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LETTER

Letter to the Editor

On the history of star formation in the bar of the Large Magellanic Cloud

A. Ardeberg[1], **B. Gustafsson**[2], **P. Linde**[1] **and P.-E. Nissen**[3]

[1] Lund Observatory, Box 43, S-221 00 Lund, Sweden
[2] Astronomical Observatory, Uppsala University, Box 515, S-751 20 Uppsala, Sweden
[3] Institute of Physics and Astronomy, Aarhus University, DK-8000 Aarhus C, Denmark

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Abstract. With the HST PC and uvby photometry, we investigate evolutionary signatures in a field in the centre of the LMC Bar. Field stars close to the turn off point in the HR diagram are used for a study of ages and evolution of the stellar populations dominating the Bar as well as for determination of the abundance of heavy elements. Including fainter stars, we derive the corresponding luminosity function. Here, we discuss some results obtained from a preliminary version of our data. The quality of our data is high. Two strong stellar populations are obvious. A young component contains approximately 30 % of the total number of stars. At least a considerable fraction of this component originated less than 500 Myears ago. The older population ranges in age between around 2 and 9 Gyears. The abundance of heavy elements is around [Me/H] = -0.6. The tentative luminosity function, down to y = 24, resembles in shape that predicted from earlier galactic and LMC data. Parallel to arrival of further HST data, our analysis continues.

Key words: Large Magellanic Cloud - stellar evolution - metallicity - luminosity function - uvby photometry

1. Introduction

Processes driving star formation and nucleosynthesis are poorly known, especially for external galaxies. For studies of such processes, the LMC offers unique possibilities. It is close enough to allow study of individual main sequence stars, it has a large spread in stellar ages and a structure permitting safe identification of different stellar populations and their properties. The LMC is thus favourable for studies of large-scale star formation and chemical evolution and for tests of current theories on the evolution of galaxies.

In the LMC, the Bar presumably dominates the chemical and dynamical evolution (Westerlund 1990), in addition to close encounters with the SMC and the Galaxy (Murai and Fujimoto 1980, Fujimoto and Murai 1984). Gravitationally dominating, the Bar is probably a motor of massive star formation (Kormendy 1981, Larson 1987). In such a scenario, clouds of gas and dust in outer parts of the galaxy are captured by the Bar and fall in its direction.

2. Some clues to LMC star-formation history

Our knowledge of LMC star formation, has, until now, been limited to data from broad-band photometry, mostly of sparsely populated fields. Due to image crowding, mainly relatively bright stars have been reached. Still, it has been clear that different parts of the LMC show different population characteristics. Effects of sporadic bursts of star formation and a stellar population a few Gyears old have been observed (Butcher 1977, Frogel and Blanco 1983, Stryker 1984, Hardy et al. 1984, Bertelli et al. 1992, Vallenari et al. 1996a,b, Gallagher et al. 1996).

Outside the Bar, two populations are mixed (Ardeberg et al. 1985), one old "halo population" and one younger "disk population". Also, LMC clusters show two populations. Older globular clusters are similar to Galaxy counterparts (Searle et al. 1980), while a younger population of clusters has a median age somewhat above 1 Gyear with some clusters up to 4 Gyears old (Flower 1984, Chiosi et al. 1988, Da Costa 1991, Vallenari et al. 1992, Girardi et al. 1995). M giant stars in a field in the Western part of the Bar seem to divide into a smaller young and a larger old population (Frogel and Blanco 1990).

In number and integrated mass, LMC stars of the youngest generations are of smaller importance. Stars defining global galactic properties are much older and may have a chemical composition considerably different from that of the youngest populations. How much older the dominating stars may be, and how different their chemical compositions are, has remained

Send offprint requests to: A. Ardeberg, address as above

Fig. 1. Our target field observed with the HST PC. The field is square with 35" side. A y picture is shown with a total exposure time of 53 min.

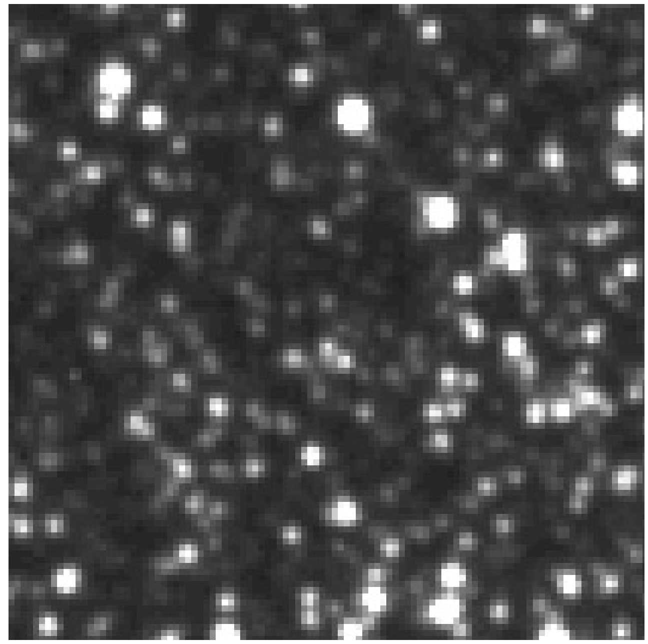

Fig. 2. Same field as in Figure 1 but observed from the ground with the ESO/MPA 2.2 m telescope at La Silla. A y picture is shown with 5 min exposure time and an image quality corresponding to FWHM = 0.9 arcsec.

unknown. Of key significance in this respect is the composition of the Bar. Before the current study, little has been known concerning the properties of the bulk population of this dominating LMC structure.

3. Hints on LMC chemical evolution

In the LMC, spectroscopy at resolutions adequate for abundance analysis can reach only intrinsically bright objects. This severely limits our knowledge of its chemical evolution. Spectroscopic studies concern supergiant stars (Kudritzki 1988, Wolf and Reitermann 1989, Spite 1989, Russell and Bessell 1989, Spite F. et al. 1989, Spite M. et al. 1989, Richtler et al. 1989, Hill et al. 1995), B stars (Rolleston 1996), AGB stars (Frogel and Blanco 1990), planetary nebulae (Dennefeld, 1989) and HII regions (Dufour, 1984). The range in [Me/H] found is from -1.4 to -0.2, with some tendency for the youngest objects to be more metal-rich. While interesting for the objects studied, these data only shed limited light on the chemical evolution of the galaxy as a whole.

4. Present programme

To be able to study evolutionary signatures of larger amounts of stars in the LMC Bar, we need observing material with excellent image quality. In addition, we need tools for reliable abundance investigations that are able to reach objects of intrinsic luminosity close to that of the Sun. We have chosen to work with the HST and Strömgren uvby photometry.

With these tools, we have initiated a study of metallicities and ages of field stars close to the turn-off point in the LMC Bar centre. Fainter stars are included for a study of the luminosity function.

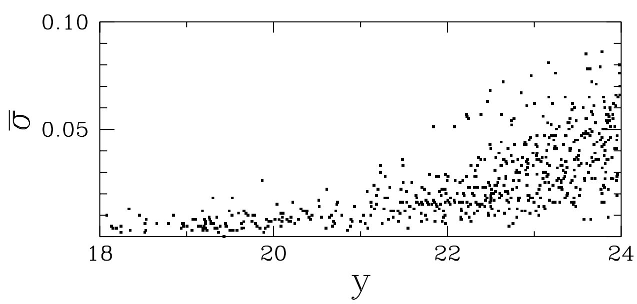

Fig. 3. The standard deviation of averaged y magnitudes is displayed versus y, both expressed in magnitudes.

5. Observations

Our programme was granted 22 primary spacecraft orbits in cycle 5 with the HST. The majority of this observing time has now been used. Only some limited, though highly essential, observations of calibration objects remain to be completed. We have commenced reduction of our HST data. The present report is based on results of our first, tentative data reduction. The preliminary analysis confirms the high quality of our observing data. Further, already these tentative results give new astrophysical insights of considerable significance.

Our primary target field is defined by the HST Planetary Camera (PC). The size of this field is around 1200 arcsec^2. The centre of our primary field has $\alpha = 05^{\rm h}\ 20^{\rm m} 52\overset{\rm s}{.}2$ and

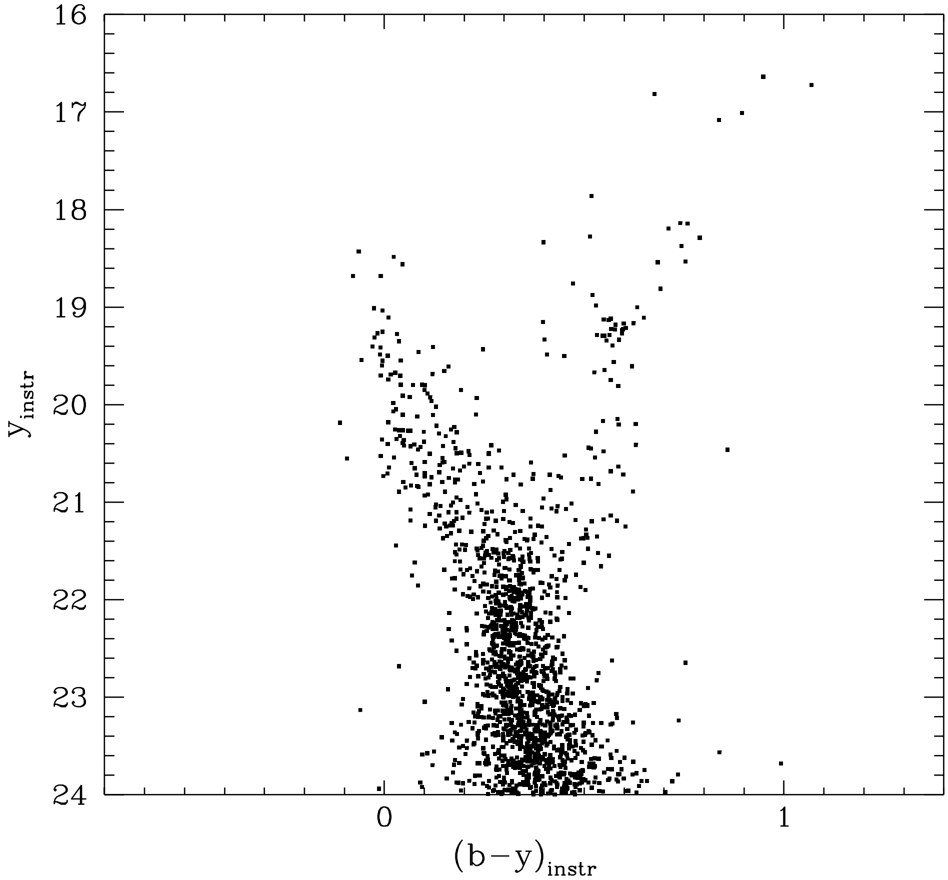

Fig. 4. A tentative colour-magnitude diagram for our LMC Bar field. y is displayed versus (b−y), both parameters on a zero point corrected instrumental system and expressed in magnitudes. Total exposure time in y is 53 min, in b 207 min.

$\delta = -69°35'31''$(epoch 2000). The total exposure times for the target field are, in y 53 min, in b 207 min and in v 320 min.

6. First results

We have derived instrumental magnitudes on the y and b scales and, to some extent, on the v scale, in the uvby system. For these data, we made tentative zero point determinations. The resulting magnitudes and colour indices, y and (b−y), were used for the preliminary conclusions reported in this paper. Whilst solid enough for the conclusions drawn, the data are still on an instrumental system. System calibration will be made to high accuracy. This work is in progress, in collaboration with STScI colleagues.

The preliminary analysis of our recent HST uvby observations in the centre of the LMC Bar confirms their high quality. A comparison between our HST PC field and the corresponding field seen from the ground is given in Figures 1 and 2. The quality of our data is demonstrated in Figure 3.

Figure 4 shows a colour magnitude diagram derived from our PC field. Various tests have shown that our distribution of stars is close to complete down to at least y = 22.5. Thus, down to this limit, number statistics can be used to derive the age distribution of stars in our target field. In this first step, effects of interstellar extinction, being modest (Ardeberg et al. 1985, Schwering and Israel 1991, Oestreicher et al. 1995), are neglected. For the young population of stars, we adopt a galactic luminosity function (LF) of the zero-age main sequence (ZAMS) based on galactic open clusters (Taff 1974). Using our number statistics and the LF, we estimate that the young stellar component contains around 30 % of the total amount of stars in the part of the Bar studied.

As a check on our conclusion regarding age distribution, we employed an alternative way to estimate the fraction of young stars in our field. As before, we used the LF for the young stellar population, whilst we adopted isochrones to estimate the total contribution of the old population from the giant branch. The result is close to that obtained from number statistics and the young star LF.

From the morphology of the horizontal branch and the colour of the horizontal and giant branches, we estimate a metallicity of around [Me/H] = −0.5. A probably better estimate of the abundance of heavy elements will later be derived from the m_1 index. The reduction of the v-band data is still rather preliminary since all calibration observations have not been acquired. However, from a tentative m_1-(b-y) diagram, we estimate [Me/H] = −0.7. There may be some indication of a real scatter in metallicity in the m_1 data, with the older population being more metal poor. This will be further investigated.

As estimated from isochrones by VandenBerg (1985), at least a considerable fraction of the young stellar component originated less than 500 million years ago. We tentatively ascribe this young population to the Bar. We will return to this topic with a statistical test.

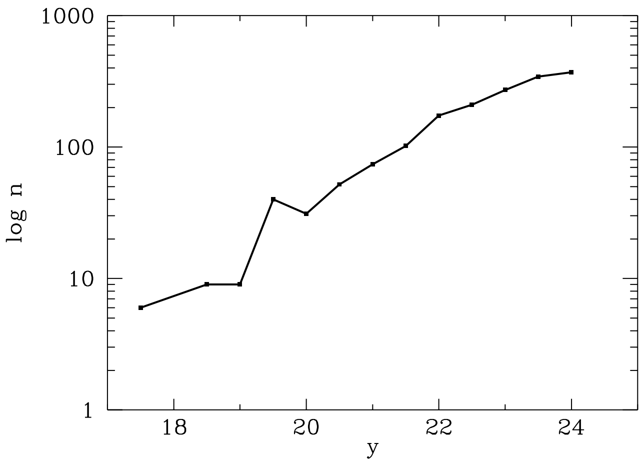

Fig. 5. A tentative bright-end luminosity function for our LMC Bar field. The number of stars observed, expressed on a logarithmic scale, is given versus y, expressed in magnitudes. For the brightest stars, number statistics are weak.

From isochrones of Bergbusch and VandenBerg (1992), we estimate that the older population ranges in age between 2 and 9 Gyears. The very small number of stars in the rectangle in Fig 4, defined by 19.5<y<20.5, 0.3<(b-y)<0.5, as compared with the evolutionary tracks of VandenBerg (1985), suggests that star formation decreased considerably before the more recent burst occurred. Improved age estimates will be based on the entire WFPC2 field sample, again taking advantage of its usefulness for the brighter stars. At any rate, stars much older than 10 Gyears seem to be scarce.

Our preliminary luminosity function, down to y = 24, is given in Figure 5. Compared to a luminosity function derived from an observed field in the LMC halo close to the Bar (Ardeberg et al. 1985) and surface density measurements (de Vaucouleurs 1957), the new, tentative, luminosity function presents a rather similar slope and even agrees quite well in over-all shape.

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