Mem. S.A.It. Vol. 77, 291

Memorie della

B, V, I photometry of the complete sample of 23 Cepheids in the field of NGC 1866

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Abstract. We present the result of *BVI* photometry, obtained by using FORS@VLT, of the Cepheids present in the field of the Large Magellanic Cloud cluster NGC 1866. We found the 22 known variables plus an additional new Cepheid located about 10' from the cluster center. The accuracy of the photometry allowed us to derive *B*, *V* and *I* mean magnitudes with an uncertainty lower than 0.02 mag for 22 out of the 23 objects, with the exception of only one Cepheid (WS9) which presents a noisy light curve due to the probable occurrence of image blending. As a result, we provide accurate observational data for a substantial sample of variables all lying at the same distance and with a common original composition. The resulting period-luminosity relations are presented and briefly discussed.

Key words. Stars: variables, Cepheids – globular clusters: individual (NGC 1866) – Galaxies: Magellanic Clouds

1. Introduction

Classical Cepheids play a fundamental role in the extragalactic distance scale. Empirical calibrations of the Period-Luminosity (PL) and Period-Luminosity-Color (PLC) relations are generally based on field Cepheids involving the uncertainties due to the spread in distance, metallicity and reddening. On the other hand, any theoretical scenario for pulsational models, to provide a robust support to empirical calibrations, needs to be confirmed through the comparison with observational data as given by suitable samples of well-observed Cepheids. Therefore, classical Cepheid members of young stellar cluster (at the same distance and with a common chemical composition and age) offer the opportunity to investigate the uncertainties affecting both empirical and theoretical estimates concerning their luminosity, color and periods. The young

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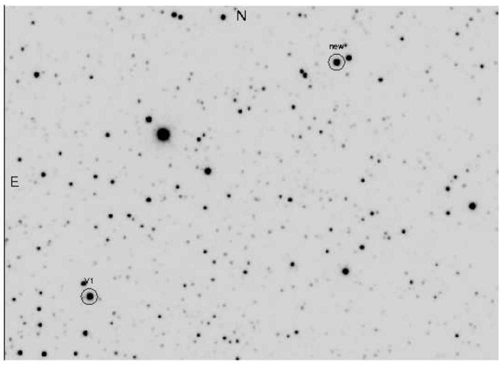

Fig. 1. Identification map for the newly discovered Cepheid in the field of NGC 1866.

Large Magellanic Cloud (LMC) globular cluster NGC1866, already known to host an exceptionally rich sample of Cepheids, as given by at least 22 variables (Welch & Stetson 1993 and references therein) represents an ideal candidate. However, in a recent paper, Brocato et al. (2004) have investigated this sample, reaching the unpleasant conclusion that only 4-6 of the known Cepheids have light curves accurate enough to allow a meaningful determination of their luminosities and colors. There remain large errors for the variables in the central crowded region. In this context, we took advantage of assigned observing time at the ESO Very Large Telescope to perform a new photometric investigation of the cluster field with the aim to obtain suitable sampling of the light curves of all the Cepheids members of the cluster.

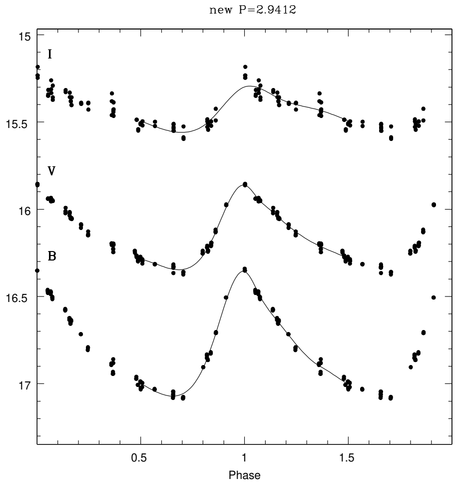

Fig. 2. The *BVI* light curves for the new Cepheid found in NGC 1866.

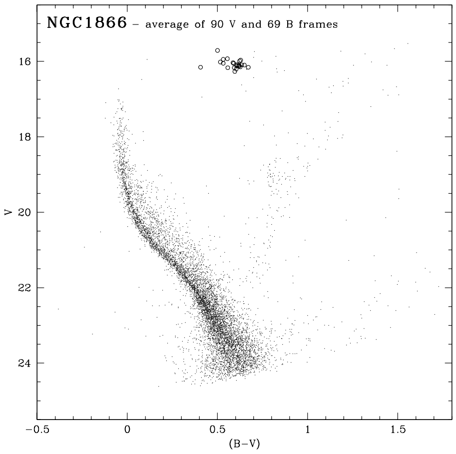

Fig. 3. The color magnitude diagram of NGC 1866 as derived in this work. The locations of the 22 well observed Cepheids studied in this work are indicated as open circles.

2. Observation and data reduction.

Observations have been carried out by means of the FORS1@VLT instrument in imaging mode. The detector was a 2048x2048 Tektronix CCD with pixel size $24\mu \times 24\mu$. Projected on the sky, the pixel size is 0.2 arcsec/pixel for a total field of view of $6.8' \times 6.8'$. We observed one field centered on NGC1866 and in total we got 69 images in B, 90 in V and 62 in I with an exposure time of 60 sec for each image in all three bands and a median seeing better than $0.7''$. Moreover, due to the periods of 3-4 days for the Cepheids in NGC1866, we require a time coverage of about three months in order to find reasonable periods for the variables. In order to pre-reduce the data we followed the standard procedure by de-biasing and flat-fielding the images. Photometry has been carried out by means of DAOPHOT/ALLFRAME packages (Stetson 1987, 1992) which couple excellent precision with high degree of automation. Special care has been taken in deriving an accurate PSF for each image because of the high degree of crowding not only in the central regions of the cluster but also in its outskirts.

The master list for ALLFRAME was built by running DAOPHOT/ALLSTAR on an image which is the combination of the best 10 B, 10 V and 10 I frames. The threshold of detection has been selected in order to avoid the presence of a high number of spurious stars. The calibration to the standard system was obtained by using the Stetson local standards (Stetson 2000, http://cadcwww.hia.nrc.ca/standards) and the final error is lower than 0.02 mag in all the bands.

2.1. NGC 1866 Cepheids

As a result, we secured photometric data for all the 22 known Cepheids, plus a newly discovered Cepheid whose identification map is reported in Fig. 1. The light curve for the new variable is reported in Fig. 2. Suspicion about the cluster membership of this new Cepheid may arise due to its location in the extreme periphery of the cluster, but the position in the CMD (Fig. 3) and the pulsational properties of this variable appear to be in close agreement with the other cluster Cepheids, supporting the idea that this star is in the same evolutionary state as the other cluster variables. The CMD in Fig. 3, obtained from the average of 90 V and 60 B frames, has a main sequence very well defined and shows the high quality of the photometric data. In particular, we have obtained very accurate light curves for 22 out of 23 Cepheids present in this field, including those located in the central crowded region (see the examples in Fig. 4), and evaluated the amplitudes and colors with an error lower than 0.02 mag. In particular, a comparison with the mean magnitudes given in Brocato et al. (2004) for the six peripheral well-studied Cepheids shows an agreement within this error. The only object with a noisy light curve (due to the probable occurrence of image blending) is WS9, which will not be included in the following discussion. Fig. 3 shows the positions of the Cepheids (open circles) in the CMD. Not surprisingly, one finds that when dealing with accurate magnitudes and colors all the Cepheids appear concentrated in a restricted region of the diagram, corresponding to the tip of the He-burning giant blue loop.The only exception is HV 1204 (see Brocato et al. 2004), which appears slightly bluer and more luminous. Fig. 5 shows the BVI PL relations for the whole set of Cepheids. One may easily detect the occurrence of two First Overtone (FO) pulsators (with $\log P < 0.44$). Moreover, since the large majority of Cepheids can be regarded as bona fide cluster members, data in figure 5 give for the first time, to our knowledge, a robust evidence of the scatter in magnitude for each given period from a sample of stars with the same age and original chemical composition.

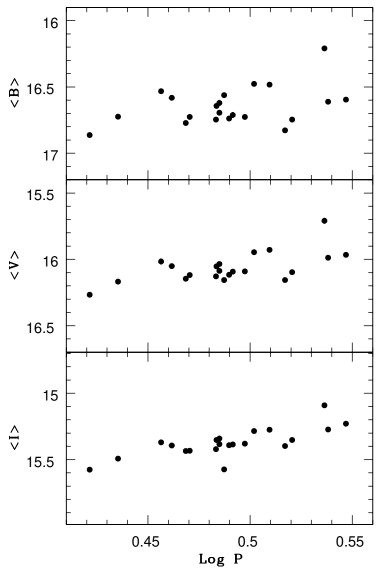

Fig. 5. The PL relationships, in the B, V and I bands, for the sample of 22 Cepheids.

3. Discussion and conclusions

As a final point, Fig. 6 compares the V, I and Wesenheit P-L relations of NGC1866 Cepheids with the same relation for the large LMC OGLE sample (including fundamental and first overtone pulsators). As a result, one finds that the two sample agree with each other very well, showing that NGC1866 Cepheids have to be regarded as a bona fide sample of LMC Cepheids. Moreover, one finds that, in the Period-Magnitude plane, NGC1866 Cepheids appear slightly less luminous than the mean LMC sequence for both fundamental

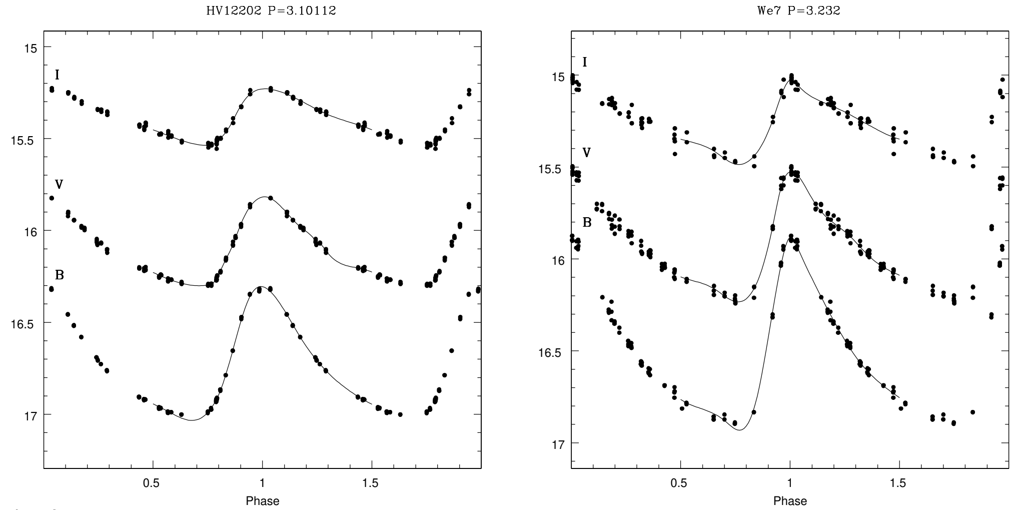

Fig. 4. The light curves of the Cepheids HV12202 and We7, located in a peripheral region and in the most crowded central region, respectively.

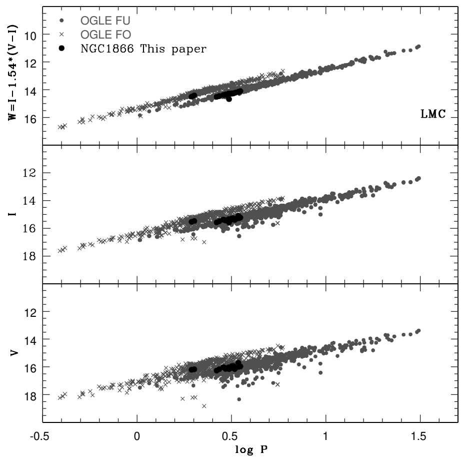

Fig. 6. The V, I and Wesenheit PL relations for the Cepheids in NGC1866 (black dots) as compared with the LMC Cepheid sample by OGLE (gray dots represent fundamental pulsators and gray crosses the first overtone ones).

(FU) and First Overtone (FO) pulsators. This could be interpreted as evidence that NGC1866 is slightly more distant than the main body of LMC Cepheids. If this is the case, the NGC1866 distance modulus appears larger by about 0.1 mag. This is only a preliminary discussion, as all the data and a more complete study will be presented in a future paper (Ripepi et al. in preparation). The large and homogeneous sample of Cepheids belonging to the star cluster NGC 1866 will allow us to improve the knowledge of the distance of NGC1866 and therefore of the LMC and to test the predictive capabilities of current theoretical models to provide independent constraints on the physical and numerical assumptions adopted in the pulsational models.

Acknowledgements. This paper is based on observations made with the ESO/VLT.

Financial support for this work was provided by MIUR-Cofin 2003, under the scientific project "Continuity and Discontinuity in the Milky Way Formation" (P.I.: Raffaele Gratton). This project made use of computational resources granted by the Consorzio di Ricerca del Gran Sasso according to the Progetto 6 'Calcolo Evoluto e sue Applicazioni (RSV6)' - Cluster C11/B.

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