy. Under the manual-entry scheme, circular or elliptical regions to be deleted are chosen by moving a cursor around on the display and the parameters describing the region are entered in a deletions file.

[^0]or estimates the parameters at that level for merged images from the known parameters at higher levels. The user then goes through the output file and specifies which images are to be analyzed and which are to be deleted.

The GASP program that extracts a surface brightness profile from the data is called PROF. PROF begins with the $x-y$ center, semi-major axis, position angle, and ellipticity stored in the file of images to be analyzed, and then samples the $C C D$ data around the ellipse specified by the starting parameters. The variation of the pixel values around the ellipse are then analyzed as a function of angle from the major axis. This periodic function can be Fourier transformed to find the mean intensity around the ellipse along with the first and second Fourier components. If the ellipse parameters are correct, there will be no deviations around the ellipse and the sine and cosine components will be zero. If these terms are not zero, then the ellipse parameters are not correct, but can be corrected in the right direction using the magnitudes of the various Fourier components. This process is repeated iteratively until the fit is declared sufficiently good by passing a residual test, or the maximum number of iterations, typically 50 , is reached.

In practice, a true Fourier transform is not performed, but instead the data are least-squares fit to the equation for the Fourier components. In this way, data in the contaminated regions specified in the deletions
file can simply be left out of the fit. Once a fit is achieved for the semi-major axis at hand, the semi-major axis is increased by a user-chosen factor, typically 1.1 (logarithmic sampling), and the fitting process is repeated. PROF terminates when too small a fraction of the ellipse lies in uncontaminated data, when the image profile starts to rise by too much, or when the profile intensity becomes sufficiently close to the background value. The output from PROF is a list of mean intensities, ellipticities, position angles, and $x-y$ centers as a function of semi-major axis. Note that because the parameters of the elliptical isophotes are allowed to vary with major axis, the surface brightness profile determined by PROF will not follow a straight line through the galaxy if the position angles or centers of the fitted ellipses are different at different radii.

Some characteristics of typical surface brightness profiles generated in this way are given in Table 2.4. The fit of the isophotes to the data was checked visually by overlaying the ellipses found by PROF for some of the galaxies onto the appropriate CCD frame on a display device. We found that most isophotes were a reasonable fit, but there were galaxies for which the last couple of isophotes were a poor fit, having reached the maximum number of iterations without passing the residual test. But of en even isophotes for which the fit falled to converge completely seemed to be a reasonable fit visually. Plots of the ellipses found by PROF for each galaxy show that in most cases the last isophote is noticeably different from the previous ones, indicating either

Table 2.4: Average Surface Brightness Profile Characteristics

| Band | KPNO | CTIO data |
| :---: | :---: | :---: |
| B: Dynamic range of the profile | 5.6 | 5.8 mag |
| Limiting isophote | 26.6 | 27.0 mag arcsec ${ }^{-2}$ |
| Error in the limiting isophote | 0.4 | 0.7 mag arcsec ${ }^{-2}$ |
| Fraction of sky of the limiting isophote | 3.1 | 2.6 percent |
| Error at the 25 mag arcsec $^{-2}$ isophote | 0.10 | 0.08 mag arcsec ${ }^{-2}$ |
| $\mathrm{R}_{J}$ : Dynamic range of the profile | 6.0 |  |
| Limiting isophote | 25.3 | 25.5 mag arcsec ${ }^{-2}$ |
| Error in the limiting isophote | 0.6 | 0.5 mag arcsec ${ }^{-2}$ |
| Fraction of sky of the limiting isophote | 2.6 | 2.0 percent |
| Error at the 23.5 mag arcsec ${ }^{-2}$ isophote | 0.08 | 0.06 mag arcsec ${ }^{-2}$ |
| I: Dynamic range of the profile |  | $4.7 \mathrm{mag} \quad-2$ |
| Limiting isophote |  | 23.4 mag arcsec ${ }^{-2}$ |
| Error in the limiting isophote |  | 1.0 mag arcsec ${ }^{-2}$ |
| Fraction of sky of the limiting isophote |  | 1.2 percent -2 |
| Error at the $22.5 \mathrm{mag} \operatorname{arcsec}^{-2}$ isophote |  | 0.09 mag arcsec ${ }^{-2}$ |

that the region of reasonable signal-to-noise has been axceeded or that the frames are not perfectly flat. No attempt was made to correct the surface brightness profiles for the effects of seeing. Not much information is lost by ignoring the seeing-dominated inner core of the surface brightness profiles. Our distant northern clusters are 72 Mpc away, on average, making pixels there 300 pc across. We would never detect in the northern data potentially interesting features like the luminosity spike observed in the center of M87 (e.g. Young et al. 1978).

## CALIBRATION

The $B$ and $R$ major axis surface brightness profiles extracted with PROF from the Kitt Peak data were calibrated with the multiaperture photoelectric photometry of Bothun et al. (1985, Table 6). Those authors tabulate $V, B-V, V-R$, and error estimates if the errors exceed 0.04 mag in $V, 0.02$ mag in $B-V$, and 0.02 mag in $V-R$. For the galaxies with no error listed, these cutoff values were assumed here in order to estimate the uncertainty in the derived magnitude zeropoint. The photoelectric measurements given by Bothun et al. were made through 23.4, 35.6, 58.6, and 82.5 arcsec apertures, with three or four apertures measured for brighter galaxies and one or two for fainter objects. The magnitude zeropoints necessary to convert our instrumental magnitudes to the UBVR J system used by Bothun et al. were determined as follows. Simulated
aperture photometry was produced at integer pixel radii from the center of the galaxy to the nearest edge of the CCD frame using the GASP program APERT. (APERT makes no attempt to interpolate between pixels to make round apertures, but this approximation makes a difference only at extremely small apertures.) Linear interpolation between the tablulated instrumental magnitudes produced an instrumental magnitude for each aperture for which Bothun et al. quoted a magnitude. The difference between the quoted magnitude and our instrumental magnitude produces a value for the magnitude zeropoint correction. If Bothun et al. quoted more than one aperture for the galaxy, the zeropoints calculated for each aperture were averaged together. The uncertainty in the mean zeropoint was taken to be the larger of either the standard deviation between the various zeropoint estimates divided by the square root of the number of zeropoints or the quoted errors in the photometry divided by the square root of the number of zeropoints, with both calculations weighted by the adopted photometric errors. A few northern galaxies did not have photometry by Bothun et al. and were calibrated using the photometry given by Longo and de Vaucouleurs (1983), assuming photometric errors of 0.05 mag.

The zeropoints obtained above were applied to the isophote intensities found by PROF to produce surface brightnesses. Error estimates for the surface brightnesses include the zeropoint error, the uncertainty in the sky background, and the standard deviation of the
intensity values around the ellipse divided by the square root of the number of points that PROF used to derive that ellipse.

In order to check the photometry of Bothun et al., a few Landolt (1983) standard stars with $U B V(R I)_{K C}$ photometry were observed each night. Three nights of photometric weather were reduced and transformations between our instrumental magnitudes and colors and the UBV(RI) KC system found. For four or five galaxies each night that have aperture photometry in Bothun et al. (1985a), B magnitudes and B-R colors were derived from the standard star measurements for each aperture with published photometry using a transformation consisting of a zeropoint and a color term. Our results were then compared to the quantities in Bothun et al., after the Bothun et al. V-R colors were converted from the Johnson system to the Kron-Cousins system using the transformations given by Bessell (1979). The mean differences for the three nights between our photometry and that of Bothun et al., in the sense of (ours - theirs), were 0.02, -0.07 , and 0.06 mag for the $B$ magnitudes with an overall mean of 0.00 mag, and $\mathbf{- 0 . 0 2 ,}$ -0.02 , and 0.06 mag for the $B-R$ colors with an overall mean of 0.01 mag. Thus the photometry derived from the standard stars agrees with the aperture photometry used here to calibrate the bulk of the northern profiles, to within the quoted errors.

The calibration of a few of the northern surface brightness profiles was adversely affected by a defect in the reduction procedures. As we
discussed above, the profile-fitting program is capable of ignoring bad regions of the data when it does the ellipse-fitting. The aperture photometry code was designed to interpolate over these bad regions, but in the calibration photometry the bad pixels were ignored instead. This effect can be important when columns within calibration apertures were masked and ignored, leading to an underestimation of the object's brightness by 0.10 magnitude or more. Galaxies whose calibration is potentially affected by this problem are noted in Cornell et al. (1987).

No calibrated aperture photometry was available for the southern galaxies, so the data were calibrated using observations of Landolt (1983) equatorial and Graham (1982) E-region standard stars made each night. Typically, we observed 10 to 12 standard stars through each of the three bandpasses during the night, and measured at least two with a wide spread in color at two elevations separated by 0.5 to 0.8 airmasses in order to determine the first and second order extinction coefficients following Hardie (1962). The E-region fields were useful because they of ten have two or more calibrated stars that fit on a CCD frame at the same time.

Total instrumental magnitudes for the standard stars were determined with the circular aperture photometry program APERT by growing the aperture radius a pixel at a time and looking for the asymptotlc value of the growth curve. Close stars and nearby bad pixels were interpolated over by replacing the offending pixel with the mean value in the annulus
at that radius (computed without including the bad pixels). Asymptotic magnitudes were typically reached at a radius of 20 pixels or about 10 arcsec. This procedure for determining the total magnitude is somewhat subjective, but agreed pretty well with small-aperture measurements that were corrected to a total magnitude via a mean growth curve.

The transformation coefficients necessary to convert the instrumental magnitudes discussed above into standard Johnson B and KronCousin $R$ and I magnitudes were determined using a set of DAOPHOT auxiliary programs, CCDOBS, CCDOBS, and CCDSTD, written by Peter Stetson (see Stetson 1987 for information on DAOPHOT and the documentation for each of above the programs). CCDSTD determines the coefficients for a usersupplied transformation equation via a weighted least-squares fit. The program allows the user to change the number and type of terms in the transformation and to fix values for previously determined coefficients while the remaining ones are computed. This feature allows one to iteratively approach a solution, including any a priori knowledge available. The program also produces error estimates from error estimates for the input data and the quality of the fit, so that the significance of each term in the transformation can be determined.

Transformations of the form:

$$
\begin{aligned}
& b=B+A 0+A 1 *(B-R)+A 2 * X, \\
& r=R+B 0+B 1 *(B-R)+B 2 * X, \text { and }
\end{aligned}
$$

$$
1=I+C 0+C 1 *(B-R)+C 2 * X
$$

were fit to each night's data, and the coefficients $A 0, A 1, A 2$, etc. were determined. Here, $b, r$, and $i$ are the instrumental magnitudes, $B, R$ and I are the magnitudes in the standard filter system, and $X$ is the airmass. The terms $A O, B O$ and $C O$ will be referred to as the zeropoints of the transformations. The coefficients $A 1, B 1, C 1$ are the color terms, and A2, B2, and $C 2$ are the extinction coefficients. This formulation of the transformation equations allows one to combine observations taken at different airmasses, or even on different nights, another important feature of CCDSTD.

We experimented with additional, second-order terms in the transformations of the form $A 3^{*}(B-R) * X$ and $A 4^{*}(B-R)^{2}$, for example, but the values of the coefficients so determined were either not significantly greater than their errors and did not repeat well from night to night, or they tended to distort the determinations of the first-order coefficients toward non-physical values. At any rate, acceptable fits to the data were obtained using only the first-order coefficients, so the second-order terms were ignored.

[^1]estimates of 0.01 mag for our instrumental magnitudes and the internal errors given by Landolt (1983) for the standard magnitudes plus an additional 0.01 mag to allow for transformation to the standard filter system. Also listed are the number of Landolt standards that went into the fits, the mean coefficients, and the $1 \sigma$ standard deviations in the 5 nights of coefficients. The average color terms and extinction coefficients at $B$ and $R$ are in pretty good agreement with those determined independently by Mateo (1987) based on data taken with a similar filter/detector combination on the same telescope in July 1987.

While we were determining the transformations for each night of photometry, it became apparent that weather for the first CTIO run, in August/September 1986, was much less photometric than that for the second run in January 1987. The photometric transformations we found for the first run were not very repeatable from night to night and differed quite a bit from typical Tololo values. Since we used basically the same filters and the same $C C D$ detector for both runs, the color terms in the transformations, which just measure how different the observational bandpasses are from the standard ones, should have been very similar for both runs. And for the most part, seasonal variation in the extinction coefficients should not have been all that great (see Rufener 1986). We therefore adopted the mean values of the color terms and the extinction coefficients from the five nights of photometry in January 1987 as the color terms and extinction for all of the Tololo data (see Table 2.5).

Table 2.5: Photometric Transformations for the January 1987 CTIO run.

| Band | Date | N | Zeropoint | Color Term | Extinction |
| :---: | :---: | :---: | :---: | :---: | :---: |
| B | 5 Jan | 21 | $-22.7214 \pm 0.0415$ | $-0.1489 \pm 0.0080$ | $0.1946 \pm 0.0296$ |
|  | 6 Jan | 21 | $-22.8225 \pm 0.0394$ | $-0.1493 \pm 0.0072$ | $0.2060 \pm 0.0284$ |
|  | 7 Jan | 21 | $-22.8325 \pm 0.0386$ | $-0.1298 \pm 0.0078$ | $0.2028 \pm 0.0275$ |
|  | 8 Jan | 23 | $-22.7207 \pm 0.0608$ | $-0.1476 \pm 0.0132$ | $0.1724 \pm 0.0421$ |
|  | 9 Jan | 23 | $-22.7347 \pm 0.0540$ | $-0.1441 \pm 0.0117$ | $0.2080 \pm 0.0372$ |
|  | Mean: |  | $-22.7664 \pm 0.0562$ | $-0.1439 \pm 0.0082$ | $0.1968 \pm 0.0145$ |
| R | 5 Jan | 23 | $-21.8313 \pm 0.0275$ | $0.0119 \pm 0.0050$ | $0.0719 \pm 0.0202$ |
|  | 6 Jan | 23 | $-21.8942 \pm 0.0239$ | $0.0088 \pm 0.0042$ | $0.0834 \pm 0.0177$ |
|  | 7 Jan | 23 | $-21.8780 \pm 0.0361$ | $0.0230 \pm 0.0071$ | $0.0691 \pm 0.0257$ |
|  | 8 Jan | 23 | $-21.8777 \pm 0.0285$ | $0.0147 \pm 0.0061$ | $0.0885 \pm 0.0198$ |
|  | 9 Jan | 23 | $-21.8836 \pm 0.0273$ | $0.0169 \pm 0.0058$ | $0.1065 \pm 0.0188$ |
|  | Mean: |  | $-21.8730 \pm 0.0242$ | $0.0151 \pm 0.0054$ | $0.0839 \pm 0.0150$ |
| I | 5 Jan | 20 | $-21.1041 \pm 0.0292$ | $-0.0019 \pm 0.0055$ | $0.0624 \pm 0.0215$ |
|  | 6 Jan | 17 | $-21.1232 \pm 0.0301$ | $-0.0071 \pm 0.0057$ | $0.0439 \pm 0.0225$ |
|  | 7 Jan | 17 | $-21.1318 \pm 0.0276$ | $-0.0047 \pm 0.0059$ | $0.0492 \pm 0.0199$ |
|  | 8 Jan | 17 | $-21.1508 \pm 0.0238$ | $-0.0093 \pm 0.0057$ | $0.0844 \pm 0.0167$ |
|  | 9 Jan | 17 | $-21.0756 \pm 0.0367$ | $-0.0083 \pm 0.0088$ | $0.0439 \pm 0.0254$ |
|  | Mean: |  | $-21.1171 \pm 0.0286$ | $-0.0063 \pm 0.0030$ | $0.0568 \pm 0.0172$ |

After fixing these quantities, we reran the fits to determine a new zeropoint for each night. Zeropoints determined in this way had typical CCDSTD errors of $0.01,0.005$, and 0.005 mag at $B, R$, and $I$ respectively for the January 1987 data, and 0.02 mag in each band for the August/September 1986 data.

Once the transformation coefficients were determined, the transforiation equations were inverted to give each standard magnitude in terms of the instrumental magnitudes. The transformations were then applied to the instrumental surface brightnesses output by PROF. The instrumental b-r magnitude for the isophote at a given major axis was computed from the ellipses having the same major axis in the $B$ and $R$ profiles. The only subtle point about this calculation is that while the blue and red ellipses were chosen to have the same major axis, the other fit parameters, i.e. ellipticity, position angle, and center, were not constrained to be the some in the two fits, so small differences in these parameters from band to band could result in a computed color that differs slightly from the true color of that region. We performed the following test in order to estimate the size of this error in the color. We ran PROF in an interactive mode on two blue frames, forcing it to compute the mean blue surface brightness of each ellipse for which parameters were derived in the normal way in the corresponding $R$ data. We then computed at each semi-major axis the difference between the blue surface brightness derived in the normal way and the surface brightness derived from the
forced fit. These differenced profiles are shown in Figure 2.3. The objects plotted are: a) NGC 7541, an object with 111-behavé isophotes that are non-concertric and have parameters that vary a great deal across the galaxy, and b) NGC 7631, a galaxy with well- behaved ellipses having ellipticities, position angles, and centers that do not vary much with radius. For NGC 7541, the mean difference for 53 ellipses is $\mathbf{- 0 . 1 4 1}$ mag $\operatorname{arcsec}^{-2}$ and the rms difference is $0.212 \mathrm{mag} \operatorname{arcsec}^{-2}$. These differences translate directly into errors in the derived instrumental colors. However, as the instrumental colors enter the calibration of the surface brightness weighted approximately by the color term, even a surface brightness difference as large as $0.5 \mathrm{mag} \operatorname{arcsec}^{-2}$ leads to an error of at most 0.07 mag arcsec ${ }^{-2}$ for a typical B-band transformation (see Table 2.5). For NGC 7631, the mean difference for all 47 isophotes of only -0.006 mag arcsec ${ }^{-2}$ and the rms difference of only $0.086 \mathrm{mag} \operatorname{arcsec}^{-2}$ would lead to negligible errors in the calibration of the surface brightness profile.

There is one additional calibration step necessary before the southern surface brightness profiles can be compared to the northern data. The R-band aperture photometry of Bothun et al. (1985a) used to calibrate the KPNO data was defined on the Johnson system, while the CTIO R data was reduced on the Kron-Cousins filter system. We devised and applied a simple transformation between the two systems for our data consisting of a zeropoint shift only. To determine the shift we took the Johnson V-R


Figure 2.3. A Comparison of the Surface Brightness Profile Derived Naturally from the Blue Data to the Blue Profile Obtained through Force-pitting the Isophotes Derived from the Red Data.


Figure 2.3. Continued.
colors for all of the galaxy aperture photometry given by Bothun et al., transformed them to Kron-Cousins $V-R$ colors via the transformations given by Fernie (1983), and then computed the observed $R$ magnitude on the KronCousins system using the tabulated $V$ Bothun et al. magnitudes. We then computed the mean difference between the Johnson and Kron-Cousins $R$ magnitudes. The average result for 486 points of aperture photometry was $\left\langle R_{J}-R_{K C}\right\rangle=-0.2399$ mag, with a standard deviation of 0.0319 mag. This procedure works because the dispersion in color for the spirals in our sample is not very great.

## CHECKS ON THE SURFACE PHOTONETRY

We can check the reproducibility of our surface photometry by intercomparing the reduced surface brightness profiles of objects observed more than once. We made repeat observations of 12 northern spirals at $B$ and of 15 objects at $R$. For each pair of profiles, we plot the difference between the surface brightnesses against the mean surface brightness at each measured isophote in Figure 2.4 for the blue data and Figure 2.5 for the red. For those pairs of frames where the grid of isophote major axes did not match, the profiles were interpolated to a common grid before subtraction using a cubic spline interpolation routine from the IMSL subroutine library.

Examination of Figures 2.4 and 2.5 shows that the agreement is quite good in general. The problem areas tend to be in the center of the galaxy, where the first few ellipses can be quite different due to centering errors and seeing differences, and the very outer regions, where small errors in the sky determination have a large affect on the inferred surface brightnesses. The worst agreement is seen in $N 6045$, an $S$-spiral with an atypical morphology and a nearby companion that was probably deleted differently in the two reductions, and in N7591, where one of the frames must have had a bad sky value. A summary of the agreement between repeated measurements is presented in Table 2.6. There we list the mean and standard deviation of the surface brightness differences in the part of the data which would be expected to exhibit the best agreement. We skip the central region within a radius of 3 arcsec to de-emphasize centering and seeing differences and include only those isophotes with an observed surface brightness higher than 26 mag arcsec ${ }^{-2}$ at $B$ or 24.5 mag $\operatorname{arcsec}^{-2}$ at $R$, to mimimize effects from errors in the background.

It is useful at this point to compare our surface brightness profiles to CCD su.face photometry of other authors, but this is possible for only two of the galaxies in the sample, NGC 7541 and NGC 7631, which have been observed by Kent (1984) as part of his CCD surface photometry survey of field galaxies. This comparison was fully discussed by Cornell et al. (1987) where it was shown that Kent's Gunn-r profile of NGC 7631 agreed with our Johnson-R profile to about 0.03 mag, after taking the


Figure 2.4. Reproducibility of Blue Surface Brightness Profiles.


Figure 2.4. Continued.


Figure 2.5. Reproducibility of Red Surface Brightness Profiles.


Pigure 2.5. Continued.


Figure 2.5. Continued.

Table 2.6: Reproducibility of Surface Brightness Profiles

| Object | B |  |  | R |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | Mean | $\sigma$ | N | Mean | $\sigma$ |
| 11173 | 26 | 0.062 | 0.128 | 24 | -0.017 | 0.049 |
| 11179 | 24 | 0.018 | 0.138 | 14 | -0.003 | 0.038 |
| N3883 | 35 | 0.062 | 0.044 | 35 | -0.014 | 0.034 |
| N6045 | 28 | -0.145 | 0.180 |  |  |  |
| N7541 |  |  |  | 37 | 0.028 | 0.126 |
| N7591 | 35 | 0.008 | 0.133 | 35 | -0.004 | 0.164 |
| N7631 | 31 | -0.010 | 0.045 |  |  |  |
| U10085 | 26 | -0.053 | 0.086 | 26 | -0.056 | 0.144 |
| U10195 | 27 | -0.100 | 0.172 | 28 | -0.097 | 0.097 |
| U12494 | 29 | -0.026 | 0.071 | 29 | -0.067 | 0.141 |
| U12497 |  |  |  | 28 | -0.103 | 0.079 |
| U4329 |  |  |  | 28 | 0.081 | 0.187 |
| Z108098 |  |  |  | 22 | -0.003 | 0.170 |
| 2108107 | 23 | 0.039 | 0.086 |  |  |  |
| Z108139 | 25 | -0.079 | 0.061 | 25 | -0.049 | 0.267 |
| 2406042 |  |  |  | 25 | -0.143 | 0.061 |
| Z406042a |  |  |  | 26 | 0.038 | 0.121 |
| 2406082 | 21 | -0.016 | 0.099 |  |  |  |
| Z421011 |  |  |  | 25 | -0.002 | 0.038 |

transformation between the two bandpasses into account. On the other hand, the agreement for NGC 7541 was poor, probably due to a difference in fitting techniques. The only major difference between the ellipse-fitting procedure used by Kent and the one in GASP is that the GASP routine allows the $X$ and $Y$ centers of the ellipse to vary with semi-major axis, while Kent holds his center fixed. Cornell et al. showed that this difference can account for most or all of the large disagreement between the two profiles.

In addition to the CCD surface photometry discussed above, there is photographic surface photometry in the literature that can be compared with our profiles. The problem with comparing our CCD data with photographic data is that in addition to differences in observed bandpass and reduction techniques, there are added complications resulting from using plates, i.e. non-linear, low-sensitivity detectors. We can expect the agreement with our data to be poorer, in general, than can be achieved with other CCD's. Nevertheless, we present in Figure 2.6 a comparison of the photometry for the three objects that we have in common with Watanabe, Kodaira, and Okamura (1982: NGC 4380) and Watanabe (1983: NGC 4246 and NGC 4651). For each of these Virgo spirals, we plot the difference between our B GASP surface brightness profile and their $V$ major axis profile against (a) our B surface brightness, and (b) distance from the center of the galaxy. The error bars include our estimated errors and assume an error of 0.1 mag for their surface brightnesses, probably an
underestimate. A B-V comparison is potentially subject to problems due to color gradients, but this effect is visible only in NGC 4246. The agreement is pretty good, with the typical B-V color being consistent with normal spirals. As with the repeat observations, the centers and the last couple of isophotes are a problem area. Also, NGC 4246 and NGC 4651 have strong arms which show up noticeably in the difference plots because GASP tried to follow the shifting isophotes more closely than did the major axis cuts of Watanabe et al.

APERTURE PHOTONETRY

A grid of elliptical aperture photometry was produced for each $C C D$ frame by summing the counts in the pixels within the ellipses determined by PROF for the corresponding R-band frame, after suitable adjustment of the ellipse centers. If no $R$ frame was available, the $B$ frame ellipses were used instead. The KPNO photometry was then calibrated using the zeropoint determination described above. Bad pixels were replaced with a value obtained from an approximate linear interpolation along the surface brightness profile between the nearest neighboring isophotes as derived from the frame being analyzed. For each isophote the magnitude within that isophote and the mean surface brightness within that isophote were tabulated. Aperture photometry for the CTIO data mas produced in a similar way, and then calibrated using the photometric transformations


Figure 2.6. Comparison of Our B Surface Brightness Profiles with the $V$ Data of Watanabe et al.


Figure 2.6. Continued.


Figure 2.6. Continued.
discussed above. Choosing a standard photometric band for the reference ellipses makes it possible to compute colors by subtracting the magnitudes directly without having to worry about pathological objects with different ellipse-fits in the different bandpasses.

## DERIVED PARAMETERS

For each object, several standard parameters were derived from the surface brightness profiles and the aperture photometry described above. Axis ratios, inclinations, and isophotal diameters were extracted from the profiles and various definitions of magnitude, surface brightness, and concentration parameter were computed from the photometry.

The ratio of the major to minor axes for each object was computed from the average ellipticity of the outer isophotes as determined by PROF for the R-band CCD frame. Specifically, we included ellipses with a $R_{J}$ surface brightness between 22.5 and 24.0 mag arcsec ${ }^{-2}$, skipping the very outer three isophotes which are of ten adversely affected by errors or nonflatness in the background. If an $R$ frame was not available, the $B$ frame was used in its place, including ellipses in the corresponding blue surface brightness range, 24.0 to 25.5 mag $\operatorname{arcsec}^{-2}$. On average, 4 ellipses were used to determine the mean ellipticity and the dispersion in that ellipticity was 0.027 . Given the axis ratio, the inclination to
the plane of the sky was computed using the standard relation

$$
\cos ^{2} i=\left[(b / a)^{2}-q_{0}^{2}\right] /\left(1-q_{0}^{2}\right),
$$

where $a$ is the major axis, $b$ is the minor axis, and $q_{0}$ is the true axial ratio of the disk, taken to be 0.2 here, independent of galaxy type.

There are two possible approaches to correcting isophotal parameters for the effects of Galactic extinction, internal absorption, and Kdimming. A common method has been to derive diameters and magnitudes in terms of an "observed", i.e. uncorrected, isophote and then apply corrections to each derived parameter that are based on simple Galactic extinction models and mean galaxy growth curves. Because estimates of the line-of-sight absorption to each cluster are available from $H$ I maps, and we have surface brightness profiles for each object, we prefer to make straightforward corrections to the profiles before deriving the desired quantities. Therefore, to obtain an isophotal diameter, for example, we first correct the surface brightness profile for line-of-sight absorption, apply a simple inclination correction, correct for $K$-dimming and the cosmological $(1+z)^{4}$ effect, read off the radii bracketing the radius where the adjusted surface brightness falls below the required value, and linearly interpolate to the desired "corrected" surface brightness. We then express the diameters in units of kpc, using the distance moduli given in Table 2.1.

Foreground reddening estimates at B-band are given in Table 2.1. The relative reddenings at the Johnson $R$-band and at the Kron-Cousins Iband were determined using the interstellar reddening curve given by Johnson (1968, Table 12) and the Johnson/Kron-Cousins transformations of Fernie (1983). We find that the ratio $A_{R} / A_{B}$ is about 0.56 and the ratio $A_{I} / A_{B}$ is 0.44.

Inclination corrections remain controversial and, as it turns out, there is no one simple correction scheme that removes the inclination dependence from all derived parameters. There are two competing effects. When a galaxy disk is viewed at an angle to the line of sight, the path through the galaxy is longer than it would be if the galaxy were viewed face-on. Thus more stars are intersected, and the surface brightness appears higher in the inclined object than in the face-on one, by a factor of secant 1 . We correct for this affect by adding a $2.5 \log R$ term to the observed surface brightness, where $R$ is the ratio of the major to the minor axis. Following Tully and Fouque (1985), we limit this correction is the maximum value achieved when the axis ratio corresponds statistically to an inclination of $90^{\circ}$. But even as projection tends to increase the surface brightness with increasing inclination, the observer's line of sight passes through more and more interstellar dust, reducing the surface brightness. This affect is taken into account using a correction of

$$
A_{1, B}=0.20(\text { secant } 1-1),
$$

with an upper limit of $A_{1, B}=0.6 \mathrm{mag}$, following Bothun et al. (1985a). The corrections at $R$ and $I$ bands are reduced by the ratios derived above. This particular correction is not very different from the corresponding one discussed by Tully and Fouque.

The final corrections applied to the surface brightness are an adjustment to allow for the $(1+z)^{4}$ dimming of surface brightness with redshift and a $K$-correction for the $B$-band using the interpolation formulae given by Bothun (1981), which were based on calculations by Pence (1976). For this last correction, a numerically coded morphological type $T$ of 5 was assumed for all spirals. Even at $B$ this correction is at most 0.06 mag for the Hercules objects, so the $K$-corrections at $R$ and $I$ were ignored.

The derivation of isophotal magnitudes and the mean surface brightness within the standard isophote proceeds in the same manner as that of the diameters. Once the radius in the profile corresponding to the corrected isophotal level is known, we interpolate along the photometric growth curves to get the desired magnitude and surface brightness. At this point the quantities correspond to the correct isophote, but still need to be corrected for reddening, inclination, and K-dimming, so the corrections discussed above are applied, as appropriate.

For each object, we calculate the axis ratio and inclination in the R-band (or at $B$, if necessary), and the diameter, magnitude, and mean surface brightness through our adopted standard isophotes of $25,23.5$, and 22.5 mag arcsec ${ }^{-2}$, at $B, R$, and $I$, respectively. We also compute a concentration parameter, defined as the ratio of the flux through the isophote with a diameter 15 percent that of the standard diameter to the flux through the standard isophote. This concentration parameter is then related to the ratio of the bulge light to the total luminosity. The fraction of 15 percent represents a compromise between the desire to make the central aperture as small as possible in order to maximize the contrast between the bulge and the total magnitude, and the need to keep the central aperture large enough to minimize the effects of seeing and centering errors. The average value of the logarithm of the blue diameter of our objects corresponds to 70 arcsec, so our central apertures are typically 10 arcsec across. Next, we estimate the total magnitude in each band from the aymptotic value of the growth curve formed by plotting the magnitude within each isophote against the surface brightness of that isophote. This realization of the growth curve is more useful than a standard magnitude/aperture relation because it allows one to confirm directly that the apertures under consideration are large enough to encompass the entire galaxy. If the surface brightness axis extends down to the typical limiting isophote, and the curve has a well-defined asymptote, one has some confidence that the derived total magnitude is meaningful. Nevertheless, total magnitudes derived in this way are
somewhat subjective, and hence not as preferable as our isophotal magnitudes. Finally, we compute a nuclear surface brightness, defined as the mean surface brightness through the isophote with a diameter 15 percent that of the standard diameter in the relevant bandpass.

One way to measure the uncertainty in our derived parameters is to see how well repeated measurements of the same object agree. We present this comparison for the 12 objects observed twice at $B$ and the 14 objects observed more than once at $R$ in Table 2.7. There we list the mean of the absolute value of the difference between two measurements of the same parameter for all of the objects at $B$ and at $R$. Also listed are the standard deviation of the differences and the number of measurements in each mean. We performed this test for the logarithm of the axis ratio and the inclination in degrees computed at $R$ (or at $B$, if necessary), the logarithm of the diameter, the mean surface brightness within the standard isophote, the logarithm of the concentration parameter, the nuclear surface brightness, the isophotal magnitude, and the total magnitude.

## ADDITIONAL PARAMETERS

In addition to the parameters we derived from the CCD surface photometry, there are several other measureable quantities available from Bothun et al. (1985a) for many of the objects. These include the total

Table 2.7: Reproducibility of Galaxy Parameters

| Parameter | B |  |  | R |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | \|Diff ${ }^{\text {l }}$ | $\sigma$ | $\bar{N}$ | $\mid$ Diff $\mid$ | $\sigma$ |
| $\log R$ | 16 | 0.0249 | 0.0160 |  |  |  |
| 1 (deg) | 16 | 2.4 | 2.0 |  |  |  |
| $\log \mathrm{D}$ | 10 | 0.0183 | 0.0229 | 13 | 0.0169 | 0.0175 |
| <SB> | 8 | 0.088 | 0.094 | 12 | 0.040 | 0.038 |
| $\log C$ | 8 | 0.0270 | 0.0347 | 10 | 0.0328 | 0.0304 |
| $\langle\mathrm{SB}\rangle_{\mathrm{n}}$ | 9 | 0.215 | 0.249 | 11 | 0.203 | 0.172 |
| M | 8 | 0.057 | 0.055 | 12 | 0.051 | 0.080 |
| $\mathrm{M}_{\mathrm{T}}$ | 8 | 0.15 | 0.12 | 13 | 0.13 | 0.18 |

optical colors $B-V$ and $U-B$, and the $H-b a n d$ magnitude and $B-H$ color, all derived from photoelectric photometry. The $H$ magnitudes and the $B-H$ colors are referred to the aperture with $\log A / D_{1}=-0.5$, where $D_{1}$ is the galaxy diameter as defined in Aaronson et al. (1982b). Bothun et al. quote nominal errors of 0.02 mag in $\mathrm{B}-\mathrm{V}, 0.04 \mathrm{mag}$ in $\mathrm{U}-\mathrm{B}, 0.03 \mathrm{mag}$ in $H_{-0.5}$, and 0.2 mag in $(B-H)_{-0.5}$. The $H_{-0.5}$ magnitudes were subsequently revised by Aaronson et al. (1986) using new diameters based on the work of Cornell et al. (1987). The new versions of the $\mathbf{H}_{-0.5}$ magnitudes are used in the discussion that follows, although the parameters derived by Bothun et al. that are based on those magnitudes were not updated. Also available are parameters derived from 21 cm observations made with the Arecibo 305 m radio telescope. The derived parameters consist of a linewidth measured at the $20 \%$ of peak level, the total $H$ I mass implied by the H I flux integral, and the distance-independent measures of $\mathrm{H} I$ content, $M_{H} / L_{B}$ and $M_{H} / L_{B}$, normalized to the total luminosity at $H$ and at $B$, respectively. Bothun et al. estimate that the typical error in the linewidths is about $20 \mathrm{~km} \mathrm{~s}^{-1}$ and that the flux integrals are good to about 30 percent or about 0.13 in the logarithm. With total magnitudes that are probably good to 0.2 mag, we estimate that the errors on the $H$ content measures are typically about 35 percent or 0.15 in the log. Finally, we will make use of the Bothun et al. and Aaronson et al. (1989) redshifts below. Bothun et al. find the internal error in their heliocentric velocities to be about $10 \mathrm{~km}^{-1}$.

## CHAPTER 3: SCATTBR IN THE TULLY-RISHER RBLATION

## INTRODUCTION

The relationship first pointed out by Tully and Fisher (1977) between the luminosity of spiral galaxies and their maximum rotation velocity, as measured by the width of their neutral hydrogen line profile, continues to be one of the best methods available to measure relative distances. The method works because it relates an objectively-determined distance-independent observable, the line-width, to a distance-dependent observable, the magnitude in some bandpass. The physical basis for the correlation is easy to understand in a crude way, as both the intrinsic luminosity and maximum rotation velocity of the galaxy are related to the total galaxian mass. In the infrared, the observational scatter about this relation is typically $0.35-0.50$ mag (Aaronson and Mould 1983; Aaronson et al. 1986), permitting relative distance estimates with an accuracy of about 20 percent. The classical Malmquist bias in a magnitude-limited sample is $1.38 \sigma^{2}$, and while the solution to the general problem is complex (see Feast 1987), it is clear that reducing the scatter about the Tully-Fisher relation by even a factor of two would make a large difference in our ability to determine the local velocity field from distances and velocities of individual galaxies. Furthermore, reducing the scatter in the cluster Tully-Fisher relations used by Aaronson et al.
(1989) to determine the peculiar velocities of various nearby concentrations of matter by this same factor of two would allow us to measure $1 \sigma$ random motions as small as $160 \mathrm{~km} \mathrm{~s}^{-1}$ for a typical cluster.

In this chapter we will discuss the scatter in the Tully-Fisher relation at infrared wavelengths, and in the next chapter we look for ways to reduce that dispersion through the inclusion of additional observational information about the galaxies under study.

## CLUSTER MERBERSHIP

A well-defined cluster of galaxies provides the appropriate environment to study the intrinsic scatter in the luminosity/line-width relation because, by definition, all of the objects are at nearly the same distance. In this study we have to combine data from several clusters, but at least our knowledge of the distance to each group improves as the square-root of the number of objects in the sample. Since we then assign to each object in a cluster the mean distance of that cluster, it is important to select cluster samples that are as free from interlopers (1.e. non-members that appear accidently in the same region on the sky) as possible. Before we examine the cluster Tully-Fisher relations in detail, we should discuss how cluster membership was determined for the objects in our CCD survey sample.

Cluster membership is fairly secure for our objects in the northern hemisphere, where we have complete redshift information from Bothun et al. (1985a) and a magnetic tape version of The Center for Astrophysics Redshift Catalogue, obtained from the Astronomical Data Center. We have basically adopted the selection criteria from Aaronson et al. (1986) as to acceptable redshift range and angular distance from the cluster center. These criteria are reproduced in Table 3.1 below. In practice, if a galaxy was listed as a cluster member by Aaronson et al., we considered it a member also. If those authors did not list it, then we applied the redshift range and angular distance cutoffs listed in Table 3.1. In the case of the Pisces cluster, the angular distance criterion is not particularly helpful, as the Pisces "cluster" is actually just a collection of galaxies taken from the middle of a linear structure that is part of the Pisces-Perseus Supercluster (see Figure 1 in Giovanelli and Haynes 1985). We therefore accepted any object that falls along that structure and has an appropriate redshift.

The situation in the southern hemisphere is not as good. We adopted redshift search ranges for Antlia, Hydra, Centaurus, and Pavo from Aaronson et al. (1989), and obtained those for NGC 1209, Telescopium, and Indus from velocity histograms kindly provided by Huchra (1988). We chose angular distance cutoffs to correspond roughly to the mean spatial radius of the northern cluster limits of 4.1 Mpc . In the south, almost all of

Table 3.1. Cluster Membership Rules

| Name | Search Radius ( ${ }^{\circ}$ ) | Search Radius <br> (Mpc) | $\begin{aligned} & \text { Search } \\ & \text { Velocities }{ }^{a} \\ & \left(\mathrm{~km} \mathrm{~s} \mathrm{~s}^{-1}\right) \end{aligned}$ |
| :---: | :---: | :---: | :---: |
| (1) | (2) | (3) | (4) |
| Pisces | 4 | 3.6 | 4200 to 6400 |
| A400 | 3 | 4.2 | 5400 to 8800 |
| A539 | 3 | 5.0 | 6600 to 10200 |
| Cancer | 4 | 4.0 | 3200 to 7000 |
| A1367 | 3 | 3.9 | 4600 to 8800 |
| Coma | 3 | 4.2 | 5000 to 8800 |
| 274-23 | 3 | 3.7 | 4000 to 7400 |
| Hercules | 3 | 5.9 | 8400 to 14400 |
| Pegasus | 4 | 2.7 | 2600 to 5400 |
| A2634/66 | 4 | 5.9 | 6800 to 10200 |
| Virgo | 6 | 1.5 | -600 to 3000 |
| NGC 1209 | 6 | 3.1 | 2200 to 3600 |
| Antlia | 6 | 3.0 | 2000 to 3600 |
| Hydra | 5 | 3.8 | 1700 to 5600 |
| Centaurus 30 | 6 | 3.2 | 1700 to 4100 |
| Centaurus 45 | 5 | 4.0 | 4100 to 5600 |
| Telescopium 27 | 6 | 3.2 | 1800 to 3400 |
| Telescopium 56 | 4 | 4.3 | 4400 to 6800 |
| Pavo | 6 | 3.2 | 2800 to 5000 |
| Indus | 6 | 5.7 | 4200 to 6000 |

${ }^{a}$ Heliocentric velocities.
the objects were chosen to be within $5^{\circ}$ of the cluster centers listed in Table 2.1, but redshifts are only available for 40 percent of the objects. Objects with bad redshifts were rejected, but for many galaxies no further decision could be made and thus they were declared cluster members. In the case of Centaurus, where there are two components, a foreground cluster and a background cluster, objects were assigned to one of the two groups through a cut in a diameter histogram. Objects that seemed too small to be in the front group were assigned to the back. A similar situation exists for the Telescopium groups, but there we had redshifts for all of the objects that were assigned to the background group.

## THE INFRARED TULLY-RISHER RELATION

As a starting point for our discussion of the scatter in the TullyFisher relation, let us examine the data presented by Aaronson et al. (1986) for ten distant clusters in the north and that of Aaronson et al. (1989) for seven relatively-nearby southern clusters. We present plots of the infrared Tully-Fisher relation in each of the northern clusters in Figure 3.1, and similar plots for the southern clusters in Figure 3.2. In each case, the $H$ ( $1.6 \mu \mathrm{H}$ ) magnitude, referred to the aperture where log $A / D_{1}=-0.5$, is plotted against the logarithm of the 21 can line-width. The magnitudes have been placed on an absolute scale using the mean cluster distance moduli listed in Table 8 of Aaronson et al. (1989).


Figure 3.1. Linear Infrared Tully-Fisher Relation for the Aaronson et al. (1986) Northern Clusters. The dashed lines are the "single-slope" fit described in the text. Clusters are Pisces, A400, A539, and Cancer.


Figure 3.1. Continued. Clusters are A1367, Coma, Z74-23, and Hercules.


Figure 3.1. Continued. Clusters are Pegasus and A2634/66.


Figure 3.2. Linear Infrared Tully-Fisher Relation for the Aaronson et al. (1989) Southern Clusters. The dashed lines are the "single-slope" fit described in the text. Clusters are Antlia, Hydra, N3557, and Cen30.


Figure 3.2. Continued. Clusters are Cen45, E508, and Pavo.
(Distances for many of these clusters are listed here in Table 2.1). Otherwise, the data are taken directly from Table 2 of each reference. On each plot we have included the best-fit line from a standard linear least-squares fit made assuming errors only in the magnitude direction. The coefficients of these fits are listed in Table 3.2 below. The points are labelled 0 through 9 and 0 through 7 , for membership in the corresponding northern or southern cluster, with the order as listed in Table 3.2. The dispersions about these least-square fits as tabulated in Table 3.2 are thus the least observational scatter we can find for Individual cluster Tully-Pisher relations.

Let us examine the fits in Table 3.2 in more detail. It is clear from the large estimated errors in the derived slopes and zeropoints that the fit coefficients are not very well constrained. In particular, the large errors make difficult any attempt to look for cluster-to-cluster variations in the Tully-Fisher relation with these data. However, the tabulated slopes are actually quite similar, with just over half the values within $1 \sigma$ of the mean slope of $\mathbf{- 9 . 5 0}$, and 76 percent of the slopes within $2 \sigma$. Histograms of the slopes, zeropoints, and scatter about the relations are given in Figure 3.3. While the distributions of the slopes and zeropoints are not exactly gaussian, most of the clusters would be compatible with a single-sloped relation. We looked for such a relation by determining the slope that minimized a figure-of-merit equal to the rms scatter about the 17 cluster fits, normaliaau by the number of degrees of

Table 3.2. Linear Infrared Tully-Fisher Relation

| Cluster | N | Slope | Zeropoint |  | r | $\sigma$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (1) | (2) | (3) | (4) |  | (5) | (6) |
| Pisces | 20 | -10.55 $\pm 0.57$ | 5.45 | $\pm 1.47$ | 0.98 | 0.36 |
| A400 | 7 | $-7.56 \pm 1.45$ | -2.47 | $\pm 3.83$ | 0.92 | 0.33 |
| A539 | 9 | $-8.30 \pm 1.77$ | -0.53 | $\pm 4.67$ | 0.87 | 0.38 |
| Cancer | 22 | $-9.23 \pm 1.18$ | 2.07 | $\pm 2.99$ | 0.87 | 0.65 |
| A1367 | 20 | $-9.91 \pm 1.34$ | 3.73 | $\pm 3.48$ | 0.87 | 0.49 |
| Coma | 13 | $-9.26 \pm 1.00$ | 2.03 | $\pm 2.63$ | 0.94 | 0.34 |
| 274-23 | 13 | $-12.76 \pm 1.53$ | 10.93 | $\pm 3.84$ | 0.93 | 0.52 |
| Hercules | 11 | $-6.55 \pm 1.37$ | -5.09 | $\pm 3.60$ | 0.85 | 0.40 |
| Pegasus | 22 | $-8.86 \pm 0.99$ | 1.38 | $\pm 2.43$ | 0.89 | 0.55 |
| A2634/66 | 11 | $-6.68 \pm 1.24$ | -4.87 | $\pm 3.34$ | 0.87 | 0.32 |
| Antlia | 10 | $-9.50 \pm 1.09$ | 2.70 | $\pm 2.82$ | 0.95 | 0.36 |
| Hydra | 10 | $-7.86 \pm 0.85$ | -1.47 | $\pm 2.21$ | 0.96 | 0.38 |
| N3557 | 5 | $-12.00 \pm 4.32$ | 9.02 | $\pm 11.03$ | 0.85 | 0.41 |
| Cen30 | 10 | $-9.19 \pm 1.46$ | 2.06 | $\pm 3.64$ | 0.91 | 0.57 |
| Cen45 | 6 | $-12.10 \pm 3.84$ | 9.42 | $\pm 9.89$ | 0.84 | 0.71 |
| E508 | 7 | $-8.16 \pm 1.25$ | -0.54 | $\pm 3.11$ | 0.95 | 0.37 |
| Pavo | 8 | $-12.95 \pm 0.89$ | 11.41 | $\pm 2.20$ | 0.99 | 0.34 |



Figure 3.3. Histograms of the Linear Tully-Pisher Relation Fit Parameters from Table 3.2: a) Slope, b) Zeropoint, c) Scatter about the Relation, and d) Fixed-Slope Zeropoint.
freedom for the 18-parameter fit. Each cluster zeropoint mas allowed to float in order to account for possible cluster-to-cluster variations in the Tully-Pisher relation or for relative distance errors. The resulting fit is thus the best we can find for which all cluster relations share the same slope. The rms scatter about this fit was 0.488 mag, only a little worse than the corresponding value of 0.474 mag computed for the completely independent cluster fits. The zeropoints and the dispersion about each fit are listed in Table 3.3 for all 17 clusters. The singleslope fits are plotted for reference in Figures 3.1 and 3.2 as dashed lines. A histogram of the fixed-slope zeropoints is given in Figure 3.3d. As the typical error in the mean cluster zeropoint is 0.15 mag , none of the clusters has a zeropoint that is more than $2 \sigma$ from the weighted mean zeropoint of 2.828.

Despite the rough correspondence with a universal single-sloped relation, the coefficients in Table 3.2 exhibit some disturbing trends. The slopes in particular depend on distance, as can be seen in Figure 3.4 where we plot the slope, zeropoint, scatter, and fixed-slope zeropoint about the fit against mean cluster distance modulus. In each plot, the zeroes correspond to northern clusters and the ones correspond to southern clusters. Particularly beyond a distance modulus of about 33.6 mag, or a redshift with respect to the Local Group of approximately $5200 \mathrm{~km} \mathrm{~s}^{-1}$, the slopes and zeropoints show a fairly strong trend with distance. Even if this trend is not strictly monotonic, at least the distant clusters

Table 3.3. Single-Slope Infrared Tully-Fisher Relation
Slope fixed at $\mathbf{- 9 . 5 3}$, rms scatter $=0.49$ mag.
Cluster $N$ <Zpt> $\sigma$
(1) (2) (3) (4)

| Pisces | 20 | 2.84 | 0.39 |
| :--- | ---: | ---: | ---: |
| A400 | 7 | 2.74 | 0.38 |
| A539 | 9 | 2.72 | 0.39 |
| Cancer | 22 | 2.84 | 0.65 |
| A1367 | 20 | 2.74 | 0.49 |
| Coma | 13 | 2.75 | 0.34 |
| Z74-23 | 13 | 2.83 | 0.62 |
| Hercules | 11 | 2.74 | 0.50 |
| Pegasus | 22 | 3.01 | 0.56 |
| A2634/66 | 11 | 2.78 | 0.41 |
|  |  |  |  |
| Antlia | 10 | 2.77 | 0.36 |
| Hydra | 10 | 2.84 | 0.46 |
| N3557 | 5 | 2.72 | 0.43 |
| Cen30 | 10 | 2.90 | 0.57 |
| Cen45 | 6 | 2.81 | 0.75 |
| E508 | 7 | 2.87 | 0.41 |
| Pavo | 8 | 3.02 | 0.64 |



Figure 3.4. Linear Tully-Fisher Relation Fit Parameters from Table 3.2 Plotted Against Distance Modulus: a) Slope, b) Zeropoint, c) Scatter about the Relation, and d) Zeropoint of the Fixed-Slope Relation.
have smaller slopes and zeropoints in the mean than the nearer clusters. This effect does not go away if one considers only the subsample of those clusters which exhibit a small ( 0.30 to 0.45 mag ) scatter about the TullyFisher relation.

Aaronson et al. (1986) alluded to the above effect and explained it in terms of a selection bias working in tandem with a Tully-Fisher relation that is intrinsically curved rather than linear in $\log \Delta V$. The selection bias in question is that in increasingly distant clusters, only the higher-luminosity, larger-line-width objects are included in the sample, at the expense of the intrinsically fainter objects. The trend in the slopes in Figure $3.4 a$ is then explained by a Tully-Fisher relation that is in fact curved with a shallower slope at larger line-widths. The selection effect is clearly present in the data, as can be seen from the histograms of $H$-magnitude presented in Figure 3.5 for the northern clusters and in Pigure 3.6 for the southern clusters. The mean infrared magnitudes for all 17 clusters are listed in Table 3.4, and are plotted against cluster distance modulus in Figure 3.7. The mean absolute magnitude for the distant cluster samples is clearly brighter than that for the nearby clusters. The Tully-Fisher relation is also clearly curved, as can be seen in Figure 2 of Aaronson et al. (1982b), for example. Thus Aaronson et al. (1986) were driven to adopt a curved relation for their magnitude calibration. Their adopted parabolic fit, whose shape is based on data from the 306 -object Local Supercluster sample


Figure 3.5. Histograms of the Infrared Magnitudes for the Aaronson et al. (1986) Northern Clusters. Clusters are Pisces, A400, A539, and Cancer.


Figure 3.5. Continued. Clusters are A1367, Coma, 274-23, and Hercules.


Figure 3.5. Continued. Clusters are Pegasus and A2634/66.


Figure 3.6. Histograms of the Infrared Magnitudes for the Aaronson et al. (1989) Southern Clusters. Clusters are Antlia, Hydra, N3557, and Cen30.


Figure 3.6. Continued. Clusters are Cen45, E508, and Pavo.

Table 3.4. Mean Cluster Infrared Magnitudes

$$
\text { Cluster } \quad m-M \quad N \quad\left\langle H_{-0.5}^{c}\right\rangle \quad \sigma
$$

| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ |
| :--- | ---: | ---: | ---: | ---: |
| Pisces | 33.59 | 20 | -21.567 | 1.558 |
| A400 | 34.55 | 7 | -22.467 | 0.756 |
| A539 | 34.89 | 9 | -22.358 | 0.715 |
| Cancer | 33.82 | 22 | -21.282 | 1.283 |
| A1367 | 34.35 | 20 | -21.996 | 0.964 |
| Coma | 34.51 | 13 | -22.235 | 0.966 |
| Z74-23 | 34.25 | 13 | -21.027 | 1.350 |
| Hercules | 35.25 | 11 | -22.293 | 0.720 |
| Pegasus | 32.97 | 22 | -20.243 | 1.206 |
| A2634/66 | 34.65 | 11 | -22.825 | 0.627 |
|  |  |  |  |  |
| Ant11a | 32.34 | 10 | -21.940 | 1.103 |
| Hydra | 33.18 | 10 | -21.769 | 1.220 |
| N3557 | 32.67 | 5 | -21.588 | 0.670 |
| Cen30 | 32.44 | 10 | -20.834 | 1.302 |
| Cen45 | 33.33 | 6 | -21.707 | 1.180 |
| E508 | 32.24 | 7 | -20.856 | 1.046 |
| Pavo | 32.48 | 8 | -20.393 | 1.902 |



Figure 3.7. Mean Infrared Magnitude Plotted Against Distance Modulus. Zeroes represent northern clusters, and ones southern clusters.
discussed by Aaronson et al. (1982b), is plotted on the northern cluster data in Figure 3.8, and on the southern cluster data in Figure 3.9.

We need to adopt a fiducial Tully-Fisher relation for our secondparameter searches, and have essentially two reasonable choices: the single-slope fit discussed above, or the Aaronson et al. (1986) parabolic relation. While the unpleasant distance-dependence of the fit parameters for the individual linear relations has been greatly reduced in the single-slope relation, the zeropoints from our best fixed-slope fit still exhibit a slight trend with distance (see Figure 3.4d). The average zeropoints decrease about 0.15 mag, going from near to distant clusters. As the typical error in any cluster zeropoint is about 0.15 mag as well, this trend is only a $1 \sigma$ effect. While any such trend has been eliminated by construction in the Aaronson et al. (1986) parabolic fit, that fit is worse in terms of rms scatter than the fixed-slope fit in almost every cluster. In Table 3.5 we have summarized the rms scatter about the fit for each of the three types of relations discussed so far. Colums 1 and 2 have the cluster name and number of objects in the sample, respectively. In Column 3, we list the scatter about the independent linear leastsquares fit. This scatter is the smallest one can derive for these data. In Column 4, we give the dispersion about the fixed-slope fits, and in Column 5 we list the rms scatter about the Aaronson et al. parabolic fit. The sumary section of the table gives the rms scatter for all 204 galaxies in the combined sample, normalized by the number of degrees of


Figure 3.8. Parabolic Infrared Tully-Fisher Relation for the Aaronson et al. (1986) Northern Clusters. Clusters are Pisces, A400, A539, and Cancer.


Figure 3.8. Continued. Clusters are A1367, Coma, 274-23, and Hercules.


Figure 3.8. Continued. Clusters are Pegasus and A2634/66.


Figure 3.8. Parabolic Infrared Tully-Fisher Relation for the Aaronson et al. (1989) Southern Clusters. Clusters are Antlia, Hydra, N3557, and Cen30.


Figure 3.9. Continued. Clusters are Cen45, E508, and Pavo.

Table 3.5. Scatter About the Infrared Tully-Fisher Relation

| Cluster <br> (1) | N (2) | $\sigma_{1}$ (3) | $\sigma_{f:}$ <br> (4) | $\sigma_{\mathbf{p}}$ <br> (5) |
| :---: | :---: | :---: | :---: | :---: |
| Pisces | 20 | 0.36 | 0.39 | 0.41 |
| A400 | 7 | 0.33 | 0.38 | 0.44 |
| A539 | 9 | 0.38 | 0.39 | 0.40 |
| Cancer | 22 | 0.65 | 0.65 | 0.74 |
| A1367 | 20 | 0.49 | 0.49 | 0.52 |
| Coma | 13 | 0.34 | 0.34 | 0.37 |
| 274-23 | 13 | 0.52 | 0.62 | 0.61 |
| Hercules | 11 | 0.40 | 0.50 | 0.48 |
| Pegasus | 22 | 0.55 | 0.56 | 0.68 |
| A2634/66 | 11 | 0.32 | 0.41 | 0.38 |
| Antlia | 10 | 0.36 | 0.36 | 0.36 |
| Hydra | 10 | 0.38 | 0.46 | 0.58 |
| N3557 | 5 | 0.41 | 0.43 | 0.54 |
| Cen30 | 10 | 0.57 | 0.57 | 0.70 |
| Cen45 | 6 | 0.71 | 0.75 | 0.87 |
| E508 | 7 | 0.37 | 0.41 | 0.72 |
| Pavo | 8 | 0.34 | 0.64 | 0.47 |
| Rms |  | 0.474 | 0.488 | 0.494 |
| $\mathrm{N}_{\text {free }}$ |  | 170 | 186 | 201 |

freedom in each fit. In almost every case, the parabolic fit is worse than the corresponding fixed-slope fit, and the rms scatter for all 204 objects taken together is largest for the parabolic fit. Thus we shall adopt the fixed-slope fit as our fiducial relation in the second-parameter analysis that follows. As we shall see, however, this choice is not very critical.

## CLUSTER BY CLOSTER ARALYSIS

Now that we have identified the observational scatter about the infrared Tully-Fisher relation in the seventeen clusters in the Aaronson et al. (1986, 1989) samples, we must examine the causes of that scatter. For the present purpose, we will discuss the scatter in terms of two components: a) the "intrinsic" scatter, having to do with the dispersion in the properties of individual galaxies and how well we can measure those properties, and b) the "extrinsic" scatter, resulting from the properties of the samples of galaxies from which we compute the scatter about the Tully-Fisher relation. Bothun and Mould (1987) give an extensive discussion of many of the obervational errors that account for the noncosmic part of the "intrinsic" scatter. These include photometric errors, errors in the line-widths, diameters, and inclinations. While we have explicitly chosen to examine the luminosity/line-width relation in clusters of galaxies, where all of the objects are supposed to be at the
same distance, in order to minimize the "extrinsic" component of the scatter, this single-distance assumption may not be valid. The extent to which our clusters can be approximated as ideal, bound groups exhibiting a small dispersion in spatial extent determines how small we can make the "extrinsic" scatter. Since this component of the scatter is fixed once we have determined the sample and we cannot make it any amaller by introducing additional information (as we hope to do with the "intrinsic" component), it is important to understand the size of the effect.

We are hampered in investigating the properties of our clusters by an imperfect knowledge of where each object is in space. We know where each object appears on the sky; we have a redshift made up of a distancedependent component and a random component, and an approximate distance, based on the very relationship we are trying to explore. An ideal cluster would exhibit a small dispersion in apparent extent on the sky, a narrow and random distribution in depth as measured by redshift or Tully-Fisher distance, and a fairly narrowly-peaked distribution in velocity with distance or position on the sky. We look for these characteristics in the Aaronson et al. northern and southern clusters in Figures 3.10 and 3.11, respectively.

For the objects in each cluster, we examine the relationships between the following parameters: distance modulus as derived from the Aaronson et al. (1986) calibration of the infrared Tully-Fisher relation,
projected distance in Mpc from the cluster center in Right Ascension (X) and Declination (Y), redshift, and peculiar velocity. Cluster centers are taken from Table 1 of Aaronson et al. (1986) for the northern clusters and Table 8 of Aaronson et al. (1989) for the southern clusters. Angular separations were converted to projected distances using the mean cluster distance moduli derived in the above references. Galaxy coordinates were taken from Table 7 of Bothun et al. (1985a), where available, or from the UGC or the ESO catalog. For the southern clusters it was more convenient to compute coordinates corresponding to Galactic Longitude ( $X^{\prime}$ ) and Galactic Latitude ( $Y^{\prime}$ ) instead of Right Ascension and Declination. Redshifts are referred to the centroid of the Local Group, and peculiar velocities are in the microwave background frame by assuming a motion of the Local Group of $600 \mathrm{~km} \mathrm{~s}{ }^{-1}$ in the direction $1=268^{\circ}, b=27^{\circ}$.

Thus we have eight plots for each cluster: distance modulus against $X$ (or $X^{\prime}$ ), distance modulus against $Y$ (or $Y^{\prime}$ ), redshift against each spatial coordinate, peculiar velocity against the two spatial coordinates, distance modulus against redshift, and peculiar velocity against redshift. A search for correlations among these distance and position parameters is summarized in Tables 3.6 and 3.7 , where we have tabulated the slopes of the linear least-squares fits plotted on each graph. The slopes are expressed in units of their standard deviations, 80 that their significance may be more easily judged. For reference, maps of each of the northern clasters are presented in Figure 3.12 as $Y$ versus $X$, with


Figure 3.10. Distance and Position Correlations for Pisces: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension ( $X$ ) and Declination (Y) directions.


Figure 3.10. Pisces Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination (Y) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for A400: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension (X) and Declination (Y) directions.


Figure 3.10. A400 Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination ( $Y$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for A539: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension ( X ) and Declination ( Y ) directions.


Figure 3.10. A539 Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination (Y) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for Cancer: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension (X) and Declination (Y) directions.


Figure 3.10. Cancer Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination ( $Y$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for A1367: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension (X) and Declination (Y) directions.


Figure 3.10. A1367 Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination (Y) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for Coma: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension (X) and Declination (Y) directions.


Figure 3.10. Coma Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination (Y) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for Z74-23: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension (X) and Declination (Y) directions.


Figure 3.10. Z74-23 Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination (Y) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for Hercules: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension ( $X$ ) and Declination ( $Y$ ) directions.


Figure 3.10. Hercules Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination (Y) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for Pegasus: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension ( $X$ ) and Declination ( $Y$ ) directions.


Figure 3.10. Pegasus Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination ( Y ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.10. Distance and Position Correlations for A2634/66: distance modulus and redshift against projected distance in Mpc from cluster center in Right Ascension ( $X$ ) and Declination ( $Y$ ) directions.


Figure 3.10. A2634/66 Continued. Peculiar velocity against projected central distance in Right Ascension (X) and Declination (Y) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. Distance and Position Correlations for Antlia: distance modulus and redshift against projected distance in Mpc from cluster center in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions.


Figure 3.11. Antlia Continued. Peculiar velocity against projected central distance in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. Distance and Position Correlations for Hydra: distance modulus and redshift against projected distance in Mpc from cluster center in Galactic Longitude ( $\mathrm{X}^{\prime}$ ) and Latitude ( $\mathrm{Y}^{\prime}$ ) directions.


Figure 3.11. Hydra Continued. Peculiar velocity against projected central distance in Galactic Longitude ( $\mathrm{X}^{\prime}$ ) and Latitude ( $\mathrm{Y}^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. N3557 Continued. Peculiar velocity against projected central distance in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. N3557 Continued. Peculiar velocity against projected central distance in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. Distance and Position Correlations for Cen30: distance modulus and redshift against projected distance in Mpc from cluster center in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions.


Figure 3.11. Cen30 Continued. Peculiar velocity against projected central distance in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. Distance and Position Correlations for Cen45: distance modulus and redshift against projected distance in Mpc from cluster center in Galactic Longitude ( $\mathrm{X}^{\prime}$ ) and Latitude ( $\mathrm{Y}^{\prime}$ ) directions.


Figure 3.11. Cen45 Continued. Peculiar velocity against projected central distance in Galactic Longitude $\left(X^{\prime}\right)$ and Latitude ( $Y^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. Distance and Position Correlations for E508: distance modulus and redshift against projected distance in Mpc from cluster center in Galactic Longitude ( $\mathrm{X}^{\prime}$ ) and Latitude ( $\mathrm{Y}^{\prime}$ ) directions.


Figure 3.11. E508 Continued. Peculiar velocity against projected central distance in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.


Figure 3.11. Distance and Position Correlations for Pavo: distance modulus and redshift against projected distance in Mpc from cluster center in Galactic Longitude ( $X^{\prime}$ ) and Latitude ( $Y^{\prime}$ ) directions.


Figure 3.11. Pavo Continued. Peculiar velocity against projected central distance in Galactic Longitude ( $\mathrm{X}^{\prime}$ ) and Latitude ( $\mathrm{Y}^{\prime}$ ) directions. Distance modulus and peculiar velocity against redshift.

Table 3.6. Northern Distance and Position Correlations

| Cluster | $\mathrm{m}-\mathrm{M}$ | m-M | $\mathrm{V}_{0}$ | $\mathrm{v}_{0}$ | $V_{\text {pec }}$ | $V_{\text {pec }}$ | m-M | $V_{\text {pec }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | X | $Y$ | X | Y | X | Y | $\mathrm{V}_{0}$ | $\mathrm{V}_{0}$ |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Pisces | 3.2 | 1.7 | 0.1 | 1.3 | 2.7 | 2.3 | 0.5 | 2.4 |
| A400 | 1.7 | 1.5 | 1.1 | 1.2 | 2.1 | 1.1 | 0.2 | 0.4 |
| A539 | 0.7 | 0.7 | 0.1 | 0.9 | 0.7 | 0.8 | 2.7 | 3.6 |
| Cancer | 2.3 | 0.7 | 2.5 | 1.7 | 1.2 | 0.4 | 6.0 | 1.1 |
| A1367 | 1.3 | 0.3 | 0.4 | 0.3 | 1.4 | 0.0 | 0.5 | 2.2 |
| Coma | 0.1 | 1.3 | 4.4 | 1.2 | 1.0 | 2.0 | 0.5 | 0.7 |
| 774-23 | 0.7 | 0.1 | 1.6 | 0.4 | 0.2 | 0.2 | 4.0 | 0.1 |
| Hercules | 2.5 | 0.3 | 1.2 | 0.7 | 1.9 | 0.1 | 3.0 | 0.8 |
| Pegasus | 0.3 | 1.3 | 1.1 | 0.5 | 0.3 | 1.5 | 3.0 | 0.1 |
| A2634/66 | 1.0 | 1.0 | 1.5 | 0.4 | 0.3 | 1.0 | 3.0 | 0.0 |

Table 3.7. Southern Distance and Position Correlations

| Cluster | $\mathrm{m}-\mathrm{M}$ | $\mathrm{m}-\mathrm{M}$ | $\mathrm{V}_{0}$ | $\mathrm{V}_{0}$ | $V_{\text {pec }}$ | $V_{\text {pec }}$ | $\mathrm{m}-\mathrm{M}$ | $V_{\text {pec }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $X^{\prime}$ | $Y^{\prime}$ | $X^{\prime}$ | $Y^{\prime}$ | X' | $Y^{\prime}$ | $\mathbf{V}_{0}$ | $\mathrm{V}_{0}$ |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Antlia | 4.0 | 0.5 | 1.2 | 0.7 | 2.5 | 0.9 | 1.4 | 0.1 |
| Hydra | 0.9 | 3.0 | 0.3 | 1.2 | 1.0 | 2.0 | 0.8 | 0.4 |
| N3557 | 0.2 | 0.5 | 0.6 | 0.7 | 0.4 | 0.6 | 0.6 | 1.1 |
| Cen30 | 1.3 | 0.3 | 0.3 | 0.8 | 1.8 | 0.4 | 0.8 | 1.3 |
| Cen45 | 0.2 | 0.8 | 1.2 | 0.2 | 0.0 | 0.7 | 2.0 | 1.3 |
| E508 | 1.8 | 0.3 | 0.1 | 0.2 | 1.6 | 0.2 | 0.1 | 0.6 |
| Pavo | 0.5 | 2.1 | 0.1 | 1.0 | 0.9 | 2.2 | 3.0 | 0.8 |

similar plots of $Y^{\prime}$ versus $X^{\prime}$ given for the southern clusters in Figure 3.13.

The most striking feature of the data given in Figures 3.10 and 3.11 and Tables 3.6 and 3.7 is that half of the clusters show a significant (greater than $2 \sigma$ ) slope in the plot of distance modulus against redshift. Many of the clusters break up into two or more well-defined clumps in this space, leading one to question whether these clusters are, in fact, single dynamical units. Bound clusters should exhibit no correlation between distance and redshift, and the assumption that all of the objects are at the same distance would then be a good one. However, since at least half of the clusters exhibit some substructure, it is clear that cluster depth will have a considerable effect on the observed scatter about any distance indicator we may choose. Let us examine this substructure in more detail, on a cluster by cluster basis.

## Pisces

The "cluster" we call "Pisces" is not really a cluster at all, but rather a portion of the long, quasi-linear chain of galaxies and clusters of galaxies that makes up the Pisces-Perseus Supercluster. The map of the Aaronson et al. (1986) objects in Pisces shown in Figure 3.12 shows this linear structure. The distance modulus plots in Figure 3.10 indicate that the southwest portion of this chain is more distant, on average, than the


Figure 3.12. Projected distance in Mpc from cluster center in Declination (Y) direction against projected distance in Right Ascension (X) direction for Aaronson et al. (1986) Northern Clusters. Clusters are Pisces, A400, A539, and Cancer.


Figure 3.12. Continued. Clusters are A1367, Coma, 274-23, and Hercules.


Figure 3.12. Continued. Clusters are Pegasus and A2634/66.


Figure 3.13. Projected distance in Mpc from cluster center in Galactic Latitude ( $Y^{\prime}$ ) direction against projected distance in Galactic Longitude ( $\mathrm{X}^{\prime}$ ) direction for Aaronson et al. (1989) Southern Clusters. Clusters are Antlia, Hydra, N3557, and Cen30.


Figure 3.13. Continued. Clusters are Cen45, E508, and Pavo.
northeast end of the segment. The gradient is about 0.7 mag across $10^{\circ}$ on the sky. On the other hand, there is a clump of objects to the north with a mean redshift about 750 km s , three times the clump internal velocity dispersion, higher than the group to the south, leading to a fairly strong gradient in the computed peculiar velocity with position. Despite these two correlations, distance modulus and redshift are uncorrelated and the two subgroups are at nearly same Tully-pisher distance, indicating that these objects are apparently part of a bound group with not very much dispersion in depth. This fact may be why it was possible for Bothun and Mould (1987) to find such a low dispersion (0.2 mag) in their I-band Tully-Fisher relation for Pisces.

A 400

A400 is not very well sampled, partly due to a lack of HI detections of objects in the region. However, the objects that are detected clump together fairly well in all plots, with the exception of two outliers: UGC 2285 to the west and UGC 2414 to the south, which appear to be in the foreground and background, respectively, from their Tully-Fisher distances, Both exhibit redshifts that are about $700 \mathrm{~km} \mathrm{~s}^{-1}$, or about the same as A400's velocity dispersion, higher than the remainder of the objects. A400 has essentially no dependence of distance modulus on redshift, as appropriate for a bound cluster.

A539

A539 is pathological in that while it exhibits a fairly strong correlation of distance modulus with redshift, the correlation is in the opposite sense of what one would expect for an unbound cluster that was simply taking part in the general Hubble expansion. Perhaps we are seeing a signature of infall onto the cluster (see Ostriker et al. 1988). The distance/redshift diagram seems to break up into two very tight clumps with one outlier at low redshift. These clumps do not separate out particularly well in apparent position on the sky, however.

## Cancer

The Cancer cluster has been studied in detail by Bothun et al. (1983), who show that the system consists of at least five subgroups that are not bound to one another. This structure is readily apparent in the distance modulus/redshift plot, where the objects are spread out over almost three magnitudes in depth, well-correlated with redshift. The clumping can be seen in the map, and shows up in the other plots, as well. It is thus no surprise that Cancer exhibits the largest Tully-Fisher scatter for a well-sampled cluster. Most of the scatter must come just from dispersion in depth along the line of sight.

The spirals in the A1367 sample are spread out over a fairly large region of space, 10 by 10 Mpc in projection and 2 mag deep, but do not show any strong trends in Figure 3.10. The distance modulus/redshift diagram shows a main clump plus a few objects at higher redshift, perhaps members of the Coma Supercluster in which A1367 is embedded. The trend of peculiar velocity with redshift is fairly strong, but it is possible to get this effect when distance and redshift are uncorrelated, as is the case here.

Coma

Coma is another cluster that shows every indication of being a bound group, with possibly a couple of interlopers from the supercluster in which it is embedded. There are two or three clumps in redshift, but distance modulus and redshift are uncorrelated, and the observed dispersion in distance is fairly small.

274-23

Although fairly narrowly distributed on the sky, 274-23 has three subgroups in redshift, two at similar Tully-Fisher distances, but with the
remaining one almost a magnitude more distant. Again the dispersion in depth leads to a large scatter about the observed Tully-Fisher relation.

## Hercules

With the exception of one outlier, UGC 10085, Hercules also shows a fairly narrow width in projection. However, it has a large breadth along the line of sight, and distance modulus correlates well with redshift. At least some of the objects are not bound to the main group, and the Tully-Pisher scatter is fairly large.

## Pegasus

Pegasus shows little correlation of distance modulus, redshift, or peculiar velocity with position across the sky, but does show a strong trend of distance modulus with redshift. Most of the effect comes from two clumps in redshift, separated by $1100 \mathrm{~km} \mathrm{~s}^{-1}$, more than three times the internal velocity dispersion in either group. The higher redshift group is also the more distant one, by 0.68 mag in the mean. It is likely that these two groups represent separate dynamical units, and that lumping them together will again lead to large Tully-Fisher scatter.

This cluster, situated several thousand $\mathrm{km} \mathrm{s}^{-1}$ behind the PiscesPerseus Supercluster, exhibits a structure in redshift similar to that of Pegasus. The distance modulus/redshift plot breaks cleanly into two groups, one at about $8000 \mathrm{~km} \mathrm{~s}^{-1}$ and one at about $9300 \mathrm{~km} \mathrm{~s}^{-1}$. Both groups have similar internal velocity dispersions, at 226 and $264 \mathrm{~km} \mathrm{~s}^{-1}$, respectively. They are separated by 0.41 mag in depth, or about 17 Mpc in Tully-Fisher distance. Again these groups appear to be distinct entities and the depth contribution to the observed Tully-Fisher scatter in A2634/66 ought to be fairly large.

## Antlia

The Antlia cluster lies in the middle of a larger, roughly linear structure called the Antlia-Hydra cloud by Tully and Fisher (1987, plate 17) that runs at a slight angle to a great circle with Galactic Latitude $20^{\circ}$. Apparently this structure is tube-like, with one end in the Aaronson et al. (1989) data about 0.8 mag farther away than the other, as can be seen from the strong correlation of distance modulus with Galactic Longitude in Figure 3.11. Redshift is pretty constant along this chain, 80 the peculiar velocities reflect the correlation of distance modulus with position. The distance modulus/redshift diagram shows a principle clump with a few outliers about 0.4 mag more distant. Note the non-zero

# mean peculiar velocity exhibited by the Antlia spirals. This is one of the significant results of Aaronson et al. (1989). 

## Hydra

Hydra has a fairly strong correlation of distance modulus with Galactic Latitude, possibly indicating a similar kind of structure as observed for Antlia (see Lucey, Currie, and Dickens 1986b, plate 1). This correlation is reflected in the peculiar velocity/latitude plot, as well. Otherwise there are no significant correlations in Figure 3.11, and only one object, E501-82, has a redshift significantly different from the others. Hydra just has a large scatter in depth, and hence a large scatter about the Tully-Fisher relation.

## N3557

This sample has already been pruned by Aaronson et al. (1989) to separate out unwanted subgroups, as the original sample exhibited a strong correlation of distance and redshift. Even so, the Tully-Fisher scatter is still pretty large.

## Centaurus

The Centaurus region has a complicated structure in redshift that
does not correspond all that well to subgroups on the sky (see Lucey, Currie, and Dickens 1986b). There are two main groups in the redshift histogram (Lucey, Currie, and Dickens 1986a) and Aaronson et al. (1989) attempted to assign their objects to either the foreground group ("Cen 30 ") or the background group ("Cen45"). It is not clear that they were entirely successful, as two of the Cen45 objects, E322-48 and E323-25 really look like they might be associated with Cen30, instead. Cen30 has a couple of low redshift outliers, as well, and both Cen30 and Cen45 exhibit considerable Tully-Fisher scatter. Depth is clearly important in the observed scatter.

E508

The E508 cluster is not particularly well-sampled, but does not exhibit any significant correlations in Figure 3.11.

## Pavo

Pavo exhibits a significant trend of distance modulus with redshift, arlsing from a background pair, IC 4934 and IC 4962, and one extreme redshift and distance outlier, IC 4992. Only the elimination of IC 4962 from the sample, homever, would decrease the computed scatter about our fixed-slope Tully-Fisher relation, as the other two objects fall right along the fiducial relation. Pavo has a very tight Tully-Fisher relation
when it is fit independently of the other clusters, but as remarked above, the derived slope for the independent fit is the most discrepant one of the seventeen clusters we have examined. Aaronson et al. (1989) point out that the mean redshift survey cluster velocity and the sample mean velocity disagree at the $2.5 \sigma$ level, suggesting that the objects we have examined may poorly sample a more complicated structure.

## THE DISPBRSION IN DBPTH

We can try to make a numerical estimate of the dispersion in depth for each of our clusters from the available redshift and distance information. Consider the dispersion in the observed radial velocities for objects in a cluster of galaxies. The dispersion comes from three sources: 1) the mean square measurement error of the velocities, 2) the dispersion in the galaxy peculiar velocities, and 3) any dispersion in distance. Formally,

$$
\begin{equation*}
V_{\text {pec }}=V-H_{o} r, \tag{3.1}
\end{equation*}
$$

where $V_{\text {pec }}$ is the peculiar velocity, $V$ is the redshift, $H_{0}$ is the Hubble constant, taken to be $92 \mathrm{~km} \mathrm{~s}^{-1} \mathrm{Mpc}^{-1}$ here, and r is the object distance in Mpc. Then,

$$
\begin{equation*}
V=V_{\text {pec }}+H_{o} r \tag{3.2}
\end{equation*}
$$

and the observed dispersion in redshift is

$$
\begin{equation*}
\sigma_{V, o b s}^{2}=\sigma_{V, e r r}^{2}+\sigma_{V}^{2}{ }_{p e c}^{2}, t+H_{o}^{2} \sigma_{d}^{2}+2 H_{o} \sigma_{d, V_{p e c}^{2}}^{2} \tag{3.3}
\end{equation*}
$$

Here, the first term represents the measurement error in the velocities, the second the true dispersion in the peculiar velocities, the third the true dispersion in depth, and the fourth term comes from any correlation between the true peculiar velocity and true distance. If we now compute the dispersion in distance, $r$, estimated from the Tully-Fisher relation, we obtain

$$
\begin{equation*}
\sigma_{r}^{2}=\sigma_{d}^{2}+\sigma_{r, e r r}^{2} \tag{3.4}
\end{equation*}
$$

where the first term is again the true dispersion in depth and the second is the dispersion due to measurement errors. Next, we compute the dispersion in $V-H_{0} r$, to obtain the observed dispersion in the peculiar velocities. This quantity will contain contributions from measurement errors in redshift and distance, and from any correlation between observed redshift and distance error, so

$$
\begin{equation*}
\sigma_{V}^{2}{ }_{\text {pec }}=\sigma_{V, p e c}^{2} t^{+} \sigma_{V, e r r}^{2}+H_{0}^{2} \sigma_{r, e r r}^{2}-2 H_{o} \sigma_{V, o b s i r}^{2}, e r r \tag{3.5}
\end{equation*}
$$

This last term is expected to be small and we will neglect it in the following discussion. Now, if we take the difference between the sum of the observed dispersions in redshift and distance and the observed dispersion in peculiar velocity, we can isolate the term for the true dispersion in depth. Thus, after a little algebra, we see that

$$
\begin{equation*}
\sigma_{V, o b s}^{2}+H_{o}^{2} \sigma_{\mathrm{r}}^{2}-\sigma_{\mathrm{V}}^{2}{ }_{\mathrm{pec}}^{2}=2 \mathrm{H}_{\mathrm{o}}^{2} \sigma_{\mathrm{d}}^{2}+2 \mathrm{H}_{0} \sigma_{\mathrm{d}, \mathrm{~V}_{\mathrm{pec}}}^{2} \tag{3.6}
\end{equation*}
$$

or

$$
\begin{equation*}
H_{o}^{2} \sigma_{\mathrm{d}}^{2}=\frac{1}{2}\left(\sigma_{V, o b s}^{2}+H_{o}^{2} \sigma_{r}^{2}-\sigma_{V}^{2} \underset{p e c}{2}-H_{0} \sigma_{d, V_{p e c}^{2}}^{2}\right. \tag{3.7}
\end{equation*}
$$

Here, $H_{o}^{2} \sigma_{d}^{2}$ is the true dispersion in depth, expressed in ka $s^{-1}$. Given the mean distance of the cluster, we can convert this quantity into a dispersion in magnitudes about the Tully-Fisher relation.

Unfortunately, the above expression cannot be applied directly to our observational data. The problem arises with the last term, the covariance between the true distance and the true peculiar velocity. We cannot compute this quantity from the observed numbers because errors in distance will produce a large and spurious correlation. We would need to know the very quantity we are trying to derive in order to sort this out. We are therefore forced to appeal to a model to proceed further.

Consider again our expression (3.7) for the true dispersion in depth. The first term on the right hand side is equivalent to the covariance between the observed redshift and the observed distance. That is,

$$
\begin{equation*}
\frac{1}{2}\left(\sigma_{V, o b s}^{2}+H_{o}^{2} \sigma_{r}^{2}-\sigma_{V}^{2}\right)=H_{0} \sigma_{V}^{2}, r^{\prime} \tag{3.8}
\end{equation*}
$$

and thus

$$
\begin{equation*}
H_{0}^{2} \sigma_{d}^{2}=H_{0} \sigma_{V, r}^{2}-H_{o} \sigma_{d, V_{p e c}}^{2} \tag{3.9}
\end{equation*}
$$

Now consider two limiting models. First assume that all of the galaxy clusters are fully collapsed and virialized. Then velocity is independent of position and the redshifts carry no distance information. There would be no correlation between observed redshift and distance and
the first term on the right hand side of equation (3.9) vanishes. In this case, the observational data cannot help us separate depth-induced dispersion from error-induced dispersion.

In the other limiting model, we assume that the clusters are unbound and simply expanding with the Hubble flow in the mean. Then the true peculiar velocities are zero, and the second correlation term in equation (3.9) vanishes. Under these circumstances, we can use the observational data to make a direct measurement of the dispersion due to depth. Since our real clusters are probably somewhere in between the fully virialized and completely unbound states, we can only set a lower limit on the dispersion due to depth equal to the square root of the correlation between observed redshift and observed distance in the appropriate units.

The results of such a computation are presented in Tables 3.8 and 3.9. In Table 3.8 we compute the lower limit to the dispersion in depth for each cluster, and in Table 3.9 we compute the average limit for the northern and southern clusters. In columns (1) and (2) of Table 3.8 we list the cluster name and number of objects with the necessary data. Colums (3) and (4) give the mean and standard deviation of the observed redshift, corrected for notion with respect to the center of the Local Group. Columns (5) and (6) contain the mean and standard deviation of the distance moduli derived fron the Aaronson et al. (1986) calibration of the infrared Tully-Fisher relation. The corresponding mean and dispersion of

Table 3.8. Tully-Pisher Scatter from Depth Effects

| Cluster |  | $\begin{aligned} & \left\langle V_{0}\right\rangle \\ & (\mathrm{km} \end{aligned}$ | $\begin{gathered} \sigma_{V_{0}} \\ -1)^{0} \end{gathered}$ | $\langle m-M\rangle$ <br> ( | $m-M$ |  | $\begin{gathered} \left\langle V_{\text {pec }}\right\rangle \\ (\mathrm{km} \end{gathered}$ | $\begin{aligned} & \sigma_{V_{p}} \\ & \left.s^{-1}\right)^{2} \end{aligned}$ | $\begin{gathered} \sigma_{d} \\ \left(\mathrm{~km} \mathrm{~s}^{-1}\right) \end{gathered}$ | $\sigma_{d}$ <br> (mag) | $\begin{gathered} \sigma_{\text {obs }} \\ \text { (mag) } \end{gathered}$ |  | $\begin{gathered} \sigma_{\mathrm{t}} \\ (\text { mag }) \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| Pisces | 20 | 5274.5 | 433.4 | 33.59 | 0.39 | 52.98 .4 | -96.6 | 997.8 |  |  | 0.389 |  |  |
| A400 | 7 | 7855.4 | 356.3 | 34.54 | 0.36 | 82.114 .0 | 60.7 | 1294.1 | 234.0 | 0.067 | 0.381 | 3.1 | 0.375 |
| A539 | 9 | 8536.4 | 305.7 | 34.88 | 0.34 | 96.015 .3 | -218.3 | 1641.8 |  |  | 0.389 |  |  |
| Cancer | 22 | 4788.9 | 872.8 | 33.82 | 0.70 | 61.220 .8 | -512.0 | 1513.1 | 1036.3 | 0.400 | 0.654 | 37.4 | 0.517 |
| A1367 | 20 | 6486.0 | 634.3 | 34.35 | 0.49 | 76.017 .3 | -118.4 | 1785.7 |  |  | 0.493 |  |  |
| Coma | 13 | 7310.0 | 474.2 | 34.51 | 0.34 | 80.712 .8 | 138.5 | 1177.2 | 328.8 | 0.096 | 0.342 | 7.9 | 0.328 |
| 274-23 | 13 | 5938.5 | 972.4 | 34.25 | 0.55 | 72.818 .2 | -484.4 | 1316.2 | 1002.1 | 0.325 | 0.618 | 27.7 | 0.526 |
| Hercules | 11 | 10732.7 | 807.9 | 35.25 | 0.43 | 114.121 .7 | 219.6 | 1632.2 | 992.2 | 0.205 | 0.499 | 16.9 | 0.455 |
| Pegasus | 22 | 4274.6 | 618.6 | 32.97 | 0.64 | 40.912 .0 | -46.2 | 927.0 | 612.5 | 0.354 | 0.560 | 40.0 | 0.434 |
| A2634/66 | 11 | 8693.5 | 714.2 | 34.65 | 0.34 | 86.213 .7 | 183.4 | 1050.4 | 708.1 | 0.194 | 0.405 | 22.9 | 0.356 |
| Antlia | 10 | 2662.2 | 214.4 | 32.34 | 0.32 | 29.64 .3 | 531.7 | 347.7 | 205.3 | 0.164 | 0.361 | 20.6 | 0.322 |
| Hydra | 10 | 3444.4 | 110.7 | 33.18 | 0.51 | 44.29 .7 | -22.7 | 860.8 | 338.1 | 0.181 | 0.462 | 15.3 | 0.425 |
| N3557 | 5 | 2753.0 | 143.8 | 32.67 | 0.38 | 34.65 .9 | 155.8 | 605.2 | ... |  | 0.431 | ... |  |
| Cen 30 | 10 | 3157.7 | 571.3 | 32.44 | 0.62 | 31.88 .8 | 741.4 | 853.0 | 352.2 | 0.261 | 0.567 | 21.2 | 0.503 |
| Cen45 | 6 | 4478.5 | 343.3 | 33.40 | 0.67 | 50.017 .4 | 390.8 | 1389.9 | 615.3 | 0.290 | 0.746 | 15.1 | 0.687 |
| E508 | 7 | 2692.7 | 179.8 | 32.22 | 0.59 | 28.77 .3 | 536.6 | 695.9 | ... | ... | 0.413 | ... |  |
| Pavo | 8 | 3229.8 | 355.4 | 32.50 | 0.40 | 32.16 .0 | 371.3 | 326.4 | 401.0 | 0.295 | 0.635 | 21.6 | 0.562 |

Table 3.9. Average Tully-Fisher Scatter from Depth Effects
Sample $N$


 $\begin{array}{llllllllllll}\text { South } & 56 & 3178.0 & 347.0 & 32.66 & 0.48 & 35.5 & 8.5 & 399.2 & 710.4 & 314.1 & 0.209\end{array}$
the distances are listed in columns (7) and (8). In columns (9) and (10) we list the mean peculiar velocity, in a frame at rest with respect to the Cosmic Microwave Background, and the corresponding standard deviation. Column (11) contains the estimated lower limit to the dispersion in depth for each cluster, in units of $\mathrm{km} \mathrm{s}^{-1}$, calculated as described above. We express that dispersion in magnitudes in column (12), and include for reference the observed scatter about the Tully-Fisher relation in column (13). The lower limit to the dispersion in depth is given as a percentage of the observed variance (1.e. square of the dispersion) in column (14). Finally, we tabulate in column (15) the difference in quadrature between the observed scatter and the lower limit to the dispersion in depth. For a few clusters, the depth computation yields a non-physical result and the affected columns were left blank.

Table 3.9 contains information similar to that in Table 3.8, with a few computational differences. The standard deviations in the redshift, distance modulus, and distance refer to the dispersion in the difference between the relevant quantity and the mean for the cluster. Thus we list the mean redshift for the sample (for reference), but give the dispersion in the difference between each object's redshift and the mean redshift of the corresponding cluster. The peculiar velocities can be directly compared, so the simple mean and standard deviation of the measurements are listed in columns (9) and (10). The lower limit on the dispersion in depth is computed as in Table 3.8.

The lower limits to the dispersion in depth listed in Tables 3.8 and 3.9 are, for the most part, not very big. If they had turned out to be large, we would have been tempted to suggest that it was likely that our clusters were closer to the second limiting model discussed above, i.e. expanding freely with the Hubble flow. Then our lower limits would have been near the true value. However, the numerical limits we can set on the importance of depth effects are not very stringent. A typical lower limit amounts to about twenty percent of the observed variance, and up to forty percent in extreme cases such as Cancer and Pegasus. If we subtract these lower limits from the observed dispersions, we obtain the upper limit to the "true" scatter listed in column (15) of Table 3.8, which amounts to 0.458 mag in the mean, with a standard deviation of 0.108 mag for 12 clusters. This upper limit to the observational scatter about the Tully-Fisher relation is quite a bit larger than other recent estimates of small Tully-Fisher scatter near 0.25 mag (e.g. Bothun and Mould 1987, Pierce and Tully 1988). Bothun and Mould (1987) discuss the various sources of observational error in the $H$-band Tully-Fisher relation and estimate their relative importance. These errors include photometric errors, line-width errors, diameter errors, and errors in inclination. The Bothun and Mould estimates of the size of these errors account for about 0.2 mag of the observed scatter in the relation. As our average observed scatter, partially corrected for depth effects, is 0.46 mag , the difference in quadrature between that and known sources of observational
error amounts to over 0.4 mag. Since we do not know how large the depth effects really are, there is still room in these data for a fairly large cosmic scatter in the $H$-band Tully-Fisher relation, although not nearly as large as some authors would suggest (e.g. Kraan-Korteweg, Cameron, and Tammann 1988).

CHAPTER A: REDUCING THE SCATTER
ABOUT THE INFRARED TULLY-PISHER RBLATION

## INTRODUCTION

Now that we have defined a fiducial infrared Tully-Fisher relation and explored some of its properties in Chapter 3, it is time to come to the central point of this dissertation. We wish to know whether we can reduce the scatter about the observed cluster Tully-Fisher relations by including additional information about the galaxies under study. That is, can we improve distance estimates through the inclusion of an extra parameter in the H-band magnitude/21 cm line-width relation? From our discussion of the cluster sample properties in the previous chapter, it is apparent that depth effects can make a significant contribution to the observed scatter. Additional information about the properties of individual objects cannot eliminate that portion of scatter, as long as we must assume that all of the cluster galaxies are at the same distance. However, the numerical limits we can set on the contribution from depth effects leave a fair amount of scatter potentially unexplained. And, as we mentioned in the introduction to Chapter 3 , extragalactic distances to individual objects are sufficiently uncertain that any significant improvement in the situation would be of considerable value.

In Table 4.1 we list the parameters that we have available for most of our objects in addition to the H-band photometry and 21 cm line-width measurements used to define an infrared Tully-Fisher relation. The data come from three sources. First there are parameters derived from the CCD surface photometry survey of cluster spirals discussed in Chapter 2. In addition to the blue measurements listed, similar information exists for many objects in the $R$ and $I$ bands. Next we include the morphological type, numerically coded from UGC or ESO catalog Hubble types according to the prescription given in the RC2. Finally, there are several quantities taken from the Bothun et al. (1985a) catalog of radio, optical, and infrared observations of spiral galaxies in clusters. They give a complete description of the derivation of each of their parameters, although some discussion of them was given here in Chapter 2.

## THE SBCOND PARAMETER SBARCH

Our strategy for searching for additional parameters in the infrared Tully-Fisher relation is simple. We plot the residuals about the fixedslope, floating zeropoint Tully-Fisher relation defined in Table 3.3 against each trial second parameter in turn, looking for a significant reduction in the scatter about the fit.

There are a couple of technical points that should be discussed before we present the results of this search. Whether an object appears in any given plot depends on the availability of the three parameters necessary to make that plot, i.e. H magnitude, 21 cm line-width, and the trial second parameter. The H-band photometry and the line-widths are taken from Aaronson et al. (1986) for their northern clusters and Aaronson et al. (1989) for their southern clusters. Because we derived the zeropoints of our fixed-slope fits from their data, we are restricted to considering their clusters below. Their clusters are listed here in Table 3.2 , for example, and do not exactly overlap in the southern hemisphere with the CCD survey clusters listed in Table 2.1. This means that $H$ magnitudes, line-widths, and Tully-Fisher zeropoints are not available for some of the CCD survey clusters. Even for those clusters that do appear in both samples, the overlap on an object-to-object basis is patchy. It therefore turns out that our second parameter search using surface photometric parameters is largely limited to northern objects. Southern objects are included where possible, but their contribution is relatively unimportant. The Bothun et al. (1985a) catalog is limited exclusively to the northern hemisphere and some clusters are better observed than others, due mostly to imperfect cooperation of the weather. Thus no southern data appears in those plots, and some northern clusters are under-represented for some parameters. Finally, morphological types were extracted from the catalogs for only those objects observed in the CCD survey discussed in Chapter 2.

Table 4.1. Additional Parameters

| Parameters based on data presented here: |  |
| :---: | :---: |
| $\log R$ | Axis Ratio defined in the $R$ - (or $\mathrm{B}-$ ) band |
| $\log \mathrm{D}_{\mathrm{B} 25}$ | Blue Isophotal Diameter |
| $\log C_{B}$ | Blue Concentration Parameter (like B/T) |
| $\left.{ }^{\langle S B}\right\rangle_{\mathrm{Bn}}$ | Blue Nuclear Surface Brightness |
| $\langle\mathrm{SB}\rangle_{\text {B }},-0.5$ | Blue SB in aperture with $\log (A / D)=-0.5$ |
| $\langle\mathrm{SB}\rangle_{\mathrm{B} 25}$ | Mean Blue Surface Brightness |
| $\mathrm{B}_{25}$ | Blue Isophotal Magnitude |
| Parameters | from catalog data: |
| T | Numerically coded Morphological Type |
| Parameters taken from Bothun et al. (1985a): |  |
| $\mathrm{B}_{\mathrm{T}}$ | Total Blue Magnitude |
| U-B | Total U-B color |
| B-V | Total B-V color |
| B-H | $B-H$ color in aperture with $\log (A / D)=-0.5$ |
| $\log \mathrm{M}_{\mathrm{HI}}$ | Mass of Hydrogen Gas |
| $\log \mathrm{M}_{\mathrm{HI}} / L_{\mathrm{B}}$ | Gas Content normalized by Blue Luminosity |
| $\log \mathrm{M}_{\mathrm{HI}} / \mathrm{L}_{\mathrm{H}}$ | Gas Content normalized by IR Luminosity |

In Pigure 4.1 we present the results of the second parameter search for the blue surface photometric properties listed in Table 4.1. For each trial second parameter, we plot the Tully-Fisher residual in the sense "observed" - "predicted", against the quantity under consideration. The point for each galaxy is labelled according to the cluster to which it has been assigned. The clusters are numbered 0 through 9 , and then $A$ through J, following the order in which they are listed in Table 2.1. We have not included the corresponding $R$-band plots as they are almost indentical to those at B. Similar plots for the Bothun et al. (1985a) parameters are presented in Figure 4.2.

In Tabie 4.2 we list the coefficients of a linear least squares fit of all of the objects taken together for each parameter. These fits are also plotted on Figures 4.1 and 4.2. The table includes the fits for parameters derived from R-band surface photometry. For each trial second parameter we list the number of points used in the fit, the slope, zeropoint, linear correlation coefficient, and scatter in magnitudes about that fit. These dispersions about the two-independent-parameter fits can be compared with the scatter of 0.488 mag about the fiducial fixed-siope Tully-Fisher relation.

From our discussion of cluster properties in Chapter 3, we should expect some clusters to be more suitable than others for assessing the


Figure 4.1.
Second Parameter Search for the Observables Derived from Surface Photometry at B. Trial parameters are logarithm of the axis ratio, Blue Isophotal Diameter, Blue Concentration Parameter, and Blue Nuclear Surface Brightness.


Figure 4.1. Continued. Parameters are Blue Surface Brightness within aperture with $\log (A / D)=-0.5$, Mean Blue Surface Brightness, Blue Isophotal Magnitude, and numerically coded Morphological Type.


Figure 4.2. Second Parameter Search for the Bothun et al. (1985a) Data. Trial parameters are Total Blue Magnitude, U-B color, $\mathrm{B}-\mathrm{V}$ color, and $\mathrm{B}-\mathrm{H}$ color.


Figure 4.2. Continued. Parameters are Mass of Hydrogen Gas, Gas Content Normalized by Blue Luminosity, and Gas Content Normalized by Infrared Luminosity.

Table 4.2. Second Parameter Correlations

potential gain from including a second parameter. A large dispersion in distance will tend to wash out any gain made by including a second parameter. We are therefore tempted to make second-parameter fits for each cluster independently. However, most of the cluster samples do not contain very many objects, and thus individual cluster fits would be rather uncertain and would not necessarily span the possible range in value that any given trial parameter can take. Therefore we have chosen to take all of the clusters together when making the above secondparameter plots (Figures 4.1 and 4.2) and least-squares fits (Table 4.2). But we will tabulate below the scatter in the observed additionalparameter Tully-Fisher relations on a cluster by cluster basis. Then we will be able to assess separately the effectiveness of each trial second parameter in each cluster.

We present the observed dispersions about the second-parameter fits from Table 4.2 in Tables 4.3 and 4.4. Table 4.3 pertains to the parameters derived from the B-band surface photometry and Table 4.4 lists the scatter about relations using the Bothun et al. (1985a) catalog data. For each parameter there are four columns. The first column lists the number of objects in each cluster which have a measurement of the trial parameter, as well as an H-band magnitude and a 21 cm line-width. The second column gives the scatter about the fixed-slope Tully-Fisher relation for that cluster using only those objects that can be included in the second-parameter fit. This number represents the "control" of the

Table 4.3. Scatter About the Extra-Parameter Tully-Fisher Relations for the Blue Surface Photometric Parameters

| Cluster | $\log R$ |  |  |  | $\log \mathrm{D}_{\mathrm{B} 25}$ |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | $\sigma_{\text {fs }}$ | $\sigma_{\text {sp }}$ | P | N | $\sigma_{\mathrm{fs}}$ | ${ }_{\mathbf{\sigma}} \mathbf{s p}$ |  |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Pisces | 13 | 0.356 | 0.357 |  | 10 | 0.381 | 0.345 | 0.168 |
| A400 | 5 | 0.206 | 0.227 |  | 3 | 0.232 | 0.511 |  |
| A539 | 5 | 0.359 | 0.313 | 0.269 | 3 | 0.376 | 0.258 | 0.165 |
| Cancer | 16 | 0.713 | 0.696 | 0.387 | 9 | 0.696 | 0.537 | 0.035 |
| A1367 | 13 | 0.435 | 0.443 | ... | 11 | 0.446 | 0.379 | 0.064 |
| Coma | 7 | 0.286 | 0.318 |  | 5 | 0.258 | 0.398 |  |
| 274-23 | 6 | 0.708 | 0.668 | 0.420 | 6 | 0.708 | 0.549 | 0.093 |
| Hercules | 7 | 0.459 | 0.428 | 0.337 | 6 | 0.492 | 0.528 | . . . |
| Pegasus | 14 | 0.473 | 0.456 | 0.320 | 13 | 0.484 | 0.497 |  |
| Cen30 | 3 | 0.604 | 0.601 | 0.879 | 3 | 0.604 | 0.591 | 0.735 |
| Pavo | 3 | 0.598 | 0.524 | 0.413 | 3 | 0.598 | 0.430 | 0.193 |
| Total | 98 | 0.508 | 0.499 | 0.063 | 78 | 0.512 | 0.463 | <0.001 |

Table 4.3. Continued

| Cluster | $\log C_{B}$ |  |  |  | $\langle S B\rangle^{\text {b }}$ |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | $\sigma_{\text {fs }}$ | $\sigma_{\text {sp }}$ | P | N | $\sigma_{\text {fs }}$ | ${ }_{\mathbf{\sigma}}^{\text {sp }}$ | P |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Pisces | 10 | 0.381 | 0.319 | 0.065 | 10 | 0.381 | 0.314 | 0.055 |
| A400 | 3 | 0.232 | 0.318 | ... | 3 | 0.232 | 0.282 |  |
| A539 | 3 | 0.376 | 0.351 | 0.555 | 3 | 0.376 | 0.222 | 0.099 |
| Cancer | 8 | 0.714 | 0.663 | 0.294 | 9 | 0.696 | 0.605 | 0.121 |
| A1367 | 11 | 0.446 | 0.395 | 0.110 | 11 | 0.446 | 0.475 |  |
| Coma | 5 | 0.258 | 0.247 | 0.536 | 5 | 0.258 | 0.308 |  |
| 274-23 | 6 | 0.708 | 0.619 | 0.223 | 6 | 0.708 | 0.606 | 0.189 |
| Hercules | 6 | 0.492 | 0.540 | . . . | 6 | 0.492 | 0.442 | 0.276 |
| Pegasus | 12 | 0.475 | 0.552 |  | 12 | 0.475 | 0.446 | 0.233 |
| Cen30 | 3 | 0.604 | 0.496 | 0.314 | 3 | 0.604 | 0.525 | 0.395 |
| Pavo | <3 | . . |  |  | 3 | 0.598 | 0.460 | 0.245 |
| Total | 75 | 0.512 | 0.493 | 0.019 | 77 | 0.511 | 0.463 | $<0.001$ |

Table 4.3. Continued

| Cluster | $\langle\mathrm{SB}\rangle_{\mathrm{B}}$ |  |  |  | $\xrightarrow{\langle S B}\rangle$ B25 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | $\sigma_{\text {f }}$ | ${ }_{\mathbf{o}} \mathbf{s p}$ | P | N | $\sigma_{\mathbf{f s}}$ | $\sigma_{\text {sp }}$ | P |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Pisces | 10 | 0.381 | 0.317 | 0.061 | 10 | 0.381 | 0.349 | 0.199 |
| A400 | 3 | 0.232 | 0.304 |  | 3 | 0.232 | 0.319 |  |
| A539 | 3 | 0.376 | 0.223 | 0.100 | 3 | 0.376 | 0.236 | 0.122 |
| Cancer | 9 | 0.696 | 0.605 | 0.122 | 8 | 0.714 | 0.645 | 0.217 |
| A1367 | 11 | 0.446 | 0.470 | . . . | 11 | 0.446 | 0.461 |  |
| Coma | 5 | 0.258 | 0.322 |  | 5 | 0.258 | 0.344 | ... |
| 274-23 | 6 | 0.708 | 0.604 | 0.184 | 6 | 0.708 | 0.630 | 0.256 |
| Hercules | 6 | 0.492 | 0.456 | 0.362 | 6 | 0.492 | 0.454 | 0.347 |
| Pegasus | 13 | 0.484 | 0.482 | 0.767 | 13 | 0.484 | 0.459 | 0.255 |
| Cen30 | 3 | 0.604 | 0.569 | 0.582 | 3 | 0.604 | 0.611 |  |
| Pavo | 3 | 0.598 | 0.524 | 0.411 | <3 |  |  |  |
| Total | 78 | 0.512 | 0.475 | 0.001 | 76 | 0.513 | 0.487 | 0.006 |

Table 4.3. Continued

| Cluster | $\mathrm{B}_{25}$ |  |  |  | T |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | $\sigma_{\text {fs }}$ | $\sigma_{\text {sp }}$ | P | N | $\sigma_{\text {fs }}$ | $\sigma_{\text {sp }}$ | P |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Pisces | 10 | 0.381 | 0.285 | 0.019 | 11 | 0.290 | 0.287 | 0.619 |
| A400 | 3 | 0.232 | 0.499 |  | 5 | 0.206 | 0.288 |  |
| A539 | 3 | 0.376 | 0.262 | 0.173 | 3 | 0.396 | 0.378 | 0.628 |
| Cancer | 8 | 0.714 | 0.532 | 0.035 | 9 | 0.656 | 0.561 | 0.102 |
| A1367 | 11 | 0.446 | 0.393 | 0.101 | 6 | 0.520 | 0.366 | 0.048 |
| Coma | 5 | 0.258 | 0.414 |  | 5 | 0.313 | 0.387 |  |
| 274-23 | 6 | 0.708 | 0.533 | 0.076 | 6 | 0.708 | 0.624 | 0.236 |
| Hercules | 6 | 0.492 | 0.495 |  | 4 | 0.542 | 0.604 |  |
| Pegasus | 13 | 0.484 | 0.484 |  | 13 | 0.454 | 0.443 | 0.429 |
| Cen30 | 3 | 0.604 | 0.599 | 0.829 | 3 | 0.604 | 0.615 |  |
| Pavo | $<3$ |  |  |  | 3 | 0.598 | 0.680 |  |
| Total | 76 | 0.513 | 0.451 | $<0.001$ | 74 | 0.500 | 0.476 | 0.008 |

Table 4.4. Scatter About the Extra-Parameter Tully-Fisher Relations for the Bothun et al. (1985a) Parameters

| Cluster | $\mathrm{B}_{\mathrm{T}}$ |  |  |  | U-B |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | ${ }^{\sigma_{f s}}$ | $\sigma_{8 p}$ | P | N | $\sigma_{\text {f3 }}$ | ${ }^{\text {sp }}$ | P |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Pisces | 18 | 0.369 | 0.299 | 0.007 | 18 | 0.369 | 0.352 | 0.196 |
| A400 | 7 | 0.322 | 0.362 | . . . | 7 | 0.322 | 0.342 |  |
| A539 | 5 | 0.359 | 0.361 | ... | 5 | 0.359 | 0.366 |  |
| Cancer | 19 | 0.654 | 0.583 | 0.038 | 19 | 0.654 | 0.644 | 0.446 |
| A1367 | 18 | 0.405 | 0.363 | 0.049 | 18 | 0.405 | 0.416 | . . . |
| Coma | 12 | 0.316 | 0.327 |  | 12 | 0.316 | 0.324 |  |
| 274-23 | 7 | 0.693 | 0.579 | 0.126 | 7 | 0.693 | 0.654 | 0.384 |
| Hercules | 8 | 0.475 | 0.501 | ... | 8 | 0.475 | 0.501 |  |
| Pegasus | 19 | 0.494 | 0.540 | $\ldots$ | 19 | 0.494 | 0.481 | 0.312 |
| A2634/66 | <3 | -•• | . $\cdot$ | -•• | <3 | -•• | -•• | . . |
| Total | 114 | 0.481 | 0.457 | 0.001 | 114 | 0.481 | 0.479 | 0.319 |

Table 4.4. Continued

| Cluster | B-V |  |  |  | B-H |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (1) | N (2) | $\sigma_{\mathrm{fs}}$ <br> (3) | $\sigma_{\mathbf{s p}}$ <br> (4) | (5) | (6) | $\sigma_{\mathrm{fs}}$ <br> (7) | $\sigma_{\mathrm{sp}}$ <br> (8) | (9) |
| Pisces | 18 | 0.369 | 0.357 | 0.274 | 18 | 0.369 | 0.349 | 0.161 |
| A400 | 7 | 0.322 | 0.340 | . . . | 7 | 0.322 | 0.347 | ... |
| A539 | 5 | 0.359 | 0.369 | ... | 4 | 0.352 | 0.361 | $\ldots$ |
| Cancer | 19 | 0.654 | 0.654 | 0.876 | 19 | 0.654 | 0.661 |  |
| A1367 | 18 | 0.405 | 0.403 | 0.681 | 18 | 0.405 | 0.396 | 0.375 |
| Coma | 12 | 0.316 | 0.329 | . . . | 12 | 0.316 | 0.322 |  |
| 274-23 | 7 | 0.693 | 0.661 | 0.434 | 7 | 0.693 | 0.644 | 0.327 |
| Hercules | 8 | 0.475 | 0.503 |  | 8 | 0.475 | 0.508 |  |
| Pegasus | 19 | 0.494 | 0.479 | 0.272 | 19 | 0.494 | 0.481 | 0.310 |
| A2634/66 | $<3$ | . . . | . . . | ... | $<3$ | . . . | . . . | . . . |
| Total | 114 | 0.481 | 0.481 | 0.773 | 113 | 0.481 | 0.480 | 0.398 |

Table 4.4. Continued

| Cluster | $\log \mathrm{M}_{\mathrm{HI}}$ |  |  |  | $\log \mathrm{M}_{\mathrm{HI}} / L_{\mathrm{B}}$ |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N | $\sigma_{\text {fs }}$ | $\sigma_{s p}$ | P | N | $\sigma_{\text {f } 8}$ | $\sigma_{\text {8p }}$ | P |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Pisces | 18 | 0.369 | 0.351 | 0.188 | 18 | 0.369 | 0.324 | 0.032 |
| A400 | 7 | 0.322 | 0.323 | . . $\cdot$ | 7 | 0.322 | 0.366 | ... |
| A539 | 9 | 0.343 | 0.365 |  | 5 | 0.359 | 0.270 | 0.107 |
| Cancer | 22 | 0.624 | 0.621 | 0.672 | 19 | 0.654 | 0.606 | 0.091 |
| A1367 | 20 | 0.468 | 0.451 | 0.229 | 18 | 0.405 | 0.393 | 0.296 |
| Coma | 13 | 0.315 | 0.315 |  | 12 | 0.316 | 0.318 | - |
| 274-23 | 12 | 0.592 | 0.566 | 0.312 | 7 | 0.693 | 0.698 |  |
| Hercules | 11 | 0.451 | 0.446 | 0.604 | 8 | 0.475 | 0.527 |  |
| Pegasus | 22 | 0.534 | 0.554 |  | 19 | 0.494 | 0.451 | 0.064 |
| A2634/66 | 10 | 0.384 | 0.386 | -•• | <3 | ... | . . | . . |
| Total | 144 | 0.476 | 0.477 |  | 114 | 0.481 | 0.463 | 0.004 |

Table 4.4. Continued

| Cluster | $\log \mathrm{M}_{\mathrm{HI}} / \mathrm{L}_{\mathrm{H}}$ |  |  |  |
| :--- | ---: | :---: | :---: | :---: |
|  | N | $\sigma_{\mathrm{fs}}$ | $\sigma_{\mathbf{S p}}$ | P |
| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ |
| Pisces | 17 | 0.377 | 0.314 | 0.014 |
| A400 | 7 | 0.322 | 0.363 | $\ldots$ |
| A539 | 9 | 0.343 | 0.295 | 0.109 |
| Cancer | 22 | 0.624 | 0.608 | 0.294 |
| A1367 | 20 | 0.468 | 0.451 | 0.236 |
| Coma | 12 | 0.327 | 0.330 | $\ldots$ |
| Z74-23 | 11 | 0.616 | 0.553 | 0.133 |
| Hercules | 10 | 0.471 | 0.515 | $\ldots$ |
| Pegasus | 22 | 0.534 | 0.483 | 0.036 |
| A2634/66 | 10 | 0.384 | 0.435 | $\ldots$ |
| Total | 140 | 0.482 | 0.466 | 0.002 |

experiment. The third column contains the dispersion about the secondparameter fit for the same objects. The fourth column gives the results of an F -test to assess the significance of the improvement, if any, in the fit obtained by adding the additional parameter. This test is described in more detail below. The results of this second-parameter search are listed separately for each cluster with at least three objects with $H$ magnitudes and line-widths, and then for all possible cluster objects taken together.

Each of the dispersions listed in Tables 4.3 and 4.4 is the square root of the sum of the squares of the residuals about the corresponding fit, divided by the number of degrees of freedom. The fixed-slope fit was derived using a superset of the data used in any of the second-parameter fits. Therefore, in the computation of the scatter about the fixed-slope fit for an individual cluster, no degrees of freedom were used up in the derivation of the applied $f i t$, and the number of degrees of freedom was taken to be the number of points in the cluster sample. Even the scatter for the total sample was computed from a different (sub-) set of data from that used to derive the fit coefficients, so again the number of degrees of freedom was taken to be the number of points. In the case of the residual fits, a single least-squares fits was performed on the total aample, using up 2 degrees of freedom in the total scatter, but no degrees of freedom for any particular cluster. Note that these assumptions are not exactly correct, as the data sets overlap in each case, and hence were
not completely independent.

Once we have computed the scatter about the fixed-slope Tully-Fisher relation, both with and without a second parameter, we wish to compare the two to see if there is any improvement with the addition of another observable. In cases where the dispersion including the extra parameter is in fact lower than that for the simpler fit, we can make a statistical test described by Bevington (1969) to see if the improvement is a significant one. We compute a statistic $F_{X}$, the ratio of the difference between the square of the "old" scatter and the square of the "improved" scatter, to the square of the "improved" scatter, divided by the number of degrees of freedom in the "improved" fit. This statistic should follow an $F$ distribution with $\nu_{1}=1$, and $\nu_{2}=$ the number of degrees of freedom in the "improved" fit. We can therefore calculate the probability that this $F_{\chi}$ statistic would be as large as it is, if the simpler fit were actually a better representation of the data than the second-parameter fit. These are the probabilities, "P", tabulated in Tables 4.3 and 4.4. A small probability indicates that it is likely that adding the extra parameter made a significant reduction in the scatter.

## DISCUSSION

Let us examine the results of the second-parameter search. The first point to consider is the nature of the trial parameters themselves.

There are two classes of additional parameters: those that depend on distance and those that do not. The most straightforwardly useful second parameter for distance scale work should be distance independent. Then consideration of this additional observational property allows us to essentially pick a subset of the possible objects to study, where this subset has a smaller intrinsic spread in properties, i.e. smaller scatter about a Tully-Fisher relation, than the entire set. Distant dependent second parameters may carry information about other dimensions in the space of galaxy properties, but are not as easy to apply to distance scale problems since the distance must be known to evaluate them in the first place.

None of the trial second parameters makes a major difference in our ability to determine distances. While several parameters allow statistically significant gains, none of the cluster or total dispersions about the additional parameter fits represent an improvement as large as 0.1 mag. Let us examine each type of parameter in turn.

## Inclination

We included the axis ratio as a trial second parameter in order to test for any residual dependence on inclination in the magitudes or linewidths. The Tully-Fisher residuals do exhibit a $2 \sigma$ slope with $\log R$, but including axis ratio as a second parameter does not make a very
significant difference in the measured dispersions.

## Blue Magnitudes

The two definitions of blue magnitude included in the search, $\mathrm{B}_{\mathbf{2 5}}$ and $B_{T}$, make very statistically significant, although small, improvements in the Tully-Fisher scatter. In fact, the correlation coefficient for the $B_{25}$ residual fit is the largest of any of the parameters. The origin of this correlation lies mostly in the least-squares fitting procedure itself. When we fit our adopted Tully-Fisher relation, we minimized the errors in the $H$ magnitude direction only. Because the correlation between $H$ magnitude and line-width is not perfect, residuals about a fit made in this way will still exhibit a small correlation with $H$ magnitude. In fact, if we plot the Tully-Fisher residuals against $H$ magnitude, we find a line with a correlation coefficient of 0.346 and a small but significant slope. Now, $B_{25}$ and $B_{T}$ both show good correlations with $H$, with $r=0.921$ and $\sigma=0.404$ mag for 78 points for $B_{25}$ and $r=0.909$ and $\sigma=0.417$ mag for 114 points for $B_{T}$, so each of these parameters shows a relatively strong correlation with the residuals about our adopted fit. Although not very helpful for distance scale work, it is interesting that the correlation of the residuals with $B_{25}$ is actually stronger than that with H magnitude. Perhaps some color dependence is contributing as well.

## Diameter

The blue diameter is another distance-dependent quantity that correlates fairly well with Tully-Fisher residuals and leads to a small, statistically significant reduction in the scatter, about 0.05 mag in the mean. Blue diameters correlate well with magnitudes, even at H-band, with a correlation coefficient of $\mathbf{- 0 . 8 3 3}$ and a scatter of 0.097 in $\log \mathrm{D}_{\mathrm{B} 25}$ for the 80 overlapping points in our data. Therefore the residual correlation effect seen above for the blue magnitudes is probably involved here, too. Principal component analyses (e.g. Whitmore 1984; Watanabe, Kodaira, and Okamura 1985) do not find significantly different behavior for magnitudes and diameters when resolving the space of galaxy properties into its primary dimensions.

## Concentration and Morphological Type

Our concentration parameter, $C_{B}$, is essentially a measure of the ratio of the bulge luminosity to the object's total luminosity, $B / T$. It is distance-independent, and correlates well with true $B / T$ ratios derived from bulge/disk decompositions of surface brightness profiles. It has the advantage, though, of being independent of any bulge/disk model, and can be derived even when a formal bulge/disk decomposition fails. Our concentration parameter also correlates fairly well with Hubble type, and

Whitmore (1984) and Watanabe, Kodaira, and Okamura (1985) both find a morphological type, $B / T$ ratio, or a concentration parameter to be a good measure of the second principal component of spiral properties. Thus we had hoped to find a significant reduction in Tully-Fisher scatter by including such a concentration parameter. Unfortunately, adding $\log C_{B}$ does not significantly improve our ability to measure distances. It is interesting, therefore, that $T$, a subjectively-defined morphological classification only crudely transferred to a numerical scale, actually results in a much more significant, although still pretty small, reduction in scatter.

## Surface Brightness

Of the distance-independent parameters, surface brightness measures result in the largest reduction in H-band Tully-Fisher scatter. Indeed, Watanabe, Kodaira, and Okamura (1985) found that surface brightness was the best second-component from their principal component analysis. We find that the most significant reduction in Tully-Fisher scatter comes from using a nuclear surface brightness, rather than a surface brightness more characteristic of the entire object. This result might have been expected from the definition of the $H$-band magnitudes used in the magnitude/line-width relation. These magnitudes are small-aperture measurements, with the aperture adjusted relative to the diameter so that $\log (A / D)=-0.5 . \quad$ These magnitudes are thus more characteristic of the
bulge of the object, and it seems reasonable that the surface brightness of the object might be an important second parameter. It is interesting, though, that the blue surface brightness within that same aperture, with $\log (A / D)=-0.5$, does not do quite as well as the nuclear one, which typically represents an aperture half as large as that of $\langle S B\rangle_{B,-0.5}$.

## Colors

The Bothun et al. (1985a) optical and optical/infrared colors do uniformly badly in reducing the scatter in the Tully-Fisher relation. This result is somewhat surprising in that Whitmore (1984) finds the B-H color to be a good representation of the second dimension in spiral properties. On the other hand, Tully, Mould, and Aaronson (1982) had previously reached essentially the opposite conclusion. Part of the disagreement may come from differences in the definition of the color, as Whitmore appears to have used some kind of total magnitudes, Tully, Mould, and Aaronson used a total $B$ magnitude and a small-aperture $H$ magnitude, while Bothun et al. (1985a) reduce both magnitudes to the same $\log (A / D)$ of $\mathbf{- 0 . 5}$ small aperture. At any rate, stellar population variations, as measured by optical or optical/infrared colors do not appear to make much difference in the final magnitude/line-width correlation. This result may simply reflect small variations in the behavior of the old disk light, as the major contributor to the total luminosity measured in the $H$-band.

Gas Mass and Gas Content

The total mass of the neutral hydrogen gas in the galaxy, as measured by the flux in the 21 cm line, a distance-dependent quantity, makes no difference in the Tully-Pisher residuals. The gas content measures, the gas mass per unit luminosity, are distance-independent parameters and allow only slight improvements in the Tully-Fisher scatter. Given that the $M_{H I} / L_{H}$ gas content correlates best with B-H color (e.g. Bothun 1984), we might have predicted this rather poor success, given our result for colors discussed in the preceeding paragraph.

## INTERPRBTATION

Although we have approached the Tully-Fisher second-parameter search with the practical goal of improving distance estimates, an equivalent way of thinking about the problem is that we are trying to determine which parameters besides total mass determine the $H$-band luminosities that we measure. Most of the trial second-parameters we have available are based on optical photometry, and are strongly influenced by ongoing and bursts of star formation. In particular, we are trying to determine the dependence of the distribution and amount of H-band luminosity on galaxy properties measured in blue light. Detailed models by Bothun et al. (1984), as discussed by Bothun et al. (1985b), suggest that current star formation in mature, constant star-formation-rate galaxies does not have
a large effect on $H$ magnitudes. On the other hand, observed integrated U-B colors together with population synthesis models indicate that the light at $B$ may be enhanced through current star formation by up to 1 mag in some of our galaxies.

Consider what happens to the observed properties of a typical latetype spiral as the disk fades by 1 mag. To be concrete, take a Freeman (1970) disk with a central blue surface brightness of 21.65 mag arcsec $^{-2}$. Also assume a typical disk scale length of 5 kpc , and a total bulge-todisk ratio of $\mathbf{0 . 1}$. The bulge component might have a $\mathrm{B}-\mathrm{H}$ coior near 4.0 as is observed for bright ellipticals (e.g. Persson, Frogel, and Aaronson 1979) and the disk component might have a $\mathrm{B}-\mathrm{H}$ color more like 3.0. While the H-band profile is more or less unchanged, the disk in blue light then fades after a Gyr or so by 1 mag to a central surface brightness of $\mathbf{2 2 . 6 5}$ mag arcsec ${ }^{-2}$, an unchanged scale length of 5 kpc , and a new total bulge-to-disk ratio of $\mathbf{0 . 2 5}$. The bulge-to-disk ratio within one scale length, approximately the radius corresponding to $\log A / D=\mathbf{- 0 . 5}$, increases from 0.38 to 0.96 . The total $\mathrm{B}-\mathrm{H}$ color of the galaxy reddens from 3.14 to $\mathbf{4 . 0}$ and the $B-H$ color within the aperture with $\log A / D=-0.5$ goes from about 3.38 to 4.0 . These computations assume that the effective radius of the bulge is much smaller than the disk scale length, but relaxing this assumption does not change the basic result. In addition, the diameter at the blue 25 th mag arcsec ${ }^{-2}$ isophote decreases from 3.1 scale lengths to 2.2 scale lengths, a reduction of 30 percent. Thus the color, surface
brightness, concentration, and apparent size of this object vary considerably with star formation, while the H-band luminosity profile remains roughly constant. Therefore the H-band luminosity of this galaxy is largely decoupled from the trial second-parameters that we would have measured for it.

In the above example we neglected an effect which may explain some of our second-parameter correlations. In the practical application of the H-band Tully-Fisher relation, the $H$ magnitudes are linearly interpolated along the object's photometric growth curve to a common aperture-to-bluediameter ratio of $\log A / D=-0.5$. This procedure leaves the $H$ magnitudes directly sensitive to star-formation-induced second-order variations in the observed diameter. The slope of the ( $H$ mag, $\log A / D$ ) growth curve is about 2 for an Sb galaxy (see Aaronson, Huchra, and Mould 1979, Figure 1). Thus decreasing the blue diameter by 30 percent, as in the example above, will decrease the measured H-band luminosity by 0.31 mag, even if the $H$ surface brightness remains unchanged. This effect may explain part of the good correlation of blue diameter, and blue magnitude which correlates very well with diameter, with Tully-Fisher residual.

It would have been easier to interpret the results of our secondparameter search if the measured galaxy properties were less subject to large random variations from current star formation. We are not completely out of luck, however, as the inner regions of many of our
objects can be expected to be dominated by bulge light. When the stellar population of the bulge dominates the measured light, we can expect much smaller variations from ongoing star formation and that the $B-H$ color there would be relatively constant. In that case, measuring the properties of the blue surface brightness profile ought to tell us directly what is happening to the H-band light distribution. A visual examination of the surface brightness profiles in Figure A. 1 reveals that about 55 percent of the profiles appear to be bulge-dominated within the aperture with $\log A / D=-0.5$. Thus we would expect blue parameters based on small aperture measurements like nuclear surface brightness, <SB>-0.5, and concentration to be more directly sensitive to changes in the $H$-band profiles. But since a large fraction of the profiles are still not obviously dominated by the bulge, even within the $\log A / D=-0.5$ aperture, we can still expect, and in fact observe, large random variations in the small aperture parameters. On the other hand, the bulge-dominated fraction will be even higher within the aperture used to define the nuclear surface brightness, typically half the size corresponding to log $A / D=-0.5$, probably explaining why the nuclear surface brightness proved to be the strongest second parameter. As we saw above, second-order variations in large-aperture, disk-light dominated observables influence the $H$ magnitude primarly through their correlation with the blue diameter. This fact may explain why the parameters more characteristic of the entire object, e.g. total blue magnitudes, mean surface brightness, integrated
colors, and gas content, do not allow much improvement as potential TullyFisher second parameters.

## CONCLUSIONS

We have discussed the scatter about the infrared Tully-Fisher relation and have shown that many of the cluster samples we examined exhibit considerable substructure, especially in the redshift/distance diagrams. Although this substructure suggests that depth effects may be important to the observed Tully-Fisher scatter, the numerical lower limits we compute for this dispersion in depth are, in fact, rather small. We then used data derived from a CCD survey of spiral galaxies in clusters of galaxies, as well as data from the literature, to search for additional parameters in the infrared magnitude/21 cm line-width correlation, with the goal of improving distance estimates based on that relation. We find no parameters that substantially reduce the Tully-Fisher scatter in our sample, although there are some observables, notably nuclear surface brightness, which do allow statistically significant improvements. Our results can be understood qualitatively by considering the effect of variations in the current star formation rate on the measured trial second parameters.

## APPENDIX: THE DATA

We list in Tables A. 1 through A. 6 the photometric parameters derived from the CCD observations discussed in Chapter 2. Tables A. 1 and A. 2 give the B-band properties, Tables $A .3$ and $A .4$ the $R_{J}$ measurements, and Tables A. 5 and A. 6 the Kron-Cousins I-band data. Objects are listed by cluster. Accurate coordinates for many of the northern galaxies are listed in Bothun et al. (1985a), and positions for the remaining objects may be found in either the UGC or the ESO catalog. Note that Tables A. 5 and A. 6 list only southern hemisphere objects, as we have little I-band data for our northern sample. There are two tables for each bandpass. The first contains various surface photometric parameters and the second table gives isophotal magnitudes at eight different isophotal levels. For each object we list the name, logarithm of the axis ratio $a / b$, logarithm of the diameter at the standard isophote, concentration parameter, nuclear surface brightness, surface brightness within an aperture corresponding to $\log (A / D)=-0.5$, surface brightness within the standard isophote, and an estimate of the total magnitude. The magnitudes in the second table are labelled as to their corresponding isophote. All surface brightnesses are in mag arcsec ${ }^{-2}$. All quantities are given in their fully corrected forms. In particular, the diameters and magnitudes have been expressed in absolute terms using distances from Table 2.1 or estimated from the redshift and the linear bi-infall model of Aaronson et al. (1989) in the
case of "miscellaneous" objects. Diameters are in kpc. Note that items are left blank if a measurement could not be made for some reason. Total magnitudes were not derived for the non-cluster objects.

In Pigure A.1, we present the surface brightness profiles for all of the objects in our CCD survey. For each observation of each object we plot surface brightness in mag arcsec ${ }^{-2}$ against semimajor axis in kpc. Up to three profiles are given for each observation. The solid lines are the B-band surface brightness profile, the dashed lines are the $R_{J}$ profiles, and the dot-dashed lines refer to the I-band profiles. Each surface brightness has been fully corrected for the effects of Galactic absorption, redshift, and inclination according to the prescriptions discussed in Chapter 2. Objects are listed by cluster; in the order corresponding to that in the tables of photometry. Multiple observations of the same object are numbered with roman numerals. Distances are taken from Table 2.1, where availible, or derived for the miscellaneous objects at the end from redshifts listed in The Center for Astrophysics Redshift Catalogue and the linear bi-infall model of Aaronson et al. (1989).

Table A. 1
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Photometric Parameters Derived from B-band Surface Photometry

| Object | $\log R$ | $\log D_{25}$ | $\log C$ | $\mu_{n}$ | $\mu_{-0.5}$ | $\mu_{25}$ | $\mathbf{B}_{T}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ | $(6)$ | $(7)$ | $(8)$ |


| Pisces |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| N296 | 0.5749 | ... | ... | .. | .. | ... | ... |
| N338 | 0.3412 | 1.6202 | -0.6141 | 20.994 | 21.786 | 23.805 | -20.4 |
| N444 | 0.6361 | 1.3615 | -1.0237 | 22.900 | 23.046 | 23.902 | -19.3 |
| N452 | 0.5864 | 1.3366 | -0.6126 | 21.760 | 21.859 | 23.165 | -20.4 |
| N523 | ... | ... | ... | ... | ... | ... |  |
| N536 | 0.5048 | 1.5571 | -0.5645 | 21.283 | 21.980 | 23.336 | -20.9 |
| N582 | 0.6004 | ... | ... | ... | ... | ... |  |
| U525 | 0.4733 | 1.3230 | -0.9400 | 22.936 | 23.262 | 24.301 | -19.1 |
| U540 | 0.2317 | 1.1032 | -0.9436 | 20.743 | 20.963 | 22.238 | -19.6 |
| U542 | 0.6649 | 1.4117 | -0.5504 | 21.605 | 22.111 | 23.585 | -19.7 |
| U556 | 0.3107 | 1.1728 | -0.9421 | 21.762 | 22.120 | 23.382 | -18.9 |
| U557 | 0.4195 | 1.2091 | -1.0812 | 22.083 | 22.278 | 23.352 | -19.0 |
| U633 | 0.6000 | $\ldots$ | ... | ... | ... | ... | ... |
| U679 | 0.6737 | 1.0838 | -1.0880 | 23.829 | 23.884 | 24.433 | -17.7 |
| U987 | 0.5133 | 1.3730 | -0.4859 | 21.094 | 21.524 | 23.188 | -20.0 |
| U1033 | 0.7429 | 1.4292 | -0.3188 | 21.815 | 22.079 | 23.327 | -20.1 |
| A400 |  |  |  |  |  |  |  |
| U2367 | 0.5466 | 1.6474 | -0.5937 | 22.124 | 22.566 | 23.781 | -20.8 |
| U2375 | 0.5532 | ... | ... | . | ... | ... | ... |
| U2399 | 0.0795 | ... | ... | ... | . | ... |  |
| U2405 | 0.4621 | 1.5229 | -0.8218 | 22.044 | 22.233 | 23.338 | -20.6 |
| U2415 | 0.5054 | ... | . ${ }^{\text {a }}$ | . |  |  |  |
| U2444 | 0.1964 | 1.3876 | -0.7167 | 21.192 | 21.461 | 23.134 | -20.0 |
| U2454 | 0.6533 | 1.4232 | -0.9198 | 22.541 | 22.752 | 23.769 | -19.7 |
| A539 |  |  |  |  |  |  |  |
| D11 | 0.2422 | $\cdots$ | ... | $\cdots$ | $\cdots$ | $\ldots$ | ... |
| U3236 | 0.3725 | ... | $\ldots$ | ... | ... | ... | ... |
| U3248 | 0.4358 | $\cdots$ | $\ldots$ | $\ldots$ | $\cdots$ | $\ldots$ |  |
| U3269 | 0.1335 | 1.4020 | -0.9339 | 20.612 | 20.907 | 22.309 | -20.9 |
| U3282 | 0.1602 | 1.5443 | -1.1070 | 21.329 | 21.749 | 23.306 | -20.7 |
| U3291 | 0.4381 | 1.4441 | -1.2445 | 21.895 | 22.008 | 23.144 | -20.5 |
| Z421011 | 0.3760 | 1.4511 | -0.8882 | 21.029 | 21.427 | 22.736 | -20.7 |
| Z421030 | 0.3594 | 1.3814 | -0.9730 | 21.347 | 21.716 | 22.916 | -20.5 |

Table A. 1 Continued
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| Object | $\log R$ | $\log D_{25}$ | $\log C$ | $\mu_{n}$ | $\mu_{-0.5}$ | $\mu_{25}$ | $B_{T}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ | $(6)$ | $(7)$ | $(8)$ |


| Cancer |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 12308 | 0.2642 |  |  |  |  |  |  |
| 12348 | 0.2718 | 1.0691 | -0.5865 | 21.143 | 21.885 | 23.264 | -18.4 |
| N2554 | 0.1867 | ... | ... | $\ldots$ | ... |  | ... |
| N2558 | 0.1859 |  |  |  |  |  |  |
| N2562 | 0.1588 | 1.2123 | -0.6346 | 20.351 | 20.675 | 22.773 | -19.6 |
| N2565 | 0.3589 | 1.4750 | -0.4502 | 20.232 | 20.902 | 22.761 | -21.0 |
| N2575 | 0.1434 | 1.5101 | -0.9212 | 21.898 | 22.255 | 23.384 | -20.4 |
| N2595 | 0.1131 | ... |  |  |  |  |  |
| N2596 | 0.4251 | 1.4175 | -0.8640 | 21.574 | 22.032 | 23.182 | -20.2 |
| N2599 | 0.0585 | 1.5420 | -0.4000 | 20.085 | 21.222 | 23.152 | -20.9 |
| U4299 | 0.7339 | 1.4353 | -0.6745 | 22.198 | 22.607 | 23.598 | -19.8 |
| U4329 | 0.0713 | 1.4512 | ... | 21.609 | 22.408 | ... | -19.6 |
| U4332 | 0.2535 | 1.3120 | -0.9057 | 21.925 | 22.219 | 23.685 | -19.4 |
| U4361 | 0.4344 | ... | ... | ... | ... |  | ... |
| U4386 | 0.5126 | 1.5043 | -0.6283 | 21.405 | 21.855 | 23.297 | -20.4 |
| U4399 | 0.4770 | ... | ... | ... |  |  |  |
| U4400 | 0.7871 | 1.2151 | -0.7290 | 22.776 | 23.008 | 24.000 | -18.4 |
| U4416 | 0.3052 | 1.5410 | -0.8598 | 21.751 | 22.017 | 23.514 | -20.4 |
| Z119051 | 0.1894 | ... | ... | ... | ... | ... | ... |
| Z119053 | 0.1322 | ... |  | $\ldots$ | .. |  |  |
| Z119066 | 0.1846 | 1.2136 | -0.8880 | 21.219 | 21.433 | 22.941 | -19.5 |
| Z119095 | 0.6204 | ... | ... | ... | ... | ... | $\ldots$ |
| Z119107 | 0.6547 | $\ldots$ | ... | $\ldots$ | ... | $\ldots$ | $\ldots$ |
| A1367 |  |  |  |  |  |  |  |
| 12951 | 0.3358 | 1.4290 | -0.5681 | 21.532 | 22.035 | 23.505 | -20.0 |
| MK181 | 0.2080 | 1.1908 | -0.9440 | 20.080 | 20.435 | 22.183 | -20.0 |
| N3697 | 0.5073 | 1.6602 | -0.7035 | 21.940 | 22.351 | 23.580 | -21.1 |
| N3816 | 0.2257 |  |  |  |  |  |  |
| N3832 | 0.1106 | 1.5604 | -1.3024 | 22.398 | 22.498 | 23.742 | -20.5 |
| N3840 | 0.1207 | 1.3522 | -0.5726 | 20.998 | 21.595 | 23.238 | -19.8 |
| N3859 | 0.5063 | 1.3562 | -0.7830 | 21.390 | 21.504 | 23.094 | -20.1 |
| N3860 | 0.2357 |  |  |  |  |  |  |
| N3861 | 0.2558 | 1.6460 | -0.5950 | 21.425 | 22.182 | 23.643 | -20.9 |
| N3883 | 0.0692 | 1.7169 | -0.7416 | 22.225 | 22.847 | 24.023 | -20.9 |
| N3947 | 0.1076 | 1.4946 | -0.7519 | 21.430 | 21.567 | 23.322 | -20.5 |
| N3951 | 0.2972 | 1.3664 | -0.8481 | 21.219 | 21.501 | 22.950 | -20.2 |
| U6614 | 0.0409 | 1.4977 | -0.4780 | 21.058 | 22.210 | 23.804 | -19.8 |
| U6686 | 0.8409 | 1.6109 | -0.5356 | 23.069 | 23.358 | 24.143 | -20.0 |
| U6697 | 0.7394 | 1.5615 | -1.2406 | 21.878 | 21.935 | 23.236 | -20.8 |
| U6876 | 0.1382 | 1.3254 | -0.7940 | 21.356 | 21.779 | 23.311 | -19.6 |
| U6891 | 0.6333 | 1.4055 | -0.5419 | 22.483 | 22.911 | 23.901 | -19.6 |
| Z97033 | 0.3308 | 1.1925 | -0.8136 | 21.688 | 22.005 | 23.160 | -19.1 |
| Z97057 | 0.4493 | 1.1211 | -0.9772 | 22.787 | 22.845 | 23.580 | -18.4 |


| Object <br> (1) | $\log R$ <br> (2) | $\log D_{25}$ <br> (3) | $\log C$ <br> (4) | $\mu_{n}$ <br> (5) | $\begin{gathered} \mu_{-0.6} \\ (6) \end{gathered}$ | $\mu_{25}$ <br> (7) | $\mathrm{B}_{T}$ <br> (8) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z97068 | 0.2323 | 1.3613 | -0.7054 | 21.186 | 21.757 | 23.306 | -19.9 |
| Z97079 | 0.2676 | 1.0777 | -1.7803 | 21.504 | 21.684 | 23.192 | -18.6 |
| Z97152 | 0.4352 | 1.2875 | -0.6275 | 21.934 | 22.372 | 23.544 | -19.3 |
| Z97185 | 0.4235 |  | ... | ... | ... | ... | ... |
| Z127056 | 0.5480 |  | ... |  |  |  |  |
| Z127082 | 0.0985 | 1.2620 | -0.8352 | 21.178 | 21.641 | 22.950 | -19.7 |
| Coma |  |  |  |  |  |  |  |
| 1842 | 0.3054 | 1.4217 | -0.9206 | 22.122 | 22.435 | 23.463 | -20.0 |
| 14088 | 0.5512 |  |  |  |  |  |  |
| N4848 | 0.5104 | 1.4649 | -0.7503 | 21.414 | 21.647 | 23.011 | -20.6 |
| N4921 | 0.0435 | ... | ... | ... | ... | ... | ... |
| N4934 | 0.7044 | ... | ... | $\ldots$ | ... | . $\cdot$ | ... |
| N4944 | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |  |
| N5081 | 0.4534 | 1.6195 | -0.6980 | 21.808 | 22.313 | 23.769 | -20.7 |
| U8013 | 0.4725 |  | ... |  | ... |  |  |
| U8017 | 0.3471 | 1.3530 | -0.9175 | 21.477 | 21.677 | 22.817 | -20.1 |
| U8161 | 0.3823 | 1.3532 | -0.5926 | 21.739 | 22.121 | 23.474 | -19.6 |
| Z160058 | 0.4762 | 1.3203 | -1.0828 | 22.220 | 22.360 | 23.411 | -19.6 |
| Z160086 | 0.1507 | 1.1506 | -0.7198 | 21.078 | 21.592 | 23.204 | -18.8 |
| Z160106 | 0.1425 | . | ... | $\ldots$ | . $\cdot$ | ... | ... |
| Z74-23 |  |  |  |  |  |  |  |
| N5409 | 0.2382 | 1.5046 | -0.6016 | 21.326 | 21.948 | 23.738 | -20.3 |
| N5416 | 0.2017 | 1.4230 | -0.8079 | 21.189 | 21.664 | 22.993 | -20.4 |
| U8918 | 0.5184 | 1.3937 | -0.8281 | 22.037 | 22.323 | 23.525 | -19.8 |
| U8948 | 0.3524 | 1.3279 | -0.9388 | 22.477 | 22.727 | 23.848 | -19.2 |
| U8951 | 0.6123 | 1.2522 | -0.9782 | 23.026 | 23.277 | 24.049 | -18.6 |
| U8967 | 0.6965 | 1.4962 | -0.7662 | 22.465 | 22.757 | 23.790 | -20.4 |
| Z74010 | 0.3897 | 1.2528 | -1.0259 | 23.375 | 23.518 | 24.284 | -18.7 |
| Z74045 | 0.0008 | 1.1980 | -0.9267 | 20.548 | 20.920 | 22.521 | -19.7 |
| Hercules |  |  |  |  |  |  |  |
| 11173 | 0.3605 | 1.4389 | -0.7557 | 22.167 | 22.406 | 23.589 | -20.0 |
| İ179 | 0.2393 | 1.4423 | -0.8457 | 22.012 | 22.523 | 23.613 | -20.0 |
| I1182 | 0.1754 | .. | $\cdots$ | . | .. | .. | $\ldots$ |
| N6045 | 0.5295 | 1.5798 | -0.6364 | 21.580 | 21.884 | 23.184 | -20.9 |
| N6050 | ... | ... | ... | ... | . | ... | $\cdots$ |
| N6054 | 0.1876 | 1.4057 | -0.7459 | 20.950 | 21.328 | 23.242 | -20.0 |
| U10085 | 0.1689 | 1.5230 | -0.8330 | 21.487 | 21.964 | 23.267 | -20.5 |
| U10121 | 0.1961 | 1.5398 | -0.8857 | 20.870 | 21.302 | 22.982 | -21.0 |
| U10190 | 0.6008 | ... | ... | ... | . | .. | . |
| U10195 | 0.5331 | 1.5044 | -0.5567 | 21.966 | 22.410 | 23.673 | -20.2 |
| Z108098 | 0.2228 | 1.3210 | -0.8000 | 21.740 | 22.115 | 23.432 | -19.4 |
| Z108107 | 0.4059 | 1.3109 | -0.8819 | 21.686 | 21.892 | 23.085 | -19.7 |

Table A. 1 Continued
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| Object <br> (1) | $\log R$ <br> (2) | $\log D_{25}$ <br> (3) | $\log C$ <br> (4) | $\begin{aligned} & \mu_{n} \\ & (5) \end{aligned}$ | $\mu_{-0.5}$ <br> (6) | $\begin{aligned} & \mu_{25} \\ & (7) \end{aligned}$ | $\begin{aligned} & B_{T} \\ & (8) \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z108108 | 0.2795 | 1.3119 | -0.8054 | 21.416 | 21.731 | 23.085 | -19.8 |
| Z108127 | 0.1554 | 1.3187 | -0.8470 | 21.446 | 21.808 | 23.192 | -19.6 |
| Z108139 | 0.3433 | 1.4769 | -0.9254 | 22.380 | 22.604 | 23.639 | -20.0 |
| Z108154 | 0.0979 | 1.3070 | -0.7958 | 21.208 | 21.650 | 23.160 | -19.6 |
| Pegasus |  |  |  |  |  |  |  |
| I1474 | 0.3154 | 1.0837 | -0.8881 | 21.720 | 21.941 | 23.152 | -18.6 |
| I5309 | 0.3244 | 1.1830 | -0.8642 | 21.825 | 22.258 | 23.605 | -18.8 |
| N7518 | 0.1404 | 1.1337 | -0.6491 | 21.099 | 21.502 | 23.167 | -18.9 |
| N7536 | 0.3476 | ... | ... | ... |  |  |  |
| N7591 | 0.2998 | 1.2680 | -0.6047 | 21.256 | 21.844 | 23.384 | -19.4 |
| N7593 | 0.1916 | 1.0755 | -0.9258 | 21.159 | 21.323 | 22.681 | -19.0 |
| N7608 | 0.5262 |  | .. |  |  | ... | ... |
| N7610 | 0.2600 | 1.4511 | $\ldots$ | 22.313 | 22.905 |  |  |
| N7631 | 0.4213 | 1.2876 | -0.7779 | 21.328 | 21.908 | 23.237 | -19.6 |
| N7643 | 0.2456 | 1.1808 | -0.7270 | 21.124 | 21.504 | 23.131 | -19.1 |
| U12304 | 0.6763 | 1.2248 | -1.4688 | 22.852 | 22.830 | 23.527 | -18.9 |
| U12361 | 0.5618 | 1.0049 |  |  | 23.630 | 24.273 | -17.6 |
| U12370 | 0.5583 | 1.1866 | -0.7234 | 22.586 | 23.005 | 23.926 | -18.4 |
| U12423 | 0.8353 | 1.3046 | -0.7061 | 22.953 | 23.013 | 24.125 | -19.1 |
| U12451 | 0.7163 | 1.1733 | -1.0912 | 23.794 | 23.952 | 24.434 | -18.0 |
| U12467 | 0.6047 | 1.1118 | -0.9502 | 23.490 | 23.613 | 24.371 | -17.9 |
| U12494 | 0.5023 | 1.1885 | -1.1477 | 22.522 | 22.840 | 23.840 | -18.5 |
| U12497 | 0.5346 | 1.1590 | -1.1339 | 22.686 | 22.923 | 23.850 | -18.3 |
| U12522 | 0.0792 | 1.0924 | -1.2240 | 23.076 | 23.311 | 24.344 | -17.6 |
| U12561 | 0.5268 | 1.1465 | -0.9118 | 23.126 | 23.354 | 24.311 | -18.0 |
| Z406031 | 0.4252 | 0.9305 | -0.8766 | 22.257 | 22.487 | 23.420 | -17.6 |
| Z406042 | 0.1856 | 0.9985 | -0.9948 | 22.688 | 22.914 | 23.910 | -17.5 |
| Z406079 | 0.3689 | 1.1113 | -0.9571 | 22.244 | 22.554 | 23.769 | -18.1 |
| Z406082 |  |  | ... | ... | ... | ... | ... |
| A2634/66 |  |  |  |  |  |  |  |
| U12721 | 0.3350 | 1.5481 | -0.6579 | 21.877 | 22.389 | 23.768 | -20.0 |
| Virgo |  |  |  |  |  |  |  |
| N4246 | 0.2829 | 0.9701 | -0.9390 | 22.540 | 22.697 | 23.773 | -17.5 |
| N4380 | 0.2782 | 1.1477 | -0.8587 | 21.875 | 22.517 | 23.681 | -18.4 |
| N4651 | 0.1842 | 1.1894 | -0.7664 | 20.526 | 21.212 | 22.957 | -19.3 |


| Object <br> (1) | $\log R$ <br> (2) | $\log D_{25}$ <br> (3) | $\log C$ <br> (4) | (5) | $\mu_{-0.5}$ <br> (6) | $\mu_{25}$ <br> (7) | $\mathrm{B}_{T}$ <br> (8) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NGC 1209 |  |  |  |  |  |  |  |
| eso024234-1730.6 | 0.1997 | 0.9313 | -1.0847 | 22.762 | 23.246 | 24.288 | -17.2 |
| eso024524-1902.9 | 0.6812 | 0.8854 | -1.0530 | 23.792 | 23.928 | 24.363 | -16.7 |
| eso024921-1816.5 | 0.7462 | 0.8910 | -1.1429 | 23.404 | 23.442 | 24.261 | -16.6 |
| eso025754-1928.1 | 0.5927 | 0.7085 | -0.6912 | 22.993 | 23.160 | 24.041 | -16.3 |
| eso030617-1754.8 | 0.3362 | 0.8560 | -0.9364 | 21.940 | 22.200 | 23.416 | -17.2 |
| eso030719-1801.2 | 0.7061 | 0.9200 | -1.0247 | 23.722 | 23.700 | 24.411 | -17.1 |
| eso031302-1805.9 | 0.2512 | 0.8546 | -0.6056 | 21.593 | 22.292 | 23.545 | -16.9 |
| eso031339-1816.2 | 0.2806 | 0.8320 | -0.9106 | 22.624 | 22.704 | 23.687 | -16.8 |
| Antlia |  |  |  |  |  |  |  |
| esol01025-3428.9 | 0.2944 | 1.2075 | -0.8863 | 22.719 | 22.985 | 23.846 | -18.5 |
| esol01232-3348.7 | 0.3634 | 1.0753 | -0.8485 | 21.685 | 22.032 | 23.398 | -18.2 |
| esol01908-3932.9 | 0.1114 | 1.0718 | -0.5578 | 20.914 | 21.692 | 23.341 | -18.1 |
| esol02507-3337.3 | 0.6813 | 1.0981 | -1.1910 | 22.786 | 22.940 | 23.816 | -18.0 |
| esol02621-3239.9 | 0.6038 | 0.6505 | ... | 24.283 | 24.280 | 24.654 | -15.7 |
| eso102750-3626.2 | ... | ... | ... | ... | ... | ... | ... |
| esol02936-3435.8 |  |  | . $\cdot$ | ... | ... | $\ldots$ |  |
| Hydra |  |  |  |  |  |  |  |
| esol02210-2318.0 | 0.2350 | 1.1619 | -0.8319 | 20.866 | 21.089 | 22.977 | -19.1 |
| esol03021-2716.2 | 0.4937 | 1.0680 | -1.4012 | 22.599 | 22.906 | 23.748 | -18.2 |
| eso103140-2954.7 | 0.6849 | 1.2940 | -0.8390 | 22.374 | 22.745 | 23.825 | -19.0 |
| esol03518-3211.1 | 0.8758 | 1.0680 | -0.9498 | 23.103 | 23.338 | 24.102 | -17.3 |
| eso103542-2754.7 | 0.8534 | 0.8973 | -0.8193 | 23.638 | 23.729 | 24.366 | -16.3 |
| esol03655-3002.3 | 0.7090 | 1.5128 | -0.7001 | 22.188 | 22.494 | 23.718 | -20.2 |
| esol03656-2634.7 | 0.5035 | 1.3746 | -0.6863 | 22.579 | 22.767 | 23.738 | -19.5 |
| Centaurus 30 |  |  |  |  |  |  |  |
| eso123654-4027.9 | 0.4471 | 1.2308 | -0.6500 | 21.328 | 21.879 | 23.427 | -19.1 |
| esol24127-3614.2 | 0.6690 | 1.0926 | -1.0064 | 22.262 | 22.386 | 23.665 | -18.2 |
| esol24410-4113.4 | 0.4428 | 1.1261 | -0.7510 | 21.360 | 21.725 | 23.134 | -18.8 |
| esol25004-4010.8 | 0.2981 | 1.2382 | -0.9359 | 21.694 | 21.965 | 23.111 | -19.5 |
| Centaurus 45 |  |  |  |  |  |  |  |
| esol23759-3628.0 | 0.6438 | 1.0573 | -0.8324 | 22.220 | 22.262 | 23.556 | -18.4 |
| esol24841-4322.9 | ... | ... |  | ... | . | . | $\ldots$ |
| esol24953-3845.4 | 0.2886 | 1.4613 | -0.9410 | 21.216 | 21.604 | 22.975 | -20.5 |
| eso125142-3927.5 | 0.5162 | 1.0293 | -1.0436 | 22.413 | 22.578 | 23.631 | -18.0 |
| Telescopium 27 |  |  |  |  |  |  |  |
| eso195939-4142.7 | 0.7423 | 0.8108 | -0.9989 | 23.547 | 23.623 | 24.304 | -16.3 |
| eso200202-4807.3 | 0.7146 | 0.8163 | -0.6855 | 23.563 | 23.791 | 24.401 | -16.3 |
| eso200211-4807.3 | 0.3161 | 1.0595 | -1.2385 | 23.015 | 23.239 | 24.070 | -17.8 |


| Object <br> (1) | $\log R$ <br> (2) | $\log D_{25}$ <br> (3) | $\log C$ <br> (4) | (5) | $\mu_{-0.5}$ <br> (6) | $\mu_{25}$ <br> (7) | $\begin{aligned} & B_{T} \\ & (8) \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso200541-4629.8 | 0.5555 | 0.8559 | -0.6896 | 22.459 | 22.660 | 23.750 | -17.2 |
| eso200735-4825.5 | 0.6949 | 1.0851 | -1.0391 | 23.253 | 23.467 | 24.212 | -17.8 |
| eso200823-4617.6 | 0.6991 | 1.3252 |  | 22.602 | 23.023 |  | -18.8 |
| eso200826-4710.4 | 0.7164 | 0.8732 | -0.8371 | 22.659 | 22.898 | 23.817 | -16.9 |
| eso201039-4858.8 | 0.1894 | 1.0571 | -0.9014 | 22.932 | 23.634 | 24.262 | -17.1 |
| eso201301-4333.6 | 0.4608 | 0.8474 | -0.9733 | 22.270 | 22.436 | 23.594 | -17.1 |
| eso201352-4440.3 | 0.3923 | 0.9371 | -1.2977 | 22.426 | 22.520 | 23.637 | -17.5 |
| eso201442-4821.8 | 0.5688 | 0.9134 | -1.0983 | 23.134 | 23.231 | 24.046 | -17.1 |
| eso201527-4514.2 | 0.6496 | 0.9757 | -0.9141 | 22.763 | 22.945 | 23.865 |  |
| eso201730-4926.4 | 0.7073 | 0.8748 | -0.7233 | 23.090 | 23.307 | 24.137 | -16.8 |
| eso202031-4409.5 | 0.3932 | 1.3254 | -0.6103 | 20.545 | 21.116 | 22.945 | -20.0 |
| eso202423-4929.9 | 0.8570 | 0.8040 | -1.0090 | 23.629 | 23.740 | 24.316 | -15.9 |
| Telescopium 56 |  |  |  |  |  |  |  |
| eso195443-4614.9 | 0.3464 | 1.4459 | -0.8209 | 22.108 | 22.306 | 23.609 | -18.5 |
| eso200559-4928.7 | 0.6217 | 1.3447 | -0.5045 | 21.464 | 22.073 | 23.334 | -18.2 |
| eso201006-4458.1 | 0.3743 | 1.4919 | -0.9326 | 22.395 | 22.601 | 23.507 | -18.8 |
| eso201024-4440.7 | 0.0915 | 1.4943 | -0.9271 | 21.566 | 21.943 | 23.208 | -19.0 |
| eso201302-4451.8 | 0.3737 | 1.3355 | -1.1330 | 21.999 | 22.219 | 23.315 | -18.2 |
| Pavo |  |  |  |  |  |  |  |
| eso191452-7219.1 | 0.0677 | 0.8963 | -1.0662 | 22.325 | 22.857 | 23.931 | -16.9 |
| eso192513-7110.4 | 0.4511 | 0.8709 | -0.9017 | 21.436 | 21.655 | 23.034 | -17.7 |
| eso195254-7035.3 | 0.5208 | 1.0114 | -0.8554 | 22.397 | 22.749 | 23.737 | -17.7 |
| eso200710-6722.7 | 0.3160 | 0.9534 | -0.7920 | 22.038 | 22.449 | 23.612 | -17.5 |
| eso201001-7251.8 | 0.1420 | 0.6686 | -1.0511 | 21.132 | 21.374 | 22.723 | -16.9 |
| eso201125-7117.0 | 0.6350 | 0.8557 | -1.0636 | 23.062 | 23.114 | 24.046 | -16.8 |
| eso201137-7402.4 | 0.3178 | 1.0997 | -0.8141 | 22.243 | 22.585 | 23.642 | -18.1 |
| eso201810-7143.5 | 0.9429 | 1.3022 | $\ldots$ | 22.794 | 23.007 | ... | -18.5 |
| eso202552-6615.9 | 0.3119 | 0.8013 | -0.6096 | 21.513 | 22.178 | 23.278 | -17.1 |
| eso204014-7134.7 | 0.3833 | 1.0068 | -0.5155 | 21.192 | 21.559 | 23.210 | -18.2 |
| Indus |  |  |  |  |  |  |  |
| eso205906-4341.3 | 0.5824 | 1.1677 | -0.7191 | 21.854 | 22.322 | 23.561 | -18.7 |
| eso210003-4308.6 | 0.5625 | 0.9544 | -0.7590 | 22.655 | 22.885 | 23.889 | -17.4 |
| eso210053-4506.0 | 0.8470 | 1.3177 | -0.6992 | 23.504 | 23.745 | 24.377 | -18.0 |
| eso210101-4826.3 | 0.1924 | 1.1344 | -0.7003 | 21.276 | 21.747 | 23.340 | -18.7 |
| eso210145-4759.3 | 0.6034 | 1.4425 | -0.8849 | 22.414 | 22.969 | 23.973 | ... |
| eso210256-4822.2 | ... | ... | ... | ... | ... | ... | $\ldots$ |
| eso210500-4407.1 | 0.1969 | 1.2390 | -0.9436 | 22.260 | 22.569 | 23.706 | -18.9 |
| eso210616-4736.6 | 0.2600 | 1.0810 | -1.1238 | 22.583 | 22.777 | 23.729 | -18.0 |
| eso210740-4354.9 | 0.6179 | 1.2408 | -0.5500 | 21.834 | 22.253 | 23.454 | -19.1 |
| eso210802-4243.7 | 0.1157 | 0.9072 | -1.0535 | 22.054 | 22.294 | 23.402 | -17.5 |
| eso212713-4325.3 | 0.0743 | 1.0816 | -1.0880 | 22.092 | 22.305 | 23.377 | -18.3 |


| Object | $\log R$ | $\log D_{25}$ | $\log C$ | $\mu_{n}$ | $\mu_{-0.5}$ | $\mu_{25}$ | $\mathrm{~B}_{T}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ | $(6)$ | $(7)$ | $(8)$ |


| Miscellaneous |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :--- |
| l701 | 0.1465 | 1.2327 | -0.9217 | 20.994 | 21.469 | 23.245 | $\ldots$ |
| I900 | 0.1741 | 1.4859 | -1.1105 | 21.641 | 21.848 | 23.077 | $\ldots$ |
| I1401 | 0.4246 | 1.3686 | -0.8545 | 22.036 | 22.305 | 23.477 | $\ldots$ |
| N173 | 0.1254 | $\ldots$ | $\ldots$ | 21.353 | 21.941 | $\ldots$ | $\ldots$ |
| N4449 | 0.1873 | 0.6820 | $\ldots$ | 19.640 | 20.720 | $\ldots$ | $\ldots$ |
| N4475 | 0.2454 | 1.5506 | -0.7712 | 22.183 | 22.597 | 23.874 | $\ldots$ |
| N4738 | 0.8020 | 1.4121 | -0.7445 | 22.286 | 22.461 | 23.561 | $\ldots$ |
| N7537 | 0.5569 | 1.1762 | -0.6357 | 21.293 | 21.791 | 23.218 | $\ldots$ |
| N7541 | 0.4661 | 1.4014 | $\ldots$ | 21.699 | 21.781 | $\ldots$ | $\ldots$ |
| N7570 | 0.2467 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| N7750 | 0.2922 | 1.2646 | -0.9402 | 21.570 | 21.722 | 22.844 | $\ldots$ |
| N7757 | 0.1509 | 1.3097 | -0.8784 | 21.964 | 22.372 | 23.440 | $\ldots$ |
| U673 | 0.4324 | 1.2547 | -0.9116 | 22.477 | 22.763 | 23.901 | $\ldots$ |
| U1045 | 0.5268 | 1.3524 | -0.7380 | 21.803 | 22.129 | 23.480 | $\ldots$ |
| U2509 | 0.5220 | 1.2467 | -1.0154 | 21.734 | 22.011 | 23.140 | $\ldots$ |
| U4375 | 0.1740 | 1.1726 | -0.9502 | 21.828 | 22.290 | 23.511 | $\ldots$ |
| U4404 | 0.5739 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| U4414 | 0.0502 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| U6586 | 0.1328 | $\ldots$ | $\ldots$ | 21.370 | 22.379 | $\ldots$ | $\ldots$ |
| U7754 | 0.4167 | 1.1975 | -0.8281 | 21.991 | 22.170 | 23.346 | $\ldots$ |
| U9558 | 0.2250 | 1.6200 | -1.0348 | 22.505 | 22.750 | 23.602 | $\ldots$ |
| U12571 | 0.2905 | 1.0318 | -0.9827 | 22.487 | 22.537 | 23.608 | $\ldots$ |
| Z160139 | 0.2394 | 1.1558 | -1.2794 | 21.884 | 22.214 | 23.479 | $\ldots$ |
| Z501035 | 0.4240 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| es0025101-1748.3 | 0.2115 | 1.5499 | -0.4600 | 21.461 | 21.540 | 23.323 | $\ldots$ |
| eso102742-3458.0 | 0.3857 | 1.0942 | -0.4374 | 20.808 | 21.750 | 23.264 | $\ldots$ |
| eso191041-6629.7 | 0.7575 | $\ldots$ | -1.1684 | 24.264 | 24.334 | 24.637 | $\ldots$ |
| eso201327-4755.6 | 0.1208 | 1.3942 | -0.8831 | 21.779 | 22.080 | 23.429 | $\ldots$ |
| eso212837-4616.8 | 0.2273 | 1.5152 | -0.5611 | 21.269 | 21.846 | 23.331 | $\ldots$ |
|  |  |  |  |  |  |  |  |

Table A. 2
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B-band Isophotal Magnitudes

| Object <br> (1) | $\mathrm{B}_{22}$ <br> (2) | $\mathrm{B}_{22.5}$ <br> (3) | $\mathrm{B}_{23}$ <br> (4) | $\mathrm{B}_{23.5}$ <br> (5) | $B_{24}$ <br> (6) | $\mathrm{B}_{24.5}$ <br> (7) | $\mathrm{B}_{25}$ <br> (8) | $\mathrm{B}_{26}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Pisces |  |  |  |  |  |  |  |  |
| N296 |  | ... |  |  | ... | ... | ... |  |
| N338 | -19.413 | -19.789 | -19.963 | -20.135 | -20.258 | -20.348 | -20.727 |  |
| N444 | ... | ... | -16.471 | -18.029 | -18.718 | -19.012 | -19.157 | -19.290 |
| N452 | -18.682 | -19.127 | -19.599 | -19.749 | -19.836 | -19.913 | -19.981 | -20.267 |
| N523 | ... | $\ldots$ | ... | ... |  |  |  |  |
| N536 | -19.205 | -19.499 | -20.159 | -20.395 | -20.501 | -20.589 | -20.666 |  |
| N582 |  | ... |  |  | ... |  |  |  |
| U525 | -14.041 | -15.182 | -15.694 | -16.166 | -17.025 | -18.251 | -18.661 | -18.986 |
| U540 | -19.207 | -19.367 | -19.443 | -19.493 | -19.523 | -19.546 | -19.557 | -19.576 |
| U542 | -18.215 | -18.568 | -18.895 | -19.100 | -19.341 | -19.527 | -19.615 | -19.920 |
| U556 | -16.795 | -17.544 | -18.017 | -18.243 | -18.468 | -18.586 | -18.664 | -18.811 |
| U557 | -15.453 | -17.490 | -18.131 | -18.552 | -18.872 | -18.954 | -18.991 | ... |
| U633 | ... | ... | ... | . |  | ... | ... |  |
| U679 | ... | ... | ... | ... | -14.988 | -16.780 | -17.245 | -17.607 |
| U987 | -19.053 | -19.328 | -19.503 | -19.682 | -19.779 | -19.883 | -19.961 | -20.025 |
| U1033 | -18.718 | -19.020 | -19.178 | -19.598 | -19.757 | -19.851 | -19.961 | -20.088 |
| A400 |  |  |  |  |  |  |  |  |
| U2367 | -18.542 | -19.118 | -19.552 | -19.934 | -20.261 | -20.503 | -20.676 | -20.795 |
| U2375 | ... | ... | ... | ... | ... | ... | ... | ... |
| U2399 | $\ldots$ |  | . |  |  |  |  |  |
| U2405 | -17.792 | -19.073 | -19.745 | -20.086 | -20.318 | -20.432 | -20.482 | -20.560 |
| U2415 | ... | ... | $\cdots$ | ... | ... | ... | . $\cdot$. |  |
| U2444 | -18.997 | -19.338 | -19.529 | -19.674 | -19.746 | -19.850 | -19.922 | -20.016 |
| U2454 | ... | -16.839 | -18.066 | -18.754 | -19.346 | -19.467 | -19.586 | -19.670 |
| A539 |  |  |  |  |  |  |  |  |
| D11 | ... | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\cdots$ | ... |  |
| U3236 | $\ldots$ | ... | ... | ... | ... | ... | ... | . $\cdot$ |
| U3248 | ... | ... | ... | ... | ... | $\cdots$ | $\ldots$ | ... |
| U3269 | -20.459 | -20.604 | -20.734 | -20.801 | -20.824 | -20.846 | -20.864 | -20.887 |
| U3282 | -18.246 | -19.340 | -20.174 | -20.392 | -20.462 | -20.554 | -20.658 |  |
| U3291 | -17.439 | -19.324 | -19.691 | -20.177 | -20.306 | -20.359 | -20.397 | -20.444 |
| Z421011 | -19.888 | -20.264 | -20.434 | -20.518 | -20.589 | -20.634 | -20.670 | -20.707 |
| Z421030 | -18.808 | -19.712 | -20.046 | -20.164 | -20.247 | -20.299 | -20.330 | -20.469 |

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| Object <br> (1) | $\mathrm{B}_{22}$ <br> (2) | $\mathrm{B}_{22.5}$ <br> (3) | $\mathrm{B}_{23}$ <br> (4) | $\mathrm{B}_{23.5}$ <br> (5) | $\mathrm{B}_{24}$ <br> (6) | $\mathrm{B}_{24.5}$ <br> (7) | $\mathrm{B}_{25}$ <br> (8) | $\mathrm{B}_{26}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Cancer |  |  |  |  |  |  |  |  |
| 12308 | ... | ... | ... |  |  | ... |  |  |
| 12348 | -17.116 | -17.360 | -17.551 | -17.764 | -18.213 | -18.298 | -18.323 | -18.359 |
| N2554 |  |  |  |  |  | ... | ... |  |
| N2558 |  |  |  |  |  |  |  |  |
| N2562 | -18.966 | -19.112 | -19.215 | -19.325 | -19.391 | -19.458 | -19.522 | -19.595 |
| N2565 | -20.112 | -20.201 | -20.307 | -20.737 | -20.808 | -20.833 | -20.855 | -20.920 |
| N2575 | -17.592 | -18.713 | -19.690 | -19.952 | -20.140 | -20.239 | -20.321 | -20.394 |
| N2595 | ... | ... |  |  |  | ... |  |  |
| N2596 | -17.927 | -18.748 | -19.682 | -19.945 | -20.037 | -20.098 | -20.149 |  |
| N2599 | -20.024 | -20.203 | -20.336 | -20.436 | -20.662 | -20.734 | -20.797 | . |
| U4299 | -17.172 | -17.758 | -18.288 | -19.041 | -19.367 | -19.500 | -19.580 | -19.722 |
| U4329 | -17.285 | -18.156 | -18.721 | -19.076 | -19.334 | -19.564 | ... |  |
| U4332 | -17.023 | -17.382 | -17.925 | -18.466 | -18.749 | -18.956 | -19.090 | -19.325 |
| U4361 | ... |  |  |  |  |  |  |  |
| U4386 | -18.756 | -19.150 | -19.663 | -19.969 | -20.117 | -20.205 | -20.272 | -20.362 |
| U4399 | ... |  | ... | $\ldots$ | $\ldots$ | ... | ... |  |
| U4400 |  | -15.054 | -16.670 | -17.270 | -17.714 | -17.955 | -18.161 | -18.247 |
| U4416 | -17.909 | -18.874 | -19.363 | -19.894 | -20.208 | -20.316 | -20.373 | -20.414 |
| Z119051 |  |  |  |  | ... | ... | ... | ... |
| Z119053 | $\cdots$ | . | $\cdots$ | $\ldots$ | ... | ... |  |  |
| Z119066 | -18.686 | -18.900 | -19.051 | -19.180 | -19.270 | -19.330 | -19.403 | -19.475 |
| Z119095 | ... | ... | ... | ... | ... | ... | ... | ... |
| Z119107 |  |  |  |  |  | ... | ... | ... |
| A1367 |  |  |  |  |  |  |  |  |
| 12951 | -18.359 | -18.633 | -18.905 | -19.353 | -19.600 | -19.769 | -19.867 | -20.014 |
| MK181 | -19.633 | -19.753 | -19.861 | -19.910 | -19.949 | -19.973 | -19.987 | -20.009 |
| N3697 | -18.766 | -19.162 | -19.803 | -20.454 | -20.746 | -20.872 | -20.962 | -21.040 |
| N3816 | ... | ... | ... | ... | ... | . | ... | ... |
| N3832 | -15.235 | -16.504 | -18.952 | -19.647 | -20.019 | -20.205 | -20.333 | -20.455 |
| N3840 | -18.679 | -18.888 | -19.052 | -19.283 | -19.542 | -19.651 | -19.710 | -19.775 |
| N3859 | -19.129 | -19.454 | -19.611 | -19.717 | -19.804 | -19.891 | -19.969 | -20.080 |
| N3860 | ... | ... | ... | .. | ... | ... | ... |  |
| N3861 | -19.147 | -19.557 | -19.960 | -20.142 | -20.306 | -20.643 | -20.808 | -20.895 |
| N3883 | -18.305 | -18.518 | -18.844 | -19.248 | -20.059 | -20.489 | -20.703 | -20.885 |
| N3947 | -18.480 | -19.392 | -19.799 | -19.972 | -20.131 | -20.254 | -20.353 | -20.442 |
| N3951 | -19.292 | -19.650 | -19.853 | -19.956 | -20.040 | -20.095 | -20.142 | -20.179 |
| U6614 | -18.514 | -18.674 | -18.818 | -18.923 | -19.036 | -19.623 | -19.783 |  |
| U6686 | ... | -16.630 | -18.041 | -18.636 | -19.091 | -19.429 | -19.768 | -19.939 |
| U6697 | -16.646 | -19.923 | -20.180 | -20.498 | -20.631 | -20.687 | -20.727 | -20.812 |
| U6876 | -17.841 | -18.249 | -18.827 | -19.156 | -19.411 | -19.501 | -19.542 | $-19.581$ |
| U6891 | -15.959 | -17.642 | -18.145 | -18.431 | -18.688 | -19.164 | -19.309 | -19.477 |
| Z97033 | -17.353 | -18.032 | -18.540 | -18.784 | -18.911 | -18.993 | -19.040 | -19.094 |
| Z97057 | ... | ... | -17.274 | -17.761 | -17.995 | -18.129 | -18.206 | -18.303 |


| Object <br> (1) | $\mathrm{B}_{22}$ <br> (2) | $\mathrm{B}_{22.5}$ <br> (3) | $B_{23}$ <br> (4) | $\mathrm{B}_{23.5}$ <br> (5) | $\mathrm{B}_{24}$ <br> (6) | $\mathrm{B}_{24.5}$ <br> (7) | $\mathrm{B}_{25}$ <br> (8) | $\mathrm{B}_{26}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z97068 | -18.573 | -18.835 | -19.052 | -19.318 | -19.532 | -19.634 | -19.713 | -19.801 |
| Z97079 | -16.860 | -17.701 | -18.000 | -18.249 | -18.357 | -18.461 | -18.524 | -18.579 |
| Z97152 | -17.247 | -17.719 | -18.094 | -18.530 | -18.865 | -18.992 | -19.106 | -19.217 |
| Z97185 |  |  |  |  | ... |  |  |  |
| Z127056 |  |  |  |  |  |  |  |  |
| Z127082 | -17.729 | -18.917 | -19.257 | -19.415 | -19.508 | -19.549 | -19.584 | -19.637 |
| Coma |  |  |  |  |  |  |  |  |
| 1842 | -16.570 | -17.745 | -18.848 | -19.460 | -19.689 | -19.800 | -19.861 | -19.924 |
| 14088 | ... | ... | ... |  | ... |  |  |  |
| N4848 | -19.285 | -20.071 | -20.210 | -20.304 | -20.373 | -20.436 | -20.515 | -20.587 |
| N4921 | ... |  | ... | ... | ... | ... | ... | ... |
| N4934 | $\ldots$ |  | $\ldots$ | ... | ... |  |  |  |
| N4944 | . |  |  | $\ldots$ | ... | ... | . | ... |
| N5081 | -18.367 | -18.693 | -19.293 | -19.662 | -20.207 | -20.490 | -20.598 |  |
| U8013 | ... | ... | ... | ... | ... | ... | ... |  |
| U8017 | -18.720 | -19.600 | -19.792 | -19.887 | -19.955 | -19.999 | -20.030 | -20.086 |
| U8161 | -18.080 | -18.454 | -18.764 | -18.973 | -19.195 | -19.400 | -19.470 | -19.593 |
| Z160058 | ... | -17.461 | -18.437 | -19.090 | -19.262 | -19.358 | -19.398 | -19.507 |
| Z160086 | -17.568 | -18.013 | -18.285 | -18.445 | -18.567 | -18.663 | -18.743 | -18.802 |
| Z160106 |  | ... | ... | ... | ... | ... | ... | ... |
| Z74-23 |  |  |  |  |  |  |  |  |
| N5409 | -18.538 | -18.965 | -19.125 | -19.214 | -19.318 | -20.053 | -20.128 | -20.223 |
| N5416 | -19.077 | -19.718 | -19.963 | -20.092 | -20.178 | -20.273 | -20.308 | -20.344 |
| U8918 | -16.701 | -18.060 | -18.749 | -19.114 | -19.370 | -19.496 | -19.599 | -19.717 |
| U8948 | ... | -16.157 | -17.570 | -18.135 | -18.430 | -18.742 | -18.898 | -19.092 |
| U8951 | ... |  | . | -16.828 | -17.783 | -18.239 | -18.430 | -18.572 |
| U8967 | ... | -17.490 | -18.609 | -19.111 | -19.555 | -19.744 | -19.915 | -20.012 |
| Z74010 | $\ldots$ | ... | ... | -16.004 | -17.119 | -18.095 | -18.335 | -18.643 |
| Z74045 | -19.075 | -19.313 | -19.466 | -19.550 | -19.605 | -19.638 | -19.662 | -19.676 |
| Hercules |  |  |  |  |  |  |  |  |
| 11173 | -17.425 | -18.191 | -18.869 | -19.252 | -19.495 | -19.682 | -19.792 | -19.968 |
| 11179 | -16.638 | -17.574 | -18.319 | -19.121 | -19.481 | -19.675 | -19.776 | -19.946 |
| 11182 | ... | ... | ... | ... | ... | ... | ... |  |
| N6045 | -19.253 | -19.829 | -20.228 | -20.467 | -20.611 | -20.693 | -20.753 | -20.869 |
| N6050 | ... | ... | .. | ... | ... | ... | ... | ... |
| N6054 | -18.929 | -19.137 | -19.307 | -19.453 | -19.715 | -19.876 | -19.922 | -19.978 |
| U10085 | -18.823 | -19.375 | -19.844 | -20.063 | -20.262 | -20.380 | -20.438 | -20.476 |
| U10121 | -20.012 | -20.304 | -20.570 | -20.717 | -20.806 | -20.868 | -20.925 | ... |
| U10190 | ... | ... | . | . | ... | ... | ... | ... |
| U10195 | -18.022 | -18.703 | -19.102 | -19.438 | -19.635 | -19.828 | -20.040 | -20.322 |
| Z108098 | -17.193 | -17.796 | -18.487 | -18.882 | -19.109 | -19.234 | -19.301 | -19.365 |
| Z108107 | -17.865 | -18.809 | -19.191 | -19.387 | -19.509 | -19.572 | -19.648 | ... |


| Object <br> (1) | $\mathrm{B}_{22}$ <br> (2) | $\mathrm{B}_{22.5}$ <br> (3) | $\mathrm{B}_{23}$ <br> (4) | $\begin{gathered} B_{23.5} \\ (5) \end{gathered}$ | $B_{24}$ <br> (6) | $\mathbf{B}_{24.5}$ <br> (7) | $\mathrm{B}_{25}$ <br> (8) | $\begin{aligned} & \mathbf{B}_{26} \\ & (9) \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z108108 | -18.151 | -18.908 | -19.223 | -19.408 | -19.529 | -19.603 | -19.678 | -19.815 |
| Z108127 | -17.612 | -18.471 | -18.958 | -19.235 | -19.383 | -19.467 | -19.514 | -19.560 |
| Z108139 | -16.412 | -17.333 | -18.604 | -19.312 | -19.630 | -19.798 | -19.871 | -19.926 |
| Z108154 | -18.434 | -18.788 | -19.058 | -19.223 | -19.328 | -19.453 | -19.520 | -19.568 |
| Pegasus |  |  |  |  |  |  |  |  |
| I1474 | -16.653 | -17.867 | -18.132 | -18.290 | -18.398 | -18.469 | -18.542 | -18.580 |
| 15309 | -16.552 | -17.176 | -17.550 | -17.992 | -18.262 | -18.417 | -18.555 | -18.686 |
| N7518 | -17.327 | -18.010 | -18.399 | -18.515 | -18.600 | -18.679 | -18.758 | -18.903 |
| N7536 | ... | ... |  |  | ... | ... | ... |  |
| N7591 | -17.981 | -18.262 | -18.491 | -18.745 | -19.070 | -19.162 | -19.236 | -19.392 |
| N7593 | -18.328 | -18.589 | -18.731 | -18.822 | -18.898 | -18.937 | -18.958 | -18.986 |
| N7608 | ... | ... | ... | ... | ... | ... | ... | ... |
| N7610 | -15.297 | -16.421 | -17.941 | -18.656 | -19.093 | -19.255 | ... |  |
| N7631 | -17.835 | -18.547 | -18.895 | -19.163 | -19.334 | -19.454 | -19.488 | -19.539 |
| N7643 | -17.773 | -18.424 | -18.600 | -18.712 | -18.850 | -18.969 | -19.012 | -19.065 |
| U12304 | ... | ... | -17.551 | -18.399 | -18.564 | -18.669 | -18.730 | -18.845 |
| U12361 | ... | ... | $\cdots$ | - | -15.912 | -16.911 | -17.057 | -17.285 |
| U12370 | -14.167 | -15.606 | -16.241 | -17.491 | -17.745 | -17.943 | -18.167 |  |
| U12423 | ... | -15.977 | -16.666 | -17.313 | -17.738 | -18.288 | -18.555 | -19.025 |
| U12451 | ... | ... | ... | ... | -15.294 | -16.852 | -17.597 | -17.920 |
| U12467 | ... | .. | $\cdots$ | -15.095 | -16.095 | -16.881 | -17.391 | -17.861 |
| U12494 | ... | -15.021 | -16.522 | -17.173 | -17.682 | -18.015 | -18.260 | -18.391 |
| U12497 | ... | -15.021 | -15.857 | -17.027 | -17.637 | -17.933 | -18.141 | -18.278 |
| U12522 | ... | ... | -14.021 | -15.262 | -16.017 | -16.995 | -17.508 |  |
| U12561 | $\ldots$ | ... | -14.363 | -15.878 | -16.543 | -17.221 | -17.642 | -17.860 |
| Z406031 | ... | -15.578 | -16.587 | -17.085 | -17.281 | -17.407 | -17.444 | -17.530 |
| Z406042 | $\ldots$ | -14.172 | -15.137 | -16.035 | -16.922 | -17.223 | -17.342 | -17.972 |
| Z406079 | ... | -16.123 | -16.795 | -17.230 | -17.753 | -17.946 | -18.074 | ... |
| Z406082 |  | ... | ... | ... | ... | ... | ... | . $\cdot$ |
| A2634/66 |  |  |  |  |  |  |  |  |
| U12721 | -17.738 | -18.310 | -19.021 | -19.320 | -19.474 | -19.657 | -19.898 | -19.983 |
| Virgo |  |  |  |  |  |  |  |  |
| N4246 | ... | -13.827 | -15.959 | -16.645 | -16.990 | -17.243 | -17.382 | -17.473 |
| N4380 | -15.601 | -16.193 | -16.921 | -17.508 | -18.065 | -18.218 | -18.337 | ... |
| N4651 | -18.468 | -18.613 | -18.796 | -19.011 | -19.142 | -19.207 | -19.254 | ... |


| Object <br> (1) | $\mathrm{B}_{22}$ <br> (2) | $\mathrm{B}_{22.5}$ <br> (3) | $\mathrm{B}_{23}$ <br> (4) | $\mathrm{B}_{29.5}$ <br> (5) | $\mathrm{B}_{24}$ <br> (6) | $\mathrm{B}_{24.5}$ <br> (7) | $\begin{aligned} & B_{25} \\ & (8) \end{aligned}$ | $\mathrm{B}_{26}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NGC 1209 |  |  |  |  |  |  |  |  |
| eso024234-1730.6 |  | -12.779 | -14.154 | -14.992 | -15.818 | -16.299 | -16.930 | -17.089 |
| eso024524-1902.9 |  |  |  | -9.877 | -14.030 | -15.748 | -16.144 | -16.553 |
| eso024921-1816.5 |  |  |  | -13.511 | -16.236 | -16.340 | -16.416 | -16.541 |
| eso025754-1928.1 |  | -12.382 | -13.721 | -14.577 | -15.123 | -15.471 | -15.741 | -16.149 |
| eso030617-1754.8 | -14.341 | -15.873 | -16.414 | -16.696 | -16.924 | -17.069 | -17.091 | -17.179 |
| eso030719-1801.2 |  |  |  | -11.149 | -15.290 | -15.951 | -16.311 | -16.891 |
| eso031302-1805.9 | -15.184 | -15.610 | -16.115 | -16.405 | -16.589 | -16.702 | -16.859 |  |
| eso031339-1816.2 |  | -13.729 | -15.366 | -16.102 | -16.466 | -16.616 | -16.716 | -16.839 |
| Antlia |  |  |  |  |  |  |  |  |
| eso101025-3428.9 |  | -15.077 | -16.115 | -17.468 | -17.890 | -18.264 | -18.348 | -18.463 |
| eso101232-3348.7 | -16.366 | -17.258 | -17.510 | -17.815 | -17.993 | -18.086 | -18.187 |  |
| esol01908-3932.9 | -16.930 | -17.203 | -17.410 | -17.630 | -17.794 | -17.920 | -18.018 | -18.062 |
| esol02507-3337.3 |  | ... | -15.319 | -17.240 | -17.555 | -17.720 | -17.830 | -17.930 |
| eso102621-3239.9 | $\ldots$ | $\ldots$ | ... | ... | ... | -14.107 | -14.733 | -15.437 |
| eso102750-3626.2 |  | $\ldots$ | ... | ... | ... | ... | ... |  |
| esol02936-3435.8 |  |  |  |  | $\ldots$ | ... |  |  |
| Hydra |  |  |  |  |  |  |  |  |
| esol02210-2318.0 | -18.309 | -18.546 | -18.720 | -18.877 | -18.987 | -19.041 | -19.083 | -19.124 |
| esol03021-2716.2 |  | -12.571 | -16.124 | -17.017 | -17.531 | -17.719 | -17.830 | -18.024 |
| eso103140-2954.7 | -14.903 | -16.223 | -16.870 | -17.673 | -18.407 | -18.600 | -18.710 | -18.832 |
| esol03518-3211.1 | ... | ... | -13.603 | -15.293 | -16.556 | -16.855 | -17.052 | -17.207 |
| eso103542-2754.7 |  |  |  | -13.043 | -15.217 | -15.582 | -15.854 | -16.056 |
| eso103655-3002.3 | -17.346 | -18.309 | -19.027 | -19.381 | -19.706 | -19.929 | -20.060 | -20.158 |
| esol03656-2634.7 | -16.184 | -17.259 | -18.114 | -18.728 | -18.990 | -19.316 | -19.397 | -19.468 |
| Centaurus 30 |  |  |  |  |  |  |  |  |
| esol23654-4027.9 | -17.688 | -18.073 | -18.352 | -18.636 | -18.780 | -18.878 | -18.991 | -19.055 |
| esol24127-3614.2 | -13.841 | -16.739 | -17.283 | -17.648 | -17.836 | -17.977 | -18.076 | -18.183 |
| esol24410-4113.4 | -17.430 | -17.906 | -18.307 | -18.502 | -18.641 | -18.711 | -18.764 | -18.808 |
| esol25004-4010.8 | -17.006 | -18.638 | -19.009 | -19.144 | -19.229 | -19.316 | -19.367 | -19.441 |
| Centaurus 45 |  |  |  |  |  |  |  |  |
| esol23759-3628.0 | -15.348 | -17.115 | -17.544 | -17.732 | -17.929 | -18.014 | -18.110 | -18.220 |
| eso124841-4322.9 | -19892 | $\underset{-20.013}{ }$ | -20.217 |  |  |  |  |  |
| esol24953-3845.4 | -19.892 | -20.013 | -20.217 | -20.293 | -20.381 | -20.423 | -20.491 | -20.521 |
| eso125142-3927.5 |  | -15.584 | -16.567 | -17.258 | -17.499 | -17.607 | -17.748 | -17.924 |
| Telescopium 27 |  |  |  |  |  |  |  |  |
| esol95939-4142.7 | $\ldots$ |  | $\ldots$ | -11.167 | -14.931 | -15.438 | -15.874 | -16.133 |
| eso200202-4807.3 | . | $\ldots$ |  | -13.688 | -14.502 | -15.199 | -15.821 | -16.114 |
| eso200211-4807.3 | $\ldots$ |  | -14.227 | -15.736 | -17.093 | -17.453 | -17.627 | -17.733 |

Table A. 2 Continued
200

| Object <br> (1) | $B_{22}$ <br> (2) | $\mathrm{B}_{22.5}$ <br> (3) | $\begin{gathered} B_{23} \\ (4) \end{gathered}$ | $\mathrm{B}_{23.5}$ (5) | $\begin{gathered} \mathrm{B}_{24} \\ (6) \end{gathered}$ | $\mathrm{B}_{24.5}$ <br> (7) | $\begin{gathered} \mathbf{B}_{25} \\ (8) \end{gathered}$ | $\begin{gathered} \mathrm{B}_{26} \\ (9) \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso200541-4629.8 | $-13.759$ | -14.956 | -15.502 | -15.942 | -16.339 | -16.603 | -16.718 | -17.097 |
| eso200735-4825.5 |  |  | -10.344 | -15.315 | -16.721 | -17.241 | -17.473 | -17.676 |
| eso200823-4617.6 |  | -14.661 | -16.668 | -17.969 | -18.485 | -18.741 |  |  |
| eso200826-4710.4 |  | -13.744 | -14.941 | -15.709 | -16.313 | -16.584 | -16.701 | -16.827 |
| eso201039-4858.8 | -12.391 | -13.519 | -14.145 | -14.935 | -15.634 | -16.385 | -16.830 | -17.044 |
| eso201301-4333.6 |  | -14.893 | -16.088 | -16.379 | -16.601 | -16.753 | -16.882 | -16.995 |
| eso201352-4440.3 |  | -13.839 | -16.153 | -16.711 | -16.989 | -17.239 | -17.317 | -17.415 |
| eso201442-4821.8 |  |  | -12.760 | -15.639 | -16.273 | -16.561 | -16.755 | -16.970 |
| eso201527-4514.2 |  | -12.580 | -15.208 | -16.471 | -16.925 | -17.135 | -17.243 | -17.342 |
| eso201730-4926.4 |  |  | -13.899 | -14.803 | -15.562 | -16.075 | -16.393 | -16.624 |
| eso202031-4409.5 | -19.199 | -19.402 | -19.621 | -19.767 | -19.855 | -19.926 | -19.981 |  |
| eso202423-4929.9 |  |  |  | -2.271 | -14.148 | -15.243 | -15.472 | -15.755 |
| Telescopium 56 |  |  |  |  |  |  |  |  |
| esol95443-4614.9 | -16.880 | -17.860 | -18.953 | -19.332 | -19.525 | -19.619 | -19.765 | -19.954 |
| eso200559-4928.7 | -18.461 | -18.809 | -19.039 | -19.191 | -19.454 | -19.552 | -19.617 | -19.682 |
| eso201006-4458.1 | -16.058 | -17.265 | -18.969 | -19.748 | -20.025 | -20.148 | -20.227 | -20.293 |
| 2so201024-4440.7 | -18.437 | -19.364 | -20.014 | -20.229 | -20.360 | -20.431 | -20.492 |  |
| eso201302-4451.8 | -15.895 | -18.516 | -18.983 | -19.280 | -19.473 | -19.563 | -19.596 | -19.635 |
| Pavo |  |  |  |  |  |  |  |  |
| esol91452-7219.1 | -12.887 | -13.925 | -14.518 | -15.660 | -16.353 | -16.679 | -16.803 | -16.898 |
| esol92513-7110.4 | -16.568 | -16.883 | -17.247 | -17.390 | -17.472 | -17.568 | -17.639 | -17.696 |
| eso195254-7035.3 | -13.915 | -15.149 | -16.098 | -16.780 | -17.400 | -17.580 | -17.662 | -17.716 |
| eso200710-6722.7 | -14.686 | -15.740 | -16.261 | -16.797 | -17.131 | -17.258 | -17.380 | -17.468 |
| eso201001-7251.8 | -16.315 | -16.523 | -16.654 | -16.750 | -16.789 | -16.823 | -16.885 | -16.928 |
| eso201125-7117.0 |  | ... | -11.009 | -15.490 | -16.013 | -16.301 | -16.468 | -16.665 |
| eso201137-7402.4 | -15.119 | -16.147 | -16.827 | -17.405 | -17.691 | -17.915 | -18.024 | -18.116 |
| eso201810-7143.5 |  | -12.552 | -15.946 | -17.550 | -17.974 | -18.272 |  |  |
| eso202552-6615.9 | -15.315 | -15.721 | -16.340 | -16.628 | -16.787 | -16.891 | -16.948 | -17.020 |
| eso204014-7134.7 | -16.997 | -17.363 | -17.571 | -17.753 | -17.874 | -17.967 | -18.059 | -18.180 |
| Indus |  |  |  |  |  |  |  |  |
| eso205906-4341.3 | -16.472 | -17.117 | -17.566 | -18.015 | -18.327 | -18.456 | -18.547 | -18.628 |
| eso210003-4308.6 |  | -14.657 | -15.636 | -16.096 | -16.579 | -16.911 | -17.082 | -17.289 |
| eso210053-4506.0 |  |  |  | -15.318 | -16.515 | -17.393 | -17.868 |  |
| eso210101-4826.3 | -16.905 | -17.483 | -17.829 | -18.164 | -18.351 | -18.461 | -18.551 | -18.657 |
| eso210145-4759.3 | -15.216 | -16.882 | -17.967 | -18.382 | -18.818 | -19.194 | -19.466 |  |
| eso210256-4822.2 |  |  |  |  | ... | ... |  |  |
| eso210500-4407.1 | -14.527 | -16.680 | -17.416 | -18.091 | -18.548 | -18.699 | -18.776 | -18.858 |
| eso210616-4736.6 |  | -13.664 | -16.141 | -17.107 | -17.645 | -17.789 | -17.899 | -17.992 |
| eso210740-4354.9 | -17.036 | -17.485 | -17.827 | -18.265 | -18.554 | -18.729 | -18.833 | -18.960 |
| eso210802-4243.7 | -13.488 | -15.963 | -16.520 | -16.930 | -17.189 | -17.312 | -17.426 | ... |
| eso212713-4325.3 | -14.244 | -16.711 | -17.481 | -17.923 | -18.059 | -18.186 | -18.231 | -18.259 |

Table A. 2 Continued

| Object <br> (1) | $\mathrm{B}_{22}$ <br> (2) | $\mathrm{B}_{22.5}$ <br> (3) | $\mathrm{B}_{23}$ <br> (4) | $\mathrm{B}_{23.5}$ <br> (5) | $\mathrm{B}_{24}$ <br> (6) | $\mathbf{B}_{24.5}$ <br> (7) | $\mathbf{B}_{25}$ <br> (8) | $\mathrm{B}_{20}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Miscellaneous |  |  |  |  |  |  |  |  |
| 1701 | -17.622 | -18.195 | -18.502 | -18.768 | -18.974 | -19.044 | -19.110 |  |
| I900 | -18.804 | -19.712 | -20.088 | -20.331 | -20.484 | -20.531 | -20.566 | -20.615 |
| I1401 | -16.970 | -17.768 | -18.744 | -19.094 | -19.401 | -19.520 | -19.606 | -19.678 |
| N173 | -17.593 | -18.433 | -18.904 | -19.328 | -19.610 | -19.854 |  |  |
| N4449 | -16.518 | -16.717 |  |  |  |  |  |  |
| N4475 | -17.512 | -17.975 | -18.721 | -19.252 | -19.719 | -19.974 | -20.144 | -20.202 |
| N4738 | ... | -17.444 | -18.386 | -18.955 | -19.315 | -19.437 | -19.532 | -19.619 |
| N7537 | -17.844 | -18.146 | -18.364 | -18.673 | -18.817 | -18.908 | -18.956 | -19.004 |
| N7541 | -19.190 | -19.689 | -19.948 | ... | ... | ... | ... |  |
| N7570 | ... |  |  |  |  |  | $\ldots$ |  |
| N7750 | -18.713 | -19.084 | -19.374 | -19.609 | -19.670 | -19.706 | -19.734 | -19.765 |
| N7757 | -16.405 | -17.612 | -18.303 | -18.828 | -19.032 | -19.186 | -19.259 | -19.328 |
| U673 |  | -15.359 | -17.174 | -17.983 | -18.262 | -18.473 | -18.677 |  |
| U1045 | -17.521 | -18.267 | -18.851 | -19.106 | -19.369 | -19.444 | -19.534 | -19.635 |
| U2509 | -17.240 | -18.341 | -19.036 | -19.247 | -19.357 | -19.417 | -19.459 | -19.500 |
| U4375 | -16.067 | -17.104 | -17.889 | -18.258 | -18.410 | -18.557 | -18.648 | -18.719 |
| U4404 | ... | ... | ... | ... | ... | ... | ... | ... |
| U4414 |  |  |  |  |  | ... | $\ldots$ |  |
| U6586 | -16.191 | -17.167 | -17.671 |  |  |  |  |  |
| U7754 | -16.154 | -17.800 | -18.328 | -18.554 | -18.702 | -18.809 | -18.882 | -18.953 |
| U9558 |  | -17.175 | -18.915 | -20.027 | -20.381 | -20.559 | -20.608 | -20.659 |
| U12571 | .. | -15.129 | -16.848 | -17.344 | -17.649 | -17.791 | -17.865 | -18.119 |
| Z160139 | -15.653 | -16.670 | -17.256 | -18.055 | -18.316 | -18.435 | -18.490 |  |
| Z501035 | ... | ... | ... | ... | . | ... | ... | .. |
| eso025101-1748.3 | -19.631 | -19.864 | -20.002 | -20.111 | -20.236 | -20.363 | -20.507 | -20.871 |
| eso102742-3458.0 | -17.627 | -17.794 | -17.940 | -18.122 | -18.515 | -18.608 | -18.652 | $\ldots$ |
| eso191041-6629.7 | ... | ... | ... | ... | ... | ... | ... | $\cdots$ |
| eso201327-4755.6 | -17.643 | -18.361 | -19.026 | -19.484 | -19.580 | -19.722 | -19.795 | -19.851 |
| eso212837-4616.8 | -19.128 | -19.520 | -19.811 | -20.021 | -20.132 | -20.240 | -20.354 | -20.458 |

Table A. 3
202
Photometric Parameters Derived from R-band Surface Photometry
Object $\quad \log \mathrm{R} \quad \log \mathrm{D}_{23.5} \quad \log \mathrm{C} \quad \mu_{\mathrm{n}} \quad \mu_{-0.5} \quad \mu_{23.5} \quad \mathrm{R}_{T}$
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)

| Pisces |  |  |  |  |  |  |  |  |
| :--- | :---: | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| N296 | 0.5749 | 1.2070 | -0.7407 | 21.683 | 21.953 | 22.726 | -20.2 |  |
| N338 | 0.3412 | 1.4338 | -0.5122 | 19.177 | 19.669 | 21.449 | -21.9 |  |
| N444 | 0.6361 | 1.2991 | -0.9126 | 21.438 | 21.684 | 22.597 | -20.4 |  |
| N452 | 0.5864 | 1.4354 | -0.4600 | 19.947 | 20.292 | 21.689 | -21.9 |  |
| N523 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |  |
| N536 | 0.5048 | 1.5082 | -0.5124 | 20.040 | 20.246 | 21.622 | -22.2 |  |
| N582 | 0.6004 | 1.4256 | -0.7258 | 20.179 | 20.461 | 21.855 | -21.6 |  |
| U525 | 0.4733 | 1.2981 | -0.7701 | 21.384 | 21.857 | 22.916 | -20.3 |  |
| U540 | 0.2317 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |  |
| U542 | 0.6649 | 1.3415 | -0.4901 | 19.706 | 20.210 | 21.771 | -21.2 |  |
| U556 | 0.3107 | 1.1637 | -0.8034 | 19.756 | 20.252 | 21.699 | -20.4 |  |
| U557 | 0.4195 | 1.1566 | -1.0168 | 20.970 | 21.285 | 22.326 | -19.9 |  |
| U633 | 0.6000 | 1.2445 | -0.5713 | 20.305 | 20.659 | 21.943 | -20.7 |  |
| U679 | 0.6737 | 0.9290 | -0.9905 | 22.523 | 22.552 | 23.050 | -18.7 |  |
| U987 | 0.5133 | 1.3261 | -0.4511 | 19.493 | 19.880 | 21.558 | -21.5 |  |
| U1033 | 0.7429 | 1.3039 | -0.3315 | 20.382 | 20.697 | 21.818 | -21.2 |  |
| A400 |  |  |  |  |  |  |  |  |
| U2367 | 0.5466 | 1.6295 | -0.5208 | 20.181 | 20.687 | 21.986 | -22.5 |  |
| U2375 | 0.5532 | 1.3856 | -0.4129 | 19.724 | 20.313 | 21.700 | -21.6 |  |
| U2399 | 0.0795 | 1.3561 | -0.9387 | 20.089 | 20.491 | 21.904 | -21.3 |  |
| U2405 | 0.4621 | 1.4629 | -0.7061 | 20.553 | 20.863 | 22.024 | -21.6 |  |
| U2415 | 0.5054 | 1.2542 | -1.0338 | 20.490 | 19.925 | 21.591 | -21.1 |  |
| U2444 | 0.1964 | 1.3669 | -0.6612 | 19.420 | 19.808 | 21.524 | -21.5 |  |
| U2454 | 0.6533 | 1.3693 | -0.8193 | 20.983 | 21.259 | 22.335 | -20.9 |  |
| A539 |  |  |  |  |  |  |  |  |
| D11 |  |  |  |  |  |  |  |  |
| U3236 | 0.2422 | $\ldots$ | $\ldots .9$ | 20.256 | 21.099 | $\ldots$ | -20.5 |  |
| U3248 | 0.3725 | 1.4650 | -0.6893 | 19.941 | 20.436 | 21.784 | -21.7 |  |
| U3269 | 0.4358 | 1.6461 | -0.5349 | 19.708 | 20.554 | 21.920 | -22.5 |  |
| U3282 | 0.1335 | 1.3636 | -0.8847 | 19.519 | 19.886 | 21.325 | -21.7 |  |
| U3291 | 0.1602 | 1.4890 | -0.9732 | 19.783 | 20.119 | 21.826 | -21.9 |  |
| Z421011 | 0.4381 | 1.3995 | -1.1192 | 20.847 | 21.110 | 22.237 | -21.1 |  |
| Z421030 | 0.3760 | 1.3841 | -0.8169 | 19.698 | 20.130 | 21.534 | -21.7 |  |
|  | 0.3594 | 1.3469 | -0.7595 | 19.631 | 20.023 | 21.485 | -21.6 |  |
|  |  |  |  |  |  |  |  |  |

Object $\quad \log R \quad \log D_{23.5} \quad \log C \quad \mu_{n} \quad \mu_{-0.5} \quad \mu_{23.5} \quad R_{T}$
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)

| Cancer |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 12308 | 0.2642 | 1.0039 | -0.6653 | 19.857 | 20.013 | 21.597 | -19.7 |
| I2348 | 0.2718 | 1.0210 | -0.5028 | 19.508 | 20.152 | 21.679 | -19.8 |
| N2554 | 0.1867 | 1.6141 | -0.4075 | 19.002 | 19.703 | 21.450 | -22.9 |
| N2558 | 0.1859 | 1.3947 | -0.5144 | 18.950 | 19.832 | 21.592 | -21.7 |
| N2562 | 0.1588 | 1.2277 | -0.5358 | 18.414 | 18.880 | 21.117 | -21.4 |
| N2565 | 0.3589 | 1.4613 | -0.4028 | 18.514 | 19.250 | 21.214 | -22.4 |
| N2575 | 0.1434 | 1.4625 | -0.8906 | 20.365 | 20.680 | 21.911 | -21.7 |
| N2595 | 0.1131 | 1.6539 | ... | 19.558 | 20.295 | ... | ... |
| N2596 | 0.4251 | 1.3593 | -0.7920 | 20.055 | 20.486 | 21.710 | -21.4 |
| N2599 | 0.0585 | 1.4722 | -0.3916 | 18.837 | 19.386 | 21.355 | -22.4 |
| U4299 | 0.7339 | 1.4213 | -0.5938 | 20.468 | 20.953 | 22.025 | -21.3 |
| U4329 | 0.0713 | 1.3290 | -1.0649 | 20.251 | 20.628 | 22.019 | -21.0 |
| U4332 | 0.2535 | 1.3073 | -0.7978 | 19.713 | 20.233 | 21.898 | -21.0 |
| U4361 | 0.4344 | 1.1428 | -0.8949 | 21.411 | 21.635 | 22.590 | -19.7 |
| U4386 | 0.5126 | 1.5029 | -0.5837 | 19.674 | 20.177 | 21.680 | -22.0 |
| U4399 | 0.4770 | 1.1802 | -0.8352 | 20.748 | 21.068 | 22.218 | -20.1 |
| U4400 | 0.7871 | 0.9813 | -0.7999 | 21.636 | 21.800 | 22.586 | -19.1 |
| U4416 | 0.3052 | 1.4929 | -0.7079 | 20.026 | 20.336 | 22.068 | -21.7 |
| Z119051 | 0.1894 | 1.0863 | -0.8593 | 20.782 | 21.168 | 22.330 | -19.5 |
| Z119053 | 0.1322 | 0.9563 | -0.7224 | 19.478 | 19.950 | 21.503 | -19.6 |
| Z119066 | 0.1846 | 1.1552 | -0.8568 | 19.805 | 20.126 | 21.511 | -20.6 |
| Z119095 | 0.6204 | 1.0592 | -0.7193 | 20.619 | 20.945 | 22.067 | -19.7 |
| Z119107 | 0.6547 | 1.0516 | -0.8747 | 20.904 | 21.153 | 22.096 | -19.7 |
| A1367 |  |  |  |  |  |  |  |
| I2951 | 0.3358 | 1.4495 | -0.5301 | 19.835 | 20.394 | 21.974 | -21.7 |
| MK181 | 0.2080 | ... | ... | ... | ... | ... |  |
| N3697 | 0.5073 | 1.6001 | -0.5752 | 20.243 | 20.706 | 22.040 | -22.3 |
| N3816 | 0.2257 | . | ... | 18.621 | 19.896 | ... | -22.5 |
| N3832 | 0.1106 | 1.5248 | -1.1434 | 20.665 | 20.707 | 22.233 | -21.8 |
| N3840 | 0.1207 | ... | ... | ... | ... | ... | ... |
| N3859 | 0.5063 | ... | . $\cdot$. | ... | ... | ... |  |
| N3860 | 0.2357 | 1.3933 | -0.6535 | 19.470 | 20.071 | 21.614 | -21.7 |
| N3861 | 0.2558 | ... | ... | ... | ... | ... | ... |
| N3883 | 0.0692 | 1.6737 | -0.6391 | 20.301 | 20.931 | 22.333 | -22.5 |
| N3947 | 0.1076 | . | ... | ... | ... | ... | ... |
| N3951 | 0.2972 | 1.3391 | -0.8080 | 19.635 | 19.968 | 21.382 | -21.6 |
| U6614 | 0.0409 | 1.4294 | -0.3962 | 19.361 | 20.063 | 21.970 | -21.5 |
| U6686 | 0.8409 | 1.3829 | -0.5927 | 21.338 | 21.407 | 22.321 | -21.4 |
| U6697 | 0.7394 | 1.4581 | -1.0923 | 21.048 | 21.058 | 22.172 | -21.4 |
| U6876 | 0.1382 | 1.3222 | -0.7150 | 19.560 | 19.985 | 21.656 | -21.2 |
| U6891 | 0.6333 | 1.3371 | -0.4892 | 20.901 | 21.241 | 22.356 | -20.9 |
| Z97033 | 0.3308 | 1.1798 | -0.7124 | 19.891 | 20.298 | 21.582 | -20.6 |
| Z97057 | 0.4493 | 1.1961 | -0.7822 | 20.156 | 20.323 | 21.500 | -20.7 |


| Object <br> (1) | $\log R$ <br> (2) | $\log D_{23.5}$ <br> (3) | $\log C$ <br> (4) | $\mu_{n}$ <br> (5) | $\mu_{-0.5}$ <br> (6) | $\mu_{23.5}$ <br> (7) | $\mathrm{R}_{T}$ <br> (8) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z97068 | 0.2323 | ... | ... | ... | ... |  |  |
| Z97079 | 0.2676 | 1.0400 | -1.2875 | 20.506 | 20.703 | 22.032 | -19.5 |
| Z97152 | 0.4352 | 1.2743 | -0.5411 | 20.060 | . 20.576 | 21.848 | -20.9 |
| Z97185 | 0.4235 | 1.2271 | -0.9093 | 20.783 | 21.015 | 22.149 | -20.4 |
| Z127056 | 0.5480 | 1.2250 | -0.7903 | 20.193 | 20.448 | 21.639 | -20.8 |
| Z127082 | 0.0985 | 1.2468 | -0.7744 | 19.686 | 20.192 | 21.581 | -21.0 |
| Coma |  |  |  |  |  |  |  |
| 1842 | 0.3054 | ... | ... | ... | ... | ... |  |
| 14088 | 0.5512 | 1.4833 | -0.6305 | 20.396 | 20.909 | 22.077 | -21.7 |
| N4848 | 0.5104 | 1.3911 | -0.7144 | 20.059 | 20.286 | 21.529 | -21.8 |
| N4921 | 0.0435 | 1.6967 | -0.7113 | 19.675 | 20.384 | 21.951 | -22.8 |
| N4934 | 0.7044 | 1.2930 | -0.6717 | 19.890 | 20.108 | 21.510 | -21.3 |
| N4944 | ... | ... | ... | ... | ... | ... | ... |
| N5081 | 0.4534 | 1.6479 | -0.6458 | 20.237 | 20.749 | 22.295 |  |
| U8013 | 0.4725 | 1.3211 | -0.6157 | 21.001 | 21.315 | 22.444 | -20.7 |
| U8017 | 0.3471 | 1.3460 | -0.7960 | 19.650 | 19.933 | 21.264 | -21.6 |
| U8161 | 0.3823 | 1.3346 | -0.5354 | 19.825 | 20.407 | 21.812 | -21.2 |
| Z160058 | 0.4762 | 1.2983 | -0.9396 | 20.594 | 20.908 | 22.054 | -20.8 |
| Z160086 | 0.1507 | ... | ... | ... | ... | ... |  |
| Z160106 | 0.1425 | 1.1401 | -0.6350 | 19.020 | 19.453 | 21.489 | -20.6 |
| Z74-23 |  |  |  |  |  |  |  |
| N5409 | 0.2382 | ... |  | .. | ... |  |  |
| N5416 | 0.2017 | 1.3971 | -0.7469 | 19.629 | 20.129 | 21.548 | -21.7 |
| U8918 | 0.5184 | ... | ... | ... | ... | ... | ... |
| U8948 | 0.3524 | ... | $\ldots$ | ... | ... | $\ldots$ | ... |
| U8951 | 0.6123 | ... | $\cdots$ | . | . | $\ldots$ | $\ldots$ |
| U8967 | 0.6965 | 1.3725 | -0.6538 | 20.826 | 21.118 | 22.241 | -21.1 |
| Z74010 | 0.3897 | 1.1723 | -0.8860 | 21.959 | 22.148 | 22.878 | -19.7 |
| Z74045 | 0.0008 | ... | ... | ... | ... | ... | ... |
| Hercules |  |  |  |  |  |  |  |
| 11173 | 0.3605 | 1.4139 | -0.6269 | 20.436 | 20.809 | 22.050 | -21.3 |
| 11179 | 0.2393 | 1.4194 | -0.7139 | 20.443 | 21.021 | 22.191 | -21.2 |
| I1182 | 0.1754 | 1.4216 | -0.4634 | 18.845 | 19.790 | 21.566 | -21.7 |
| N6045 | 0.5295 | ... | ... | ... | ... | ... | ... |
| N6050 | ... | $\cdots$ | $\ldots$ | $\cdots$ | $\cdots$ | ... | $\ldots$ |
| N6054 | 0.1876 | ... | ... | ... | ... | ... | ... |
| U10085 | 0.1689 | 1.4723 | -0.7766 | 19.927 | 20.388 | 21.807 | -21.8 |
| U10121 | 0.1961 | 1.4728 | -0.7997 | 19.367 | 19.676 | 21.413 | -22.2 |
| U10190 | 0.6008 | 1.1928 | ... | 21.675 | 21.793 | 22.571 | -19.9 |
| U10195 | 0.5331 | 1.5048 | -0.4939 | 20.233 | 20.747 | 22.095 | -21.6 |
| Z108098 | 0.2228 | ... | ... | ... | ... | ... | $\ldots$ |
| Z108107 | 0.4059 | 1.2880 | -0.7394 | 20.386 | 20.549 | 21.834 | -20.8 |


| Object <br> $(1)$ | $\log R$ <br> $(2)$ | $\log D_{23.5}$ <br> $(3)$ | $\log C$ <br> $(4)$ | $\mu_{n}$ <br> $(5)$ | $\mu_{-0.5}$ <br> $(6)$ | $\mu_{23.5}$ <br> $(7)$ | $R_{T}$ <br> $(8)$ |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z108108 | 0.2795 | 1.2795 | -0.6248 | 19.638 | 20.119 | 21.677 | -20.9 |
| Z108127 | 0.1554 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| Z108139 | 0.3433 | 1.4750 | -0.8510 | 20.786 | 21.023 | 22.194 | -21.4 |
| Z108154 | 0.0979 | 1.2726 | -0.7619 | 19.797 | 20.259 | 21.772 | -20.8 |
| Pegasus |  |  |  |  |  |  |  |
| I1474 | 0.3154 | 1.0544 | -0.8245 | 20.012 | 20.289 | 21.513 | -20.1 |
| I5309 | 0.3244 | 1.1494 | -0.8124 | 20.136 | 20.553 | 21.989 | -20.2 |
| N7518 | 0.1404 | 1.1338 | -0.5840 | 19.212 | 19.704 | 21.516 | -20.5 |
| N7536 | 0.3476 | 1.1853 | -0.9082 | 20.294 | 20.464 | 21.763 | -20.6 |
| N7591 | 0.2998 | 1.2507 | -0.5396 | 19.296 | 19.952 | 21.585 | -21.1 |
| N7593 | 0.1916 | 1.0514 | -0.8490 | 19.749 | 19.954 | 21.405 | -20.2 |
| N7608 | 0.5262 | 1.1695 | -0.8445 | 20.789 | 20.962 | 22.052 | -20.2 |
| N7610 | 0.2600 | 1.3397 | -0.8642 | 21.014 | 21.367 | 22.427 | -20.5 |
| N7631 | 0.4213 | 1.2652 | -0.7158 | 19.691 | 20.288 | 21.702 | -21.0 |
| N7643 | 0.2456 | 1.1977 | -0.6809 | 19.405 | 19.839 | 21.595 | -20.7 |
| U12304 | 0.6763 | 1.2145 | -1.3722 | 21.200 | 21.326 | 22.136 | -20.3 |
| U12361 | 0.5618 | 0.9042 | $\ldots$ | $\ldots$ | 22.409 | 22.965 | -18.4 |
| U12370 | 0.5583 | 0.9872 | -0.7639 | 21.202 | 21.507 | 22.365 | -19.2 |
| U12423 | 0.8353 | 1.2619 | -0.6267 | 21.083 | 21.168 | 22.333 | -20.5 |
| U12451 | 0.7163 | 1.0134 | -0.9908 | 22.608 | 22.686 | 23.136 | -19.1 |
| U12467 | 0.6047 | 0.9743 | -0.9231 | 21.981 | 22.081 | 22.877 | -19.0 |
| U12494 | 0.5023 | 1.0546 | -1.1484 | 21.375 | 21.535 | 22.636 | -19.5 |
| U12497 | 0.5346 | 1.0399 | -1.0877 | 21.545 | 21.708 | 22.615 | -19.3 |
| U12522 | 0.0792 | 0.9873 | -1.1731 | 21.420 | 21.606 | 22.692 | -19.0 |
| U12561 | 0.5268 | 0.8860 | -0.9932 | 22.052 | 22.080 | 22.795 | -18.2 |
| Z406031 | 0.4252 | 0.8567 | -0.9477 | 21.117 | 21.346 | 22.239 | -18.5 |
| Z406042 | 0.1856 | 0.9853 | -0.8988 | 20.900 | 21.313 | 22.414 | -19.0 |
| Z406079 | 0.3689 | 1.0329 | -0.9879 | 21.129 | 21.380 | 22.469 | -19.2 |
| Z406082 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| A2634/66 |  |  |  |  |  |  |  |
| U12721 | 0.3350 | 1.4620 | -0.5499 | 19.994 | 20.362 | 21.966 | -21.5 |
| Virgo |  |  |  |  |  |  |  |
| N4246 | 0.2829 | 0.9154 | -0.9648 | 20.999 | 21.160 | 22.277 | -18.8 |
| N4380 | 0.2782 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| N4651 | 0.1842 | $\ldots$ | $\ldots$ | $\ldots$ | $\cdots$ | $\cdots$ | $\ldots$ |
|  |  |  |  |  |  |  |  |

Object
(1)
$\log R$
(2)
(3)
(4)
(5)
$\mu_{-0.5}$
(6)
$\mu_{23.5} \quad \mathrm{R}_{T}$

| Object <br> (1) | $\log R$ <br> (2) | $\log D_{23.5}$ <br> (3) | $\log C$ <br> (4) | $\mu_{n}$ <br> (5) | $\mu_{-0.5}$ <br> (6) | $\mu_{23.5}$ <br> (7) | $\mathrm{R}_{T}$ <br> (8) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NGC 1209 |  |  |  |  |  |  |  |
| eso024234-1730.6 | 0.1997 | 0.8257 | -0.8859 | 21.478 | 21.976 | 22.831 | -18.1 |
| eso024524-1902.9 | 0.6812 | 0.5195 | -1.1912 | 22.767 | 22.689 | 23.140 | -17.4 |
| eso024921-1816.5 | 0.7462 | 0.7772 | -1.0493 | 22.248 | 22.305 | 22.833 | -17.6 |
| eso025754-1928.1 | 0.5927 | 0.6154 | -0.6545 | 21.175 | 21.363 | 22.409 | -17.6 |
| eso030617-1754.8 | 0.3362 | 0.7619 | -0.8409 | 20.284 | 20.502 | 21.825 | -18.5 |
| eso030719-1801.2 | 0.7061 | 0.5157 | -1.1069 | 22.802 | 22.756 | 23.125 | ... |
| eso031302-1805.9 | 0.2512 | 0.8322 | -0.5834 | 19.874 | 20.421 | 21.740 | -18.7 |
| eso031339-1816.2 | 0.2806 | 0.7783 | -0.8027 | 20.919 | 21.041 | 22.128 | -18.2 |
| Antlia |  |  |  |  |  |  |  |
| eso101025-3428.9 | 0.2944 | 1.1845 | -0.8459 | 21.482 | 21.799 | 22.663 | -19.6 |
| eso101232-3348.7 | 0.3634 | 1.0031 | -0.8441 | 20.233 | 20.394 | 21.774 | -19.6 |
| eso101908-3932.9 | 0.1114 | 1.1197 | -0.5174 | 19.197 | 20.038 | 21.780 | -19.9 |
| eso102507-3337.3 | 0.6813 | 1.0796 | -1.0415 | 21.033 | 21.263 | 22.263 | -19.4 |
| eso102621-3239.9 | 0.6038 | 0.2129 | ... | 23.117 | ... | 23.186 | -16.8 |
| eso102750-3626.2 | ... | ... | ... | ... | ... | ... |  |
| esol02936-3435.8 |  | $\ldots$ | ... | ... | ... | $\cdots$ |  |
| Hydra |  |  |  |  |  |  |  |
| esol02210-2318.0 | 0.2350 | 1.1505 | -0.6916 | 18.921 | 19.272 | 21.297 | -20.8 |
| esol03021-2716.2 | 0.4937 | 1.0566 | -1.3478 | 21.252 | 21.649 | 22.503 | -19.4 |
| eso103140-2954.7 | 0.6849 | 1.2619 | -0.7472 | 20.538 | 20.885 | 22.114 | -20.5 |
| eso103518-3211.1 | 0.8758 | 0.9929 | -0.9077 | 21.460 | 21.685 | 22.494 | -18.6 |
| eso103542-2754.7 | 0.8534 | 0.5506 | -0.8156 | 22.346 | 22.318 | 22.848 | -17.3 |
| eso103655-3002.3 | 0.7090 | 1.4259 | -0.6388 | 20.472 | 20.772 | 22.088 | -21.5 |
| eso103656-2634.7 | 0.5035 | 1.3280 | -0.6424 | 20.926 | 21.283 | 22.278 | -20.7 |
| Centaurus 30 |  |  |  |  |  |  |  |
| esol23654-4027.9 | 0.4471 | 1.1578 | -0.6079 | 19.616 | 20.228 | 21.817 | -20.3 |
| esol24127-3614.2 | 0.6690 | 0.9512 | -1.0700 | 21.164 | 21.307 | 22.295 | -19.0 |
| esol24410-4113.4 | 0.4428 | 1.1163 | -0.7185 | 19.733 | 20.101 | 21.548 | -20.4 |
| esol25004-4010.8 | 0.2981 | 1.2180 | -0.8829 | 20.206 | 20.530 | 21.722 | -20.8 |
| Centaurus 45 |  |  |  |  |  |  |  |
| esol23759-3628.0 | 0.6438 | 0.9025 | -0.9066 | 21.173 | 21.353 | 22.273 | -19.2 |
| esol24841-4322.9 | ... | ... | . | ... | . | ... | ... |
| eso124953-3845.4 | 0.2886 | 1.3550 | -0.9306 | 19.721 | 19.930 | 21.395 | -21.7 |
| eso125142-3927.5 | 0.5162 | 1.0052 | -0.9822 | 20.867 | 21.084 | 22.208 | -19.3 |
| Telescopium 27 |  |  |  |  |  |  |  |
| eso195939-4142.7 | 0.7423 | 0.6202 | -1.2698 | 22.133 | 22.173 | 22.767 | -17.4 |
| eso200202-4807.3 | 0.7146 | 0.7127 | -0.6910 | 21.698 | 21.947 | 22.666 | -17.7 |
| eso200211-4807.3 | 0.3161 | 0.9790 | -1.2002 | 21.923 | 22.133 | 22.854 | -18.8 |


| Object <br> (1) | $\log \mathrm{R}$ <br> (2) | $\log D_{23.5}$ <br> (3) | $\log C$ <br> (4) | $\begin{aligned} & \mu_{n} \\ & (5) \end{aligned}$ | $\mu_{-0.5}$ <br> (6) | $\mu_{23.5}$ <br> (7) | $\mathrm{R}_{T}$ <br> (8) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso200541-4629.8 | 0.5555 | 0.8118 | -0.6428 | 20.453 | 20.733 | 22.040 | -18.7 |
| eso200735-4825.5 | 0.6949 | 0.9863 | -1.1492 | 22.456 | 22.634 | 23.059 | -18.5 |
| eso200823-4617.6 | 0.6991 | 1.2796 | -0.8571 | 21.104 | 21.461 | 22.406 | -20.0 |
| eso200826-4710.4 | 0.7164 | 0.8512 | -0.7435 | 20.898 | 21.178 | 22.219 | -18.4 |
| eso201039-4858.8 | 0.1894 | 0.8047 | -0.9731 | 21.463 | 21.516 | 22.684 | -18.3 |
| eso201301-4333.6 | 0.4608 | 0.7471 | -0.9737 | 21.104 | 21.253 | 22.315 | -18.1 |
| eso201352-4440.3 | 0.3923 | 0.9124 | -1.2593 | 21.117 | 21.255 | 22.393 | -18.4 |
| eso201442-4821.8 | 0.5688 | 0.8330 | -1.0428 | 21.889 | 22.007 | 22.698 | -18.2 |
| eso201527-4514.2 | 0.6496 | 0.8968 | -0.8646 | 21.495 | 21.678 | 22.550 | -18.5 |
| eso201730-4926.4 | 0.7073 | 0.8948 | -0.6443 | 21.097 | 21.349 | 22.327 | -18.6 |
| eso202031-4409.5 | 0.3932 | 1.3208 | -0.5384 | 18.853 | 19.520 | 21.423 | -21.5 |
| eso202423-4929.9 | 0.8570 | 0.6867 | -0.9209 | 22.299 | 22.405 | 22.948 | -17.0 |
| Telescopium 56 |  |  |  |  |  |  |  |
| esol95443-4614.9 | 0.3464 | 1.3349 | -0.7883 | 20.390 | 20.562 | 21.879 | -19.8 |
| eso200559-4928.7 | 0.6217 | 1.3126 | -0.4472 | 19.731 | 20.364 | 21.656 | -19.8 |
| eso201006-4458.1 | 0.3743 | 1.4732 | -0.8205 | 20.901 | 21.170 | 22.185 | -20.1 |
| eso201024-4440.7 | 0.0915 | 1.4461 | -0.8599 | 19.997 | 20.359 | 21.660 | -20.5 |
| eso201302-4451.8 | 0.3737 | 1.3026 | -0.9930 | 20.507 | 20.902 | 22.092 | -19.3 |
| Pavo |  |  |  |  |  |  |  |
| eso191452-7219.1 | 0.0677 | 0.8899 | -0.8943 | 20.108 | 20.721 | 22.113 | -18.7 |
| eso192513-7110.4 | 0.4511 | 0.7889 | -0.9764 | 20.617 | 20.822 | 21.928 | -18.5 |
| esol95254-7035.3 | 0.5208 | 0.9711 | -0.7277 | 20.671 | 21.174 | 22.290 | -18.9 |
| eso200710-6722.7 | 0.3160 | 0.8777 | - 0.8615 | 20.804 | 21.270 | 22.356 | -18.4 |
| eso201001-7251.8 | 0.1420 | 0.6295 | -1.1175 | 19.958 | 20.234 | 21.485 | -18.0 |
| eso201125-7117.0 | 0.6350 | 0.7144 | -0.9634 | 22.179 | 22.252 | 22.815 | -17.5 |
| eso201137-7402.4 | 0.3178 | 1.0361 | -0.8302 | 20.945 | 21.312 | 22.334 | -19.3 |
| eso201810-7143.5 | 0.9429 | 1.2404 | -0.7571 | 21.551 | 21.853 | 22.577 | -19.3 |
| eso202552-6615.9 | 0.3119 | 0.7889 | -0.5171 | 19.748 | 20.454 | 21.657 | -18.6 |
| eso204014-7134.7 | 0.3833 | 0.9818 | -0.5051 | 19.487 | 19.981 | 21.601 | -19.7 |
| Indus |  |  |  |  |  |  |  |
| eso205906-4341.3 | 0.5824 | 1.1421 | -0.6357 | 20.172 | 20.670 | 21.993 | -20.1 |
| eso210003-4308.6 | 0.5625 | 0.9348 | -0.6585 | 20.742 | 21.148 | 22.177 | -18.9 |
| eso210053-4506.0 | 0.8470 | 1.2686 | -0.6559 | 21.654 | 21.937 | 22.612 | -19.6 |
| eso210101-4826.3 | 0.1924 | 1.1407 | -0.6617 | 19.465 | 19.983 | 21.701 | -20.4 |
| eso210145-4759.3 | 0.6034 | 1.3894 | -0.8491 | 20.666 | 20.973 | 22.069 | -21.3 |
| eso210256-4822.2 | ... | ... |  | ... | $\ldots$ | ... |  |
| eso210500-4407.1 | 0.1969 | 1.1863 | -0.8905 | 20.711 | 21.052 | 22.236 | -20.2 |
| eso210616-4736.6 | 0.2600 | 1.0603 | -1.0887 | 21.050 | 21.247 | 22.262 | -19.4 |
| eso210740-4354.9 | 0.6179 | 1.2493 | -0.4651 | 19.830 | 20.346 | 21.700 | -20.8 |
| eso210802-4243.7 | 0.1157 | 0.9189 | -0.9188 | 20.509 | 20.730 | 22.097 | -19.0 |
| eso212713-4325.3 | 0.0743 | 1.0385 | -0.9904 | 20.711 | 20.967 | 22.112 | -19.4 |

Object
$\log R \quad \log D_{23.5} \quad \log C$
$\mu_{n}$
$\begin{array}{lll}\mu_{-0.5} & \mu_{23.5} \quad R_{T}\end{array}$
(1)
(2) (3)
(4)
(5)
(6)
(7)
(8)

| Miscellaneous |  |  |  |  |  |  |  |
| :--- | :---: | :--- | :--- | :--- | :--- | :--- | :--- |
| I701 | 0.1465 | $\ldots$ |  |  |  |  |  |
| I900 | 0.1741 | 1.4615 | -1.0153 | 19.965 | 20.293 | 21.648 | $\ldots$ |
| I1401 | 0.4246 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| N173 | 0.1254 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| N4449 | 0.1873 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| N4475 | 0.2454 | 1.5047 | -0.7047 | 20.618 | 21.002 | 22.298 | $\ldots$ |
| N4738 | 0.8020 | 1.3751 | -0.6916 | 20.597 | 20.753 | 21.931 | $\ldots$ |
| N7537 | 0.5569 | 1.0875 | -0.6080 | 19.808 | 20.274 | 21.689 | $\ldots$ |
| N7541 | 0.4661 | 1.3720 | $\ldots$ | 19.717 | 20.141 | $\ldots$ | $\ldots$ |
| N7570 | 0.2467 | 1.2806 | -0.4131 | 19.455 | 20.007 | 21.702 | $\ldots$ |
| N7750 | 0.2922 | 1.2449 | -0.8719 | 20.132 | 20.371 | 21.569 | $\ldots$ |
| N7757 | 0.1509 | 1.2413 | -0.9245 | 20.717 | 21.082 | 22.179 | $\ldots$ |
| U673 | 0.4324 | 1.1656 | -0.9701 | 21.182 | 21.388 | 22.361 | $\ldots$ |
| U1045 | 0.5268 | 1.2985 | -0.6771 | 20.503 | 20.904 | 22.148 | $\ldots$ |
| U2509 | 0.5220 | 1.2246 | -0.8852 | 20.082 | 20.461 | 21.657 | $\ldots$ |
| U4375 | 0.1740 | 1.1430 | -0.8836 | 20.098 | 20.582 | 21.891 | $\ldots$ |
| U4404 | 0.5739 | 1.3596 | -0.9099 | 20.887 | 21.087 | 22.071 | $\ldots$ |
| U4414 | 0.0502 | 1.4689 | -0.4581 | 18.642 | 19.395 | 21.690 | $\ldots$ |
| U6586 | 0.1328 | 1.1170 | -0.9210 | 20.443 | 20.672 | 21.898 | $\ldots$ |
| U7754 | 0.4167 | 1.1251 | -0.7908 | 20.726 | 20.919 | 22.017 | $\ldots$ |
| U9558 | 0.2250 | 1.6042 | -0.9173 | 20.816 | 21.179 | 22.151 | $\ldots$ |
| U12571 | 0.2905 | 1.0191 | -0.8956 | 20.670 | 20.765 | 22.011 | $\ldots$ |
| Z160139 | 0.2394 | 1.1082 | -1.2725 | 20.880 | 21.123 | 22.441 | $\ldots$ |
| Z501035 | 0.4240 | 1.1970 | -0.9888 | 20.900 | 21.125 | 22.135 | $\ldots$ |
| eso025101-1748.3 | 0.2115 | 1.4141 | -0.4765 | 19.819 | 19.946 | 21.604 | $\ldots$ |
| eso102742-3458.0 | 0.3857 | 1.0833 | -0.3868 | 19.340 | 20.114 | 21.618 | $\ldots$ |
| eso191041-6629.7 | 0.7575 | $\ldots$ | -1.1408 | 22.932 | 23.008 | 23.158 | $\ldots$ |
| eso201327-4755.6 | 0.1208 | 1.3403 | -0.8152 | 20.230 | 20.616 | 21.953 | $\ldots$ |
| eso212837-4616.8 | 0.2273 | 1.5013 | -0.5189 | 19.501 | 20.091 | 21.661 | $\ldots$ |

Table A. 4
R-band Isophotal Magnitudes

| Object <br> (1) | $\mathrm{R}_{20.5}$ <br> (2) | $R_{21}$ <br> (3) | $\mathrm{R}_{21.5}$ <br> (4) | $\mathrm{R}_{22}$ <br> (5) | $\mathrm{R}_{22.5}$ <br> (6) | $\mathrm{R}_{23}$ <br> (7) | $\mathbf{R}_{23.5}$ <br> (8) | $\mathbf{R}_{24.5}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Pisces |  |  |  |  |  |  |  |  |
| N296 | ... |  | -17.263 | -18.043 | -18.564 | -19.028 | -19.516 | -19.925 |
| N338 | -21.099 | -21.341 | -21.514 | -21.653 | -21.750 | -21.822 | -21.879 | -21.980 |
| N444 |  |  | -17.523 | -18.501 | -19.423 | -19.835 | -20.119 | -20.298 |
| N452 | -20.634 | -21.015 | -21.304 | -21.446 | -21.531 | -21.600 | -21.702 | -21.864 |
| N523 |  |  |  |  |  |  |  |  |
| N536 | -20.979 | -21.337 | -21.701 | -21.913 | -22.007 | -22.076 | -22.150 | -22.331 |
| N582 | -19.644 | -20.550 | -20.858 | -21.053 | -21.307 | -21.420 | -21.490 | -21.564 |
| U525 | -15.847 | -16.855 | -17.386 | -17.746 | -18.121 | -18.899 | -19.722 | -20.137 |
| U540 | ... |  |  |  |  |  |  |  |
| U542 | -20.060 | -20.323 | -20.516 | -20.691 | -20.834 | -20.951 | -21.049 | -21.154 |
| U556 | -19.126 | -19.589 | -19.845 | -19.999 | -20.124 | -20.231 | -20.300 | -20.405 |
| U557 | ... | -16.783 | -18.114 | -18.907 | -19.312 | -19.626 | -19.744 | -19.847 |
| U633 | -18.947 | -19.425 | -19.771 | -20.106 | -20.298 | -20.424 | -20.525 | -20.616 |
| U679 | ... | ... | ... | ... | -15.244 | -16.713 | -17.720 | -18.447 |
| U987 | -20.583 | -20.823 | -20.980 | -21.106 | -21.211 | -21.300 | -21.374 | -21.460 |
| U1033 | -19.078 | -20.063 | -20.260 | -20.501 | -20.730 | -20.853 | -20.939 | -21.060 |
| A400 |  |  |  |  |  |  |  |  |
| U2367 | -20.850 | -21.251 | -21.592 | -21.833 | -22.086 | -22.231 | -22.342 | -22.444 |
| U2375 | -20.442 | -20.629 | -20.811 | -21.079 | -21.268 | -21.368 | -21.431 | -21.510 |
| U2399 | -18.935 | -19.856 | -20.437 | -20.772 | -20.995 | -21.107 | -21.184 | -21.298 |
| U2405 | -19.115 | -19.891 | -20.607 | -20.998 | -21.248 | -21.416 | -21.498 | -21.586 |
| U2415 | -17.807 | -20.236 | -20.473 | -20.624 | -20.728 | -20.832 | -20.887 | -20.984 |
| U2444 | -20.511 | -20.846 | -21.043 | -21.169 | -21.256 | -21.325 | -21.394 | -21.461 |
| U2454 | ... | -17.993 | -19.315 | -19.890 | -20.222 | -20.519 | -20.685 | -20.799 |
| A539 |  |  |  |  |  |  |  |  |
| D11 | -18.104 | -19.131 | -19.783 | -20.072 | -20.316 | -20.464 |  |  |
| U3236 | -20.111 | -20.761 | -21.107 | -21.341 | -21.531 | -21.624 | -21.698 |  |
| U3248 | -21.042 | -21.285 | -21.589 | -21.934 | -22.103 | -22.334 | -22.419 | -22.512 |
| U3269 | -20.638 | -21.150 | -21.372 | -21.513 | -21.596 | -21.642 | -21.672 | -21.704 |
| U3282 | -19.769 | -20.354 | -21.056 | -21.472 | -21.604 | -21.684 | -21.778 | -21.854 |
| U3291 | ... | -18.131 | -19.481 | -20.253 | -20.674 | -20.905 | -21.008 | -21.093 |
| Z421011 | -20.421 | -20.908 | -21.202 | -21.379 | -21.467 | -21.540 | -21.590 | -21.659 |
| Z421030 | -20.187 | -20.621 | -21.078 | -21.267 | -21.345 | -21.396 | -21.445 | -21.542 |

Object $R_{20.5}$
$\mathrm{R}_{21} \quad \mathrm{R}_{21.5}$
$\mathrm{R}_{22} \quad \mathrm{R}_{22.5}$
$\mathrm{R}_{23} \quad \mathrm{R}_{23.5}$
$\mathbf{R}_{24.5}$
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)

| Cancer |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 12308 | -18.674 | -18.999 | -19.268 | -19.398 | -19.483 | -19.561 | -19.621 | -19.695 |
| 12348 | -18.693 | -18.891 | -19.041 | -19.202 | -19.554 | -19.641 | -19.682 | -19.740 |
| N2554 | -22.043 | -22.226 | -22.395 | -22.506 | -22.613 | -22.689 | -22.752 | -22.839 |
| N2558 | -20.583 | -20.757 | -21.061 | -21.367 | -21.517 | -21.577 | -21.635 | -21.721 |
| N2562 | -20.846 | -20.957 | -21.046 | -21.129 | -21.193 | -21.245 | -21.291 | -21.353 |
| N2565 | -21.715 | -21.812 | -21.910 | -22.078 | -22.267 | -22.309 | -22.335 | -22.365 |
| N2575 | -19.059 | -20.057 | -20.929 | -21.245 | -21.413 | -21.532 | -21.613 | -21.699 |
| N2595 | -20.348 | -20.583 | -21.273 | -21.813 | -22.143 | -22.300 |  |  |
| N2596 | -19.406 | -19.997 | -20.620 | -20.991 | -21.195 | -21.263 | -21.301 | -21.348 |
| N2599 | -21.646 | -21.792 | -21.903 | -21.989 | -22.159 | -22.229 | -22.271 | -22.359 |
| U4299 | -19.059 | -19.563 | -20.029 | -20.529 | -20.808 | -20.960 | -21.045 | -21.162 |
| U4329 | -18.585 | -19.376 | -19.984 | -20.327 | -20.531 | -20.730 | -20.853 | -20.970 |
| U4332 | -19.396 | -19.774 | -20.089 | -20.398 | -20.605 | -20.744 | -20.832 | -20.949 |
| U4361 | ... | ... | -16.869 | -17.860 | -18.504 | -19.061 | -19.305 | -19.544 |
| U4386 | -20.570 | -20.923 | -21.358 | -21.588 | -21.725 | -21.817 | -21.875 | -21.949 |
| U4399 | -15.959 | -17.919 | -18.821 | -19.263 | -19.535 | -19.812 | -19.926 | -20.017 |
| U4400 | ... | ... | -15.830 | -17.290 | -17.948 | -18.328 | -18.654 | -18.921 |
| U4416 | -19.760 | -20.316 | -20.704 | -20.993 | -21.294 | -21.533 | -21.628 | -21.698 |
| Z119051 |  | -17.045 | -17.801 | -18.362 | -18.873 | -19.187 | -19.317 | -19.396 |
| Z119053 | -18.500 | -18.892 | -19.120 | -19.281 | -19.410 | -19.482 | -19.525 | -19.575 |
| Z119066 | -19.555 | -19.917 | -20.088 | -20.225 | -20.327 | -20.391 | -20.449 | -20.517 |
| Z119095 | -16.829 | -18.057 | -18.543 | -18.911 | -19.195 | -19.343 | -19.446 | -19.579 |
| Z119107 |  | -16.932 | -18.389 | -19.016 | -19.325 | -19.473 | -19.561 |  |
| A1367 |  |  |  |  |  |  |  |  |
| 12951 | -20.201 | -20.419 | -20.663 | -21.065 | -21.305 | -21.427 | -21.538 | -21.641 |
| MK181 |  |  |  |  |  |  |  |  |
| N3697 | -20.461 | -20.802 | -21.103 | -21.516 | -21.898 | -22.062 | -22.154 | -22.256 |
| N3816 | -21.694 | -21.891 | -22.066 | -22.209 | -22.349 | -22.448 |  |  |
| N3832 | -17.841 | -18.608 | -20.190 | -20.960 | -21.296 | -21.488 | -21.616 | -21.747 |
| N3840 | ... | ... | ... | ... | ... | ... | ... | ... |
| N3859 |  |  |  |  | .. |  |  |  |
| N3860 | -20.451 | -20.866 | -21.111 | -21.289 | -21.394 | -21.483 | -21.549 | -21.620 |
| N3861 |  |  |  |  |  |  |  |  |
| N3883 | -20.367 | -20.647 | -20.955 | -21.283 | -21.740 | -22.074 | -22.269 | -22.428 |
| N3947 | ... | ... | ... | ... | ... | ... |  |  |
| N3951 | -20.630 | -21.020 | -21.226 | -21.338 | -21.418 | -21.478 | -21.518 | -21.566 |
| U6614 | -20.548 | -20.676 | -20.782 | -20.867 | -20.950 | -21.271 | -21.381 | -21.484 |
| U6686 | -16.952 | -19.039 | -19.762 | -20.190 | -20.535 | -20.787 | -20.969 | -21.253 |
| U6697 | ... | -17.141 | -20.100 | -20.593 | -20.848 | -21.057 | -21.166 | -21.304 |
| U6876 | -19.818 | -20.231 | -20.578 | -20.835 | -21.056 | -21.140 | -21.181 | -21.231 |
| U6891 | -18.002 | -19.162 | -19.626 | -19.908 | -20.096 | -20.242 | -20.569 | -20.756 |
| Z97033 | -19.279 | -19.754 | -20.111 | -20.310 | -20.428 | -20.498 | -20.547 | -20.596 |
| Z97057 | -19.323 | -20.100 | -20.326 | -20.468 | -20.551 | -20.613 | -20.660 | -20.706 |


| Object <br> (1) | $\mathbf{R}_{20.5}$ <br> (2) | $\mathbf{R}_{21}$ <br> (3) | $\mathrm{R}_{21.5}$ <br> (4) | $\mathrm{R}_{22}$ <br> (5) | $\mathbf{R}_{22.5}$ <br> (6) | $\mathrm{R}_{23}$ <br> (7) | $\mathbf{R}_{23.5}$ <br> (8) | $\mathrm{R}_{24.5}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z97068 | ... | ... | ... | ... | . | ... | ... | ... |
| Z97079 |  | -17.661 | -18.505 | -18.831 | -19.069 | -19.195 | -19.305 | -19.429 |
| Z97152 | -19.384 | -19.696 | -20.012 | -20.328 | -20.532 | -20.650 | -20.731 | -20.811 |
| Z97185 |  | -17.907 | -19.047 | -19.625 | -19.876 | -20.077 | -20.183 | -20.300 |
| Z127056 | -18.900 | -19.754 | -20.171 | -20.434 | -20.552 | -20.617 | -20.665 | -20.721 |
| Z127082 | -19.150 | -19.957 | -20.418 | -20.642 | -20.755 | -20.825 | -20.868 | -20.920 |
| Coma |  |  |  |  |  |  |  |  |
| 1842 | ... | $\ldots$ | ... | ... | ... | ... | ... | ... |
| I4088 | -19.621 | -20.144 | -20.544 | -20.944 | -21.235 | -21.456 | -21.550 | -21.630 |
| N4848 | -20.396 | -21.091 | -21.304 | -21.427 | -21.508 | -21.577 | -21.632 | -21.733 |
| N4921 | -20.979 | -21.257 | -21.654 | -22.225 | -22.512 | -22.648 | -22.713 | -22.784 |
| N4934 | -20.235 | -20.637 | -20.868 | -21.009 | -21.096 | -21.160 | -21.210 | -21.272 |
| N4944 | ... | ... | ... | ... |  |  | ... | ... |
| N5081 | -20.102 | -20.427 | -21.036 | -21.324 | -21.782 | -21.991 | -22.151 | $\ldots$ |
| U8013 |  | -18.390 | -18.821 | -19.271 | -19.707 | -20.055 | -20.297 | -20.545 |
| U8017 | -20.642 | -21.109 | -21.292 | -21.390 | -21.458 | -21.504 | -21.534 | -21.586 |
| U8161 | -19.938 | -20.229 | -20.448 | -20.635 | -20.785 | -20.941 | -21.026 | -21.105 |
| Z160058 |  | -18.814 | -19.525 | -20.023 | -20.407 | -20.537 | -20.615 | -20.704 |
| Z160086 | ... | ... | ... | ... | ... | ... | ... | ... |
| Z160106 | -19.689 | -19.874 | -20.028 | -20.188 | -20.323 | $-20.403$ | -20.454 | -20.522 |
| Z74-23 |  |  |  |  |  |  |  |  |
| N5409 |  |  |  |  |  |  |  |  |
| N5416 | -20.404 | -20.975 | -21.228 | -21.403 | -21.498 | -21.581 | -21.629 | -21.674 |
| U8918 | ... | ... | ... | ... | ... | ... | ... | ... |
| U8948 | ... | ... | ... | $\ldots$ | ... | ... | ... | ... |
| U8951 |  |  | ... | . | . | . | ... | ... |
| U8967 | -18.472 | -19.136 | -19.701 | -20.209 | -20.508 | -20.776 | -20.920 | -21.072 |
| Z74010 | ... | ... | ... | -16.722 | -17.714 | -18.367 | -19.001 | -19.532 |
| 274045 |  | ... | ... | ... | ... | ... | ... | ... |
| Hercules |  |  |  |  |  |  |  |  |
| 11173 | -19.166 | -19.736 | -20.261 | -20.632 | -20.853 | -21.004 | -21.122 | -21.245 |
| 11179 | -18.229 | -19.057 | -19.552 | -20.107 | -20.595 | -20.879 | -21.024 | -21.182 |
| I1182 | -20.938 | -21.117 | -21.280 | -21.439 | -21.544 | -21.654 | -21.719 | ... |
| N6045 | ... | ... | ... | ... | ... | ... | ... | ... |
| N6050 | .. | $\ldots$ | ... | ... | ... | ... | ... | $\ldots$ |
| N6054 | ... | . | ... | . | . | $\cdots$ | $\cdots$ | ... |
| U10085 | -20.259 | -20.699 | -21.059 | -21.320 | -21.469 | -21.594 | -21.673 | -21.738 |
| U10121 | -21.226 | -21.535 | -21.770 | -21.917 | -22.011 | -22.072 | -22.112 | -22.165 |
| U10190 | .. | ... | ... | -18.201 | -18.947 | -19.376 | -19.600 | -19.816 |
| U10195 | -20.147 | -20.548 | -20.863 | -21.115 | -21.268 | -21.388 | -21.587 | -21.761 |
| Z108098 | ... | ... | $\cdots$ | $\cdots$ | ... | $\cdots$ | $\cdots$ | 20.800 |
| Z108107 | ... | -19.578 | -20.083 | -20.348 | -20.508 | -20.610 | -20.684 | -20.800 |


| Object | $\mathrm{R}_{20.5}$ | $\mathrm{R}_{21}$ | $\mathrm{R}_{21.5}$ | $\mathrm{R}_{22}$ | $\mathrm{R}_{22.5}$ | $\mathrm{R}_{23}$ | $\mathrm{R}_{23.5}$ | $\mathrm{R}_{24.5}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (1) | $(2)$ | $(3)$ | $(4)$ | $(5)$ | $(6)$ | $(7)$ | $(8)$ | $(9)$ |


| Z108108 | -20.030 | -20.035 | -20.350 | -20.533 | -20.660 | -20.769 | -20.835 | -20.936 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z108127 | ... |  |  |  |  |  |  |  |
| Z108139 | -18.396 | -19.029 | -20.059 | -20.650 | -20.983 | -21.195 | -21.307 | -21.428 |
| Z108154 | -19.493 | -19.887 | -20.167 | -20.356 | -20.507 | -20.622 | -20.702 | -20.764 |
| Pegasus |  |  |  |  |  |  |  |  |
| I1474 | -18.471 | -19.397 | -19.686 | -19.826 | -19.912 | -19.982 | -20.024 | -20.077 |
| 15309 | -18.372 | -18.835 | -19.180 | -19.549 | -19.786 | -19.931 | -20.035 | -20.168 |
| N7518 | -19.357 | -19.801 | -20.086 | -20.194 | -20.269 | -20.337 | -20.411 | -20.527 |
| N7536 | -17.993 | -19.162 | -19.793 | -20.125 | -20.254 | -20.335 | -20.387 | -20.454 |
| N7591 | -20.038 | -20.243 | -20.402 | -20.615 | -20.820 | -20.892 | -20.944 | -21.050 |
| N7593 | -18.993 | -19.609 | -19.819 | -19.935 | -20.012 | -20.082 | -20.117 | -20.157 |
| N7608 | -15.743 | -17.980 | -19.027 | -19.509 | -19.747 | -19.904 | -19.996 | -20.100 |
| N7610 | -16.664 | -17.531 | -18.467 | -19.303 | -19.803 | -20.013 | -20.309 | -20.497 |
| N7631 | -19.539 | -20.032 | -20.330 | -20.562 | -20.705 | -20.821 | -20.875 | -20.936 |
| N7643 | -19.611 | -20.071 | -20.246 | -20.378 | -20.515 | -20.605 | -20.662 | -20.708 |
| U12304 | ... | ... | -18.723 | -19.554 | -19.813 | -19.952 | -20.053 | -20.173 |
| U12361 | $\ldots$ | ... | ... | ... | ... | -17.229 | -17.820 | -18.200 |
| U12370 | ... | -16.414 | -17.296 | -17.809 | -18.527 | -18.778 | -18.923 | -19.108 |
| U12423 | -17.518 | -18.207 | -18.804 | -19.237 | -19.618 | -19.903 | -20.089 | -20.397 |
| U12451 |  | ... | ... |  |  | -16.581 | -17.878 | -18.730 |
| U12467 | $\ldots$ | $\ldots$ | ... | -16.035 | -17.058 | -17.787 | -18.320 | -18.909 |
| U12494 | ... | ... | -16.275 | -17.492 | -18.161 | -18.584 | -18.910 | -19.268 |
| U12497 | $\cdots$ | ... | -16.275 | -17.132 | -18.121 | -18.550 | -18.827 | -19.111 |
| U12522 | ... | -12.655 | -15.844 | -16.743 | -17.522 | -18.217 | -18.546 | -18.966 |
| U12561 | $\ldots$ | ... | ... | -15.420 | -16.863 | -17.547 | -17.926 | -18.597 |
| Z406031 | ... | -14.708 | -16.826 | -17.518 | -18.029 | -18.210 | -18.322 | -18.429 |
| Z406042 | ... | -16.220 | -16.924 | -17.575 | -18.147 | -18.593 | -18.756 | -18.911 |
| Z406079 |  | -14.255 | -17.281 | -17.830 | -18.202 | -18.756 | -18.936 | -19.115 |
| Z406082 |  |  | ... | ... | ... | ... | ... | ... |
| A2634/66 |  |  |  |  |  |  |  |  |
| U12721 | -19.901 | -20.424 | -20.684 | -20.904 | -21.051 | -21.204 | -21.334 | -21.440 |
| Virgo |  |  |  |  |  |  |  |  |
| N4246 | -14.452 | -15.603 | -17.037 | -17.868 | -18.202 | -18.442 | -18.581 | -18.735 |
| N4380 | ... | ... | ... | ... | ... | ... | . | ... |
| N4651 | ... | $\cdots$ | $\ldots$ |  |  |  | ... |  |


| Object | $\mathrm{R}_{20.5}$ | $\mathrm{R}_{21}$ | $\mathrm{R}_{21.5}$ | $\mathrm{R}_{22}$ | $\mathrm{R}_{22.5}$ | $\mathrm{R}_{23}$ | $\mathrm{R}_{23.5}$ | $\mathrm{R}_{24.5}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ | $(6)$ | $(7)$ | $(8)$ | $(9)$ |


| NGC 1209 |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso024234-1730.6 |  | -13.349 | -14.691 | -15.491 | -16.088 | -16.661 | -17.305 | -17.856 |
| eso024524-1902.9 |  |  |  |  | -11.320 | -14.920 | -16.048 | -16.972 |
| eso024921-1816.5 |  |  |  |  | -15.620 | -16.685 | -17.088 | -17.413 |
| eso025754-1928.1 |  | -15.166 | -15.756 | -16.241 | -16.560 | -16.833 | -17.092 | -17.353 |
| eso030617-1754.8 | -16.223 | -17.173 | -17.631 | -17.998 | -18.160 | -18.281 | -18.343 | -18.456 |
| eso030719-1801.2 |  |  |  |  |  | -14.346 | -15.993 | -16.888 |
| eso031302-1805.9 | -17.334 | -17.726 | -18.061 | -18.274 | -18.427 | -18.546 | -18.607 | -18.689 |
| eso031339-1816.2 | -14.832 | -15.882 | -16.709 | -17.408 | -17.705 | -17.890 | -17.999 | -18.120 |
| Antlia |  |  |  |  |  |  |  |  |
| esol01025-3428.9 |  | -15.122 | -16.680 | -17.750 | -18.690 | -19.048 | -19.408 | -19.570 |
| esol01232-3348.7 | -17.860 | -18.682 | -18.945 | -19.172 | -19.330 | -19.439 | -19.508 | -19.619 |
| esol01908-3932.9 | -18.916 | -19.109 | -19.311 | -19.455 | -19.598 | -19.737 | -19.847 | -19.928 |
| esol02507-3337.3 |  | -15.652 | -17.360 | -18.355 | -18.882 | -19.064 | -19.166 | -19.297 |
| esol02621-3239.9 |  |  |  |  | ... | ... | -14.788 | -16.202 |
| eso102750-3626.2 |  |  |  |  |  |  |  |  |
| esol02936-3435.8 |  |  |  |  |  |  |  |  |
| Hydra |  |  |  |  |  |  |  |  |
| esol02210-2318.0 | -20.021 | -20.197 | -20.349 | -20.512 | -20.604 | -20.665 | -20.698 | -20.737 |
| esol03021-2716.2 |  |  | -16.410 | -17.491 | -18.453 | -18.801 | -19.003 | -19.183 |
| esol03140-2954.7 | -17.725 | -18.491 | -19.073 | -19.580 | -19.934 | -20.101 | -20.208 | -20.333 |
| esol03518-3211.1 |  |  | -15.777 | -16.970 | -17.806 | -18.147 | -18.344 | -18.535 |
| eso103542-2754.7 |  |  |  |  | -14.708 | -15.727 | -16.219 | -16.862 |
| esol03655-3002.3 | -19.337 | -19.949 | -20.469 | -20.803 | -21.075 | -21.235 | -21.367 | -21.491 |
| eso103656-2634.7 | -17.895 | -18.698 | -19.375 | -19.918 | -20.205 | -20.443 | -20.618 | -20.735 |
| Centaurus 30 |  |  |  |  |  |  |  |  |
| eso123654-4027.9 | -19.090 | -19.379 | -19.618 | -19.829 | -19.988 | -20.106 | -20.201 | -20.291 |
| esol24127-3614.2 |  | -13.697 | -17.103 | -17.990 | -18.334 | -18.585 | -18.728 | -18.899 |
| eso124410-4113.4 | -19.088 | -19.542 | -19.886 | -20.079 | -20.187 | -20.257 | -20.305 | -20.359 |
| esol25004-4010.8 | -18.042 | -19.713 | -20.176 | -20.395 | -20.495 | -20.578 | -20.648 | -20.745 |
| Centaurus 45 |  |  |  |  |  |  |  |  |
| $\begin{aligned} & \text { eso123759-3628.0 } \\ & \text { esol24841-4322.9 } \end{aligned}$ |  | -15.152 | -17.062 | -17.972 | -18.298 | -18.514 | -18.656 | -18.844 |
| eso124953-3845.4 | -20.664 | -21.050 | -21.283 | -21.405 | -21.472 | -21.523 | -21.576 | -21.639 |
| eso125142-3927.5 |  | -16.788 | -17.864 | -18.413 | -18.687 | -18.869 | -19.010 | -19.140 |
| Telescopium 27 |  |  |  |  |  |  |  |  |
| eso195939-4142.7 | $\ldots$ | $\ldots$ |  | -13.487 | -15.478 | -16.345 | -16.659 | -17.117 |
| eso200202-4807.3 | $\ldots$ | $\ldots$ | -14.757 | -15.865 | -16.397 | -16.792 | -17.186 | -17.477 |
| eso200211-4807.3 | ... | ... | ... | -15.224 | -16.625 | -17.889 | -18.301 | -18.652 |


| Object <br> (1) | $\mathbf{R}_{20.5}$ <br> (2) | $\mathrm{R}_{21}$ <br> (3) | $\mathbf{R}_{21.5}$ <br> (4) | $\mathbf{R}_{22}$ <br> (5) | $\mathbf{R}_{22.5}$ <br> (6) | $\mathbf{R}_{2 \mathrm{~s}}$ <br> (7) | $\mathbf{R}_{23.5}$ <br> (8) | $\mathbf{R}_{24.5}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso200541-4629.8 | -16.619 | -17.210 | -17.614 | -17.859 | -18.090 | -18.269 | -18.385 | -18.594 |
| eso200735-4825.5 |  |  |  |  | -15.348 | -16.819 | -17.805 | -18.278 |
| eso200823-4617.6 |  | -16.805 | -18.290 | -19.288 | -19.835 | -20.035 | -20.244 |  |
| eso200826-4710.4 | -13.665 | -16.016 | -16.890 | -17.454 | -17.826 | -18.048 | -18.166 | -18.277 |
| eso201039-4858.8 | -12.959 | -14.729 | -15.497 | -16.050 | -16.636 | -17.261 | -17.735 | -18.163 |
| eso201301-4333.6 |  | -14.611 | -16.234 | -17.000 | -17.386 | -17.589 | -17.767 | -17.951 |
| eso201352-4440.3 |  | -13.782 | -16.405 | -17.408 | -17.958 | -18.286 | -18.434 | -18.539 |
| eso201442-4821.8 |  |  |  | -15.127 | -16.808 | -17.335 | -17.623 | -17.918 |
| eso201527-4514.2 |  |  | -15.385 | -16.811 | -17.518 | -17.854 | -18.110 | -18.316 |
| eso201730-4926.4 | -14.044 | -15.991 | -16.771 | -17.495 | -17.867 | -18.097 | -18.276 | -18.445 |
| eso202031-4409.5 | -20.738 | -20.924 | -21.111 | -21.256 | -21.353 | -21.426 | -21.478 |  |
| eso202423-4929.9 |  |  |  |  | -14.650 | -15.631 | -16.279 | -16.716 |
| Telescopium 56 |  |  |  |  |  |  |  |  |
| esol95443-4614.9 | -18.872 | -19.679 | -20.375 | -20.693 | -20.888 | -20.996 | -21.070 | -21.231 |
| eso200559-4928.7 | -20.175 | -20.413 | -20.611 | -20.768 | -20.958 | -21.057 | -21.116 | -21.186 |
| eso201006-4458.1 | -17.803 | -18.779 | -19.757 | -20.746 | -21.105 | -21.304 | -21.400 | -21.502 |
| eso201024-4440.7 | -19.831 | -20.740 | -21.333 | -21.541 | -21.678 | -21.766 | -21.807 | -21.930 |
| eso201302-4451.8 | -17.445 | -18.878 | -19.690 | -20.117 | -20.363 | -20.539 | -20.648 | -20.720 |
| Pavo |  |  |  |  |  |  |  |  |
| eso191452-7219.1 | -16.247 | -16.798 | -17.420 | -17.957 | -18.298 | -18.501 | -18.594 | -18.673 |
| eso192513-7110.4 | -13.447 | -16.724 | -17.482 | -17.811 | -18.034 | -18.153 | -18.233 | -18.338 |
| eso195254-7035.3 | -15.857 | -16.857 | -17.588 | -18.074 | -18.386 | -18.688 | -18.841 |  |
| eso200710-6722.7 | -14.403 | -15.822 | -16.815 | -17.388 | -17.874 | -18.116 | -18.303 |  |
| eso201001-7251.8 | -16.773 | -17.360 | -17.588 | -17.719 | -17.810 | -17.881 | -17.922 | -17.993 |
| eso201125-7117.0 |  |  |  |  | -15.695 | -16.549 | -16.925 | -17.246 |
| eso201137-7402.4 | -15.793 | -16.770 | -17.684 | -18.193 | -18.600 | -18.872 | -19.050 | -19.199 |
| eso201810-7143.5 |  | -13.282 | -16.098 | -17.801 | -18.530 | -18.901 | -19.173 |  |
| eso202552-6615.9 | -17.274 | -17.543 | -17.979 | -18.203 | -18.353 | -18.440 | -18.497 | -18.578 |
| eso204014-7134.7 | -18.523 | -18.863 | -19.114 | -19.260 | -19.366 | -19.460 | -19.531 | -19.615 |
| Indus |  |  |  |  |  |  |  |  |
| eso205906-4341.3 | -18.307 | -18.793 | -19.158 | -19.421 | -19.629 | -19.840 | -19.930 | -20.021 |
| eso210003-4308.6 | -15.932 | -17.017 | -17.510 | -17.951 | -18.245 | -18.511 | -18.632 | -18.786 |
| eso210053-4506.0 | . | . | -15.490 | -17.962 | -18.681 | -19.173 | -19.427 | ... |
| eso210101-4826.3 | -18.991 | -19.405 | -19.719 | -19.963 | -20.087 | -20.200 | -20.264 | -20.345 |
| eso210145-4759.3 | -18.535 | -19.137 | -20.146 | -20.548 | -20.832 | -20.994 | -21.097 | -21.232 |
| eso210256-4822.2 | . | ... | ... |  |  | ... |  |  |
| eso210500-4407.1 | -16.589 | -17.969 | -18.668 | -19.214 | -19.541 | -19.807 | -19.935 | -20.055 |
| eso210616-4736.6 |  | -15.630 | -17.562 | -18.417 | -18.926 | -19.144 | -19.248 | -19.348 |
| eso210740-4354.9 | -19.432 | -19.765 | -20.050 | -20.323 | -20.486 | -20.584 | -20.642 | -20.709 |
| eso210802-4243.7 | -16.251 | -17.448 | -17.974 | -18.268 | -18.503 | -18.678 | -18.816 | -18.954 |
| eso212713-4325.3 | -15.049 | -17.117 | -18.109 | -18.676 | -18.932 | -19.202 | -19.276 | -19.353 |

Table A. 4 Continued
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| Object <br> (1) | $\mathrm{R}_{20.5}$ <br> (2) | $R_{21}$ <br> (3) | $\mathrm{R}_{21.5}$ <br> (4) | $\mathrm{R}_{22}$ <br> (5) | $\mathrm{R}_{22.5}$ <br> (6) | $\mathrm{R}_{23}$ <br> (7) | $\mathbf{R}_{23.5}$ <br> (8) | $\mathrm{R}_{24.5}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Miscellaneous |  |  |  |  |  |  |  |  |
| 1701 |  |  |  |  |  |  |  |  |
| 1900 | -20.215 | -20.949 | -21.357 | -21.587 | -21.746 | -21.830 | -21.868 | -21.928 |
| I1401 |  |  |  |  |  |  |  |  |
| N173 |  |  |  |  |  |  |  |  |
| N4449 |  |  |  |  |  |  |  |  |
| N4475 | -19.156 | -19.639 | -20.185 | -20.579 | -21.011 | -21.209 | -21.403 | -21.580 |
| N4738 | -18.574 | -19.338 | -20.157 | -20.539 | -20.797 | -20.913 | -20.981 | -21.069 |
| N7537 | -18.954 | -19.297 | -19.504 | -19.689 | -19.853 | -19.960 | -20.021 | -20.090 |
| N7541 | -20.237 | -20.937 | -21.242 | -21.383 | ... |  |  |  |
| N7570 | -19.982 | -20.089 | -20.263 | -20.622 | -20.801 | -20.931 | -20.982 | -21.034 |
| N7750 | -18.991 | -20.103 | -20.392 | -20.662 | -20.807 | -20.865 | -20.899 | -20.935 |
| N7757 | -17.072 | -18.112 | -18.823 | -19.391 | -19.827 | -20.038 | -20.196 | -20.289 |
| U673 |  | -15.877 | -17.906 | -18.643 | -19.119 | -19.414 | -19.570 | -19.801 |
| U1045 | -18.208 | -18.914 | -19.467 | -19.886 | -20.135 | -20.327 | -20.466 | -20.579 |
| U2509 | -18.803 | -19.731 | -20.263 | -20.484 | -20.622 | -20.695 | -20.738 | -20.789 |
| U4375 | -18.098 | -18.853 | -19.421 | -19.735 | -19.913 | -20.026 | -20.114 | -20.206 |
| U4404 |  | -18.378 | -19.695 | -20.179 | -20.539 | -20.665 | -20.755 | -20.861 |
| U4414 | -20.971 | -21.095 | -21.209 | -21.385 | -21.754 | -21.812 | -21.869 | -21.909 |
| U6586 | -17.653 | -18.512 | -18.965 | -19.603 | -19.770 | -19.874 | -19.978 | -20.112 |
| U7754 | -16.656 | -17.996 | -18.978 | -19.406 | -19.614 | -19.759 | -19.847 | -19.953 |
| U9558 |  | -19.330 | -20.447 | -21.309 | -21.701 | -21.874 | -21.966 | -22.040 |
| U12571 | -16.591 | -17.368 | -18.430 | -18.872 | -19.189 | -19.315 | -19.389 | -19.567 |
| Z160139 | ... | -16.361 | -17.564 | -18.173 | -18.613 | -19.164 | -19.338 | -19.482 |
| Z501035 | ... | -17.532 | -18.739 | -19.503 | -19.809 | -19.951 | -20.053 | -20.159 |
| eso025101-1748.3 | -20.727 | -20.937 | -21.130 | -21.257 | -21.345 | -21.440 | -21.531 | -21.845 |
| eso102742-3458.0 | -19.273 | -19.419 | -19.545 | -19.694 | -20.006 | -20.091 | -20.138 | -20.211 |
| eso191041-6629.7 | ... | $\cdots$ | ... | $\cdots$ | ... | ... | ... | ... |
| eso201327-4755.6 | -18.829 | -19.412 | -19.976 | -20.460 | -20.728 | -20.843 | -20.924 | -21.018 |
| eso212837-4616.8 | -20.993 | -21.280 | -21.500 | -21.671 | -21.767 | -21.869 | -21.953 | -22.046 |

Table A. 5
Photometric Parameters Derived from I-band Surface Photometry

| Object <br> (1) | $\log R$ <br> (2) | $\log D_{22.5}$ <br> (3) | $\log C$ <br> (4) | $\mu_{n}$ <br> (5) | $\begin{gathered} \mu_{-0.5} \\ (6) \end{gathered}$ | $\mu_{22.5}$ <br> (7) | $\begin{aligned} & \mathrm{I}_{T} \\ & (8) \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NGC 1209 |  |  |  |  |  |  |  |
| eso024234-1730.6 | 0.1997 | 0.3725 | -1.3224 | 21.186 | 20.963 | 21.901 | -18.2 |
| eso024524-1902.9 | 0.6812 | -0.4896 | ... | 22.521 | ... | 22.484 | -17.4 |
| eso024921-1816.5 | 0.7462 | 0.5499 | -1.5628 | 21.929 | 21.960 | 22.193 | -17.7 |
| eso025754-1928.1 | 0.5927 | 0.3530 | -0.9044 | 20.510 | 20.552 | 21.547 | -17.7 |
| eso030617-1754.8 | 0.3362 | 0.6782 | -0.8559 | 19.832 | 20.035 | 21.232 | -18.7 |
| eso030719-1801.2 | 0.7061 | -0.5926 | ... | 22.606 |  | 22.476 | -16.6 |
| eso031302-1805.9 | 0.2512 | 0.7253 | -0.6664 | 19.427 | 19.817 | 20.989 | -19.0 |
| eso031339-1816.2 | 0.2806 | 0.5927 | -0.9682 | 20.365 | 20.558 | 21.419 | -18.5 |
| Antlia |  |  |  |  |  |  |  |
| esol01025-3428.9 | 0.2944 | 0.8988 | -1.1230 | 21.179 | 21.204 | 21.896 | -19.8 |
| esol01232-3348.7 | 0.3634 | 0.9314 | -0.8282 | 19.792 | 19.959 | 21.152 | -19.9 |
| esol01908-3932.9 | 0.1114 | 0.9133 | -0.6111 | 18.198 | 18.953 | 20.860 | -20.1 |
| esol02507-3337.3 | 0.6813 | 1.0353 | -0.9885 | 20.577 | 20.810 | 21.639 | -19.7 |
| esol02621-3239.9 | 0.6038 | ... | ... | ... | ... | ... | -16.1 |
| esol02750-3626.2 | ... | ... | ... | ... | ... | ... | ... |
| esol02936-3435.8 |  |  |  |  |  | ... |  |
| Hydra |  |  |  |  |  |  |  |
| esol02210-2318.0 | 0.2350 | 1.0782 | -0.6805 | 18.461 | 18.721 | 20.667 | -21.1 |
| esol03021-2716.2 | 0.4937 | 0.9278 | -1.3626 | 21.041 | 21.312 | 21.884 | -19.6 |
| esol03140-2954.7 | 0.6849 | 1.1873 | -0.7016 | 19.967 | 20.292 | 21.388 | -20.8 |
| esol03518-3211.1 | 0.8758 | 0.8471 | -0.9397 | 21.049 | 21.169 | 21.801 | -18.9 |
| esol03542-2754.7 | 0.8534 | 0.1231 | ... | 22.021 | 21.978 | 22.136 | -16.8 |
| esol03655-3002.3 | 0.7090 | 1.2755 | -0.6585 | 19.895 | 20.157 | 21.284 | -21.8 |
| esol03656-2634.7 | 0.5035 | 1.0953 | -0.7703 | 20.371 | 20.626 | 21.461 | -21.0 |
| Centaurus 30 |  |  |  |  |  |  |  |
| esol23654-4027.9 | 0.4471 | 1.0139 | -0.6737 | 19.107 | 19.518 | 21.033 | -20.6 |
| esol24127-3614.2 | 0.6690 | 0.7739 | -1.1879 | 20.918 | 20.992 | 21.705 | -19.1 |
| esol24410-4113.4 | 0.4428 | 1.0499 | -0.7633 | 19.282 | 19.609 | 20.892 | -20.7 |
| esol25004-4010.8 | 0.2981 | 1.1275 | -0.9322 | 19.842 | 20.015 | 21.105 | -21.1 |
| Centaurus 45 |  |  |  |  |  |  |  |
| esol23759-3628.0 | 0.6438 | 0.7265 | -0.9468 | 20.977 | 21.080 | 21.718 | -19.3 |
| esol24841-4322.9 | . | . | ... | ... | .. | ... | ... |
| esol24953-3845.4 | 0.2886 | 1.2117 | -1.0375 | 19.328 | 19.465 | 20.772 | -21.9 |
| esol25142-3927.5 | 0.5162 | 0.8909 | -1.3272 | 20.459 | 20.628 | 21.523 | ... |
| Telescopium 27 |  |  |  |  |  |  |  |
| eso195939-4142.7 | 0.7423 | ... | ... | $\cdots$ | $\cdots$ | . | ... |
| eso200202-4807.3 | 0.7146 | ... | ... | ... | ... | ... | . $\cdot$ |
| eso200211-4807.3 | 0.3161 | $\ldots$ | ... | ... | ... | ... |  |


| Object <br> (1) | $\log R$ <br> (2) | $\log D_{22.5}$ <br> (3) | $\log C$ <br> (4) | (5) | $\mu_{-0.5}$ <br> (6) | $\mu_{22.5}$ <br> (7) | $\mathrm{I}_{T}$ <br> (8) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso200541-4629.8 | 0.5555 | 0.6565 | -0.7513 | 19.808 | 20.001 | 21.184 | -19.0 |
| eso200735-4825.5 | 0.6949 |  |  |  |  |  |  |
| eso200823-4617.6 | 0.6991 | 1.1164 | -1.0886 | 20.571 | 20.899 | 21.734 | -20.6 |
| eso200826-4710.4 | 0.7164 | ... | ... | ... | ... | ... | ... |
| eso201039-4858.8 | 0.1894 | ... | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso201301-4333.6 | 0.4608 | ... | ... | ... | ... | ... | $\ldots$ |
| eso201352-4440.3 | 0.3923 | $\ldots$ | ... | ... | ... | $\ldots$ | $\ldots$ |
| eso201442-4821.8 | 0.5688 | ... | ... | $\ldots$ | $\ldots$ | ... |  |
| eso201527-4514.2 | 0.6496 | ... | ... | $\ldots$ | $\ldots$ | ... | $\ldots$ |
| eso201730-4926.4 | 0.7073 | ... | ... | $\ldots$ | ... | ... | $\ldots$ |
| eso202031-4409.5 | 0.3932 | 1.2588 | -0.5734 | 18.352 | 18.967 | 20.780 | -21.9 |
| eso202423-4929.9 | 0.8570 |  | ... |  | ... | ... | ... |
| Telescopium 56 |  |  |  |  |  |  |  |
| eso195443-4614.9 | 0.3464 | 1.2674 | -0.7877 | 19.913 | 20.153 | 21.198 | -20.0 |
| eso200559-4928.7 | 0.6217 | ... | ... | ... | ... | ... | ... |
| eso201006-4458.1 | 0.3743 | ... | ... | ... | ... | ... |  |
| eso201024-4440.7 | 0.0915 | 1.4344 | -0.8518 | 19.438 | 20.002 | 21.283 | -20.8 |
| eso201302-4451.8 | 0.3737 | ... | ... | ... | ... | ... | ... |
| Pavo |  |  |  |  |  |  | . |
| eso191452-7219.1 | 0.0677 | ... | ... | ... | ... | ... | $\ldots$ |
| eso192513-7110.4 | 0.4511 | $\ldots$ | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso195254-7035.3 | 0.5208 | $\ldots$ | ... | ... | $\cdots$ | $\cdots$ | ... |
| eso200710-6722.7 | 0.3160 | ... | ... | ... | $\ldots$ | ... | ... |
| eso201001-7251.8 | 0.1420 | $\ldots$ | ... | ... | ... | $\ldots$ | ... |
| eso201125-7117.0 | 0.6350 | $\ldots$ | ... | $\ldots$ | ... | $\ldots$ | ... |
| eso201137-7402.4 | 0.3178 | ... | ... | ... | ... | . | ... |
| eso201810-7143.5 | 0.9429 | 0.9757 | -0.9413 | 21.259 | 21.343 | 21.866 | -19.5 |
| eso202552-6615.9 | 0.3119 | ... | ... | ... | ... | ... | ... |
| eso204014-7134.7 | 0.3833 |  | ... | $\cdots$ | ... | $\cdots$ | ... |
| Indus |  |  |  |  |  |  |  |
| eso205906-4341.3 | 0.5824 | ... | ... | $\ldots$ | ... | ... | $\ldots$ |
| eso210003-4308.6 | 0.5625 | $\ldots$ | ... | ... | ... | ... |  |
| eso210053-4506.0 | 0.8470 | 1.0948 | -0.7418 | 21.275 | 21.383 | 21.896 | -19.9 |
| eso210101-4826.3 | 0.1924 | ... | ... | ... | ... | ... | ... |
| eso210145-4759.3 | 0.6034 | ... | ... | ... | ... | ... | ... |
| eso210256-4822.2 | ... | $\ldots$ | $\ldots$ | ... | ... | ... | ... |
| eso210500-4407.1 | 0.1969 | ... | ... | ... | ... | ... | ... |
| eso210616-4736.6 | 0.2600 | ... | ... | ... | ... | ... | ... |
| eso210740-4354.9 | 0.6179 | ... | ... | ... | ... | ... | . $\cdot$ |
| eso210802-4243.7 | 0.1157 |  | ... | ... | ... | ... | ... |
| eso212713-4325.3 | 0.0743 | ... | ... | ... | . $\cdot$ | . $\cdot$ | . $\cdot$ |

Table A. 5 Continued

| Object | $\log R$ | $\log \mathrm{D}_{22.5}$ | $\log \mathrm{C}$ | $\mu_{n}$ | $\mu_{-0.5}$ | $\mu_{22.5}$ | $\mathrm{I}_{\boldsymbol{T}}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ | $(6)$ | $(7)$ | $(8)$ |


| Miscellaneous |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso025101-1748.3 | 0.2115 | 1.1781 | -0.7013 | 18.789 | 19.171 | 20.683 | $\ldots$ |
| eso102742-3458.0 | 0.3857 | 1.0287 | -0.3782 | 18.788 | 19.552 | 20.980 | $\ldots$ |
| eso191041-6629.7 | 0.7575 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso201327-4755.6 | 0.1208 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso212837-4616.8 | 0.2273 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |

Table A. 6
I-band Isophotal Magnitudes

| Object <br> (1) | $\mathrm{I}_{19.5}$ <br> (2) | $\mathrm{I}_{20}$ <br> (3) | $\mathrm{I}_{20.5}$ <br> (4) | $\mathrm{I}_{21}$ <br> (5) | $\mathrm{I}_{21.5}$ <br> (6) | $\mathrm{I}_{22}$ <br> (7) | $\mathrm{I}_{22.5}$ <br> (8) | $\mathrm{I}_{23.5}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| NGC 1209 |  |  |  |  |  |  |  |  |
| eso024234-1730.6 |  |  | ... | -14.056 | -15.236 | -15.892 | -16.588 | -17.673 |
| eso024524-1902.9 |  |  |  |  |  |  | -11.902 | -15.994 |
| eso024921-1816.5 | ... |  | ... |  |  | -14.974 | -16.656 | -17.369 |
| eso025754-1928.1 |  |  | -15.188 | -15.923 | -16.469 | -16.725 | -17.057 | -17.418 |
| eso030617-1754.8 | -14.902 | -16.263 | -17.215 | -17.743 | -18.129 | -18.345 | -18.464 | -18.635 |
| eso030719-1801.2 |  |  |  | ... |  |  | -11.997 | -15.639 |
| eso031302-1805.9 | -17.110 | -17.583 | -18.052 | -18.375 | -18.617 | -18.772 | -18.866 | -19.019 |
| eso031339-1816.2 |  | -14.897 | -15.927 | -16.617 | -17.458 | -17.928 | -18.044 | -18.322 |
| Antlia |  |  |  |  |  |  |  |  |
| eso101025-3428.9 | $\cdots$ | $\cdots$ | -13.807 | -16.297 | -17.318 | -18.427 | -18.967 | -19.603 |
| esol01232-3348.7 | -16.161 | -17.608 | -18.858 | -19.216 | -19.426 | -19.611 | -19.753 | -19.890 |
| esol01908-3932.9 | -18.976 | -19.270 | -19.477 | -19.662 | -19.805 | -19.904 | -20.046 |  |
| esol02507-3337.3 | ... | ... | -16.014 | -17.619 | -18.477 | -19.024 | -19.339 | -19.570 |
| esol02621-3239.9 | ... | ... | ... | ... | ... | ... | ... | -15.373 |
| eso102750-3626.2 |  |  | ... | ... | ... | ... | ... | ... |
| eso102936-3435.8 |  |  |  | $\ldots$ |  |  |  |  |
| Hydra |  |  |  |  |  |  |  |  |
| esol02210-2318.0 | -19.970 | -20.283 | -20.484 | -20.638 | -20.776 | -20.911 | -20.975 | -21.045 |
| esol03021-2716.2 |  | ... |  | -14.291 | -17.615 | -18.262 | -18.839 | -19.239 |
| eso103140-2954.7 | -17.024 | -18.335 | -19.057 | -19.546 | -19.975 | -20.247 | -20.441 | -20.615 |
| eso103518-3211.1 | ... | ... | ... | -15.566 | -17.139 | -17.788 | -18.263 | -18.658 |
| eso103542-2754.7 | $\cdots$ | … | $\ldots$ | ... | ... | -14.335 | -15.363 | -16.428 |
| esol03655-3002.3 | -18.949 | -19.594 | -20.213 | -20.698 | -21.064 | -21.321 | -21.499 | -21.714 |
| esol03656-2634.7 | -17.213 | -18.024 | -18.826 | -19.559 | -20.007 | -20.386 | -20.574 | -20.914 |
| Centaurus 30 |  |  |  |  |  |  |  |  |
| esol23654-4027.9 | -18.855 | -19.288 | -19.604 | -19.836 | -20.049 | -20.206 | -20.341 | -20.500 |
| esol24127-3614.2 | ... | . | . | -16.017 | -17.678 | -18.262 | -18.559 | -18.846 |
| eso124410-4113.4 | -18.648 | -19.294 | -19.813 | -20.170 | -20.391 | -20.527 | -20.593 | -20.700 |
| eso125004-4010.8 | -17.680 | -18.179 | -19.605 | -20.316 | -20.644 | -20.768 | -20.865 | -21.015 |
| Centaurus 45 |  |  |  |  |  |  |  |  |
| esol23759-3628.0 | ... | $\ldots$ | ... | -16.058 | -17.385 | -17.919 | -18.364 | -18.727 |
| esol24841-4322.9 |  |  |  |  | ... |  | ... |  |
| esol24953-3845.4 | -19.402 | -20.595 | -21.066 | -21.428 | -21.594 | -21.671 | -21.732 | -21.839 |
| esol25142-3927.5 | ... |  | -16.585 | -18.009 | -18.566 | -18.858 | -19.133 | -19.350 |
| Telescopium 27 |  |  |  |  |  |  |  |  |
| esol95939-4142.7 | $\cdots$ | . | ... | ... | $\cdots$ | ... | ... | $\cdots$ |
| eso200202-4807.3 | ... | $\cdots$ | ... | ... | $\cdots$ | ... | ... | ... |
| eso200211-4807.3 | ... | ... | ... | ... | ... | ... |  |  |


| Object <br> (1) | $\mathrm{I}_{19.5}$ <br> (2) | $\mathrm{I}_{20}$ <br> (3) | $\mathrm{I}_{20.5}$ <br> (4) | $\mathrm{I}_{21}$ <br> (5) | $\mathbf{I}_{21.5}$ <br> (6) | $\mathrm{I}_{22}$ <br> (7) | $\mathrm{I}_{22.5}$ (8) | $\mathrm{I}_{23.5}$ <br> (9) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso200541-4629.8 | -15.856 | -17.014 | -17.581 | -18.007 | -18.276 | -18.480 | -18.620 | -18.796 |
| eso200735-4825.5 | ... | ... |  |  |  |  |  |  |
| eso200823-4617.6 |  |  | -16.307 | -18.476 | -19.433 | -20.068 | -20.387 | $\ldots$ |
| eso200826-4710.4 |  | $\ldots$ | ... | ... | ... | ... | ... | $\ldots$ |
| eso201039-4858.8 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |  |
| eso201301-4333.6 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |  |
| eso201352-4440.3 | $\ldots$ | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso201442-4821.8 | $\ldots$ | $\ldots$ | $\cdots$ | $\cdots$ | $\cdots$ | ... | $\ldots$ | $\ldots$ |
| eso201527-4514.2 | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | ... | $\ldots$ |
| eso201730-4926.4 |  |  |  |  |  |  |  |  |
| eso202031-4409.5 | -20.682 | -21.017 | -21.240 | -21.436 | -21.622 | -21.731 | -21.819 | $\ldots$ |
| eso202423-4929.9 |  |  |  |  |  |  |  |  |
| Telescopium 56 |  |  |  |  |  |  |  |  |
| esol95443-4614.9 | -17.968 | -19.003 | -19.757 | -20.456 | -20.885 | -21.106 | -21.221 | -21.421 |
| eso200559-4928.7 | ... | ... | ... | ... | ... | ... | ... | ... |
| eso201006-4458.1 |  |  |  |  |  |  |  | ... |
| eso201024-4440.7 | -19.270 | -19.942 | -20.736 | -21.574 | -21.812 | -22.000 | -22.128 | $\ldots$ |
| eso201302-4451.8 |  | ... |  | ... | ... | ... | ... |  |
| Pavo |  |  |  |  |  |  |  |  |
| esol91452-7219.1 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso192513-7110.4 | $\ldots$ | ... | $\ldots$ | $\ldots$ | $\ldots$ | ... | $\ldots$ | $\ldots$ |
| eso195254-7035.3 | $\ldots$ | $\ldots$ | ... | ... | $\ldots$ | ... | $\ldots$ | ... |
| eso200710-6722.7 | $\ldots$ | $\ldots$ | ... | ... | $\ldots$ | $\ldots$ | $\ldots$ | ... |
| eso201001-7251.8 | ... | ... | $\ldots$ | $\ldots$ | ... | $\ldots$ | $\ldots$ | ... |
| eso201125-7117.0 | $\ldots$ | $\ldots$ | $\ldots$ | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ |
| eso201137-7402.4 | $\ldots$ | $\ldots$ | $\ldots$ | $\cdots$ |  |  |  |  |
| eso201810-7143.5 | $\ldots$ | $\ldots$ | $\ldots$ | -16.051 | -17.327 | -18.514 | -18.944 | -19.410 |
| eso202552-6615.9 | ... | ... | $\ldots$ | ... | ... | ... | ... | ... |
| eso204014-7134.7 | ... | $\ldots$ | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | ... |
| Indus |  |  |  |  |  |  |  |  |
| eso205906-4341.3 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso210003-4308.6 | $\ldots$ | ... | ... |  |  |  |  |  |
| eso210053-4506.0 | $\ldots$ | $\ldots$ | ... | -14.882 | -18.203 | -18.959 | -19.491 | -19.846 |
| eso210101-4826.3 | $\ldots$ | $\ldots$ | $\ldots$ | ... | ... | ... | ... | ... |
| eso210145-4759.3 | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | ... | $\ldots$ | $\cdots$ |
| eso210256-4822.2 | ... | ... | $\ldots$ | $\cdots$ | $\cdots$ | $\ldots$ | $\ldots$ | $\cdots$ |
| eso210500-4407.1 | $\ldots$ | $\ldots$ | $\ldots$ | $\cdots$ | $\ldots$ | $\cdots$ | $\cdots$ | $\ldots$ |
| eso210616-4736.6 | $\ldots$ | $\ldots$ | ... | $\ldots$ | $\ldots$ | .. | $\ldots$ | $\cdots$ |
| eso210740-4354.9 | ... | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso210802-4243.7 | $\ldots$ | $\cdots$ | ... | $\ldots$ | $\ldots$ | ... | $\ldots$ | ... |
| eso212713-4325.3 | ... | ... | ... | ... | ... | ... | ... | ... |

Table A. 6 Continued

| Object | $\mathrm{I}_{19.5}$ | $\mathrm{I}_{20}$ | $\mathrm{I}_{20.5}$ | $\mathrm{I}_{21}$ | $\mathrm{I}_{21.5}$ | $\mathrm{I}_{22}$ | $\mathrm{I}_{22.5}$ | $\mathrm{I}_{23.5}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $(1)$ | $(2)$ | $(3)$ | $(4)$ | $(5)$ | $(6)$ | $(7)$ | $(8)$ | $(9)$ |


| Miscellaneous |  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| eso025101-1748.3 | -20.475 | -20.776 | -20.995 | -21.181 | -21.308 | -21.462 | -21.516 | -21.616 |
| eso102742-3458.0 | -19.387 | -19.591 | -19.749 | -19.871 | -19.997 | -20.277 | -20.399 | -20.488 |
| eso191041-6629.7 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso201327-4755.6 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ |
| eso212837-4616.8 | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\ldots$ | $\cdots$ | $\ldots$ | $\cdots$ |



Pigure A.1. CCD Surface Brightness Profiles.


Pigure A.1. Continued.


Figure A.1. Continued.


Figure A. $1 . \quad$ Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Pigure A.1. Continued.


Figure A.1. Continued.


Pigure A.1. Continued.


Pigure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Pigure A.1. Continued.


Figure A.1. Continued.


Pigure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Pigure A. 1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Pigure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Pigure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A.1. Continued.


Figure A. 1. Continued.

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[^0]:    For some of our galaxies, the extent of overlapping stars or companion galaxies was not completely obvious. For such cases, GASP provides an automatic image-detection program called MULTIM which looks In the data at various intensity thresinolds for images whose parameters are similar at consecutive thresholds. The program then either finds the parameters for each image at a user-specified margin above the sky level,

[^1]:    To give the reader an idea of the repeatability of the transformation coefficients determined as described above, we give in Table 2.5 a summary of the coefficients computed by CCDSTD for the January 1987 CTIO run. The error estimates are based on input data error

