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THE DIRECT PROJECT: CATALOGS OF STELLAR OBJECTS IN NEARBY GALAXIES. II. EASTERN ARM AND NGC 206 IN M31

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ABSTRACT

DIRECT is a project to directly obtain the distances to two important galaxies in the cosmological distance ladder, M31 and M33, using detached eclipsing binaries and Cepheids. As part of our search for these variables, we have obtained photometry and positions for thousands of stellar objects within the monitored fields, covering an area of 557.8 arcmin^2. Here we present the equatorial coordinates and BVI photometry for 26,712 stars in the M31 galaxy, along the eastern arm and in the vicinity of the star-forming region NGC 206.

Key words: galaxies: individual (M31) — galaxies: stellar content

On-line material: machine-readable tables

1. INTRODUCTION

Starting in 1996 we undertook a long-term project, DIRECT, to obtain the distances to two important galaxies in the cosmological distance ladder, M31 and M33. These "direct" distances will be obtained by determining the distance of Cepheids using the Baade-Wesselink method and by measuring the distance to detached eclipsing binaries (DEBs).

As the first step of the DIRECT project, we have searched for DEBs and new Cepheids in M31 and M33. In the M31 galaxy we have analyzed five $11' \times 11'$ fields, A–D and F (Kaluzny et al. 1998, 1999; Mochejska et al. 1999; Stanek et al. 1998, 1999). A total of 410 variables, mostly new, were found: 48 eclipsing binaries, 206 Cepheids, and 156 other periodic, possible long-period, or nonperiodic variables. In the first paper of the series of stellar catalogs, we presented the catalog of stars in the central part of M33 (Macri et al. 2001). In this paper, we present the equatorial coordinates and BVI photometry for 26,712 stars detected in the M31 galaxy within the monitored area of 557.8 arcmin^2.

2. OBSERVATIONS AND DATA REDUCTION

We have observed five fields, A–D, concentrated on the rich spiral arm, and F, containing the giant star formation region known as NGC 206 (Fig. 1). The center (α, δ) J2000 coordinates of the fields were as follows: A, (11°.34, 41°.73); B, (11°.20, 41°.59); C, (11°.10, 41°.42); D, (11°.03, 41°.27); F, (10°.10, 40°.72).

M31 was primarily observed in 1996 with the 1.3 m McGraw-Hill Telescope at the Michigan-Dartmouth-MIT (MDM) Observatory. We used the front-illuminated Loral 2048^2 CCD "Wilbur" (Metzger, Tonry, & Luppino 1993). Data for M31 were also obtained, mostly in 1997, with the 1.2 m telescope at the F. L. Whipple Observatory (FLWO), where we used "AndyCam" (Szentgyorgyi et al. 2001), with a thinned, back-illuminated, AR-coated Loral 2048^2 pixel CCD. The pixel scale was essentially the same at both telescopes, 0″.32 pixel^{-1}, giving a field of view of roughly $11' \times 11'$. The average seeing for the frames used in the construction of this catalog was 0″.95 in V, 1″.11 in I, and 1″.72 in B.

For a full description of the applied data reduction, calibration, and astrometry procedures, the reader is referred to Kaluzny et al. (1998). Here we present only a very brief summary. Stellar profile photometry was extracted using the DAOPHOT/ALLSTAR package (Stetson 1987). The transformation of instrumental magnitudes to the standard system was based on 18 standard stars (Landolt 1992) observed on the night of 1996 September 14/15 at MDM. The residuals in V, $V-I$, and $B-V$ showed no overall offsets and no dependence on color (see Fig. 2 in Kaluzny et al. 1998). A comparison with the photometry of Magnier et al. (1992) showed very good agreement in V (average $V - V_{\rm Ma92} = 0.013$ for stars with $V < 20$) and a strong trend in $V-I$ residuals with the $V-I$ color, with a slope of ~ 0.3 for stars with $V-I < 1$ and ~ 0 for redder stars (Fig. 4 in Kaluzny et al. 1998). We have obtained independent calibrations at MDM on the night of 1996 October 2/3 with the "Charlotte" 1024^2 CCD (field B) and at FLWO on the night of 1997 October 9/10 (fields C, D, F). The offsets in V and $V-I$ respectively were 0.040 and 0.016 in field B, 0.012 and 0.024 in field C, −0.014 and 0.047 in field D, and −0.020 and 0.057 in field F. Apart from the offsets, we did not see anything resembling the strong trend in the $V-I$ residuals seen in the comparison with the Magnier et al. (1992) photometry. Though we are confident of our $V-I$ calibration, this discrepancy certainly deserves further attention. To check the internal consistency of our calibration, we have compared the photometry in the overlapping regions between the fields. The offsets in V and I respectively were 0.022 and 0.018 between fields A and B, 0.034 and 0.024 between B and C, and −0.063 and −0.040 between C and D. The offset in B between fields C and D was 0.007.

The transformation from rectangular to equatorial coordinates was derived using stars from the list published by Magnier et al. (1992) for fields A–D, and the USNO-A2.0 catalog (Monet et al. 1996) for field F.

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TABLE 1

A. Stellar Objects in Field M31A

ID	α (J2000.0)	δ (J2000.0)	V	I	B	σ_V	σ_I	σ_B	J_S
D31 J004452.5+414823.4.....	00 44 52.49	41 48 23.40	20.57	19.54	...	0.03	0.05	...	0.57
D31 J004453.7+413938.3.....	00 44 53.67	41 39 38.31	20.66	18.64	...	0.04	0.05	...	0.34
D31 J004453.8+413901.7.....	00 44 53.78	41 39 01.72	21.71	19.18	...	0.07	0.08	...	1.27
D31 J004452.7+414703.8.....	00 44 52.70	41 47 03.76	22.14	20.30	...	0.11	0.13	...	0.14
D31 J004453.3+414237.0.....	00 44 53.30	41 42 37.04	22.20	20.44	...	0.13	0.15	...	−0.12

Note.—Tables 1A–1E are available in their entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding their form and content. Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

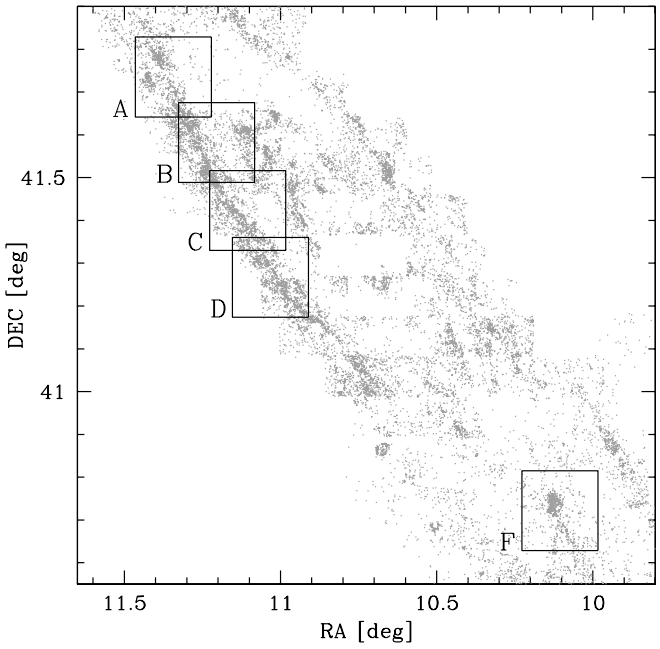

Fig. 1.—Fields A–D and F observed in M31, based on the photometric survey of M31 by Magnier et al. (1992) and Haiman et al. (1994). Only blue stars, with $B-V < 0.4$, are shown.

3. THE CATALOG

In Figure 2, we plot the $(V, V-I)$ and $(V, B-V)$ color-magnitude diagrams (CMDs) from the combined field A–D and F catalogs. In the $(V, V-I)$ CMD (*left*), stars near $V \sim 22$ and $V-I \sim 1.8$ represent the top of the evolved red giant population. The vertical strip of stars with $0.6 < V-I < 1.2$ and $V < 20$ are Galactic foreground stars. Stars bluer than $V-I < 0.6$ are the upper main-sequence stars in M31. In the $(V, B-V)$ CMD (*right*), the most prominent feature is the upper main sequence at $B-V \sim 0$. The Galactic foreground stars are also present, between 0.4 and 1.0 in $B-V$.

In Tables 1A–1E, we present the catalogs for fields A–D and F, with the equatorial coordinates and photometry in VI (fields A and B) and BVI (C, D, F). For each star, we list the ID, J2000 equatorial coordinates, standard V, I, and B magnitudes with their respective errors, and the Stetson variability index J_S (Stetson 1996). The IDs, based on the equatorial coordinates, are in the format D31 J*hhmmss.s*+*ddmmss.s*. The first three correspond to right ascension, expressed in hours (*hhmmss.s*), and the last three to declination in degrees (*ddmmss.s*).

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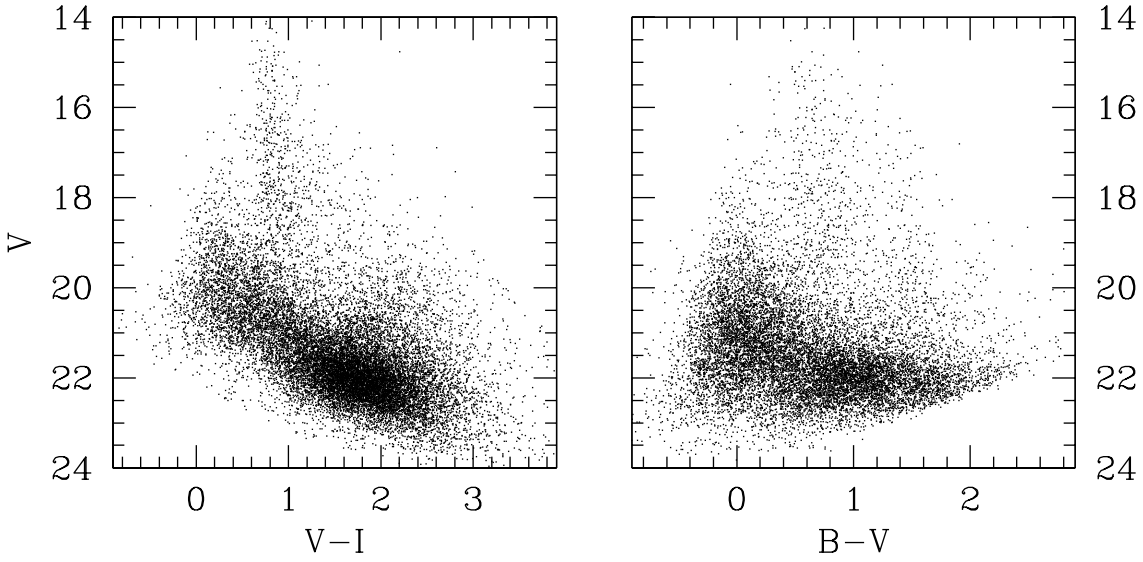

Fig. 2.—$(V, V-I)$ and $(V, B-V)$ color-magnitude diagrams

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REFERENCES

Haiman, Z., et al. 1994, A&A, 286, 725
Kaluzny, J., Mochejska, B. J., Stanek, K. Z., Krockenberger, M., Sasselov, D. D., Tonry, J. L., & Mateo, M. 1999, AJ, 118, 346
Kaluzny, J., Stanek, K. Z., Krockenberger, M., Sasselov, D. D., Tonry, J. L., & Mateo, M. 1998, AJ, 115, 1016
Landolt, A. U. 1992, AJ, 104, 340
Macri, L. M., Stanek, K. Z., Sasselov, D. D., Krockenberger, M., & Kaluzny, J. 2001, AJ, 121, 861
Magnier, E. A., Lewin, W. H. G., van Paradijs, J., Hasinger, G., Jain, A., Pietsch, W., & Trümper, J. 1992, A&AS, 96, 379
Metzger, M. R., Tonry, J. L., & Luppino, G. A. 1993, in ASP Conf. Ser. 52, Astronomical Data Analysis Software and Systems II, ed. R. J. Hanisch, R. J. V. Brissenden, & J. Barnes (San Francisco: ASP), 300
Mochejska, B. J., Kaluzny, J., Stanek, K. Z., Krockenberger, M., & Sasselov, D. D. 1999, AJ, 118, 2211
Monet, D., et al. 1996, USNO-A2.0 (Flagstaff: US Nav. Obs.)
Stanek, K. Z., Kaluzny, J., Krockenberger, M. Sasselov, D. D., Tonry, J. L., & Mateo, M. 1998, AJ, 115, 1894
———. 1999, AJ, 117, 2810
Stetson, P. B. 1987, PASP, 99, 191
———. 1996, PASP, 108, 851
Szentgyorgyi, A., et al. 2001, in preparation