Astronomical Notes
Astronomische Nachrichten

BV photometry of a possible open star cluster pair NGC 7031/ NGC 7086

V. S. Kopchev and **G. T. Petrov**

Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarigradsko chaussee Blvd, 1784 Sofia, Bulgaria

Received 2007 Feb 2, accepted 2008 Aug 2
Published online 2008 Sep 22

Key words open clusters and associations: individual (NGC 7031, NGC 7086) – techniques: photometric

We present a CCD BV photometry of the possible binary open star cluster NGC 7031/NGC 7086. The aim is to confirm or disprove their common nature on the grounds of their age and distance. An age of 224 $\pm$ 25 Myr and a distance of 831 $\pm$ 72 pc was determined for NGC 7031, and 178 $\pm$ 25 Myr, 955 $\pm$ 84 pc for NGC 7086, respectively. Based on these differences in age and distance we conclude that the two clusters are most likely not formed together from one and the same giant molecular cloud and thus do not form a true binary cluster.

Astron. Nachr. / AN **329**, No. 8, 845 – 848 (2008) / **DOI** 10.1002/asna.200711009

Astron. Nachr. / AN **329**, No. 8, 845 – 848 (2008) / **DOI** 10.1002/asna.200711009

BV photometry of a possible open star cluster pair NGC 7031/ NGC 7086

V. S. Kopchev⋆ and **G. T. Petrov**

Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarigradsko chaussee Blvd, 1784 Sofia, Bulgaria

Received 2007 Feb 2, accepted 2008 Aug 2
Published online 2008 Sep 22

Key words open clusters and associations: individual (NGC 7031, NGC 7086) – techniques: photometric

We present a CCD BV photometry of the possible binary open star cluster NGC 7031/NGC 7086. The aim is to confirm or disprove their common nature on the grounds of their age and distance. An age of 224 ± 25 Myr and a distance of 831 ± 72 pc was determined for NGC 7031, and 178 ± 25 Myr, 955 ± 84 pc for NGC 7086, respectively. Based on these differences in age and distance we conclude that the two clusters are most likely not formed together from one and the same giant molecular cloud and thus do not form a true binary cluster.

1 Introduction

A binary open star cluster is an object consisting of two open clusters. They can be basically described as: (i) binary physical systems with common origin formed together from one and the same giant molecular cloud (GMC), having comparable ages and chemical compositions (we call this a true binary cluster); (ii) binary physical systems arising from clusters formed in different parts of the Galaxy and forming a pair through gravitational capture. Cluster pairs formed through tidal capture have different ages and/or chemical composition.

The existence of star cluster pairs in our neighbouring galaxies, the Magellanic Clouds, was confirmed by several authors (e.g. Bhatia & Hatzidimitriou 1988; Bica et al.1992; Vallenari et al. 1998; Dieball & Grebel 2000; de Oliveira et al. 2000). Dieball (2002) proposed a catalogue of binary and multiple cluster candidates in the Large Magellanic Cloud with 473 members. There are more than 1600 open clusters in our Galaxy but only one well established double or binary cluster, namely $h+\chi$ Persei (see e.g. Uribe et al. 2002; Kharchenko et al. 2005). Our Galaxy seems to show a lack of binary or multiple clusters as compared to the Magellanic Clouds. It is still an open question why such objects do not exist in our Galaxy. The reasons could be that they have already merged or dissipated, or that they simply do not form. Several lists of binary open cluster candidates have been proposed and studied by various authors: Lyngå & Wramdemark (1984), Pavlovskaya & Filippova (1989), Tignanelli et al. (1990), Subramaniam et al. (1995), Loktin (1997), and Muminov (2000). One of the most complete and well studied lists is the one of Subramaniam et al. (1995) with 18 candidate pairs, including the clusters NGC 7031 and NGC 7086 studied here. Basic parameters of NGC 7031 and NGC 7086 as given in Dias et al. (2002) and the WEBDA[1] database are presented in Table 1.

Table 1 Basic parameters of the clusters NGC 7031 and NGC 7086.

Parameter	NGC 7031	NGC 7086
R.A. (2000)	21:07:12	21:30:27
Dec. (2000)	+50:52:30	+51:36:00
Distance (pc)	900	1298
Ang. diam. (arcmin)	14.0	12.0
$E(B-V)$ (mag)	0.854	0.807
$\log(\mathrm{age/yr})$	8.138	8.142

Table 2 presents previous photographic studies of the open clusters NGC 7031 and NGC 7086. The scatter, especially in the ages, is quite large for each cluster; all studies agree on a larger distance to NGC 7086 in comparison with the distance proposed for NGC 7031.

For a good selection criterion for a binary cluster Dieball (2002) considers: (i) the maximum centre-to-centre separation is ≈20 pc, and (ii) the age difference between the components of a binary cluster is either ≤10 Myr, or their ages agree well within the uncertainties of their age determination. Based on N-body simulations Portegies Zwart & Rusli (2007) conclude that a cluster pair with a smaller initial separation tends to merge in $\lesssim$60 Myr due to loss of angular momentum from escaping stars, while clusters with a larger initial separation tend to become even more widely separated due to mass loss from the evolving stellar populations. This suggests that 20 pc is a good selection criterion.

The aim of our investigation is to determine more precisely cluster parameters such as reddening, distance and

⋆ Corresponding author: kopchev@astro.bas.bg

[1] http://www.univie.ac.at/webda

Table 2 Previous studies of the open clusters NGC 7031 and NGC 7086.

Name	Reference	Distance (pc)	Age (Myr)	$E(B-V)$ (mag)
NGC 7031	Svolopoulos 1961	760		1.03
	Hoag et al. 1961	900	137	0.85
	Lindoff 1968	910	56	
	Hassan & Barbone 1973	710	56	0.71
	Ruprecht et al. 1981		280	
	Janes & Adler 1982	700		0.71
NGC 7086	Hassan 1967	1170	600	0.69
	Lindoff 1968	1205	85	
	Janes & Adler 1982	1200		0.70

Table 3 Observation log.

Name	Filter	Exposure (s)	Airmass
NGC 7031	B	5×20	1.10
	V	5×10	1.10
NGC 7086	B	5×25	1.16
	V	5×15	1.16

age using CCD photometry and applying criterion for binarity in order to confirm or disprove their binarity.

2 Observations and data reduction

The clusters were observed in the night of 2006 May 30 with the 2-m Ritchey-Chretien telescope of Rozhen National Astronomical Observatory, Bulgaria. The telescope is equipped with standard Johnson filters and 1340×1300 VersArray 1300B CCD camera with 20 μm pixel size that corresponds to 0.26 arcsec, giving a field of 5×6 arcmin^2 in the sky. The angular separation between the centres of the clusters is approximately 1° and we cannot observe them on a single frame. The cluster fields are shown in Figs. 1 and 2. Table 3 presents an observation log, the seeing was between 1.6–1.9 arcsec. Standard IRAF routines were used to reduce the data, photometry was carried out with DAOPHOT II. The accuracy of the photometry is given in Fig. 3 where colour and magnitude errors are plotted as a function of the V magnitude. Instrumental magnitudes have been transformed to standard Johnson-Cousin system using a standard field around the cluster M92 (Majewski et al. 1994). The calibration equations we received are

$$b = B - (0.049 \pm 0.006) + (0.28 \pm 0.02)X - (0.114 \pm 0.006)(B-V),$$
$$v = V - (0.737 \pm 0.006) + (0.16 \pm 0.02)X - (0.038 \pm 0.006)(B-V),$$

where X is the airmass, the capital letters represent the standard magnitudes and colour and lower-case letters denote instrumental magnitudes.

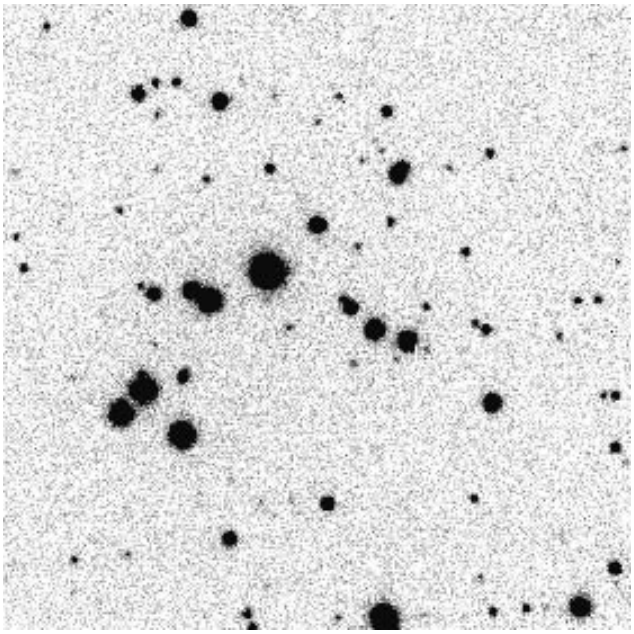

Fig. 1 $5' \times 6'$ V-band image of NGC 7031. North is to the top, East to the left.

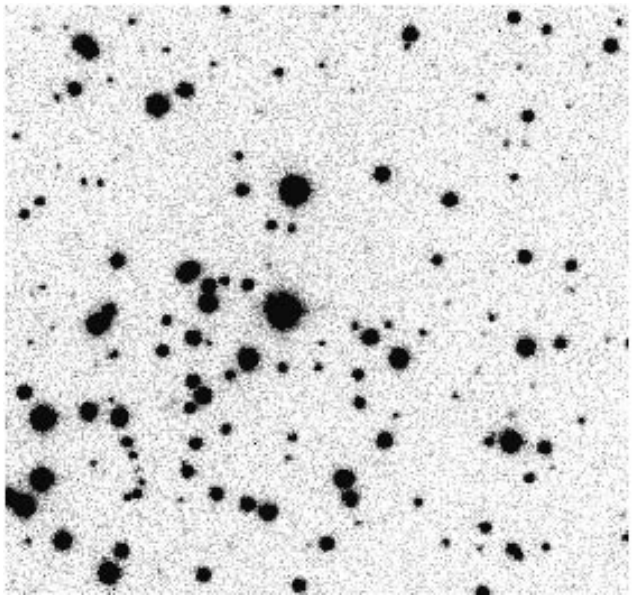

Fig. 2 $5' \times 6'$ V-band image of NGC 7086. North is to the top, East to the left.

3 Colour-magnitude diagrams and cluster parameters

The luminosity function of the clusters is presented in Fig. 4 with a dashed line for NGC 7031 and a solid line for NGC 7086. Colour-magnitude diagrams (CMDs) are presented in Fig. 5 for NGC 7031 and Fig. 6 for NGC 7086, where the solid line represents the zero age main sequence (ZAMS) taken from Schmidt-Kaler (1982). Both CMDs reveal the presence of a reasonably broad and slightly evolved main sequence (MS), typical of an early intermediate-age open

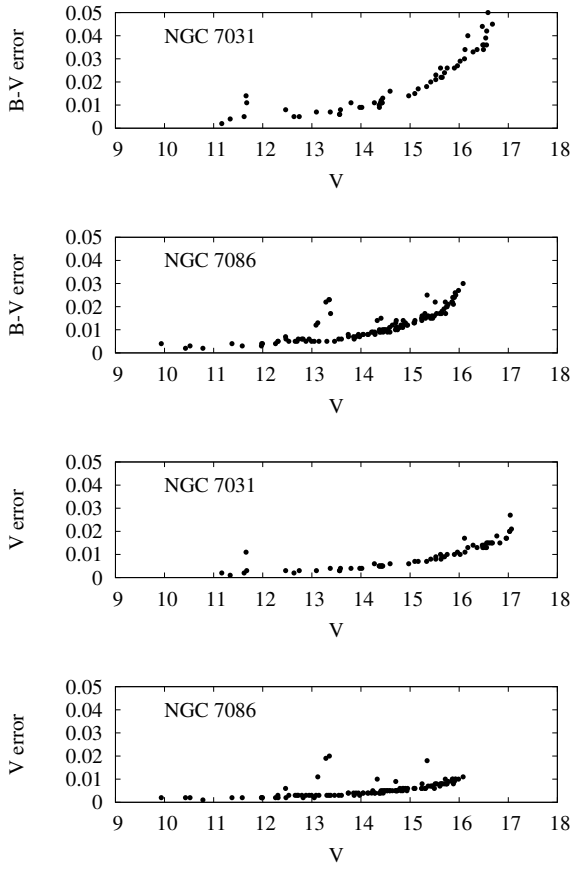

Fig. 3 The color and magnitude errors from DAOPHOT as a function of the V magnitude.

Table 4 Derived cluster parameters.

Parameter	NGC 7031	NGC 7086
$E(B-V)$ (mag)	1.05 ± 0.05	0.75 ± 0.05
$(m-M)_V$ (mag)	9.6 ± 0.2	9.9 ± 0.2
Distance (pc)	831 ± 72	955 ± 84
$\log(age/\mathrm{yr})$	8.35	8.25
age (Myr)	224 ± 25	178 ± 25

cluster. The MS extends over a range of 6 magnitudes, completeness limits are around $V = 15$. To estimate the field star contamination (see, e.g. Bonatto & Bica 2008) we used the Besancon model of stellar population[2]. The simulations determine how many field stars can be expected in the fields of view of the clusters. For cluster NGC 7031 we do not expect field star contamination in the range $V = 11$–12, but for NGC 7086 the simulation showed one field star in the range $V = 10$–11. Distance module, reddenings and ages of the clusters have been derived by matching by eye the observed CMDs to isochrones with $Z = 0.020$ from the Geneva group (Schaller et al. 1992), paying particular attention to the most likely shape of the main sequence, the turn-off point and the location of the evolved stars. In Table 4 we present our determination of cluster parameters.

[2] http://bison.obs-besancon.fr/modele/

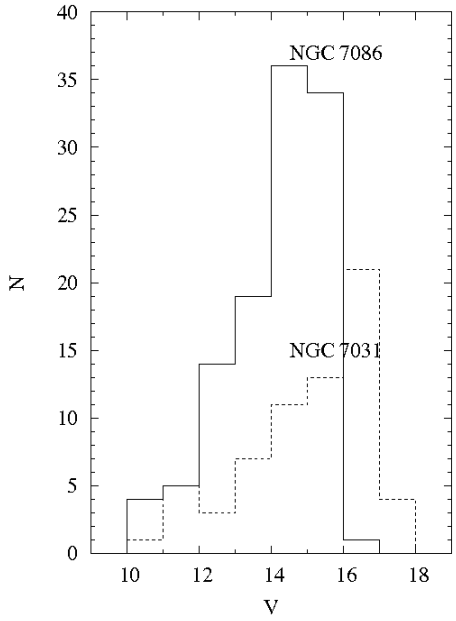

Fig. 4 Luminosity function of NGC 7031 and NGC 7086.

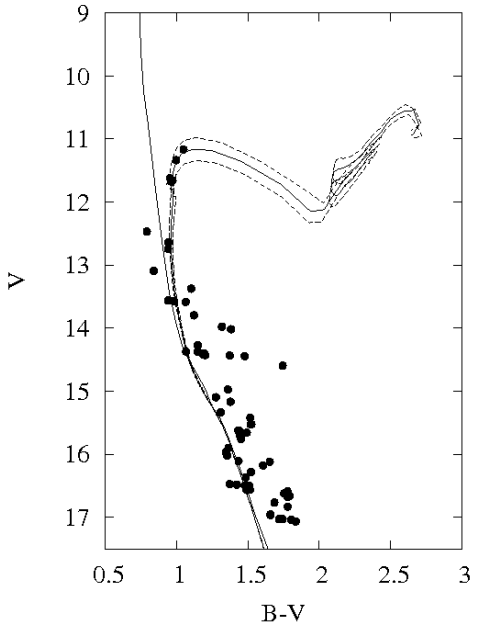

Fig. 5 The observed $V, (B-V)$ diagram of NGC 7031 and the best isochrones fit with $\log(age) = 8.35$ (solid curve).

4 Summary and conclusion

We have presented BV CCD photometry of the closely projected open star clusters NGC 7031 and NGC 7086. The results have been summarized in Table 4. Our estimations of the age difference between NGC 7031 and NGC 7086, and difference in distance along the line of sight are 46 Myr and 124 pc, respectively. These results do not match with the criterion for a binary cluster and based on these results we conclude that the two clusters are most likely not formed to-

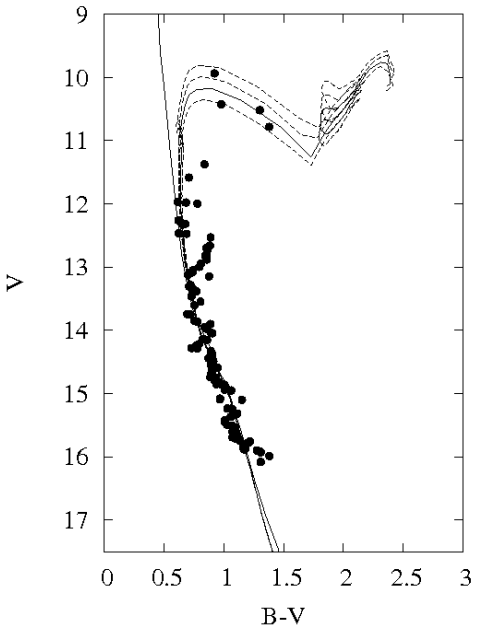

Fig. 6 The observed $V, (B-V)$ diagram of NGC 7086 and the best isochrones fit with $\log(age) = 8.25$ (solid curve).

gether from one and the same GMC and they are not a true binary cluster.

However, the ages of the two clusters roughly agree within the errors, and if we assume a mean distance of 893 pc and an angular separation of 1°, this corresponds to a separation of 15 pc between the two clusters. These results are close enough for a true binary cluster. We caution that the distance differences seem to indicate that the cluster separation is probably larger than 120 pc, thus it seems unlikely the two clusters form a true binary cluster, but it cannot be completely ruled out. Follow-up observations to determine the radial velocities of the clusters members and the motion of the clusters itself could put more light to this problem.

Acknowledgements. This research has made use of the WEBDA database, operated at the Institute for Astronomy of the University of Vienna.

References

Bhatia, R.K., Hatzidimitriou, D.: 1988, MNRAS 230, 215
Bica, E., Clariá, J.J., Dottori, H.: 1992, AJ 103, 1859
Bonatto, C., Bica, E.: 2008, A&Ap 479, 741
de Oliveira, M.R., Dutra, C.M., Bica, E., Dottori, H.: 2000, A&AS 146, 57
Dias, W.S., Alessi, B.S., Moitinho, A., Lèpine, J.R.D.: 2002, A&A 389, 871
Dieball, A.: 2002, PhD Thesis
Dieball, A., Grebel, E.K.: 2000, A&A 358, 897
Hassan, S.M.: 1967, ZA 66, 6
Hassan, S.H., Barbon, R.: 1973, MmSAI 44, 39
Hoag, A.A., Johnson, H.L., Iriarte, B., Mitchell, R.I., Hallam, K.L., Sharpless, S.: 1961, Publ. US. Nav. Obs. 17, 347
Janes, K., Adler, D.: 1982, ApJS 49, 425
Kharchenko, N.V., Piskunov, A.E., Röser, S., Schilbach, E., Scholz, R.-D.: 2005, A&Ap 438, 1163
Lindoff, U.: 1968, ArA 5, 1
Loktin, A.V.: 1997, A&AT 14, 181
Lyngå, G., Wramdemark, S.: 1984, A&A 132, 58
Majewski, S.R., Kron, R.G., Koo, D.C., Bershady, M.A.: 1994, PASP 106, 1258
Muminov, M.: 2000, AGM 16poster 70
Pavlovskaya, E.D., Filippova, A.A.: 1989, SvA 33, 602
Portegies Zwart, S.F., Rusli, S.P.: 2007, MNRAS 374, 931
Ruprecht, J., Balazs, B., White, R.: 1981, *Catalogue of Star Clusters and Associations*, Akademiai Kiado, Budapest
Schaller, G., Schaerer, D., Meynet, G., Maeder, A.: 1992, A&AS 96, 269
Schmidt-Kaler, T.S.: 1982, in: K. Schaifers, H.H. Voigt (eds.), *Landolt-Börnstein, New Series, Group VI*, Vol. 2b, p. 1
Subramaniam, A., Gorti, U., Sagar, R., Bhatt, H.C.: 1995, A&A 302, 86
Svolopoulos, S.N.: 1961, ApJ 134, 612
Tignanelli, H., Vazquez, R.A., Mostaccio, C., Gordillo, S., Feinstein, A., Plastino A.: 1990, RMxAA 21, 305
Uribe, A., Garcia-Varela, J.-A., Sabogal-Martinez B.-E., Higuera, G.M.A., Brieva, E.: 2002, PASP 114, 233
Valenari, C., Bettoni, D., Chiosi, C.: 1998, A&A 331, 506

