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Classical Cepheids as age indicators

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Abstract. Theoretical Period-Age and Period-Age-Color relations for different chemical compositions have been recently derived using an updated homogeneous set of evolutionary and pulsational models. We apply these relations to Cepheids in the Magellanic Clouds to constrain the recent star formation history of these dwarf galaxies. Finally, we also compare the radial distribution of classical Cepheids with young clusters and star forming regions.

Key words. Stars: Variables: Cepheids, Galaxy: Stellar Content, Stars: Evolution, Stars: Oscillations

1. Introduction

Classical Cepheids are traditionally used as primary distance indicators, since their pulsation periods, colors, and intrinsic luminosity are tightly connected. Moreover, they are good tracers of intermediate-mass stars in the Galactic disk (Kraft & Schmidt 1963), and star-forming regions in extragalactic systems (Elmegreen & Efremov 1996). The use of Cepheids as tracers of young stellar population was soundly supplemented by the evidence that if these objects obey to a PL relation, and to a Mass-Luminosity (ML) relation, they also obey to a Period-Age (PA) relation. In particular, an increase in period implies an increase in luminosity, i.e. an increase in the stellar mass, and in turn a decrease in the Cepheid age. On the basis of these plain physical arguments several empirical and semiempirical PA relations for Galactic, LMC, and M31 Cepheids have been derived to constrain the recent star formation history of the explored regions (Efremov 1978; Magnier et al. 1997; Efremov & Elmegreen 1998; Grebel & Brandner 1998; Efremov 2003). The PA relation presents the following advantages: i) age estimates rely on the pulsation period, an observable marginally affected by systematic errors; ii) it can be applied to individual objects; iii) the application to cluster Cepheids provides a unique opportunity to evaluate the age of the parent cluster, even if the photometry of Turn-Off stars is lacking or poor. However, current PA relations are calibrated using cluster Cepheids. This means that the slope and

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the zero-point of the PA relation might be affected by distance and reddening uncertainties, as well as by the period range covered by cluster Cepheids. Finally, age estimates based on the PA relations rely on the assumption that the Cepheid instability strip has a negligible width in temperature. This working hypothesis introduces systematic errors for periods longer than ~ 8 days. In order to overcome this problem *pulsational* ages should account for the color dependence by using a Period-Age-Color (PAC) relation. To provide a new theoretical framework we constructed detailed sets of evolutionary tracks and nonlinear convective pulsation models covering a broad range of stellar masses and chemical compositions (Bono et al. 2005). On the basis of these calculations we derived new PA and PAC relations both for fundamental and first overtone pulsators. We performed a detailed comparison between evolutionary and pulsation ages for a sizable sample of LMC (15) and SMC (12) clusters and for two Galactic clusters (Bono et al. 2005). As a result, we found that the different age estimates agree at the level of 20% for LMC and Galactic clusters and of 10% for SMC clusters. These findings support the use of PA and PAC relations to supply accurate estimates of individual stellar ages in the Galaxy and in external Galaxies. In this paper we extend the analysis to field Cepheids in the Magellanic Clouds.

2. PA and PAC relations

The sample of Magellanic Cepheids is based on the huge database collected by the OGLE project (Udalski et al. 1999a,b) together with the old Payne-Gaposchkin catalogue (see Figs. 1 and 2) for long-period objects. In order to evaluate the individual ages of selected Cepheids we applied predicted PA and V-I color PAC relations for Z=0.008, Y=0.25 (LMC) and Z=0.004, Y=-0.25 (SMC) to fundamental and first overtone pulsators. For the OGLE samples we derived pulsation age estimates by averaging the results obtained from the PA and the V-I PAC relations, while for the Payne-Gaposchin sample both the colors and the pulsation mode are not available and we used the fundamental PA relation.

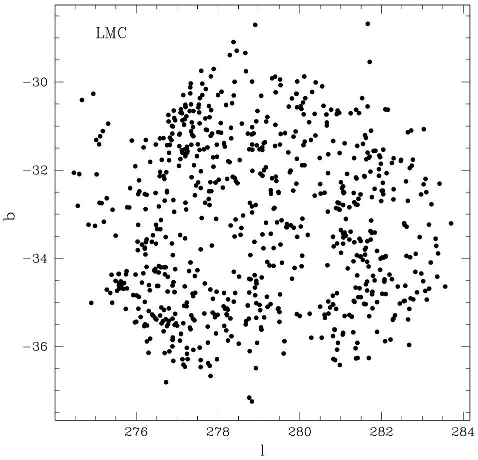

Fig. 1. Distribution in Galactic coordinates of the Payne-Gaposchin LMC Cepheids.

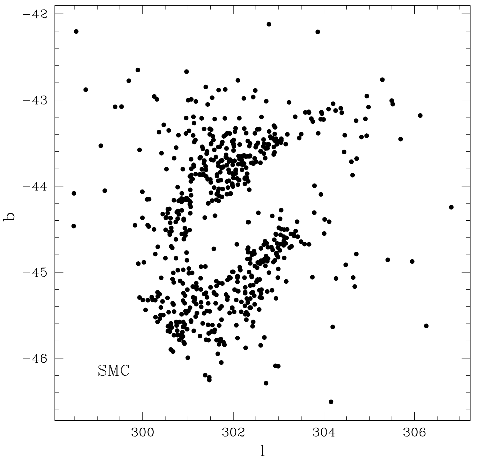

Fig. 2. Distribution in Galactic coordinates of the Payne-Gaposchin SMC Cepheids.

In the left panels of Figs. 3, 4, and 5 we show the Cepheid distributions in Galactic coordinates for LMC (top) and SMC (bottom) objects and stellar ages ranging from less than 20 to more than 80 Myr. The right panels show the same distribution but for stellar clusters with age estimates based on integrated photometry or CMD properties (Pietrzynski & Udalski 1999, 2000; Efremov 2004; Girardi et

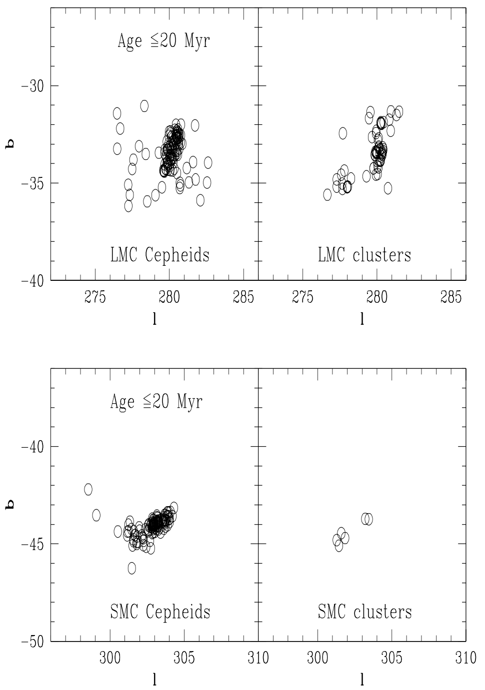

Fig. 3. Cepheid versus clusters distributions for ages younger than 20 Myr in the LMC (top) and in the SMC (bottom).

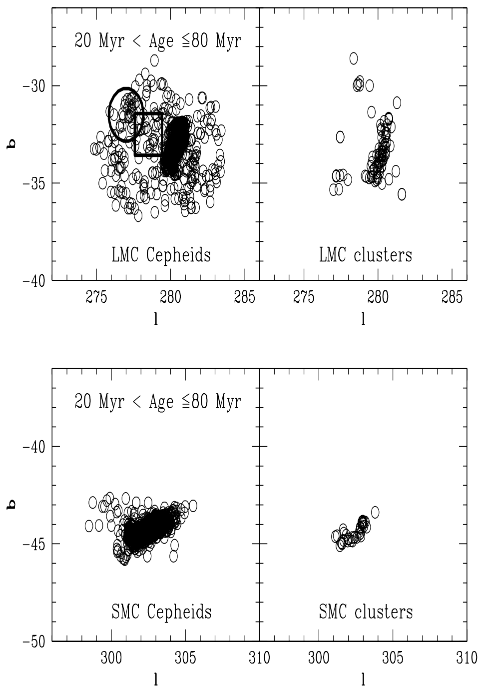

Fig. 4. Same as in Fig. 3, but for ages ranging from 20 to 80 Myr. The large symbols plotted in the top left panel mark the position of two well-known star forming regions, namely 30 Dor (square) and LH77 (circle).

al. 1995; Mackey & Gilmore 2003a,b). As expected, the radial distribution of very young Cepheids ($t \leq 20$ Myr) is peaked on the center of the MCs. In this age range are available a limited nuumber of clusters (see Fig. 3), but the two radial distributions appear quite similar. Young associations are also present in the MCs, but their age estimates are not as accurate as for star clusters. For ages ranging from 20 to 80 Myr the radial distribution of Cepheids present a more complex pattern when compared with the star clusters. The star clusters appear to be good tracers of the LMC bar. On the other hand, the Cepheids are good tracers not only for the bar but also for the star forming regions (30 Dor and LH77, see Fig. 4). They also display a disk like distribution in the regions located outside the bar that the star clusters do not show. The radial distribution of Cepheids and star clusters in SMC show the typical cigar-like shape. However, Cepheids show a spur located at $l < 300$ and $b \sim -44$ degrees that is not present in the star cluster distribution.

The radial distribution of LMC Cepheids with ages older than 80 Myr presents a complex patter when compared with the star clusters. The latter objects trace very-well the LMC bar, while the Cepheids show several off-center peaks outside the bar. One of this peaks ($l \sim 277$ and $b \sim -31$) is associated with 30 Dor, thus suggesting the ongoing star formation activity in this region for at least 60 Myr. The radial distribution of the SMC with ages older than 80 Myr is quite similar to the distribution of the star clusters. The larger extent in longitude might only be due to selection effects.

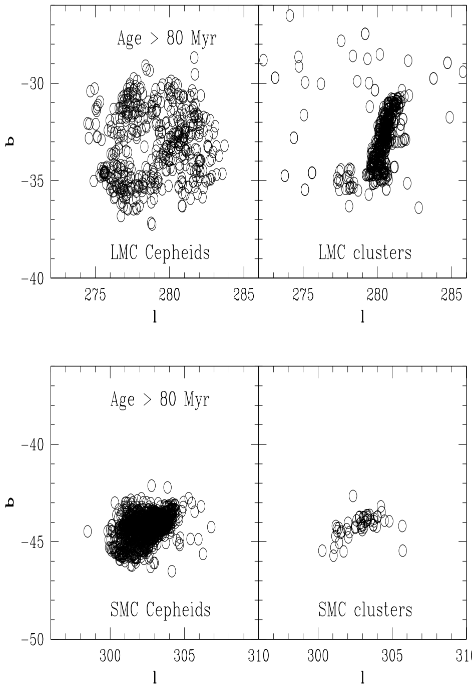

Fig. 5. Same as in Fig. 3, but for ages older than 80 Myr.

3. Conclusions

New accurate PA and PAC relations have been recently obtained on the basis of homogeneous and updated sets of evolutionary and pulsational computations (Bono et al. 2005). These relations have been applied to extended databases of Magellanic field Cepheids to derive individual *pulsational* ages. The radial distribution in Galactic coordinates of the investigated pulsators for different age bins provides useful constraints on the star formation history of the Magellanic Clouds. In particular, the comparison with similar results based on cluster ages estimated from independent methods, seems to suggest that Cepheid age estimates may provide a more detailed picture (higher spatial resolution) of recent star formation episodes in the MCs.

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