A&A 416, 111–118 (2004)
DOI: 10.1051/0004-6361:20034557

Astronomy
&
Astrophysics

Carbon star survey of Local Group galaxies

X. Wolf-Lundmark-Melotte a galaxy with an extreme C/M ratio[⋆,⋆⋆]

P. Battinelli[1] and S. Demers[2]

[1] INAF, Osservatorio Astronomico di Roma Viale del Parco Mellini 84, 00136 Roma, Italia
[2] Département de Physique, Université de Montréal, CP 6128, Succursale Centre-Ville, Montréal, Québec H3C 3J7, Canada
e-mail: `demers@astro.umontreal.ca`

Received 21 October 2003 / Accepted 26 November 2003

Abstract. We used the CFH12K wide field camera to survey the carbon star population of the Wolf-Lundmark-Melotte system using the CN–TiO technique. 149 C stars are identified with a mean $\langle I \rangle = 20.28$, corresponding to $\langle M_I \rangle = -4.65$, a mean luminosity similar to what we found in other irregular galaxies. Star counts in and around the main body of WLM reveal that its stellar distribution is quite elliptical ($\epsilon = 0.58$) with major and minor axes of $26'$ and $11'$. Comparison of the density profile of C stars and old red giants shows that their scale lengths differ by only 15% pointing to mixed populations. WLM is found to be unique among dwarf irregular galaxies by having essentially a handful of early-type AGB M stars thus leading to an extreme C/M ratio. We conclude that like NGC 3109, WLM is a disk shaped galaxy, seen at an inclination of $\sim 69°$ and devoid of an extended spherical stellar halo.

Key words. galaxies: individual: Wolf-Lundmark-Melotte

1. Introduction

While there are more than a dozen Galactic globular clusters that have been given the name of their discoverer, very few galaxies in the Universe have taken the name of an astronomer. The only one in the Local Group with such a name has retained three names! The Wolf-Lundmark-Melotte (hereafter WLM) dwarf irregular galaxy was discovered by Wolf (1909) and independently by Melotte (1926) who stated that Lundmark had also noted this nebula. Holmberg (1950) appears to be the first one to include WLM among the Local Group members. Indeed, Baade (1944) does not include it in his list of Local Group galaxies. Holmberg (1950) concluded that WLM is a nearby object from a comparison of the apparent magnitude of its brightest stars with those of IC 1613. WLM, known as DDO 221, is also named A2359-15 in de Vaucouleurs & de Vaucouleurs' (1964) first catalogue. This name is however obsolete since precession moved it near the top of the list. Its coordinates are now: $\alpha = 0^{\rm h}01^{\rm m}57.8^{\rm s}$, $\delta = -15°27'51''$ (J2000).

The first photometric investigation of WLM was published by Ables & Ables (1977). They used an electrographic technique to determine the distance of WLM from the apparent magnitudes of its brightest blue stars. A few years later, Sandage & Carlson (1985) obtained a more accurate distance from the mean magnitude of a dozen Cepheids. During the 1980's a CCD investigation was published by Ferraro et al. (1989). More recently, Minniti & Ziljstra (1996, 1997) established the presence of an extended, slightly flattened halo consisting of Population II stars, around WLM. Finally, from HST observations, Dolphin (2000) determined a distance modulus of $(m - M)_0 = 24.88 \pm 0.08$ by fitting the entire colour-magnitude diagram. Rejkuba et al. (2000), also using deep HST data, obtained a distance of $(m - M)_0 = 24.95 \pm 0.15$ from the apparent magnitude of the horizontal branch stars. These two investigations adopted a reddening of $E(V - I) = 0.03$. For the purpose of our investigation, we adopt a weighted mean modulus $(m - M)_0 = 24.90 \pm 0.07$ (955 kpc). The above reddening transforms into: $E(R - I) = 0.016$, and $A_I = 0.03$ using Rieke & Lebofsky (1985) ratios.

In terms of brightness, thus mass, WLM falls in the mid-range of dwarf irregular galaxies, its absolute magnitude being similar to IC 1613, Sextans A and Sextans B. From the compilation of Mateo (1998), adjusted for the adopted distance, its $M_v = -14.6$. Little is known about the kinematical properties of WLM's HI. Huchtmeier et al. (1981) have shown that WLM has an extended HI envelope with a diameter of $36'$. Similar large HI envelope has been seen in a number of Local Group dwarf irregular galaxies. No mention of a velocity gradient, suggesting a disk rotation, is made.

Send offprint requests to: P. Battinelli,
e-mail: `battinel@oarhp1.rm.astro.it`

[⋆] Based on observations carried out at the Canada-France-Hawaii Telescope, operated by the National Research Council of Canada, the Centre National de la Recherche Scientifique de France, and the University of Hawaii.

[⋆⋆] Full Table 2 is only available in electronic form at the CDS via anonymous ftp to `cdsarc.u-strasbg.fr (130.79.128.5)` or via `http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/416/111`

Table 1. Summary of the WLM observations.

Filter	*exp. times*	*average seeing* ('')	*mean airmass*
WLM North			
R	500 s	0.77	1.228
I	280 s	0.79	1.243
CN	1200 s	0.66	1.262
TiO	1200 s	0.64	1.239
WLM South			
R	500 s	0.60	1.229
I	280 s	0.62	1.241
CN	1200 s	0.64	1.365
TiO	1200 s	0.67	1.308

2. Observations

The results presented here are based on observations obtained, in Service Queue observing mode in August 2002, with the CFH12K camera installed at the prime focus of the 3.66 m Canada-France-Hawaii Telescope. The camera consists in a 12 k × 8 k pixel mosaic covering a field of $42' \times 28'$, each pixel corresponding to 0.206 arcsec. Images were obtained through Mould I and R filters and narrowband CN and TiO filters, centered at 808.6 nm and 768.9 nm, respectively. WLM is a disk-like galaxy with its major axis aligned in the North-South direction. Because the prime-focus cage cannot be rotated and because the largest dimension of the CFH12K camera is in the East-West direction we decided, to be certain to acquire the whole disk of the galaxy, to obtain two CFH12K fields, centered on WLM but offset in the N-S direction by $15'$.

A summary of the acquired data is presented in Table 1. The total exposure time to acquire the C star population was just over 100 min, under sub-arcsec seeing. The data distributed by the CFHT have been detrended. This means that the images have already been corrected with the master darks, biases, and flats. Fringes have been removed on I exposures under 60 s and large scale structures such as the "Skyring" effect have been removed when relevant. This pre-analysis normalizes the responses of the 12 CCD's of the mosaic.

The photometric reductions were done by fitting model point-spread functions (PSFs) using DAOPHOT-II/ALLSTAR series of programs (Stetson 1987, 1994). Instrumental magnitudes are calibrated using equations provided by the CFHT QSO team. The equations for R and I magnitudes are:

$$R = 26.190 + m_r - 0.09(X_r - 1) + 0.0094(R - I),$$
$$I = 26.185 + m_i - 0.04(X_i - 1) - 0.0511(R - I),$$

where X_r and X_i are the airmasses of the R and I exposures. For the instrumental magnitudes r and i, obtained with DAOPHOT, and for the given exposure times, m_r and m_i correspond to:

$$m_r = (r - 25.0) + 2.5\log(500),$$
$$m_i = (i - 25.0) + 2.5\log(280).$$

By substracting the above R and I equations and using the appropriate airmasses we obtain:

$$(R - I) = 0.662 + 1.064(r - i),$$
$$I = i + 7.294 - 0.0511(R - I).$$

The southern I and R images were, unfortunately, obtained under partly cloudy sky. Because the field has a substantial overlap with the northern one, we can easily adjust the zero points of the photometry. Using nearly one thousand stars with excellent photometry we determine: $\Delta_I = 0.217$ and $\Delta_R = 0.775$.

The zero point of the (CN–TiO) index is established following the procedure outlined by Letarte et al. (2002). We assume that the mean (CN–TiO) of stars with $(R-I)_0 < 0.45$ is equal to zero because hot stars are expected to have featureless spectra in the CN and TiO regions.

3. Results

Because WLM has a Galactic latitude of $b = -73.6$, an impressive number of galaxies are seen in the field. We have therefore elected to delete from the photometric files all objects with a sharpness, as defined by DAOPHOT, larger than 1.0. The application of this criterion reduced the number of field objects by 47% in the database with *RI* magnitudes and 36% in the four-colour dataset.

Figure 1 shows the colour-magnitude diagram ~10 000 stars with photometric error $\sigma_{(R-I)} < 0.10$. The observations reach more than one magnitude below the tip of the red giant branch (TRGB) deep enough to acquire the C star population. The asymptotic giant branch (AGB) is quite obvious extending above the TRGB. Numerous blue stars, $(R - I) < 0.0$ are seen. They are all concentrated in the central bar of WLM and have been seen by Dolphin (2000). The vertical ridge at $(R - I) \approx 0.35$ corresponds to the G dwarf turnoff seen along the line of sight. Its location confirms that the reddening is quite low.

Figure 2 presents the colour-colour diagram which allows the discrimination of C stars from M stars. Only stars with a combined error $\epsilon = \sqrt{\sigma^2_{(R-I)} + \sigma^2_{(\mathrm{CN-TiO})}}$ smaller than 0.125 mag are retained. Some 7000 stars are plotted. The two boxes define the regions of O-rich and C-rich stars as explained by Letarte et al. (2002). 149 stars fall into the C box, there are obviously more C stars, with bluer colours, but they will not be included in our sample because, as explained by Demers & Battinelli (2002) they are fainter than those in the C box. This number of C stars is expected for a galaxy of such luminosity (Battinelli & Demers 2000), 195 were identified in IC 1613.

The colour-colour diagram shows a number of stars, in the M box, but above the M branch. Such stars have not been noticed in other galaxies. These ~300 objects are evenly distributed over the CFH12K field, thus they do not belong to WLM. Their $\langle I \rangle = 21.1$ and $\langle R - I \rangle = 1.4$, their photometric errors are normal for stars of such magnitudes and their *FWHM* are similar to stars.

Could these stars be actually faint background galaxies? The number of $I \approx 21$ galaxies in the CFH12K is expected to be about 1600 (Cotter et al. 2002). Galaxies in the nearby Universe

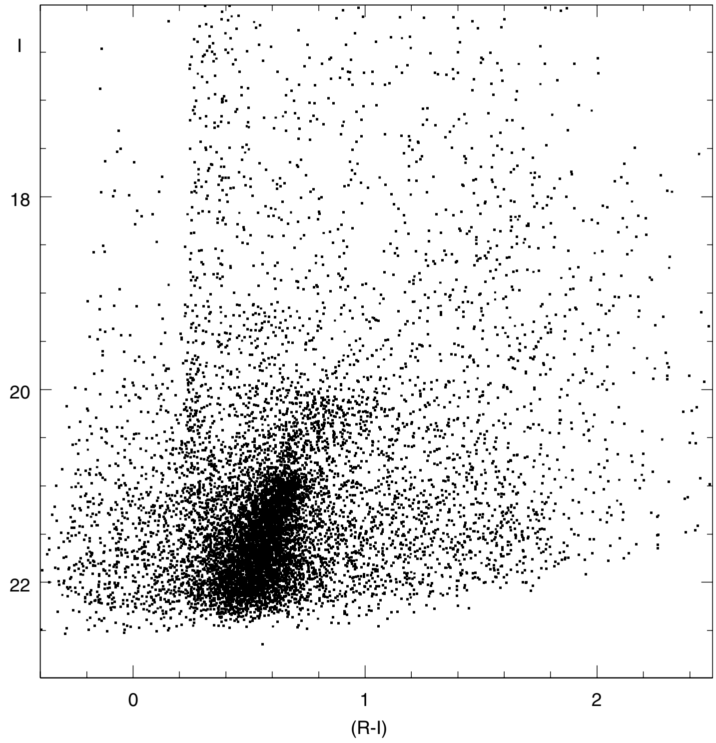

Fig. 1. Colour-magnitude diagram of the WLM field, stars with colour errors <0.10 are plotted.

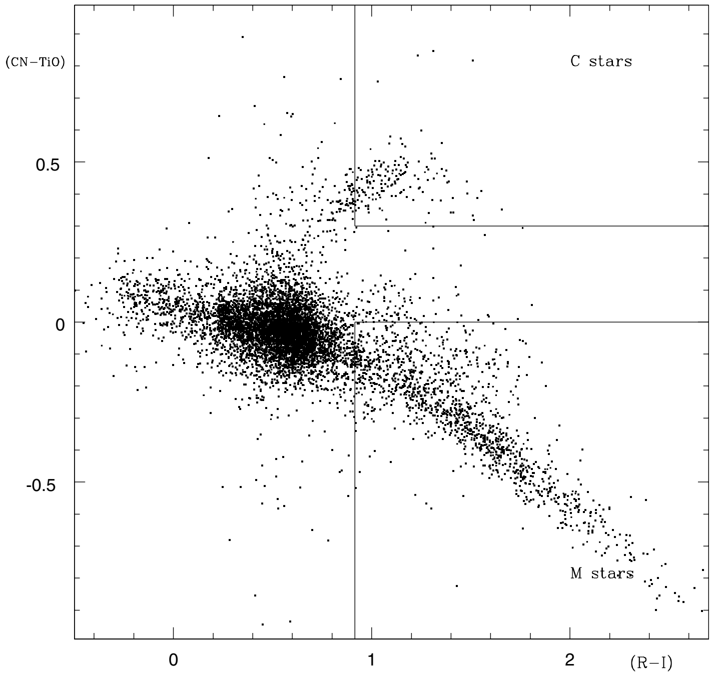

Fig. 2. Colour-colour diagram showing the boxes of C stars and M stars.

have mean colours $V-I \approx 1.2$, which corresponds to $R-I \approx 0.6$ (Karick et al. 2003; Idiart et al. 2003). Nearby galaxies should then be buried in the central concentration of the colour-colour diagram, their CN–TiO are expected to be neutral. Galaxies of this magnitude are expected to be highly redshifted, so much so that the K correction is far from negligible. For elliptical galaxies, the K correction on the $(R-I)$ colour varies from 0.8 mag, for $z = 1$, to reach 1.2 mag for $z = 2$ (Poggiante 1997). The colours of spirals are not so much redshifted because their evolution is more pronounced. We believe that we are seeing a few redshifted galaxies which otherwise would be masked by the numerous stars with similar colours.

Table 2. C stars in WLM[a].

id	RA	Dec	I	σ_I	$R-I$	σ_{R-I}	CN−TiO	$\sigma_{\mathrm{CN-TiO}}$
1	00 : 01 : 44.38	−15 : 30 : 58.60	20.744	0.023	0.985	0.043	0.458	0.040
2	00 : 01 : 49.54	−15 : 32 : 17.90	20.800	0.026	1.172	0.044	0.490	0.032
3	00 : 01 : 50.79	−15 : 34 : 33.80	19.910	0.013	1.382	0.026	0.436	0.025
4	00 : 01 : 51.06	−15 : 33 : 34.40	20.550	0.020	1.034	0.035	0.459	0.031
5	00 : 01 : 52.64	−15 : 31 : 00.10	20.289	0.020	1.050	0.033	0.442	0.032
6	00 : 01 : 53.08	−15 : 31 : 13.50	20.520	0.021	1.137	0.039	0.490	0.037
7	00 : 01 : 53.45	−15 : 35 : 00.20	20.797	0.023	0.938	0.040	0.419	0.040
8	00 : 01 : 55.70	−15 : 31 : 55.40	20.484	0.018	1.303	0.039	0.512	0.033
9	00 : 01 : 55.72	−15 : 31 : 56.50	20.133	0.015	1.367	0.034	0.457	0.026
10	00 : 01 : 55.75	−15 : 32 : 27.40	21.398	0.038	1.074	0.067	0.320	0.074
11	00 : 01 : 56.78	−15 : 33 : 49.60	20.315	0.017	0.916	0.027	0.376	0.030
12	00 : 01 : 57.69	−15 : 29 : 10.80	20.161	0.019	1.317	0.030	0.511	0.034
13	00 : 01 : 58.15	−15 : 30 : 19.50	20.226	0.020	1.002	0.033	0.469	0.030
14	00 : 01 : 58.23	−15 : 31 : 35.70	20.547	0.019	0.949	0.033	0.447	0.035
15	00 : 01 : 58.45	−15 : 33 : 44.60	20.119	0.018	1.300	0.035	0.527	0.031

[a] Table 2 is available in its entirety, in electronic form, at the CDS via anonymous ftp to `cdsarc.u-strasbg.fr (130.79.128.5)` or via `http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/416/111`. A portion is shown here for guidance regarding its form and content. Units of right ascensions are hours, minutes and seconds, and units of declination are degrees, arcminutes and arcseconds.

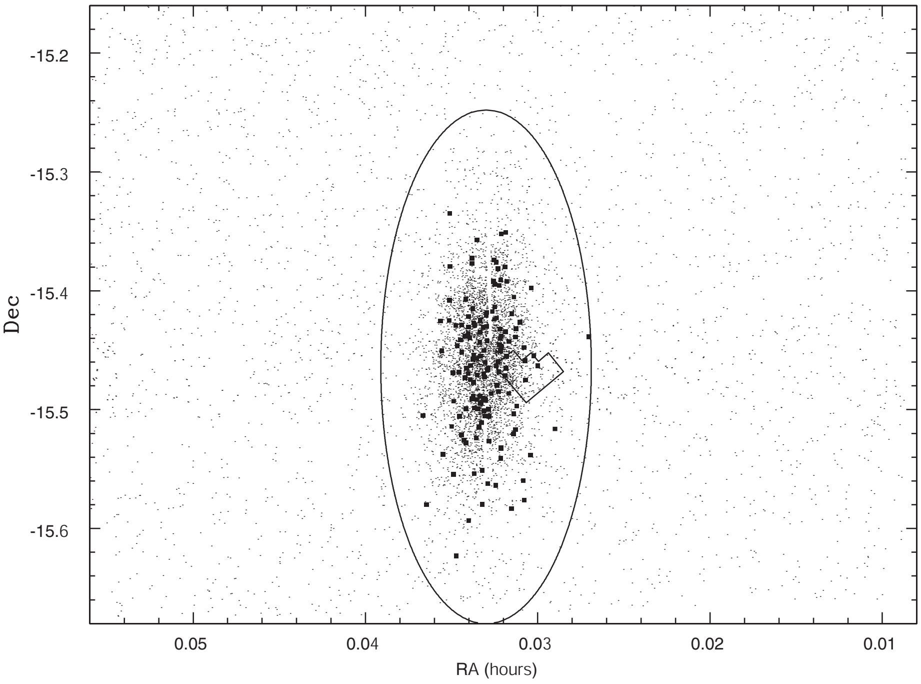

Fig. 3. The WLM field, carbon stars identified in this study are represented by big dots. Small dots correspond to stars plotted in Fig. 1. The limit of the galaxy, as determined from star counts, is outlined, see Sect. 4.2. The HST field investigated by Dolphin (2000), well within this ellipse, is also traced. This figure does not represent the whole area surveyed, a 14′ wide band further south is not shown. One of the gaps between CCDs is quite obvious in the high density central part of WLM. North is on top, East is on the left.

We list, in Table 2, the J2000.0 coordinates of the C stars shown, along with their magnitude and colours. The 149 C stars are identified, in the mosaic of the field in Fig. 3, by large dots.

4. Discussion

4.1. The photometric properties of C stars

The I magnitude distribution of the 149 C stars is displayed in Fig. 4, a Gaussian with a $\sigma = 0.30$ is traced over the magnitude distribution. The $\langle I \rangle = 20.28$, corresponds to $\langle M_I \rangle = -4.65$ for the adopted distance and extinction and $\langle R - I \rangle = 1.12$, thus $\langle (R - I)_0 \rangle = 1.10$. This mean magnitude is in excellent agreement with the average mean magnitude of C stars in similar dwarf galaxies (Demers et al. 2003).

It is notoriously laborious to evaluate the completeness of a four-colour survey when stars are selected from a two-colour diagram. In the past, we have evaluated the C star completeness from two sets of observations of the same field.

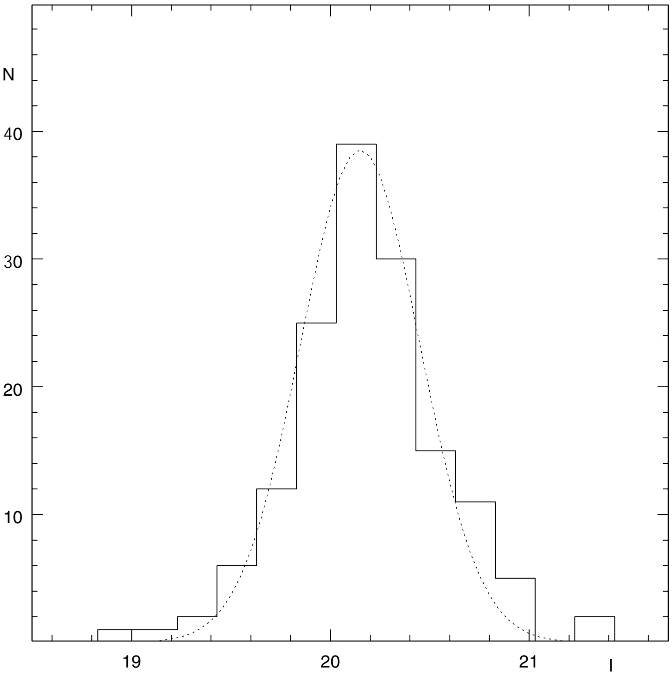

Fig. 4. Luminosity function of the C stars in WLM. A Gaussian with a $\sigma = 0.3$ is eye-fitted to the data.

Albert et al. (2000) estimate the completeness at 86% for the dense central part of IC 1613, while Battinelli et al. (2003) find a completeness factor of 96% for a field in the disk of M 31. We clearly see, however, from the density profiles discussed in the next section, that some stars are missing in the crowded center.

4.2. The size of WLM

Obviously, Fig. 3, reveals that the main body of WLM is not surrounded by an extended halo of intermediate-age stars that would have been traced by C stars. Like NGC 3109 (Demers et al. 2003), the intermediate-age population of WLM follows closely the bulk of the stars acquired by our observations. These stars include mostly red giants (see Fig. 1) thus represent the old population of WLM. Since our wide field observations provide a global view of WLM we can determine the shape and full extend of this population. Figure 5 displays the stellar isodensity contours of WLM revealing, as expected, a rather elongated structure.

Stellar density profiles of WLM red stars (defined as $0.3 < R - I < 1.8$ and $18.0 < I < 22.0$) along the major and minor axes are displayed in Figs. 6 and 7. Stars along the minor axis are counted in 20.6″ (100 pixels) wide strips extending the whole NS length of Fig. 3 while counts along the major axis are in strips of the same width but extending to ±5.5′ on both side of the major axis. Counts on both sides of the center are found to be quite similar, they are thus averaged. WLM does not show a marked asymmetry in this respect. For this exercise we assume that the position angle of the major axis of WLM is zero degree (Ables & Ables 1977, quote PA = 355°). Our wide field permits a robust estimate of the foreground surface density of red stars, defined above. The dashed line corresponds to 1.627 stars per arcmin^2. From these profiles we estimate that the semi-major axis of the stellar halo of WLM is 13′ and its semi-minor axis is at most 5.5′. The length of the major axis of WLM is then 7.2 kpc. Its ellipticity of $\epsilon = (1 - b/a) = 0.58$. This value agrees quite well with Ables & Ables (1977) who give $<b/a> = 0.41$. They conclude that the true shape of WLM might be an oblate spheroid seen at an inclination of 69°.

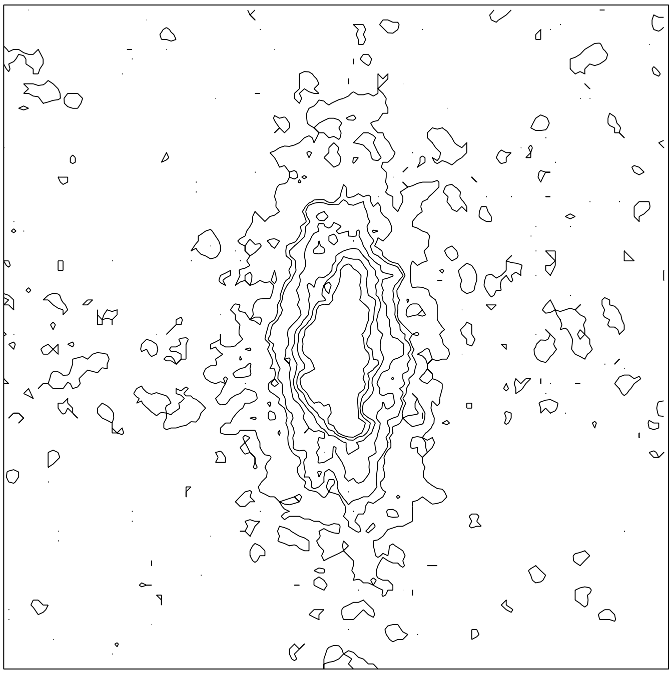

Fig. 5. Isodensity contours of the stellar content of WLM. This figure is based on our photometry to $I \approx 22$. The size of the area represented is 25.7′ × 25.5′. The values of each contour are 9, 33, 45, 78, 111, 145, and 178 stars per arcmin^2.

Our results do not support Minniti & Zijlstra (1996) conclusion that WLM is surrounded by an extended stellar halo. The density profile reveal that, for distances larger than ~5.5′ from the major axis, the counts become indistinguishable from the foreground counts. Furthermore, we can see from Fig. 3 that all C stars are within the ellipse determined from star counts. The “halo” region observed by Dolphin (2000) is also well within this ellipse.

Clearly, we face here a semantic problem: how to define halo. Halos of galaxies are usually defined in term of our own halo as: *spherical aggregation of stars, globular clusters and thin gas clouds, centered on the nucleus of the galaxy and extending beyond the known extremities of the galactic disk.* The radius of the halo of the Milky Way is quite big compared to the radius of its disk. Halos of dwarf galaxies are not so large compared to the bar or central part. The halo of the Large Magellanic Cloud has a 20° diameter, which would appear to be 1.1° at 955 kpc. WLM is not as massive as the LMC thus it is not expected to be as big. NGC 6822, which more closely compares to WLM in luminosity, has at least a 40′ spherical halo which would correspond to 20′ at the distance of WLM. WLM certainly does not possess such halo.

Using the above ellipticity we determine the surface density of WLM red stars, defined above, and of C stars in elliptical annulii of the appropriate shape. Their density profiles are

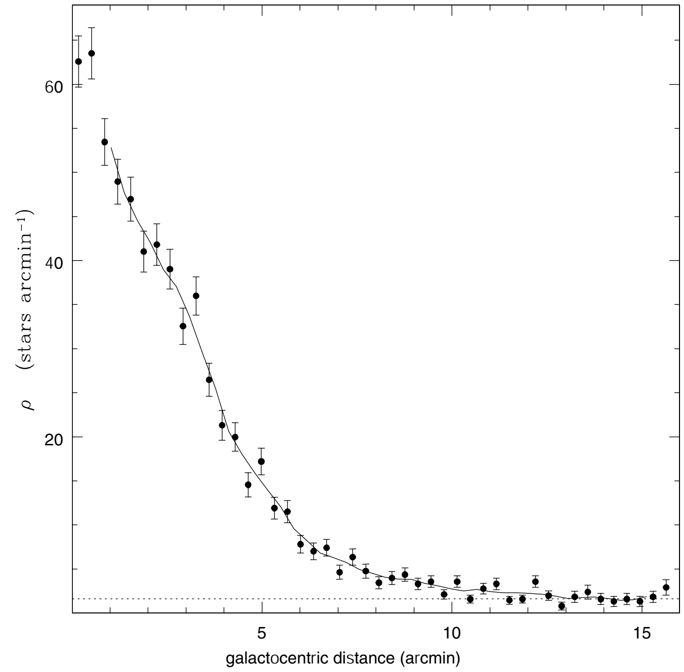

Fig. 6. Folded density profile along the major axis of WLM. The solid line corresponds to the running-mean (weights: 0.2, 0.3, 0.3, 0.2) of the data points. The dashed line represents the foreground density well established from counts far from WLM.

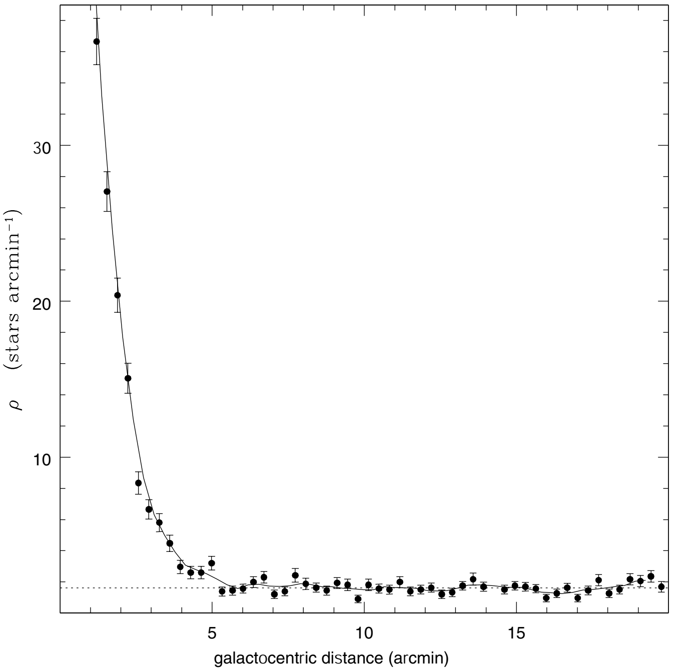

Fig. 7. Folded density profile along the minor axis of WLM. The solid line corresponds to the running-mean (weights: 0.2, 0.3, 0.3, 0.2) of the data points. The dashed line represents the foreground density well established from counts far from WLM.

displayed in Fig. 8. The red stars (brighter than $I = 22$) follow a power law with a scale length of $1.85 \pm 0.03'$ while the C stars have a marginally smaller scale length of $1.58 \pm 0.06'$. The last two points of the red star profile, outside of the 13′ ellipse, are barely 9% and 3% above the foreground. Both profiles show that stars have been missed in the crowded central region. The fact that the intermediate-age and old populations have nearly similar scale lengths suggests that the two are mixed.

The region of current star formation is concentrated in a narrower ellipse. Following Minniti & Zijlstra (1997) (see their Fig. 9), we present in Fig. 9, a plot of the distance of stars from the major axis as a function of their $(R - I)$ colours. We see a sharp cutoff at a distance of 100″ for blue stars. RGB and C stars can be distinguished up to 250″.

4.3. The C/M ratio

The metallicity of the old population of WLM has been estimated by Minnitti & Zijlstra (1997), from the position of the TRGB, to be $[\mathrm{Fe/H}] = -1.45 \pm 0.2$. Dolphin (2000) modeled the observed CMD to show that the initial abundance is -2.18 ± 0.28. Few stars seemed to have formed at this low metallicity. He calculates that the metallicity is $[\mathrm{Fe/H}] = -1.34 \pm 0.14$ at the tail end of 3 Gyr. It is then reasonable to assume that intermediate-age stars would have a metallicity as low as −1.4. This abundance is quite low when compared to other dwarf irregular galaxies. Recently, Venn et al. (2003) determined the abundance, from high resolution spectroscopy, of two young supergiants. They obtain $[\mathrm{Fe/H}] = -0.3$ suggesting than WLM is more chemically evolved that currently interpreted by its CMD.

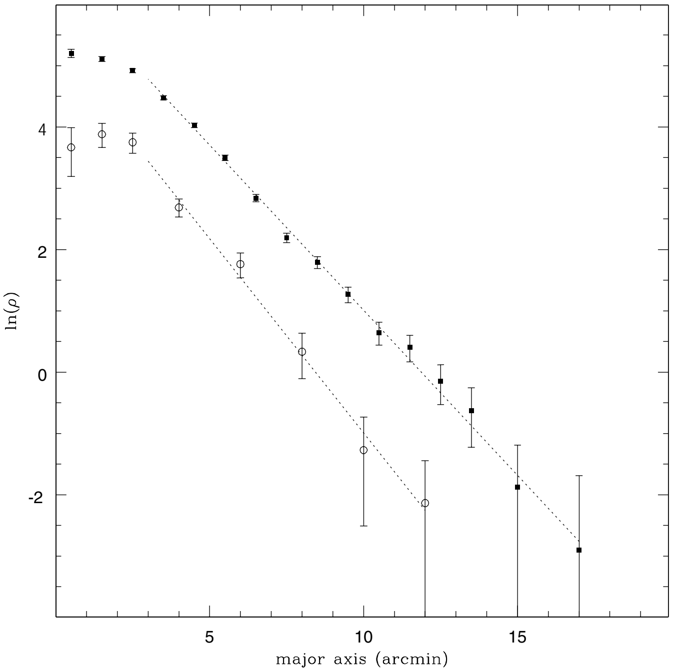

Fig. 8. Surface density profiles of red stars (solid dots) and C stars (open circles) have similar scale lengths. The dashed lines are least square fits through the outer points. To facilitate the comparison, 2 is added to the ln (ρ) of C stars.

Cook et al. (1986) surveyed, using the same CN–TiO technique, a small region in the center of WLM. They found in WLM the largest C/M ratios (for C/M3+ and C/M5+) among the five dwarf irregular galaxies surveyed. There is no doubt that this reflects the low metallicity of WLM when compared to

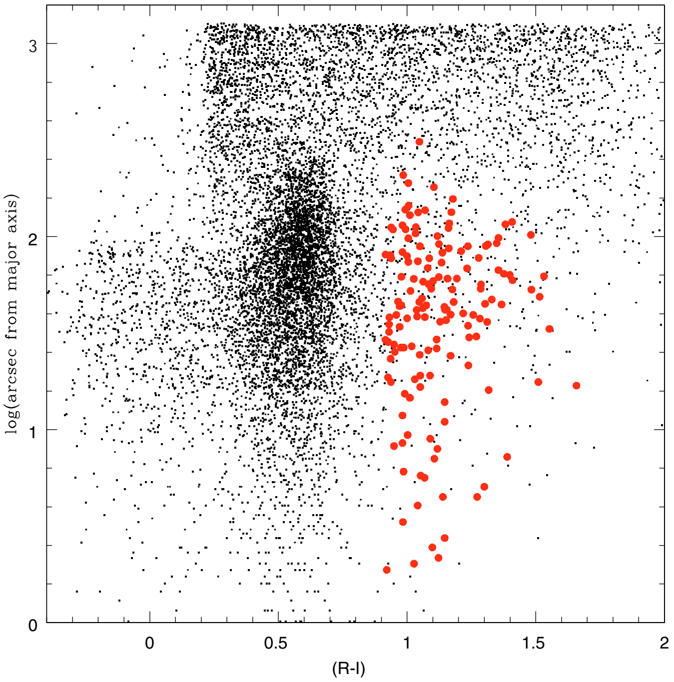

Fig. 9. The distance of stars from the major axis are plotted in term of their colours. We distinguish three populations: the blue stars concentrated closer to the center, the RGB and C stars (big dots) which occupy a larger volume.

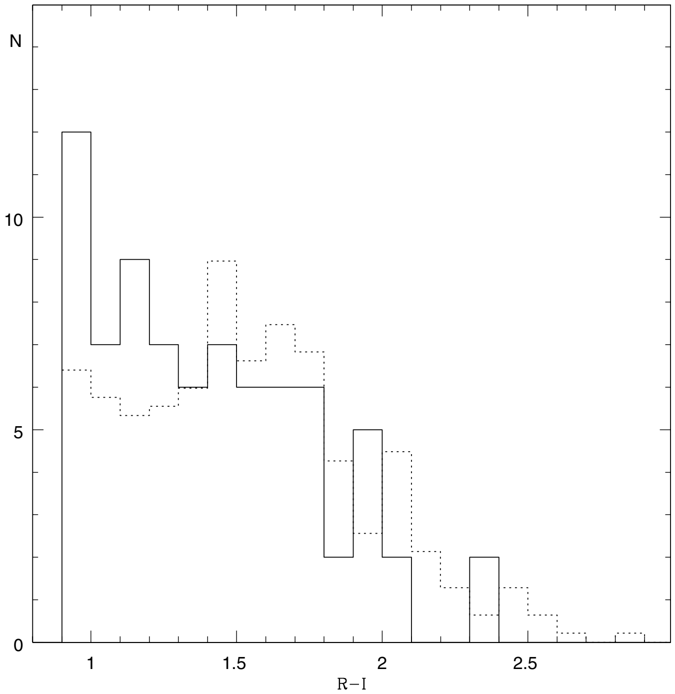

Fig. 10. Colour distribution of the AGB M stars within the ellipse (solid line) and outside the ellipse (dashed line), scaled to match the area of the ellipse.

NGC 6822, IC 1613, and the Magellanic Clouds. The C/M ratio of a stellar population is known to be function of the metallicity of that population (Groenewegen 1999) but the relationship is not well defined. Cioni & Habing (2003) recently mapped the C/M ratios across the Large Magellanic Clouds. The large variations seen suggest a rather patchy metallicity. Furthermore, their compilation of Local Group C/M ratios yields a rather poor relationship with abundances. We feel that there is a definite need for a more coherent approach to the determination of C/M ratios.

In the case of WLM, to select AGB M stars we follow the procedure adopted by Battinelli et al. (2003) which consists in rejecting stars with $M_{\rm bol}$ fainter than the TRGB luminosity as well as those brighter than the brightest members of the galaxy. The bright cutoff for the selection of AGB M stars is $I_0 = 19.00$ which corresponds to the value used by Battinelli et al. (2003) for M 31 scaled for the the different distance and absorption of WLM.

Following these criteria, there are 443 M stars in the area plotted in Fig. 3. 77 of them are within the ellipse of 13′ semi-major axis and 366 are outside. If one assume that the stars outside are foreground Galactic dwarfs, then one would expect 77.9 ± 4.1 such stars within the ellipse. This simple comparison would suggest that WLM has few if any AGB M stars. It is, however, possible that the few WLM M stars are overwhelmed by late M dwarfs. To investigate this possibility, we present in Fig. 9 the colour histograms of the AGB M stars inside and outside of the 13′ ellipse, scaled to correspond to the area of the ellipse. This figure reveals that there is a surplus of a dozen AGB M stars, with $(R-I) < 1.3$, inside of the ellipse. This would yield a C/M ratio of 12.4 ± 3.7, with a rather large uncertainty. According to the spectral type colour relation of Thé et al. (1984), $(R-I) = 1.25$ corresponds to M 3, thus confirming the lack of AGB stars later than M 3 in WLM (Groenewegen 2002).

5. Conclusion

Our C star survey has shown that halos of dwarf galaxies come out in two flavours, either consisting in a well mixed populations of old and intermediate-age stars or completely missing; in other words, no halos of pure old stars seem to exist among dwarf galaxies. WLM and NGC 3109 (Demers et al. 2003) are examples of the latter while IC 1613 (Albert et al. 2000), NGC 6822 (Letarte et al. 2002), NGC 147 (Battinelli & Demers 2004a) and NGC 185 (Battinelli & Demers 2004b) present extended halos containing old and intermediate-age stars. The nature of such halo dichotomy is still to be explained.

Among the dwarf irregular galaxies, WLM presents the highest C/M ratio reflecting the low metallicity of its intermediate-age population. It seems, however, that currently available C/M ratios are not easily correlated to metallicity. For instance, on the basis of its C/M = 1.75, NGC 3109 should be more metal rich than WLM while its metallicity is [Fe/H] = −1.8 (Minniti et al. 1999), a value lower than WLM's one. We reckon that most of the problems in the determining a reliable C/M–[Fe/H] relation from data available in the literature comes from two circumstances: i) metallicity estimates are often related to different age populations (e.g. TRGB, PNe, individual stars...) and thus may not well represent the chemical composition of the intermediate-age population; ii) C stars are selected using different criteria and observational techniques that lead to numbers of C stars not homogeneously defined from galaxy to galaxy. In this context, our present survey of C stars certainly solves the latter point. We will discuss, in a forthcoming paper, the current C/M estimates for various spectral types and investigate their usefulness for metallicity estimates.

Acknowledgements. This research is funded in parts (S.D.) by the Natural Science and Engineering Council of Canada.

References

Albert, L., Demers, S., & Kunkel, W. E. 2000, AJ, 119, 2780
Ables, H. D., & Ables, P. G. 1977, ApJS, 34, 245
Baade, W. 1944, ApJ, 100, 147
Battinelli, P., & Demers, S. 2000, AJ, 120, 1801
Battinelli, P., Demers, S., & Letarte, B. 2003, AJ, 125, 1298
Battinelli, P., & Demers, S. 2004a, A&A, in press
Battinelli, P., & Demers, S. 2004b, A&A, in press
Brewer, J. P., Richer, H. B., & Crabtree, D. R. 1995, AJ, 109, 2480
Cioni, M.-R. L., & Habing, H. J. 2003, A&A, 402, 133
Cook, K. H., Aaronson, M., & Norris, J. 1986, ApJ, 305, 634
Cotter, G., Haynes, T., Baker, J. C., et al. 2002, MNRAS, 334, 283
Demers, S., & Battinelli, P. 2002, AJ, 123, 238
Demers, S., Battinelli, P., & Letarte, B. 2003, A&A, 410, 795
de Vaucouleurs, G., & de Vaucouleurs, A. 1964, Reference Catalogue of Bright Galaxies (Univ. Texas Press)
Dolphin, A. E. 2000, ApJ, 531, 804
Ferraro, F. R., Fusi Pecci, F., Tosi, M., & Buonanno, R. 1989, MNRAS, 241, 433
Groenewegen, M. A. T. 1999, in Asymptotic Giant Branch Stars, ed. T. Le Bertre, A. Lebre, & C. Waelkens, IAU Symp., 191, 535
Groenewegen, M. A. T. 2002, Ringberg Castle Workshop [astro-ph/0208449]
Holmberg, E. 1950, Medd. Lunds Obs. Ser., 2, No. 128
Huchtmeier, W. K., Seiradakis, J. H., & Materne, J. 1981, A&A, 102, 134
Idiart, T. P., Michard, R., & de Freitas Pacheco, J. A. 2003, A&A, 398, 949
Karick, A. M., Drinkwater, M. J., & Gregg, M. D. 2003, MNRAS, 344, 188
Letarte, B., Demers, S., Battinelli, P., & Kunkel, W. E. 2002, AJ, 123, 832
Mateo, M. 1998, ARA&A, 36, 435
Melotte, P. J. 1926, MNRAS, 86, 1936
Minniti, D., & Zijlstra, A. A. 1996, ApJ, 467, L13
Minniti, D., & Zijlstra, A. A. 1997, AJ, 114, 147
Minniti, D., Zijlstra, A. A., & Alonso, M. V. 1999, AJ, 117, 881
Poggianti, B. M. 1997, A&AS, 122, 399
Rejkuba, M., Minniti, D., Gregg, M. D., et al. 2000, AJ, 120, 801
Rieke, G. M., & Lebofsky, M. J. 1995, ApJ, 288, 618
Sandage, A., & Carlson, G. 1985, AJ, 90, 1464
Stetson, P. B. 1987, PASP, 99, 191
Stetson, P. B. 1994, PASP, 106, 250
Thé, P. S., Steenman, H. C., & Alcaino, G. 1984, A&A, 132, 385
Venn, K. A., Tolstoy, E., Kaufer, A., et al. 2003, AJ, 126, 1326
Wolf, M. 1909, AN, 183, 187