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TNG photometry of the open cluster NGC 6939

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Abstract.
We present CCD UBVI photometry of the intermediate age open cluster NGC 6939 for three TNG-DOLORES fields. The fields A and B cover the center of the cluster; the third one is located about 30′ away, and is used for field stars decontamination.
The V-I, B-V and U-B color-magnitude diagrams (CMDs), obtained joining very different exposures show: i) a Main Sequence (MS) extending down to V = 24, much deeper (~ 5 magnitudes) than any previous study; ii) a clearly defined Turn Off (TO) and iii) a well populated Red Giant Clump (RC) at about V = 13.

Key words. Hertzsprung-Russell (HR) diagram – open clusters and associations: general – open clusters and associations: individual: NGC 6939

1. Introduction

Open clusters are ideal tracers of the Galactic disk properties, covering a large interval in position, metallicity, and age. They can be used to study not only the present day situation, but also the time evolution of the disk (e.g. Friel 1995). We are building a large sample of open clusters homogeneously studied (see Bragaglia & Tosi 2003 and references therein), concentrating on the old ones. In this paper we present our results on another open cluster. Given its relative proximity, NGC 6939 (RA(2000) = 20:31:32, DEC(2000) = +60:39:00, or l = 95.88, b = 12.30) has been the target of several studies in the past: the first bibliographic entry is 80 years ago (Kustner 1923) but, surprisingly, the first CCD data appeared only in 2002 (Rosvick & Balam 2002, hereafter RB02). As usual, the cluster parameters found in literature do not agree well, and we present new and improved photometric results to be used in the future to give new determinations for this intermediate age open cluster. Photometry has been previously presented by several authors, but old photographic photometry only reached about one magnitude below the main sequence Turn-Off. Mermilliod, Huestamendia, & del Rio (1994) took UBV photoelectric photometry of 37 members stars all in the red clump phase, with the intent of discriminating between different evolutionary models (with or without overshooting) by comparison with isochrones. The recent work

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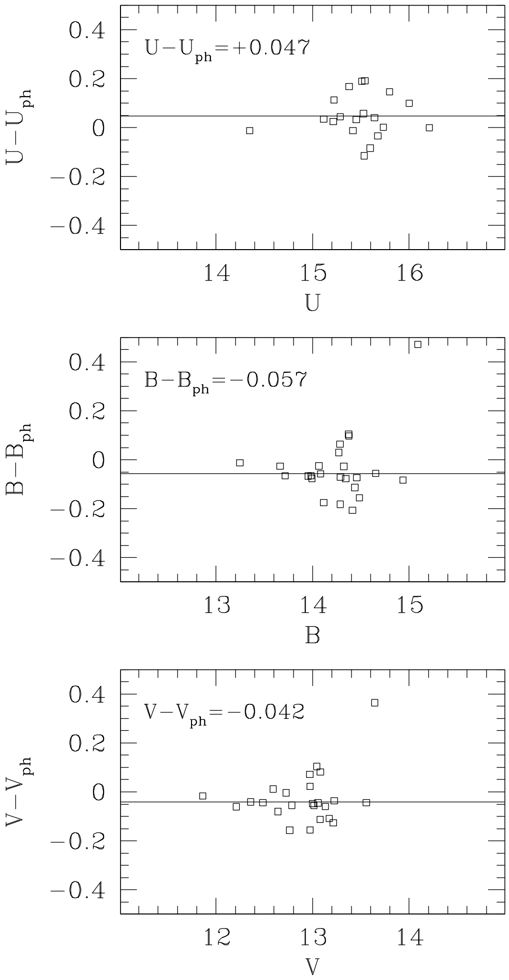

Fig. 1. Comparison of our U,B,V photometry with the photoelectric values given in Mermilliod et al (1994).

by RB02 has presented the first deep BVI CCD data. They used the 1.85m Dominion Astrophysical Observatory telescope, covering the central part of NGC 6939 (more or less our field A, see later). Their CMDs show considerable scatter, which they do not attribute to contamination from field stars (even if they could not prune their diagrams on the MS, since no proper motion survey on this cluster has reached so deep), but to differential reddening [E(B-V) = 0.29 to 0.41], which also influences the distance derivation [$(m-M)_V = 12.21$ to 12.39]. Using the Girardi et al. (2000) solar metallicity isochrone, they obtain a cluster age of 1.6 ± 0.3 Gyr

2. Observations and data reduction

Our data were acquired at the Telescopio Nazionale Galileo, using DOLORES (Device Optimized for the LOw RESolution) on two different runs (see Table 1 for details). In both

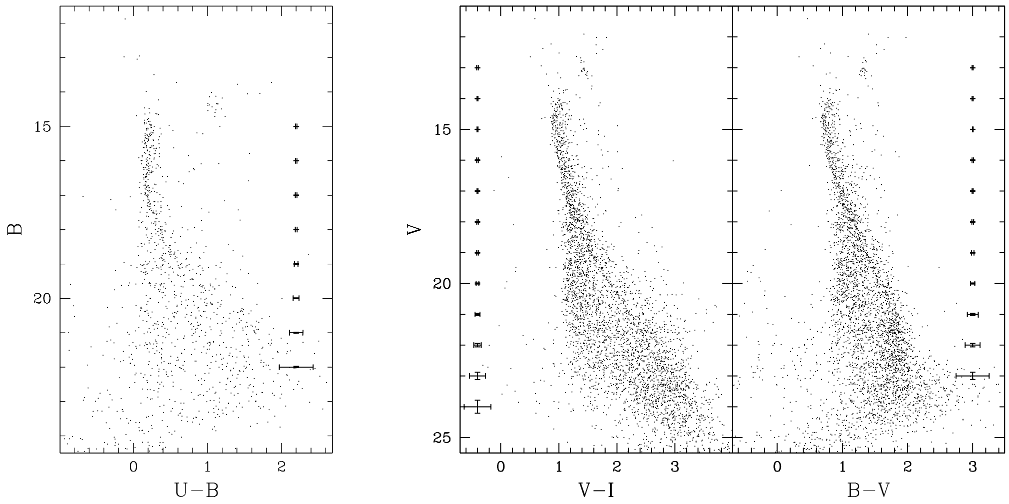

Fig. 2. V-I, B-V CMDs for NGC 6939. The mean errors per interval in magnitude V are also plotted

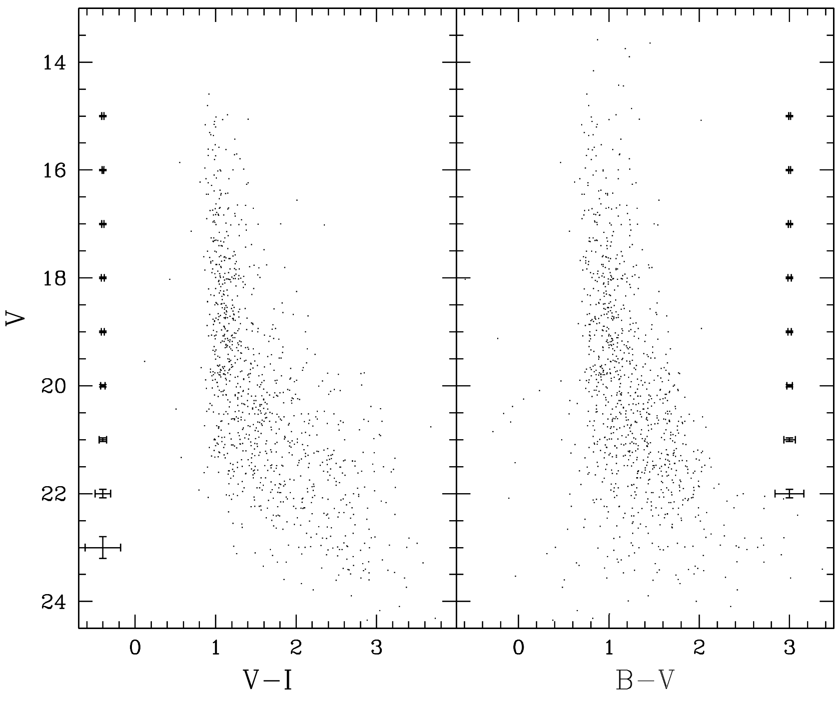

Fig. 3. V-I, B-V CMDs for the external field. The mean errors per interval in magnitude V are also plotted.

Table 1. Log of our observations. For each field we list the dates of the observations, the filters used and the corresponding ranges of exposure time (in seconds)

Field	coords (2000)	UT dates	t_U	t_B	t_V	t_I
Field A	20:31:31 +60:29:21	2000 Nov 24, 25	60-1200	600-20	300-60	300-10
		2001 Aug 17		5-2	10-2	5-2
Field B	20:31:30 +60:46:51	2000 Nov 26		600-40	300-20	300-20
		2001 Aug 18		5-2	5-2	5-2
external	20:31:32 +60:09:23	2000 Nov 25		600-20	300-10	300-20

cases the images have been observed with a scale of 0.275 ″/pix, (field of view 9.4′ × 9.4′). Three different fields have been observed: one centred on the cluster (field A), one slightly North of it (field B), and the last (that may be used for field stars decontamination) about 30′ away. Corrections to the raw data for bias, dark and flat-fielding were performed using the standard IRAF routines. Subsequent data reduction and analysis was done following the same procedure for the three data-sets and using the Daophot-Allframe packages (Stetson-version 3, 1997) with a quadratically varying point spread function. The identified candidates were measured on each of the individual I, V, B and U frames of each field and two final catalogs (one for the cluster and one for the comparison field) have been created. The calibration equations were derived by using the objects in the standard areas PG0231+051 and Rubin 149, plus the two isolated stars G156–31, and G26–7 (Landolt 1992):

$$U = u + 0.1796 \times (u - b) - 0.9120$$

$$B = b + 0.0525 \times (b - v) + 1.4187$$

$$V = v - 0.1490 \times (b - v) + 1.2389$$

$$I = i + 0.0282 \times (v - i) + 0.7854$$

where u, b, v, i, are the aperture corrected instrumental magnitudes, after further correction for extinction and for exposure time, and U, B, V, I are the output magnitudes, calibrated to the Johnson-Cousins standard system. To check our calibration we directly compared our U, B, V magnitudes for 24 stars in common with the photoelectric values given in Mermilliod et al. (1994). This study has shown that no trend is present between the two data-sets but only zero point shifts, as indicated in Fig. 1.

3. Data analysis and discussion

The final cluster CMDs are shown in Fig. 2, where we also plot the mean photometric errors per interval of magnitude, to understand the data quality. We emphasize that these CMDs represent by far the best photometric results found in literature for this cluster. From the figure it is possible to see a very clear MS extending down to V ∼ 24, nearly 5 mag deeper than the only previous CCD photometry (RB02), together with a prominent red giant clump, including ∼ 40 stars. A contamination from field stars is also evident, especially in the fainter parts, while the brighter stars are almost free from field interlopers. In order to account for field stars contamination, we may use data from the external field, observed far enough from the cluster so that the contamination by cluster members - if any - is minimal. Figure 3 shows the resulting V-I and B-V CMDs for the stars located in this comparison field. In the following part of our study, the observed CMDs will be compared to synthetic ones to derive the cluster parameters distance, reddening, age and approximate metallicity, using a procedure amply described in Tosi et al. (1991) and in the other papers of the open clusters series (see e.g. Bragaglia & Tosi 2003). These synthetic CMDs are built using different evolutionary tracks with the same number of stars, error distribution, and incompleteness factors of the observed ones, taking also into account the possibility of binary systems.

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