Hogg 12 and NGC 3590: a new open cluster binary system candidate

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ABSTRACT

We have obtained CCD $UBVI_{KC}$ photometry down to V $\sim$ 22.0 for the open clusters Hogg 12 and NGC 3590 and the fields surrounding them. Based on photometric and morphological criteria, as well as on the stellar density in the region, we present enough evidence to affirm that Hogg 12 is a genuine open cluster. NGC 3590 was used as a control cluster. The color-magnitude diagrams of Hogg 12, cleaned from field star contamination, reveal that this is a solar metal content cluster, affected by $E(B-V) = 0.40 \pm 0.05$, located at a heliocentric distance $d = 2.0 \pm 0.5$ kpc and of an age similar to that of NGC 3590 ($t = 30$ Myr). Both clusters are surprinsingly small objects whose radii are barely $\sim$ 1 pc and which are separated in the sky by scarcely 3.6 pc. These facts, added to their similar ages, reddenings and metallicities, allow us to consider them a new open cluster binary system candidate. Out of the $\sim$ 180 open cluster binary systems estimated to exist in the Galaxy, out of which 27 are actually well known, Hogg 12 and NGC 3590 appear to be one of the two closest pairs.

Subject headings: Galaxy: open clusters and associations: general - open clusters and associations: individual: Hogg 12, NGC 3590 - Galaxy: general - techniques: photometric

1. Introduction

As it is commonly accepted, the presence of an apparent concentration of stars in the sky does not necessarily imply that such concentration constitutes a real physical cluster. This is indeed possible only in the case of globular clusters or very concentrated open clusters (OCs). However, for most of the apparent stellar concentractions in the sky, it is necessary to have supplementary information on proper motions, radial velocities, spectral types and photometry in order to be able to confirm their physical reality. Frequently, however, the photometric data are the only available information from which the existence of an OC may be inferred.

Any of the following factors or a combination of them could account for the presence of an apparent concentration of stars in a certain region of the sky: (i) the presence of a genuine OC, (ii) an accidental distribution of stars along the line of sight or (iii) the non uniform distribution of interstellar material. In the last few years, several CCD photometric studies of OC candidates included in the Lyngå (1987) catalogue have been carried out with the main purpose of determining if they are genuine physical systems (see, e.g., Piatti, Bica & Clariá 2000a, and references therein). Even though in some cases the studied objects have been confirmed as genuine OCs (see, e.g., Piatti et al. 1998; Piatti, Clariá & Bica 2000b), in some other cases, there exists evidence that the objects catalogued as OCs are not real clusters but rather random fluctuations of the stellar density in a given region (e.g., Carraro & Patat 1995; Piatti & Clariá 2001). The physical nature of some OC candidates is still highly debatable. A typical example is NGC 6994, which Bassino, Waldhausen & Martínez (2000) considered a 2-3 Gyr OC, but which Carraro (2000) believed to be simply a random enhancement of four bright stars above the background level rather than a real OC. Since star clusters are known to evolve dynamically and stellar depletion effects eventually lead to cluster dissolution, it is probable that some unconfirmed clusters are in fact cluster remnants or fossil remains (de la Fuente Marcos 1998; Bica et al. 2001).

Hogg 12 (IAU designation C1110-604), also known as ESO 129-SC11 (Lauberts 1982), is another arguable case. This is a small-sized object located in a rich star field in Carina at equatorial coordinates α_{2000} = 11^h 13^m 01^s, δ_{2000} = -60° 47′ and Galactic coordinates l = 291.21° and b = -0.17°, as found in the WEDBA OC Database (Mermilliod & Paunzen 2003). Hogg 12 has been classified as a Trumpler (1930) class III-2p system by Archinal & Hynes (2003), i.e. a poor, detached cluster with no noticeable central concentration and medium-range bright stars. Ruprecht (1966), however, referred to this object as belonging to Trumpler class I-3p. According to Archinal & Hynes (2003), the cluster angular diameter is about 2.0′. Since it was first recognized as an OC by Hogg (1965a,b), it was alternatively considered as a probable random fluctuation of the field star density by Moffat & Vogt (1975) or as a genuine OC by Ahumada et al. (2001). Moffat & Vogt (1975) based their conclusion on UBV photoelectric photometry of 11 stars, while Ahumada et al. (2001) estimated its basic parameters from the comparison of the observed integrated cluster spectrum with template spectra of OCs with well known fundamental parameters, as well as from the measurements of the Balmer line equivalent widths. They derived for Hogg 12 an age of about 100 Myr and $E(B-V)$ = 0.04 from template **matching**, while the age obtained from the Balmer lines turned out to be only slightly younger. Ahumada et al. (2001) found the spectral features of Hogg 12 quite similar to those of the also observed, more reddened cluster Hogg 3. The cluster parameters derived by Ahumada et al. (2001), however, should be treated with caution due to the relatively low signal-to-noise ratio of the cluster integrated spectrum.

Up to now, more than half of the 1788 currently catalogued OCs have been poorly studied or even unstudied. Therefore, the sole confirmation of the physical reality of a cluster candidate is a valuable contribution to further knowledge of the Galactic OC system. In this context, the current paper is part of a larger systematic survey whose aim is to obtain good-quality photometric data not only to enlarge the sample of studied OCs but also to estimate their fundamental parameters more accurately. This study represents a further, intermediate step in a long-term program devoted to obtain the fundamental parameters of some unstudied OCs or to refine the quality of observationally determined properties for some poorly studied ones.

The present work attemps at shedding light on the nature of Hogg 12 by using high-quality CCD $UBVI_{KC}$ photometry down to $V \approx 22$ in the cluster field. Fortunately, the proximity of the well-known OC NGC 3590 in the same field allowed us to use it as a control cluster, not only to check the quality of our photometry but also to compare their stellar densities and their fiducial cluster features. In this study we confirm the physical reality of Hogg 12 and we use the present photometric data to determine its reddening, distance, age and metallicity. The layout of this paper is as follows: Section 2 presents the observational material and the data reduction. In Section 3, we describe a method to filter the photometry from uniform patterns in terms of spatial density, magnitude and color distributions and we estimate the cluster's size. In Section 4, we derive the cluster fundamental parameters from the color-magnitude and **color-color diagrams.** Section 5 deals with the probable binary character of Hogg 12 and NGC 3590. Finally, Section 6 summarizes our findings and conclusions.

2. Data collection and reduction

We obtained CCD images for Hogg 12 in the nights of December 27th and 29th (2000) with the $UBVI_{KC}$ filters and a 2048×2048 pixel Tektronix CCD attached to the 0.9 m telescope -scale of $0.4''$ pixel^{-1}- at Cerro Tololo Inter-American Observatory (CTIO, Chile). **The field of view is 13.6×13.6 arcmin^2.** We controlled the CCD through the CTIO ARCON 3.3 data acquisition system in the standard quad amplifier mode. At the beginning of each observing night, we obtained a series of bias and dome and sky flat-field exposures per filter to calibrate the CCD instrumental signature. In order to standardize our photometry, we carried out observations of standard stars of the Selected Areas PG0231+051, 92 and 98 of Landolt (1992). The selected standard stars cover a wide color range **(-0.30 $< B-V <$ 2.20).** In particular, stars in the selected area PG231+051 were observed at low and high airmasses to adjust the extinction coefficients properly. By the end of each night, we had collected an average of 48 different measures per filter for the selected standard star sample. Table 1 shows the logbook of the observations with filters, exposure times, airmasses and seeing estimates.

The standard prescriptions for the data reduction, stellar point spread function photometry and transformation to the standard system were applied using IRAF[1] routines. **We obtained the following transformation equations between instrumental and standard magnitudes through least square fits:**

$$u = (3.768 \pm 0.055) + U + (0.425 \pm 0.039) \times X_U - (0.014 \pm 0.013) \times (U - B), \qquad (1)$$

$$b = (2.096 \pm 0.027) + B + (0.248 \pm 0.018) \times X_B + (0.101 \pm 0.008) \times (B - V), \qquad (2)$$

$$v = (1.933 \pm 0.012) + V + (0.144 \pm 0.008) \times X_V - (0.026 \pm 0.003) \times (B - V), \qquad (3)$$

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[1] IRAF is distributed by the National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation

$$i = (2.845 \pm 0.023) + I + (0.058 \pm 0.014) \times X_I + (0.023 \pm 0.011) \times (V - I), \qquad (4)$$

where X represents the effective airmass and capital and lowercase letters stand for standard and instrumental magnitudes, respectively. The standard star photometry shows the root-mean-square deviation of the observations from the fits to be 0.054 for u, 0.024 for b, 0.014 for v and 0.022 for i, indicating that the nights were photometric. Once the standard magnitudes and colors were obtained, we built Table 2 containing the average of V, $U - B$, $B - V$, and $V - I$, their errors $\sigma(V)$, $\sigma(U - B)$, $\sigma(B - V)$ and $\sigma(V - I)$ and the number of observations per filter for each star, respectively. Only a part of Table 2 (12150 entries) is shown here for guidance regarding its form and content. Table 2 is available in its entirety in the online version of this journal. Fig. 1 shows a 200s V image of the observed field.

2.1. Data quality and scope

A simple inspection of Table 2 shows that **each star can have different number of observations per filter. Thus, those stars** with three measures of $U - B$, $B - V$ **or** $V - I$ colors extend from the brightest limit down to V = 17, 20 and 21 mag, respectively. The stars with two measures of the said colors cover V ranges from 11 to 18 mag, from 17 to 21 mag and from 15 to 22 mag, respectively. Finally, the stars with only one measure of $U - B$, $B - V$ **or** $V - I$ are fainter than V = 16.5, 17 and 16 mag, respectively, reaching in each case the photometric magnitude limits. **Bearing in mind the above V mag ranges for stars with different number of observations per filter, we conclude that** the stars lying within the ∼ 10 brightest magnitudes out of the ∼ 12 mag range along which our photometry extends were **observed** two or three times. **Therefore, they are more**

appropriate to derive the cluster fundamental parameters than those observed only once in each filter. The behaviour of the photometric errors for the V magnitude and $U-B$, $B-V$ and $V-I$ colors as a function of V is shown in Fig. 2, which allows us to rely on the accuracy of the morphology and position of the main cluster features in the color-magnitude and **color-color diagrams.**

Moffat & Vogt (1975) and Clariá (1976) obtained UBV photoelectric photometry for stars in the field of Hogg 12 and NGC 3590, **respectively**. For the 26 stars we measured in common with Moffat & Vogt (1975), we derived $V_{\rm MV}$ - $V_{\rm our}$ = -0.05 ± 0.07 mag, $(U-B)_{\rm MV}$ - $(U-B)_{\rm our}$ = 0.02 ± 0.05 mag and $(B-V)_{\rm MV}$ - $(B-V)_{\rm our}$ = -0.02 ± 0.05 mag, with a marginal dependence with the V magnitude (see Fig. 4). On the other hand, the comparison with the photometry of Clariá (1976) for the 26 stars **measured** in common yields $V_{\rm Claria}$ - $V_{\rm our}$ = -0.02 ± 0.14 mag, $(U-B)_{\rm Claria}$ - $(U-B)_{\rm our}$ = -0.02 ± 0.14 mag and $(B-V)_{\rm Claria}$ - $(B-V)_{\rm our}$ = 0.02 ± 0.09 mag. **Consequently, our photometry shows very good agreement with both previously mentioned photometric scales.**

3. Photometric data analysis

The resulting color-magnitude and **color-color diagrams** for all the observed stars in the cluster field are drawn in Fig. 3. A very broad star sequence is clearly seen in the color-magnitude diagrams (CMDs). The lack of stars with $U-B$ colors in relation to those with $B-V$ and $V-I$ colors is quite noticeable. This is due to the fact that during the night of Dec. 27, we did not obtain U images and centered the telescope slightly offset with respect to the night of Dec. 29, 2000, so there was not an exact **overlap. However,** we obtained comparatively deeper exposures in the I passband. We based our decision of obtaining U images on the hunch that the cluster could be relatively young, since its field contains several bright stars projected onto a relatively fainter star field. We found it difficult to identify accurately the cluster Main Sequence (MS) from the $(V, U-B)$, $(V, B-V)$ and $(V, V-I)$ CMDs because a crowded MS arises from the magnitude limit up to $V \sim 15$. From $V \sim 15$ towards brighter magnitudes, the broad MS would appear to split into different evolved MSs, some of which could be connected with subgiant star branches. In addition, since the young OC NGC 3590 lies within our field of observation, the various possible evolved MSs could be the result of the superposition of the MSs of NGC 3590 and Hogg 12 and of foreground/background field stars. Note that clusters and field stars are affected by nearly the same interstellar reddening, which is quite likely to cause the overlapping of their MSs. Bearing 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 & Maeder 1973). This becomes an additional difficulty when the cluster CMDs are cleaned. Sequences of observed field stars may be discriminated from those of the real clusters because the former show a **lower** envelope of different curvature, because the field stars have incompatible positions in the various CMDs and because the field apparent luminosity function reaches its maximum at the limiting magnitude observed.

With the aim of estimating a magnitude from which the characteristics of the observed field stars are undistinguishable from those of the clusters in terms of spatial density, magnitude and color distributions, we applied a statistical method to filter the field stars from the CMDs and from the **color-color diagrams.** Since the observed MS **cover a wide** V **mag range**, this method becomes a valuable tool to disentangle the peculiar features of the CMDs. We then divided the observed region which covers [0:2000,0:2000] pixels into 64 boxes of 250 pixels a side and built for each of them the corresponding CMDs. At first glance, some differences can be seen between the various box extracted CMDs, a fact which reveals a lack of homogeneity in the spatial distribution of the brightness and colors of the stars. The method used consists in alternatively adopting any of the box extracted

’reference’ CMDs to statistically filter the remaining ones. We repeated this filtering task using each of the box extracted CMDs as a reference CMD. At the end of this process, each box extracted CMD was individually filtered, using each time a different reference CMD. The filtering was performed in such a way that we counted how many stars lie in different magnitude-color bins sized (ΔV,$\Delta(U-B)$=$\Delta(B-V)$=$\Delta(V-I)$) = (0.5,0.2) mag. We then subtracted from each CMD the number of stars counted for each range of the reference CMDs, by removing those stars closer in magnitude and color to the ones of the CMD used as reference. With the aim of comparing the resulting residuals, we carried out this filtering procedure by using bins of (1.0,0.2) mag and (0.5, 0.1) mag as well as boxes of 500x500 pixels. The selected box sizes and bins enabled us to keep the main intrinsic differences among the CMDs stars removed from each box extracted CMD.

When comparing the various filtered CMDs corresponding to a given box with the observed one, we can find the residuals from box-to-box variations and the fiducial CMD features of that box. This is due to the fact that a star that has magnitude and colors within the typical values found in the reference field CMDs is in most cases eliminated. Thus, the fewer times a star is removed in a given box, the larger its probability of representing a fiducial feature in that box. **Therefore, we** adopted any star that was removed fewer than 20 per cent of the times as a probable fiducial feature star. We found in this way that our photometry does not permit to distinguish cluster stars from field stars for V magnitudes fainter than $\sim$ 16.

3.1. Morphologies and dimensions of Hogg 12 and NGC 3590

In order to examine more carefully the stellar distribution of the subtracted field, we applied a statistical method which **consists of** tracing the stellar density profiles projected onto the directions of the x and y axes. We determined the coordinates associated to the geometrical centers of NGC 3590 and Hogg 12 by fitting a Gaussian distribution to those profiles. We counted the number of stars distributed along the observed full-width in the direction of the y axis in order to build the x projected density profile. Then, we used the observed full-width along the x axis to construct the y projected density profile. To build these profiles, we experimented with bins of 50, 100, 120 and 150 pixels wide, which allowed us to spot out any spurious effects caused by the presence of localized groups of stars, rows or columns of stars. We chose the bin which most appropriately fitted the intrinsic spatial resolution of the observed field. Taking into account the mean free path between two stars, **we finally** adopted a bin size of 100 pixels in the subsequent analysis. Using the previously filtered CMDs, we built such projected density profiles for different V magnitude ranges, **varying in** steps of $\Delta V = 1$ mag.

The coordinates of the centers of Hogg 12 and NGC 3590 and their estimated uncertainties were determined by fitting Gaussian distributions to the star counts in the x and y directions. We then made an average of the central coordinates for the different V intervals. The fits of the Gaussians were performed using the NGAUSSFIT routine in the STSDAS/IRAF package. We adopted a single Gaussian and fixed **the constant to the corresponding background levels and the linear terms to zero.** The center of the Gaussian, its amplitude and its full width at half-maximum (FWHM) acted as variables. Once a couple of scattered points were eliminated, the fitting procedure converged after an average of one iteration. The resulting coordinates for the cluster centers turned out to be $(x_{\rm c}, y_{\rm c}) = (820 \pm 30, 1210 \pm 30)$ pixels and $(1670 \pm 30, 1000 \pm 50)$ pixels, equivalent to $\alpha_{2000} = 11^h\ 12^m\ 23.5^s$, $\delta_{2000} = \text{-}60^\circ\ 46'\ 52''$ and $\alpha_{2000} = 11^h\ 12^m\ 46^s$, $\delta = \text{-}60^\circ\ 48'\ 15''$ for Hogg 12 and NGC 3590, respectively.

With the aim of finding out the clusters' morphologies more precisely, we considered the possibility of their being elliptically shaped. We made use of the N2GAUSSFIT program in the STSDAS/IRAF package, which allows a 2-dimensional elliptical Gaussian fit represented by the Gaussian amplitude, the x and y centers, the FWHMs, the ellipticity, the position angle and the background level. We selected the deepest V image and kept all seven coefficients so that they could be varied during the fit. After **one or two** iterations, we derived the best values for the seven coefficients based on the smallest obtained chi-square value, the rms and the individual coefficient errors. The x and y coordinate centers showed excellent agreement with those derived before, the ellipticity being around 0.5 in both cases. We overplotted in Fig. 1 the corresponding ellipses obtained from the 2-dimensional Gaussian fit. **The semi-major axes of the ellipses turned out to be $1.8'$ and $1.0'$ for NGC 3590 and Hogg 12, respectively.**

Finally, we applied the method of Pavani & Bica (2007) to measure how different the stellar densities encompassed by the adopted ellipses are with respect to the field star density. Pavani & Bica (2007) defined the R^2 statistics which reflects the distribution of field fluctuactions and density contrast in the CMD between those of the clusters and those in the star field. Thus, we built 70 different CMDs for boxes of 250×250 pixels distributed throughout the field, as well as the CMDs for NGC 3590 and Hogg 12. Then, we built the histogram of the R^2 distributions and performed a Gaussian fit. We found that the R^2 values for both NGC 3590 and Hogg 12 exceed in more than 10σ the mean value derived for the field. Since NGC 3590 is a well known real OC, the above mentioned result implies that Hogg 12 also constitutes a genuine physical system, in contrast with the assumption of Moffat & Vogt (1975) that it is a random fluctuation of the field star density.

4. Estimates of Hogg 12 fundamental parameters

Clariá (1976) reported photoelectric measurements in the UBV system for 28 stars in the region of NGC 3590, most of them early-type stars. His observations performed within

$2'$ from the cluster center allowed him to conclude that NGC3590 is an elongated, uniformly reddened system with a heliocentric distance of 2.28 kpc, $E(B-V) = 0.51$ and an age of 36 Myr. The cluster color excess and distance were derived on the basis of **cluster members** with $U - B <$ -0.1 mag, whereas the cluster age was estimated from an equation given by Sandage (1957) which takes into account the mass and luminosity of a turnoff star.

Fig. 5 depicts the filtered CMDs and **color-color diagrams** for stars distributed within the NGC 3590 ellipse of Fig. 1. Despite the presence of some unavoidable interlopers, most of the stars appear to trace the cluster fiducial MS. Thus, we adopted the $E(B-V)$ color excess and apparent distance modulus from Clariá (1976) and overplotted the Zero Age Main Sequence (ZAMS) of Lejeune & Schaerer (2001) to the (V,$B-V$), (V,$U-B$) and ($U-B$,$V-V$) diagrams. We also fitted the (V,$V-I$) and ($U-B$,$V-I$) diagrams by using a $E(V-I)$ color excess of 0.60 mag. When selecting ZAMSs for different Z values to assess the metallicity effect in the cluster fundamental parameters, we followed the general rule of starting without adopting a prearranged metallicity. Instead, we used chemical compositions of Z = 0.008, 0.020 and 0.040 which cover the metallicity range of most of the Galactic OCs studied in detail (Mermilliod & Paunzen 2003). The ZAMS which best resembles the cluster features is the one of solar metal content.

The widely used procedure of fitting theoretical isochrones to the observed CMDs was applied to estimate the age of NGC 3590. We fitted theoretical isochrones computed by Lejeune & Schaerer (2001) to the cleaned (V, $U-B$), (V, $B-V$) and (V, $V-I$) CMDs. The isochrones, which cover an age range from 10^3 yr to 16-20 Gyr in steps of $\Delta\log t =$ 0.05 dex, were calculated for the entire set of non-rotating Geneva stellar evolution models. They also cover masses from 0.4-0.8 to 120-150 $M_\odot$ and metallicities from Z = 0.0004 to 0.1. Next, we selected a large number of isochrones and used the adopted pair of distance modulus and reddening values to estimate the cluster age. The isochrone of $\log t = 7.50$

$\pm$ 0.20 ($t = 30^{+20}_{-10}$ Myr) and solar metal content turned out to be the one which most accurately reproduces the cluster features in the three CMDs, as shown in Fig. 5. The age derived is in excellent agreement with the value estimated by Clariá (1976).

Once we checked that the filtering procedures of both CMDs and **color-color diagrams** and that the isochrone fitting method reproduced the fundamental parameter values of NGC 3590 derived by Clariá (1976), we applied the same methods to Hogg 12. Fig. 6 shows the cleaned CMDs and **color-color diagrams** for the stars within the corresponding ellipse drawn in Fig. 1. Surprisingly, most of the stars in the ($U-B$,$B-V$) diagram can be matched by a ZAMS of solar metal content reddened by $E(B-V) = 0.40$ $\pm$ 0.05. The width of such ZAMS does not take into account differential reddening. On the other hand, the ZAMS reddened by $E(V-I) = 0.50 \pm 0.05$ corresponding to an apparent distance modulus of $V - M_V = 12.75 \pm 0.25$ matches reasonably well the star distributions in the ($U-B$,$V-I$) diagram as well as in the three CMDs. If we applied the criteria defined by Clariá & Lapasset (1986) to assess the membership status of the stars measured in Hogg 12, we would find that most of them would be probable cluster members. Such criteria require that the location of a given star in the three CMDs must correspond to the same evolutionary stage and that its location in the two **color-color diagrams** must be close to the cluster MS, the maximum accepted deviation being 0.10 mag. Note that according to these criteria, a few probable members could be discarded simply because they fall out of the MS in some of the three CMDs, which would possibly be due to **an incorrect color value.**

With the aim of comparing the ages of Hogg 12 and NGC 3590, we overlapped their **extracted** CMDs. The resulting diagrams are shown in Fig. 7, where we represent the stars of Hogg 12 and of NGC 3590 with filled and open circles, respectively. As can be seen, both clusters seem to be nearly the same age. We believe that the relatively old age ($\sim$ 100

Myr) and the remarkably low reddening value ($E(B-V) = 0.04$) estimated by Ahumada et al. (2001) for Hogg 12 is most probably due to the fact that the cluster integrated spectrum is contaminated by comparatively bright foreground stars.

We used the derived reddening and apparent distance modulus values and the most frequently used $A_V/E(B-V)$ ratio (Straizys 1992, = 3.2) to obtain the cluster true distance moduli $V_o - M_V = 11.47 \pm 0.41$ mag and the heliocentric distance d = 2.0 ± 0.5 kpc. The distance error was computed with the expression : $\sigma(\mathrm{d}) = 0.46\times[\sigma(V-M_V) + 3.2\times\sigma(E(B-V))]\times\mathrm{d}$, where $\sigma(V-M_V)$ and $\sigma(E(B-V))$ represent the estimated errors in $V - M_V$ and $E(B-V)$, respectively. If we assume the Sun's distance from the center of the Galaxy to be 8.5 kpc, the recently estimated distance for Hogg 12 yields the cluster Galactic coordinates (X,Y,Z) = (7.78, -1.86, -0.01) kpc and a Galactocentric distance R_{GC} = 8.0 kpc.

5. Open cluster binarity

If we accept that the major axes of the corresponding ellipses (Fig. 1) represent the dimensions of each cluster, the resulting angular radii are $1.00'$ and $1.78'$, equivalent to linear radii of 0.6 pc and 1.2 pc for Hogg 12 and NGC 3590, respectively. Given the fact that many young OCs have radii of $\sim$ 500 pc or even longer, both Hogg 12 and NGC 3590 appear to **be very** small OCs. These objects present an angular separation in the sky of $5.8'$, which is equivalent to 3.85 pc or 3.37 pc, depending on which clusters' heliocentric distance is used. Therefore, both OCs are physically **separated 3.6 ± 0.2 pc,** which makes them one of the closest pairs of OCs carefully studied up to the present (de la Fuente Marcos & de la Fuente Marcos 2009). In fact, de la Fuente Marcos & de la Fuente Marcos compiled 27 candidate binary clusters from the Dias et al. (2002)'s catalogue and found that only Bica 1 and Bica 2 pair does have a spatial separation (S) of 3 pc, **whereas** the remaining binary clusters **have** S values between 7 and 30 pc. The spatial separation of these two almost coeval OCs, compared to their large heliocentric dsitances, suggests that both objects were formed together. Although de la Fuente Marcos & de la Fuente Marcos (2009) did not include Hogg 12 and NGC 3590 in their study, both **clusters match** very well the relationships obtained by these authors between age difference of OC pairs as a function of their age and of their physical separation (see their Figs. 2 and 3). In addition, since de la Fuente Marcos & de la Fuente Marcos (2009) concluded that the OC binary fraction in the Galaxy is at least 10%, one should expect to find $\sim$ 150 new Galactic OC physical pairs.

6. Summary

New CCD $UBVI_{KC}$ photometry in the field of the OCs NGC 3590 and Hogg 12 is reported here. The analysis of the photometric data leads to the following main conclusions:

(i) By filtering the photometry from uniform patterns in terms of spatial density, magnitude and color distributions, we revealed the peculiar characteristics of the observed field. Then, we estimated the centers of Hogg 12 and NGC 3590 and their dimensions. Both objects were found to be small OCs with radii of $\sim$ 1 pc.

(ii) We confirmed the physical reality of Hogg 12 as a genuine OC based on photometric and morphological criteria as well as on the spatial density in the region. We used NGC 3590 as a control cluster. The latter is a 30 Myr old OC with solar metal abundance.

(iii) The cleaned-extracted CMDs and **color-color diagrams** of Hogg 12 revealed that this is a nearly solar metal content cluster, reddened by $E(B-V) = 0.40$ and located at a heliocentric distance $d = 2.0$ kpc. Hogg 12 seems to be as old as NGC 3590 **(30 Myr).**

(iv) Both clusters are scarcely separated in the sky by 3.6 pc. This fact, together with their similar ages, reddenings and metallicities, makes them one of the closest OC binary systems in our Galaxy. Up to present time, there are only 27 known OC pairs out of $\sim$ 180 pairs estimated to exist in the Galaxy.

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Table 1. Observation log of Hogg 12

Date	filter (sec)	exposure	airmass ($''$)	seeing
Dec. 27	B	20	1.18	1.8
	B	300	1.18	1.9
	V	20	1.18	1.9
	V	200	1.18	1.9
	I	10	1.17	1.6
	I	50	1.17	1.9
	I	300	1.17	2.2
Dec. 29	V	20	1.19	1.2
	V	60	1.19	1.3
	V	200	1.19	1.3
	B	20	1.19	1.5
	B	60	1.18	1.5
	B	360	1.18	1.4
	I	10	1.18	1.2
	I	90	1.18	1.2
	U	60	1.17	1.7
	U	420	1.17	1.5

Table 2. CCD $UBVI$ data of stars in the field of Hogg 12 and NGC 3590.

ID	x (pix)	y (pix)	V (mag)	$\sigma(V)$ (mag)	n_V	$U-B$ (mag)	$\sigma(U-B)$ (mag)	n_{UB}	$B-V$ (mag)	$\sigma(B-V)$ (mag)	n_{BV}	$V-I$ (mag)	$\sigma(V-I)$ (mag)	n_{VI}
1	48.423	1.482	18.346	0.930	2	99.999	9.999	0	99.999	9.999	0	3.022	0.496	2
2	1690.638	1.589	18.049	0.089	2	99.999	9.999	0	2.934	0.006	2	2.342	0.010	2
3	781.099	3.156	16.086	0.043	6	0.494	0.025	2	1.025	0.027	3	1.055	0.083	4
4	986.964	2.553	18.037	0.032	6	0.606	0.016	2	1.231	0.021	3	1.418	0.175	4
5	1063.979	4.595	19.376	0.035	4	99.999	9.999	0	1.556	0.056	1	1.627	0.022	3

Note. — (x,y) coordinates correspond to the reference system of Fig. 1. Magnitude and color errors are the standard deviations of the mean or the observed photometric errors for stars with only one measurement. **Only a part of Table 2 is shown here for guidance regarding its form and content. Table 2 is available in its entirety in the online version of this journal.**

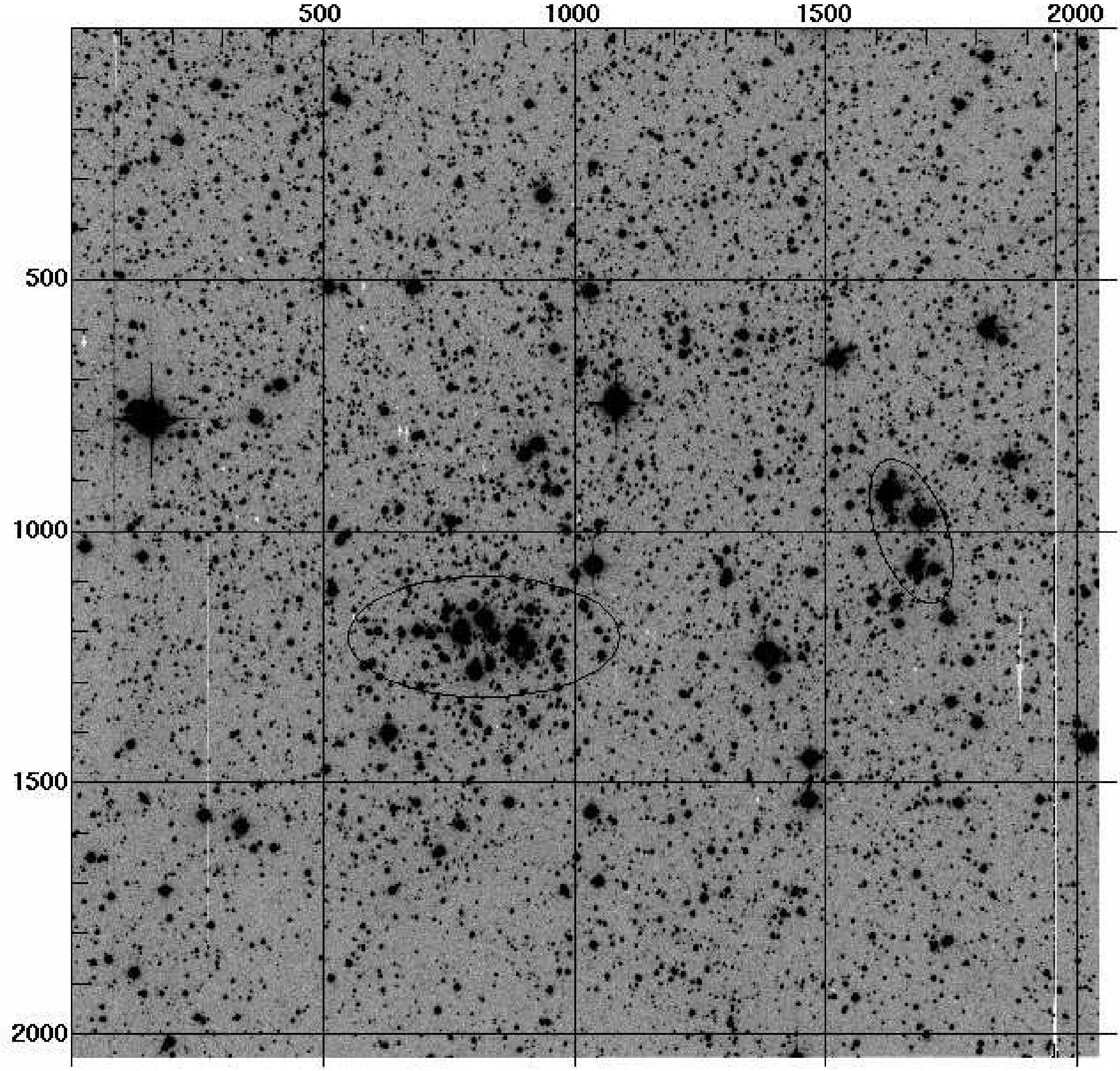

Fig. 1.— 200 s V image obtained in the field of NGC 3590 and Hogg 12. Coordinates are given in pixels. North is up and east is to the left. The ellipses **centered on** ($x_{\rm c}$, $y_{\rm c}$) **= (820, 1210) and (1670, 1000) pixels encompass the NGC 3590 and Hogg 12 regions, respectively.**

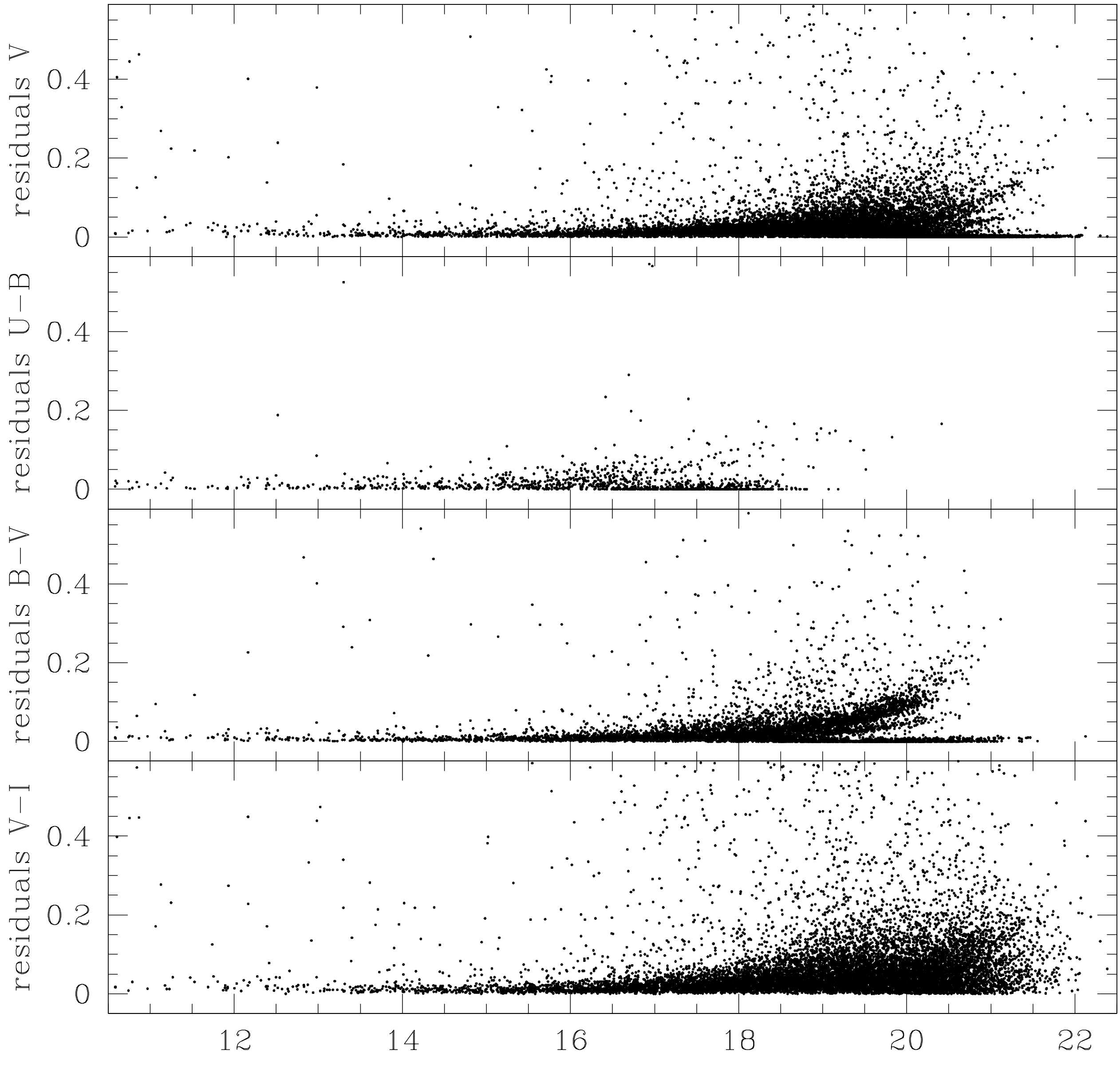

Fig. 2.— Magnitude and color photometric errors as a function of V.

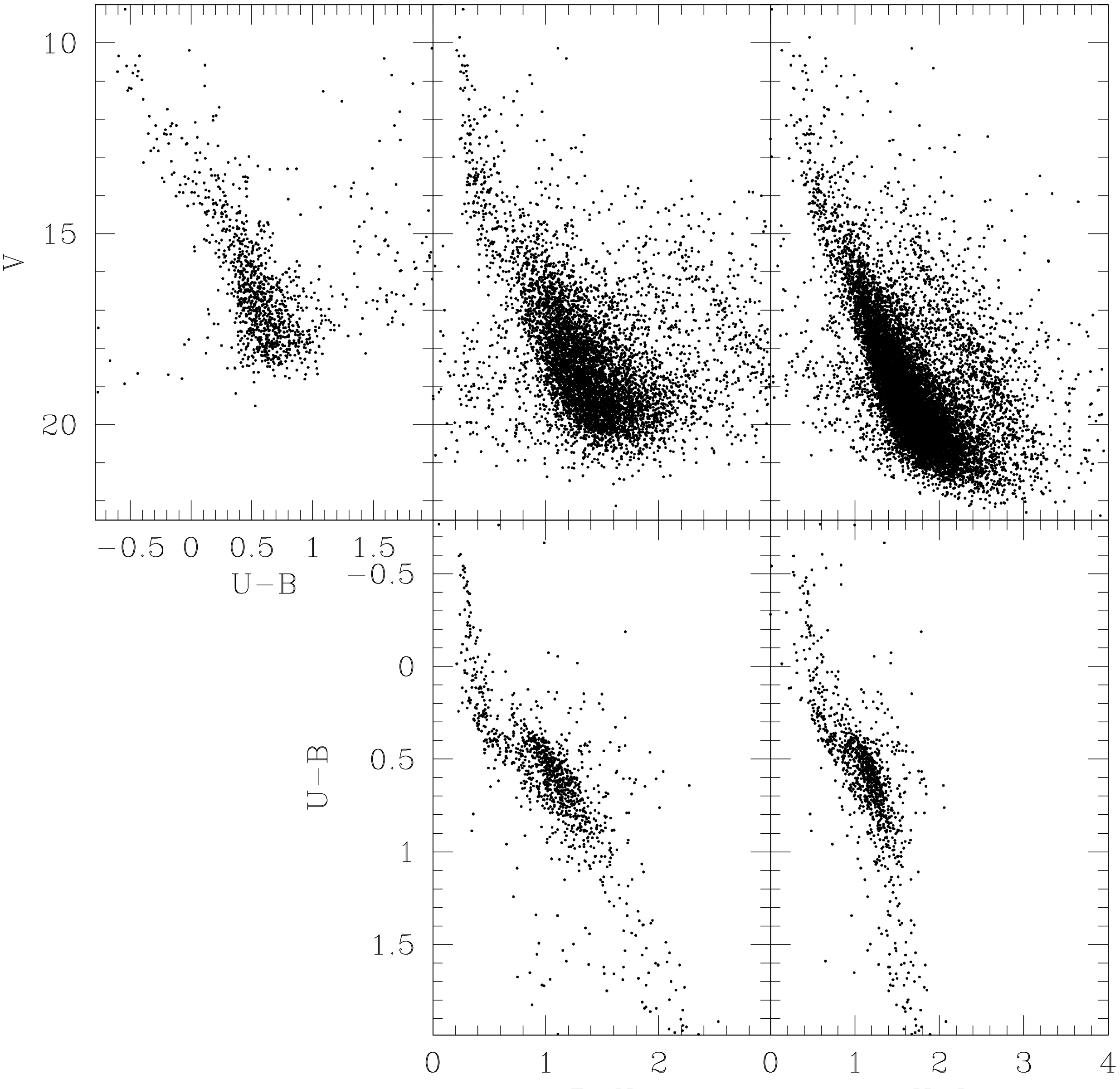

Fig. 3.— The $(V, U-B)$, $(V, B-V)$, and $(V, V-I)$ diagrams (*top*), and $(U-B, B-V)$ and $(U-B, V-I)$ diagrams (*bottom*) for the stars measured in the field of Hogg 12.

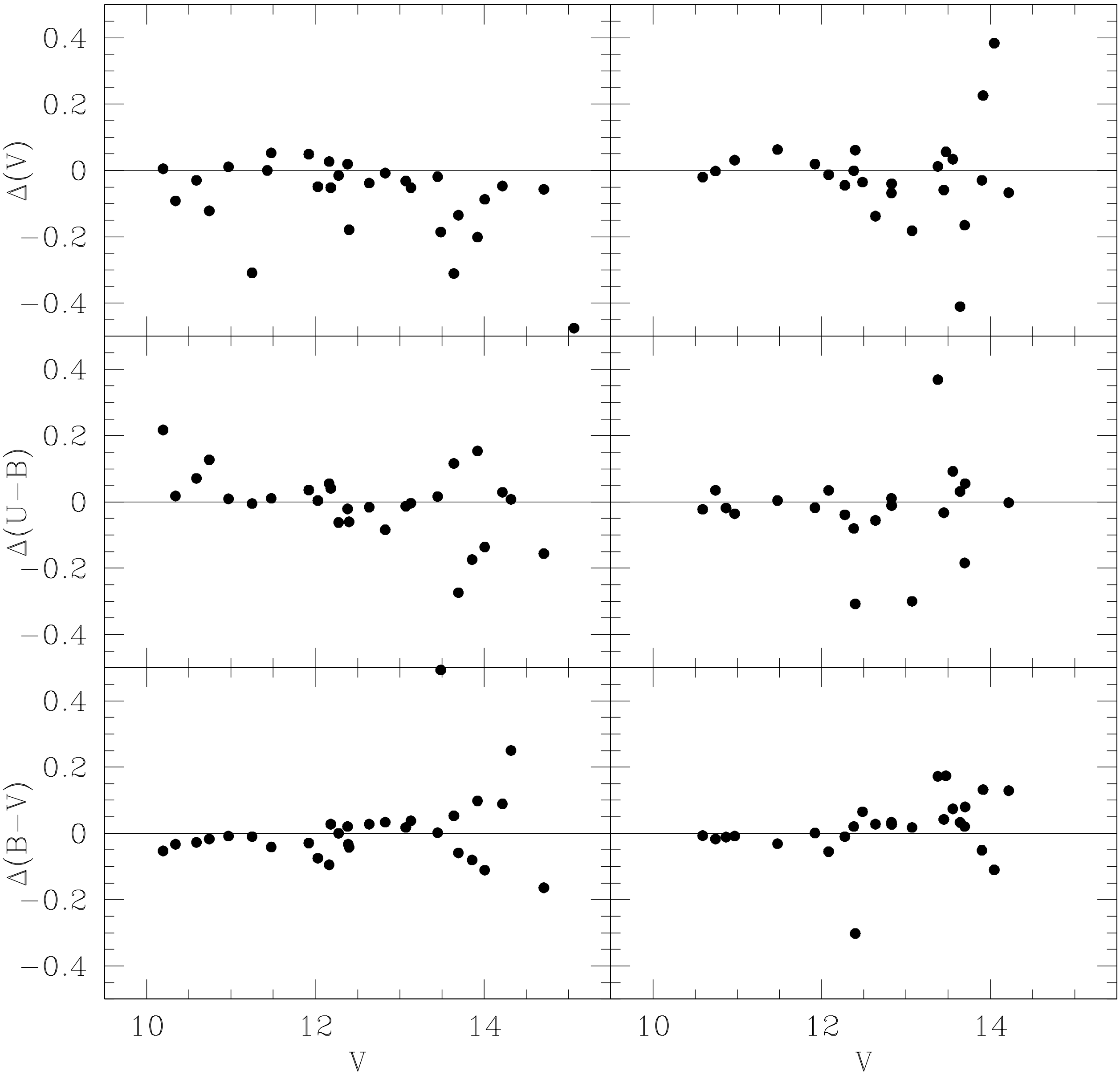

Fig. 4.— Comparison between our **photometry and Moffat & Vogts's (1975) (left panels) and Clariá's (1976) ones** (right panels).

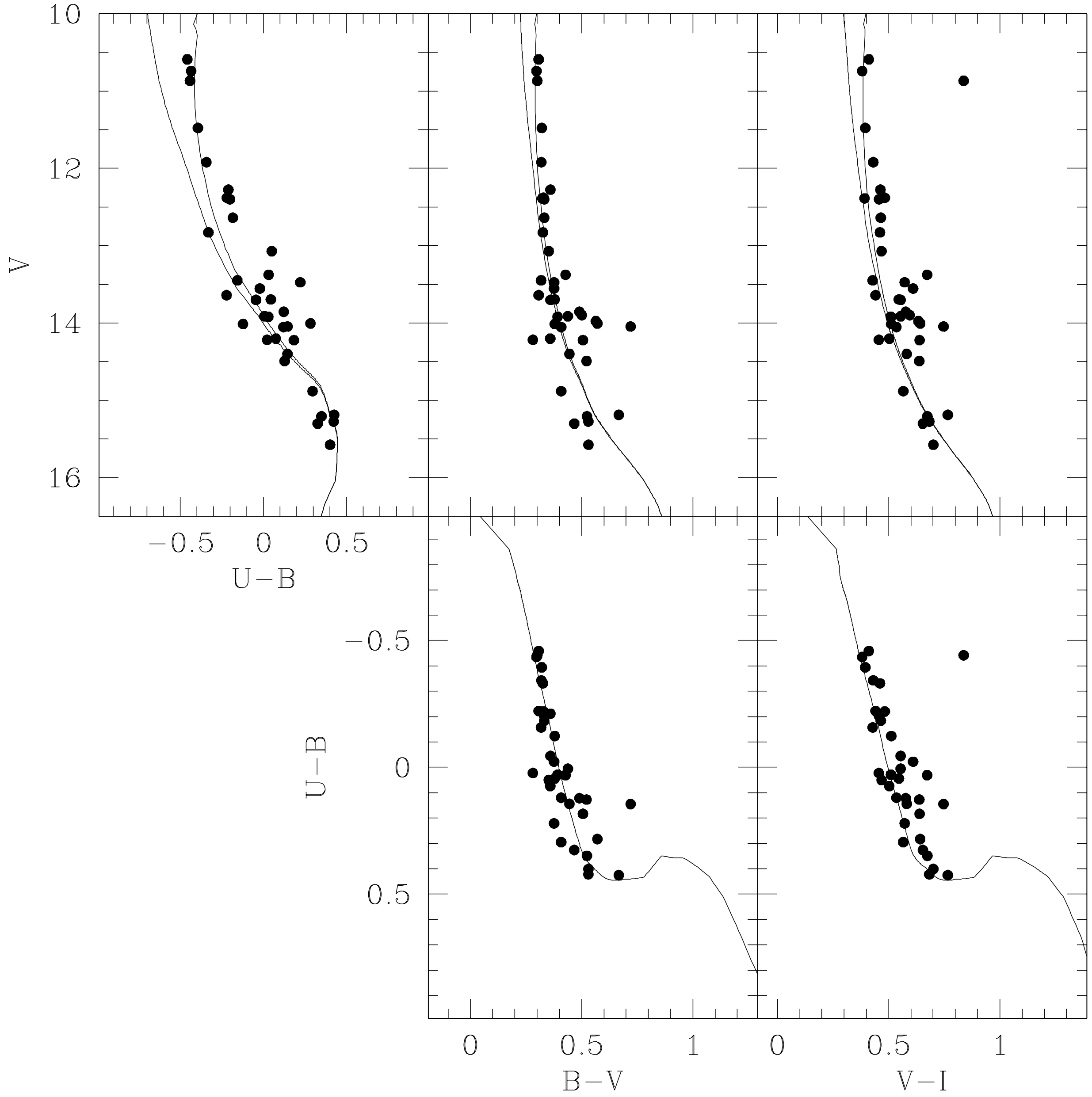

Fig. 5.— The cleaned-extracted $(V, U-B)$, $(V, B-V)$, and $(V, V-I)$ diagrams (*top*), and $(U-B, B-V)$ and $(U-B, V-I)$ diagrams (*bottom*) for NGC 3590. The ZAMS and the isochrone for $\log t = 7.5$ are overplotted.

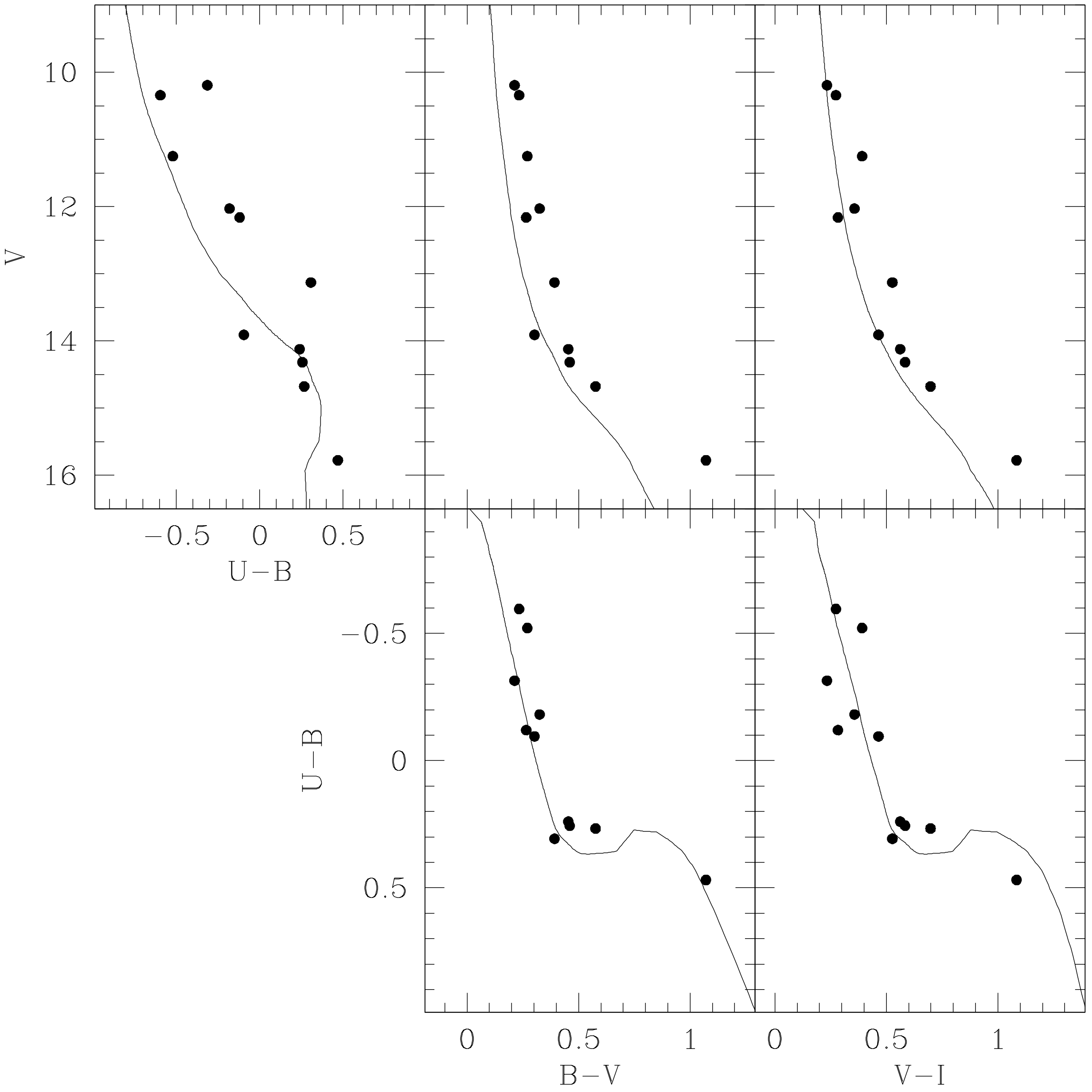

Fig. 6.— The cleaned-extracted $(V, U-B)$, $(V, B-V)$, and $(V, V-I)$ diagrams (*top*), and $(U-B, B-V)$ and $(U-B, V-I)$ diagrams (*bottom*) for Hogg 12. The ZAMS is overplotted.

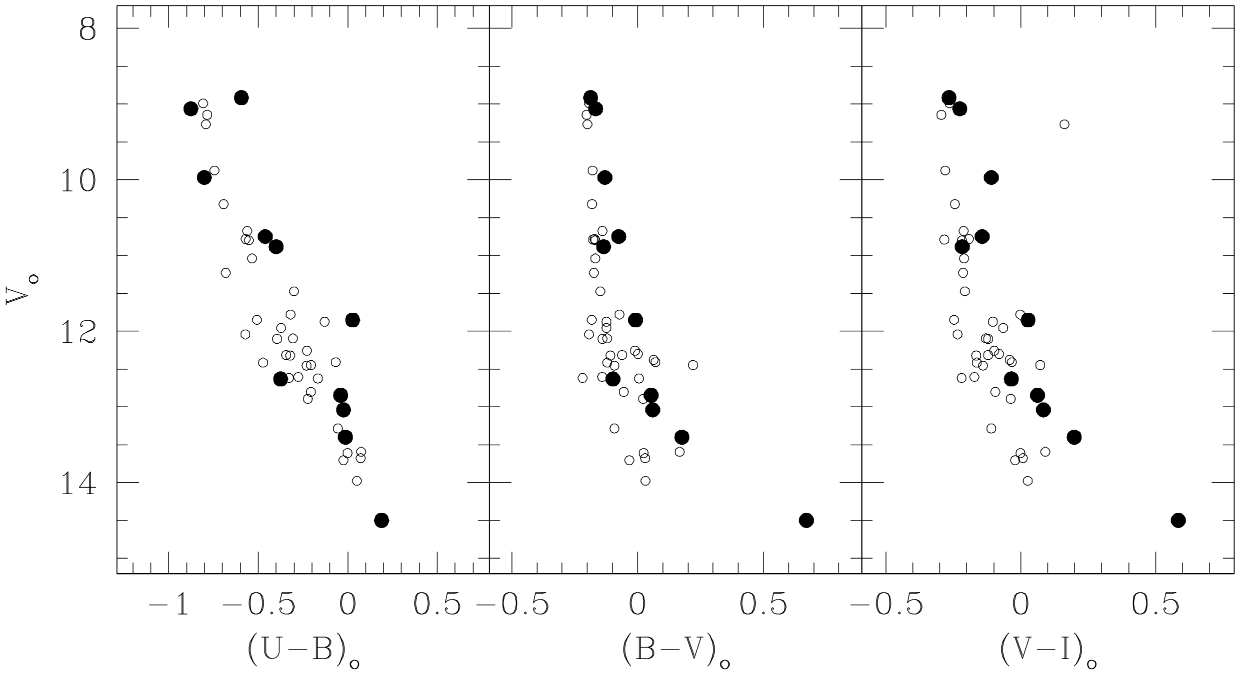

Fig. 7.— The $(V, U - B)$, $(V, B - V)$, and $(V, V - I)$ diagrams for the probable members of Hogg 12 (filled circles) superimposed to those of NGC 3590 (open circles).