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Variable Stars in the LMC: the Photometric Catalogue

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Abstract. New B, V, I photometry was obtained for a sample of 152 variables (125 RR Lyrae's, 4 anomalous Cepheids, 11 classical Cepheids, 11 eclipsing binaries and one δ Scuti star) in two regions near the bar of the Large Magellanic Cloud (LMC). We derived complete and well sampled B and V light curves, very accurate periods, epochs of maximum light, amplitudes, intensity and magnitudes average apparent luminosities for about 95% of the RR Lyrae stars. All these information are contained in the photometric catalogue. Metallicities from the Fourier decomposition of the V light curves were derived for 29 of the ab type RR Lyrae's and are compared with the ΔS metal abundances from low resolution spectra obtained with the Very Large Telescope (VLT).

Key words. Magellanic Clouds – Stars: oscillations – Techniques: photometric

1. Introduction

A large number of variables of various types have been detected in the LMC by the MACHO (Alcock et al. 1996) and OGLE (Udalski et al. 2000) microlensing experiments. Discovery of more than 7900 RR Lyrae's in the bar of the LMC is reported by Alcock et al. (1996), as well as of a large number of Cepheids and eclipsing binaries. RR Lyrae's and Cepheids are of particular interest since they are primary distance indicators for the LMC and for Local Group galaxies, in general.

Notwithstanding the large amount of observational data collected for the variables in the LMC by the microlensing experiments, the nonstandard photometric passbands used by some of these missions (MACHO) and the fact that RR Lyrae's are close to the limiting magnitude of these surveys set constraints on the use of those photometric databases. Besides, because in these experiments variables have mainly been observed in I and to a lesser extent in V and B, this

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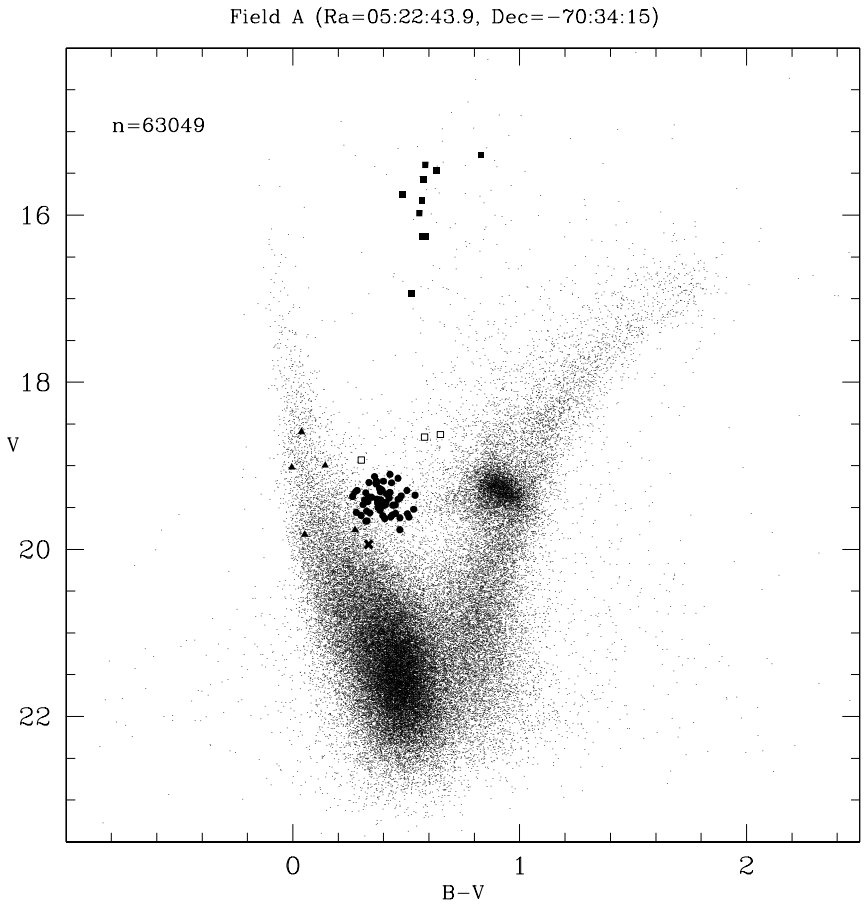

Fig. 1. V *vs* B - V color - magnitude diagram of Field A from the ALLFRAME reduction of the 2001 data. Different symbols mark the variables identified in this field (RR Lyrae stars: filled circles; anomalous Cepheids: open squares; Cepheids: filled squares; binaries: filled triangles; crosses: δ Scuti).

makes more difficult the comparison with most of the Galactic sample observations which generally are in B and V, instead.

2. Observations and reductions

Time series B, V, and I exposures of two $13\prime \times 13\prime$ fields (hereinafter called Field A and B) close to the bar of the LMC and contained in Field #6 and #13 of the MACHO microlensing experiment (Alcock et al. 1996) were obtained with the 1.54 m Danish telescope at ESO (La Silla, Chile) in two observing runs respectively in January 1999 and 2001. Field A also has a 40% overlap with the OGLE-II field LMC_SC21 (Udalski et al. 2000). The full data-set consists of 72, 41 and 15 frames in V, B, and I respectively. Reduction and analysis of the 1999 photometry were done using the package DoPHOT (Schechter, Mateo & Saha 1993), while photometric reductions of the 2001 data were done using the packages DAOPHOT/ALLSTAR II (Stetson 1998) and ALLFRAME (Stetson 1994).

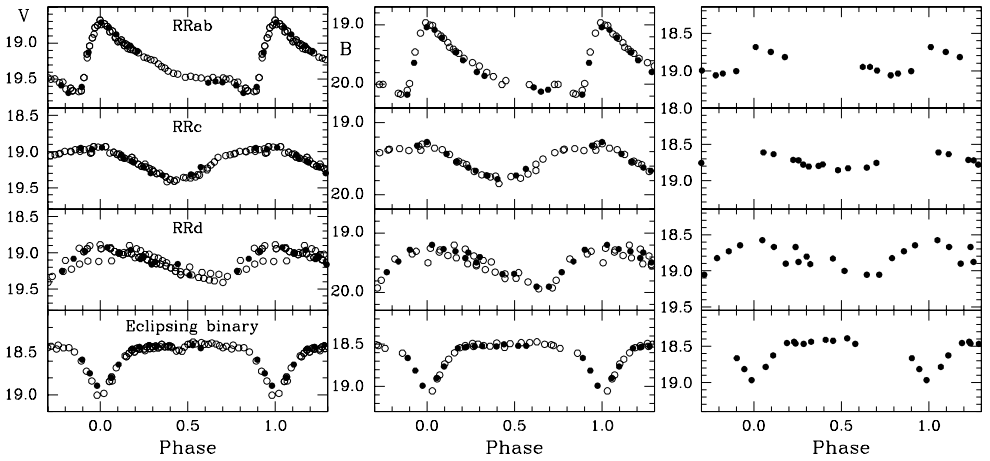

Fig. 2. Some examples of our light curves. Open circles are from Clementini et al. (2001), filled dots are the new data points.

3. Data Analysis

Variable stars were identified on the 1999 time series data-set using the program VARFIND (private software by P. Montegriffo), and then counteridentified in the 2001 data-set. VARFIND displays the scatter diagram of the average measurements, from which candidate variables are identified due to their large standard deviations. Each candidate variable identified with VARFIND was then checked for variability using the program GRATIS (GRaphycal Analyzer TIme Series), a software developed at Bologna Observatory by P. Montegriffo, G. Clementini and L. Di Fabrizio, directly interfaced to VARFIND, which performs a period search on the data using both the Lomb periodogram (Lomb 1976, Scargle 1982) and a best-fit of the data with a truncated Fourier series (Barning 1963). About two thousand objects were checked for variability in both field A and B. Among them we detected 152 certain variables and in addiction 7 candidates of unknown type. In the sample, there are 125 RR Lyrae stars (77 RRab, 38 RRc, 10 RRd), 4 anomalous Cepheids, 11 classical Cepheids, 11 eclipsing binaries and one δ Scuti star. Our identification of the RRab variables in Field B should be complete, while identification may be less complete in Field A, because of the larger crowding conditions. Moreover some RRc's may have escaped detection in both fields, due to their smaller amplitudes. Figure 1 shows the location of the variable stars on the HR diagram of Field A; variables are plotted according to their intensity-average magnitudes and colors, and with the different symbols corresponding to the various types.

Thanks to the two years time base line spanned by our observations, we were able to:

a) derive periods and epochs for all the 152 variables with a precision better than the fourth decimal place, depending on the light curve data sampling (in the best cases is 72 V, 41 B and 14 I);
b) solve aliasing problems and check the actual variability of some candidate variables detected in 1999;
c) identify the Blazhko modulation of the light curves in about 15% of the total sample of our RR Lyrae stars;

d) derive complete and well sampled B and V light curves for about 95% of the RR Lyrae stars.

GRATIS allows to perform also a search for multiple periodicities and was run on the data of the 10 double-mode pulsators falling in our fields, one of which newly discovered. In figure 2 we show the multicolor light curves for an RRab, an RRc, an RRd and an eclipsing binary in our sample.
The period distribution of the single-mode RR Lyrae's shows two peaks, corresponding to the *ab* (77 objects) and *c* (38 objects) type pulsators. The mean periods are $0.^d580$ (σ=0.064) and $0.^d327$ (σ=0.047) for *ab* and *c* pulsators, respectively. The preferred period of the RRab's falls between the periods of the Galactic globular clusters of Oosterhoff (1939) type I (OoI) and II (OoII), and actually closer to the OoI type. The overlap in the transition region between *ab* and *c* type is small (6 objects) and the transition period occurs at $P_{tr} \sim 0.^d40$. B and V amplitudes were calculated as the difference between maximum and minimum of the best fitting models for all the RR Lyrae's having full coverage of the light curve. These amplitudes have been used together with the derived periods to build-up period-amplitude diagrams. We compared the derived period-amplitude distributions with relations defined by the RRab's in the globular clusters M3, M15 and ω Centauri. RR Lyrae's in Field B seem to follow better the amplitude-period relations of the variables in M3 and to belong to OoI type. Variables in Field A, instead, have pulsational properties more intermediate between the two Oosterhoff types.
We derived also metallicities and absolute magnitudes from the parameters of the Fourier decomposition of the V light curves; we applied Jurksic & Kovács (1996) and Walker & Kovács (2001) techniques to 29 RRab's that satisfy the completeness and regularity criteria defined by Jurksic (1995). The derived average metallicity is [Fe/H]=−1.27 dex (σ=0.35). This value is in good agreement with our previous estimate of [Fe/H]=-1.49 ± 0.11 dex (σ=0.28) (Bragaglia et al. 2001) determined applying the ΔS method (Preston 1959) to 6 RRd's, once differences in the metallicity scale are taken into account. Metallicities obtained in 2001 for 101 of the RR Lyrae stars in our sample, from a spectroscopic survey with FORS at the VLT, are again in agreement with the previous results, giving an average metal abundance of [Fe/H]=-1.48 ± 0.03 dex (σ=0.29) (Gratton et al. 2002).

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