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On the physical nature of six galactic open cluster candidates

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Abstract. We present CCD UBVI$_{KC}$ photometry in the fields of the unstudied open cluster (OC) candidates Haffner 3, Haffner 5, NGC 2368, Haffner 25, Hogg 3 and Hogg 4. Our analysis shows that none of these objects are genuine OCs since no clear main sequences or other typical features can be seen in their colour-magnitude and colour-colour diagrams. Star counts performed within and outside the OC candidate fields not only support these results but also suggest that these objects are not OC remnants. A detailed version of this work can be seen in New Astronomy, 16, 161 (2011).

Resumen. Presentamos fotometría CCD UBVI$_{KC}$ en la región de los candidatos a cúmulos abiertos (CAs), previamente no estudiados, Haffner 3, Haffner 5, NGC 2368, Haffner 25, Hogg 3 y Hogg 4. Nuestro análisis demuestra que ninguno de estos objetos son CAs genuinos dado que no se distinguen en sus diagramas color-magnitud y color-color claras secuencias principales u otras características típicas de los CAs. Recuentos estelares realizados dentro y fuera de las regiones de estos objetos no sólo favorecen estos resultados sino que también sugieren que los mismos no son remanentes de CAs. Una versión detallada del trabajo puede verse en New Astronomy, 16, 161 (2011).

1. Photometric diagrams

Among the 1787 current catalogued OCs, more than half have been poorly studied or even unstudied. Therefore, the mere confirmation of the physical reality of an OC candidate means a significant contribution to better knowledge of the Galactic OC system. This study aims at clarifying the nature of 6 objects listed as OC candidates in different catalogues, namely: Haffner 3, Haffner 5, NGC 2368, Haffner 25, Hogg 3 and Hogg 4. None of them has ever been photometrically studied before. We obtained CCD images of these 6 objects with the UBVI$_{KC}$ filters and the Cerro-Tololo Inter-American Observatory (Chile) 0.9 m telescope. In Fig. 1 we only show the colour-magnitude diagrams (CMDs) and colour-colour diagrams (CCDs) of the Haffner 3 field.

2. Data analysis

We analyzed the possible existence of genuine OCs following two different approaches. We examined first the distribution of stars in the CMDs and CCDs and, then, we compared the number of stars counted within and outside the fields of the OC candidates. Without a careful analysis of the observed sequences in the CMDs, one might conclude that such sequences are in fact clusters' main sequences (MSs). However, all the observed CMDs exhibit different MSs more or less superimposed. This means that the different MSs could be affected by nearly similar reddenings, which makes it difficult to analise these CMDs. To estimate a magnitude from which the characteristics of the different observed MSs are undistinguishable in terms of spatial density, magnitude and colour distributions, we applied the statistical method described by Piatti et al. (2010). Thus, it became clear that our photometry does not permit to distinguish different MSs for stars with $V > 16$. To evaluate cluster membership among the stars with $V < 16$, we applied two different photometric criteria described by Clariá and Lapasset (1986). To identify which stars fulfill the first criterion, we superimposed the Zero-Age Main Sequence (ZAMS) of Lejeune and Schaerer (2001) to the observed ($U-B$,$B-V$) diagram by adopting $E(U-B)/E(B-V) = 0.72$ and the $E(B-V)$ value corresponding to the bluest envelope of the observed sequence. If we adopt $E(V-I)/E(B-V) = 1.25$ (Dean et al. 1978), this value implies $E(U-B)/E(V-I) = 0.58$. Hence, by sliding the ZAMS according to this reddening line in the ($U-B$,$V-I$) diagram, we discarded as cluster members all the stars that fall beyond 0.10 mag from the ZAMS. Then, using all the stars that complied with this first requirement, we kept as probable members those whose locations correspond to the same evolutionary stage in the three CMDs. For that purpose, we superimposed the ZAMS to the three CMDs by adopting the above $E(B-V)$ value, using the apparent distance modulus $m-M$ which best fits the ZAMS to the unevolved star sequence. Finally, by carefully inspecting the three CMDs and the two CCDs, we could distinguish the possible cluster members. We repeated this procedure for different $E(B-V)$ values which we increased in steps of 0.05 mag each time. Although some star sequences seem to delineate a cluster MS in both CCDs, they are in general composed of field stars more or less aligned along the sight of view, since none of them have their counterpart MS in the three CMDs. These results suggest that the six studied objects would not be genuine OCs. The method described presupposes that the colour excesses are uniform across the observed fields, which was confirmed in each of them using the extinction maps of Schlegel et al. (1998).

3. Star counts

We estimated the mean stellar density representative of each observed field by fitting Gaussian distributions to the star counts in 100 non-overlapped boxes of 200 pixels a side. We obtained average numbers of stars per box and also the number of stars in a box of 200x200 pixels centred on the suspected clusters. As these last values lie within 1.2σ of the mean values, they do not favour the possibility that the studied objects are real physical systems. A real OC

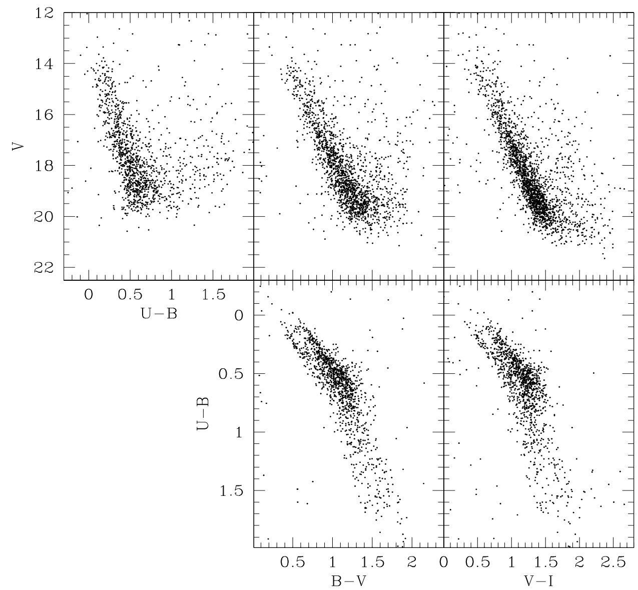

Figure 1. The $(V, U-B)$, $(V, B-V)$, and $(V, V-I)$ diagrams (*top*), and $(U-B, B-V)$ and $(B-V, V-I)$ diagrams (*bottom*) for the stars measured in Haffner 3

is sometimes composed of stars more or less sparsed in a relatively large area of the sky or it may contain only a handful of comparatively bright stars. In such cases, the stellar density alone could not be a meaningful indicator of the presence of an OC. For this reason, we applied the method described by Piatti et al. (2010) to statistically clean the CMDs from stars that can potentially belong to the foreground/background fields. Although the cleaning process was applied to an extended region surrounding the catalogued objects, Fig. 2 shows with filled circles the circular extracted CMDs and CCDs that were obtained for Haffner 3, after being cleaned for field star contamination. In this figure, we show overplotted the CMDs and CCDs directly obtained with all the measured stars in the corresponding circular region (dots). When comparing observed and cleaned CMDs and CCDs, the differences in stellar composition did not become evident. Keeping in mind that field stars may give rise to well defined sequences in the CMDs, the presence of such sequences must not be considered in itself a proof of the existence of an OC (Burki and Maeder 1973). Sequences of observed field stars may be discriminated from those of real OCs for the following 3 reasons: (i) the former show a limiting envelope of different curvature, (ii) the field stars have incompatible positions in the various CMDs, (iii) the field apparent luminosity function reaches its maximum at the observed limiting magnitude. Figure 2 and others corresponding to the other objects allow us to come to the conclusion that the six observed objects are not genuine OCs. We finally applied the method of Pavani and Bica (2007) to measure how different the stellar densities encompassed by the adopted circles/ellipses are from the field star density. Pavani and Bica (2007) defined the R^2 statistics that reflects the distribution of field fluctuations and stellar density contrast in the CMD between those of the clusters and those in the star field. We thus built ∼ 100 CMDs for different boxes of 200x200 pixels distributed throughout the field, in addition to the CMDs for the catalogued objects. We computed R^2 for each box, then built the histograms of the R^2 distributions for each observed field and performed Gaussian fits for each of them. The resulting R^2 averaged values for the catalogued objects do not exceed in more than 1σ the mean value derived for their respective fields, except in the case of Haffner 5 whose value is 1.3σ. These results imply that the six catalogued objects constitute neither genuine physical systems nor OC remnants but should be considered instead random fluctuations of the field star density.

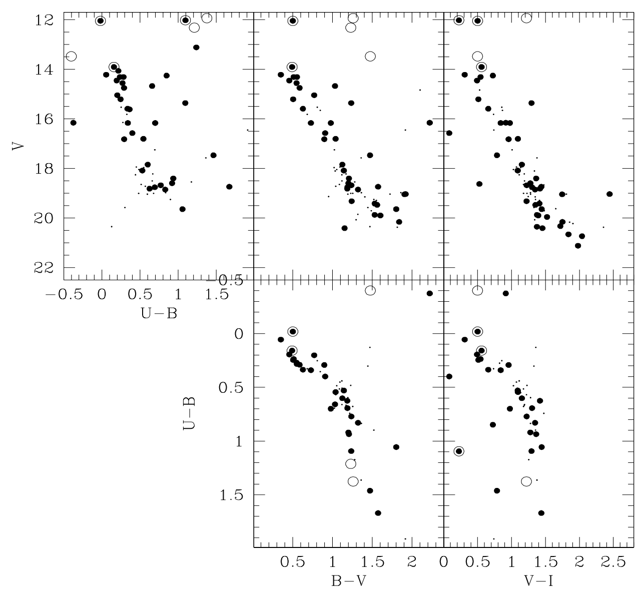

Figure 2. The extracted $(V, U-B)$, $(V, B-V)$, and $(V.V-I)$ diagrams (*top*), extracted $(U-B, B-V)$ and $(B-V, V-I)$ diagrams (*bottom*) for the Haffner 3 circular region (dots), compared with those statistically cleaned from field star contamination (filled circles). Open circles represent stars of the northern group according to Babu (1983).

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