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Variable stars as tracers of stellar populations in Local Group galaxies: Leo I and NGC 6822

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Abstract. Results are presented of a study of the variable star populations in the dwarf spheroidal galaxy Leo I and in the dwarf irregular galaxy NGC 6822, based on time series photometry obtained with the Wide Field Imager of the 2.2 m ESO/MPI telescope (Leo I) and the Very Large Telescope (NGC 6822). We found about 250 (lower limit) variables in Leo I most of which are RR Lyrae stars. In NGC 6822 we identified 450 candidate variables among which about 20 are RR Lyrae stars, and many are low-luminosity, small-amplitude Cepheids.

Key words. Local Group galaxies – variable stars – stellar populations

1. Introduction

Variable stars allow to sample different stellar populations in galaxies and their radial distributions. The RR Lyrae stars and the Population II Cepheids trace the oldest stellar component (age $>$ 10 Gyr), while the Anomalous and Classical Cepheids trace younger population components.

2. Leo I

The dwarf spheroidal galaxy Leo I has long been thought to host only young and intermediate age stellar populations (Lee et al. 1993; Fox & Pritchet 1987; Reid & Mould 1991; Demers, Irwin & Gambu 1994). Based on HST WFPC2 data Gallart et al. (1999b) concluded that the bulk of the stellar formation in Leo I was delayed, although some hints of an old stellar population were noted by Gallart et al. (1999a) and Caputo et al. (1999). A delayed first epoch of star formation was in contrast with the general trend of the Local Group dwarf spheroidal galaxies, all of which have been found to contain an old stellar component. The presence of stars as old as $t > 10$ Gyr remained unproven in Leo I until the study by Held et al. (2000), who reported the first observational evidence of a well extended (from blue to red) horizontal branch (HB) in the external regions of the galaxy. A further confirmation was the first

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detection of a conspicuous populations of RR Lyrae stars in the galaxy (Held et al. 2001, paper I). Paper I focused on the RR Lyrae stars identified in only two chips of the WFI mosaic. Here we present results on the variables detected in all the 8 chips of the mosaic.

2.1. Observations and data reduction

Observations (40 *V*, 22 *B* and 5 *I* 15-min exposures) of Leo I were obtained with the Wide Field Imager (WFI) at the 2.2m ESO/MPI telescope. The 34 × 33 arcmin field of view of the WFI allows to fully cover the galaxy in just one exposure. Photometric reductions were performed using DAOPHOT and ALLFRAME (Stetson 1994), and the WFI reduction pipeline developed by the Padova group (Rizzi & Held 2003, in prep.). Candidate variables were identified using ISIS2.1 (Alard 2000), a package based on an optimal image subtraction method. In chip 1, where the small number of objects did not allow to run ISIS2.1, variables were identified using a variability index related to the large scatter of their photometric measurements. Because of telescope pointing drifts during the observations we had to cut images to a same common area to allow geometrical alignment, with a loss of about 1/3 in the sky coverage. The total number of candidate variables identified in Leo I is ∼ 1000. However, only about 300 of them are present in both the *V* and *B* master co-added images created by ISIS. Thus, a large fraction of the objects flagged as candidate variables could be spurious identifications. All candidate variables are being analyzed with GRATIS, a code developed at the Bologna Observatory (see Clementini et al. 2000) in order to check their actual light variation and to determine periods, amplitudes, mean magnitudes and type classification, whenever possible. The full catalogue of variable stars in Leo I will be presented in a forthcoming paper (Clementini et al. 2003, in prep.).

2.2. Color Magnitude Diagrams

Figure 1 shows the color magnitude diagrams of the 8 individual chips of the mosaic. Filled squares mark the position of the candidate variables. For a preliminary qualitative analysis, we will consider here only chips 6, 7 and 8 where most of the Leo I stars are located, with the galaxy center being in chip 7. The color magnitude diagram of chip 7 is mainly populated by an intermediate age population. The red giant branch (RGB) and the red clump stars are the most visible structures. The Leo I HB is completely hidden by the main sequence, subgiant branch and red clump star populations, and can be recognized thanks to the RR Lyrae stars (see Held et al. 2001). Several other candidate variables are present in the CMD. The most striking feature is a group of variables found in the strip about 1.4 mag brighter than the HB. Their position is consistent with the location in the HR diagram of the intermediate mass helim-burning pulsating stars that have been found in several Local Group dwarf spheroidal galaxies (see Pritzl et al. 2002, and references therein) and that are generally referred to as Anomalous Cepheids (Wallerstein & Cox, 1984). On the other hand, it seems unlikely that these stars could be Population II Cepheids, i.e. post HB stars (t> 10 Gyr, M $\leq 1 M_{\odot}$) coming from the bluer part of the HB and crossing the instability strip in their evolution to the Asymptotic Giant Branch. Population II Cepheids are commonly found in globular clusters with extended blue tails, but have rarely been found in dwarf galaxies. Moreover, Held et al. (2000) showed that the blue HB of Leo I is less extended than that of M5. Chip 6 and 8 can roughly be considered as representative of the outer regions of Leo I. Their CMDs look very similar to each other, and are different from that of chip 7. The RGBs are narrower than in chip 7 and the HBs are clearly visible and populated by several RR Lyrae stars. Conversely, the two diagrams do not show evidence for a conspicuous population of variables above the HB. All these considerations suggest that in Leo I the old population is present all the way through the inner regions of the galaxy, while the younger popu-

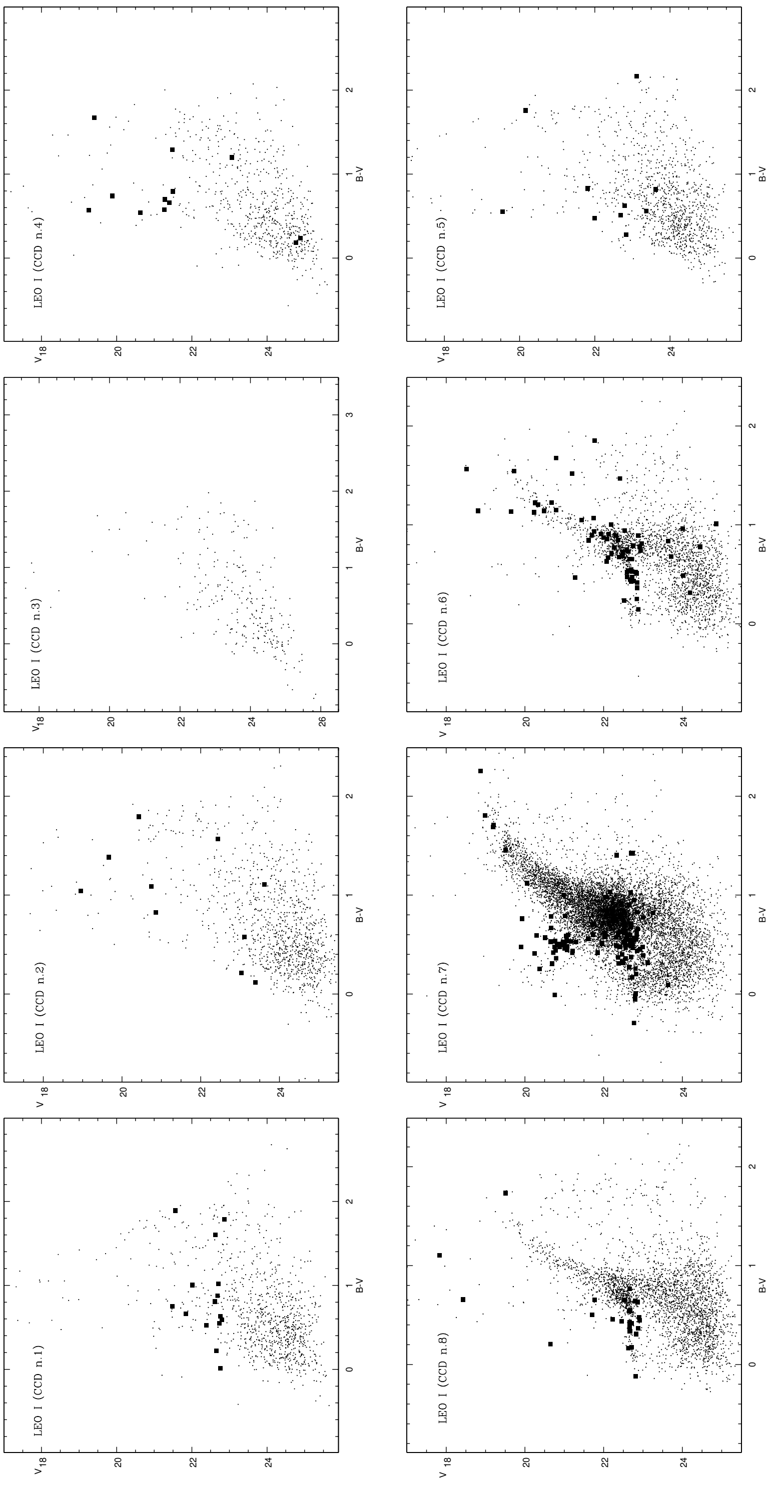

Fig. 1. Color-magnitude diagrams of Leo I, showing the location of variable stars (filled squares).

lations, traced by the variables 1.4 mag brighter than RR Lyrae stars, are more centrally concentrated. Such a trend is commonly observed in many dwarf galaxies (Held et al. 2000, and references therein).

3. NGC 6822

The star formation history of the dwarf irregular galaxy NGC 6822 has been investigated by Gallart (1996a,b) and Wyder (2001, 2003) and found to be consistent with both a first epoch of star formation about 10 Gyr ago and a star formation started about 6 Gyr ago. Here we briefly summarize our results on the search for short period variable stars in NGC 6822, a more extended discussion being presented in Clementini et al. (2003) and in a forthcoming paper (Held et al. 2003, in prep.). Based on VLT time series observations (36 V and 11 B frames) we detected 450 candidate variables in a region covering about 1/4 of the galaxy. Among the subsample of faint variables ($V > 23$ mag) we found a few (~ 20) RR Lyrae stars tracing the galaxy's HB, and several Cepheids characterized by low luminosities (LL Cepheids, a few tenth of magnitude brighter than the HB) and small amplitudes (0.1 - 0.4 mag). The detection of RR Lyrae stars in NGC 6822 breaks the degeneracy in the galaxy star formation history scenarios, providing indisputable evidence that NGC 6822 started forming stars at least 10 Gyr ago, and allowing us to determine the galaxy distance using for the first time a Pop. II distance indicator: $(m - M)_0$=23.36 ±0.17 mag (Clementini et al. 2003). The nature of the many small-amplitude LL Cepheids detected in NGC 6822 is still unclear, but theoretical models of Anomalous Cepheids predict objects with luminosities and amplitudes similar to those we have detected in NGC 6822 (Fiorentino et al. 2003, Caputo et al. 2003 in prep.).

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