Confirming Bologna A: an old star cluster in the SMC

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Bologna A (Bo A) was discovered by Bellazzini et al. (2005, B05, hereafter) as a small (angular radius $\sim 40''$) stellar system in the background of the massive Galactic globular cluster (GC) 47 Tuc, just $\simeq 15'$ apart from its center. Its location in the sky, angular scale and appearance suggested that Bo A was a star cluster in the outskirts of the Small Magellanic Cloud (SMC), and, indeed, Bica et. al (2008) included it in their updated list of SMC clusters. However the Color Magnitude Diagram (CMD) presented by B05 was not sufficiently deep and populated to draw definitive conclusion on the nature of the system and to estimate its age. Recently Stetson et al. (2019) published very accurate wide-field UBVRI photometry for a set of 48 Galactic GCs, including 47 Tuc. Bo A is clearly visible in the stellar map of this cluster presented in their Fig. 2. We take advantage of this new catalog, whose photometry is significantly deeper, more complete and more accurate than the one used by B05, to obtain a fresh view of Bo A. In the following we adopt E(B-V)=0.04 from Harris (1996) and $(m - M)_0^{SMC} = 19.03$ from McConnachie (2012).

In Fig. 1 we show the CMDs, of a circular field of radius $40.0''$, centered on Bo A, and on three Control Fields (CF) located at the same angular distance from the center of 47 Tuc. The main feature in all the CMDs is the Main Sequence (MS) of 47 Tuc, crossing the plot in diagonal. Around $(B - I)_0 \simeq 1.0$ and for $I_0 < 20.0$ the upper MS of the SMC population, in the background, can also be noted. The Bo A field contains an overdensity of these stars at more than 5-σ with respect to all the CFs.

The new CMD of Bo A superposes very nicely with the old/intermediate age population that dominates the stellar content of the SMC in the background of 47 Tuc (not shown here). It reveals a fully developed Red Giant Branch (RGB), implying an age in excess of $\simeq 2$ Gyr. Indeed, the superposed isochrone, with [M/H]$= -0.9$ and age=4.5 Gyr, and shifted to the distance of the SMC, provides a nice fit to the sequences attributable to Bo A.

We matched the Bo A stars shown in Fig. 1 with the Gaia DR2 catalog (Brown et al. 2018). Gaia proper motions (PM) and parallaxes in the range of magnitudes of Bo A stars are affected by significant uncertainties, especially in very crowded fields like this. Due to the Gaia magnitude limit we found only six RGB stars that are likely members of Bo A, according to their position in the CMD. All of them have PM that are more compatible with the distribution of SMC stars than with that of 47 Tuc stars, and parallax consistent with large distances, within the large uncertainties. In particular, the only one having PM errors smaller than 1.0 mas/yr, Gaia Source ID=4689811477840066688, has `pmra,pmdec`$=(0.15 \pm 0.34, -1.37 \pm 0.28)$ mas/yr, well within the core of the PM distribution of the SMC stars in this region, and tens of σ apart from the mean motion of 47 Tuc, `pmra,pmdec`$=(5.248 \pm 0.002, -2.519 \pm 0.002)$ mas/yr (Helmi et al. 2018).

In conclusion, thanks to the newly available data from Stetson et al. (2019) and Gaia DR2, we have firmly established that Bologna A is a star cluster of old/intermediate age belonging to the SMC. Concerning all the other properties of the cluster we confirm the results by B05.
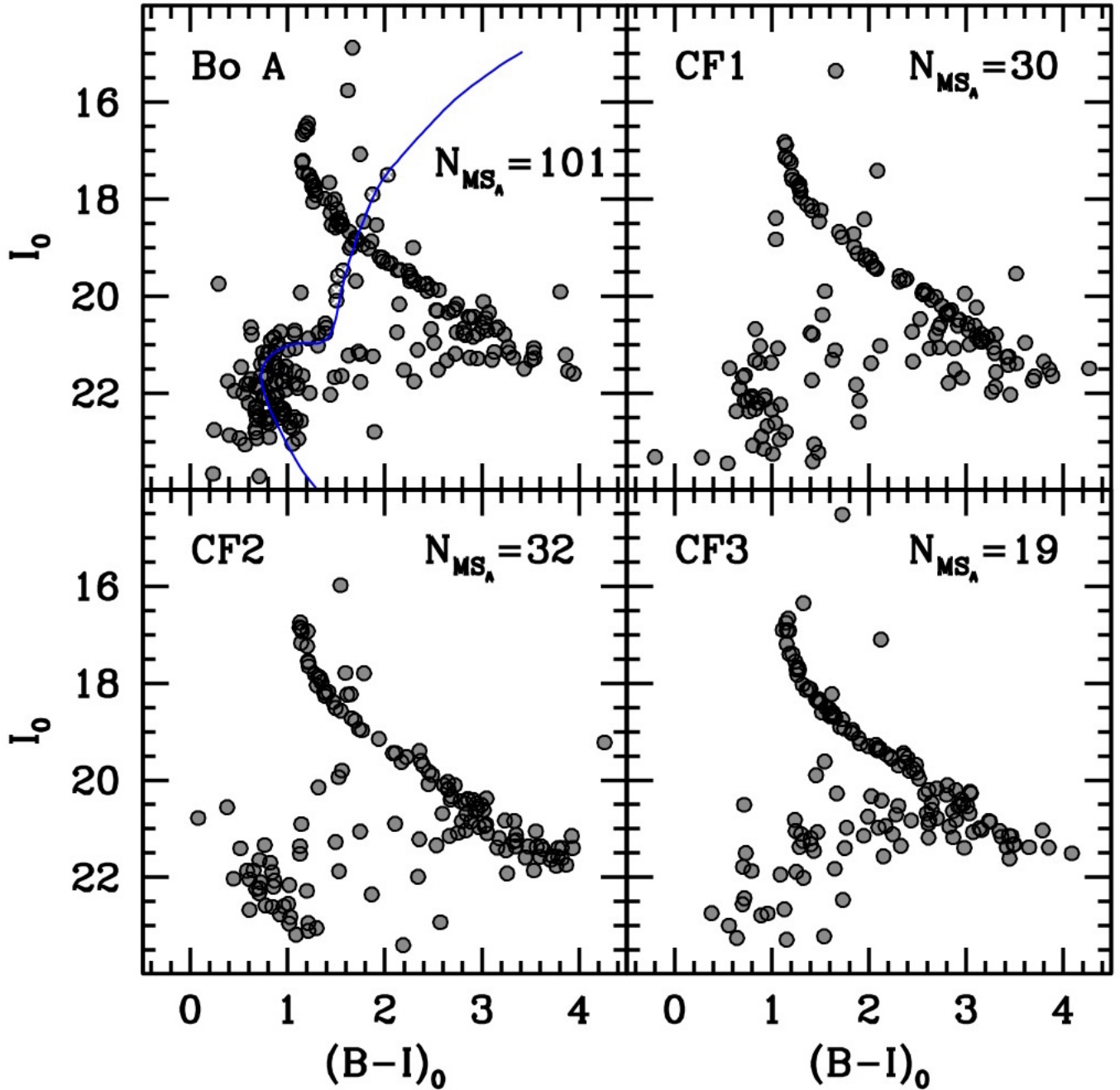
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Figure 1. Extinction-corrected CMDs of four circular fields, with radius=40.0″, centered on Bo A (upper left panel) and on three Control Fields (other panels). CF1 and CF2 are almost adjacent to Bo A, CF 3 is straight to the west of the center of 47 Tuc. White × symbols mark the six candidate RGB stars of Bo A for which we found the PMs in the Gaia DR2 source catalog. The isochrone over-plotted to the CMD of Bo A is from the PARSEC set (Marigo et al. 2017) and have [M/H]= −0.9 and age=4.5 Gyr. N_{MS_A} is the number of stars in the box $0.0 < (B − I)_0 < 1.4$ and $20.0 < I_0 < 23.0$, aimed at selecting the upper MS of Bo A.

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