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BVRI photometry of NGC 3231, NGC 7055, and NGC 7127★ (Research Note)

E. Paunzen[1,2], L. Hermansson[3], and P. Holmström[3]

[1] Department of Theoretical Physics and Astrophysics, Masaryk University, Kotlarska 2, 611 37 Brno, Czech Republic
e-mail: epaunzen@physics.muni.cz
[2] Rozhen National Astronomical Observatory, Institute of Astronomy of the Bulgarian Academy of Sciences, PO Box 136, 4700 Smolyan, Bulgaria
[3] Sandvretens Observatory, Linnégatan 5A, 75332 Uppsala, Sweden

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ABSTRACT

Context. Open clusters are often used as tracers for the formation and evolution of the Milky Way. But they can also be used to study distinct "local stellar populations" and all kind of stellar groups. All these studies crucially depend on their unambiguous detection and classification separating them from the fore- and background field population.

Aims. Still more than one third of the catalogued galactic open clusters are unstudied to date. We have chosen three northern open cluster fields, namely NGC 3231, NGC 7055, and NGC 7127 which have been never studied before to shed more light on their true nature.

Methods. We present Johnson-Cousins *BVRI* photometry down to $V \approx 19$ mag. After the transformation to the standard systems, colour–magnitude diagrams were generated. These diagrams were used to fit solar abundant isochrones to determine the distance modulus, reddening and apparent age of the main sequences.

Results. As reported before, a significant plate-dependent distortion of the UCAC3 compared to the PPMXL within all three star fields was found. No correlation of this distortion with the apparent magnitude of the objects was detected. From the analysis of the colour–magnitude diagrams and the available proper motions we conclude that NGC 7055 and NGC 7127 are young, real, open clusters with ages of about 10 and 100 Myr, respectively. They are located in a distance of about 3300 as well as 5700 pc from the Sun. NGC 3231, on the other hand, is probably a high galactic latitude open cluster remnant.

Key words. open clusters and associations: general – open clusters and associations: individual: NGC 3231 – open clusters and associations: individual: NGC 7055 – open clusters and associations: individual: NGC 7127

1. Introduction

Several sky surveys within the recent and forthcoming years, for example 2MASS, SuperCOSMOS, VISTA, to mention a few, resulted in a significant progress of our knowledge of open clusters. We know of about 2100 galactic stellar aggregates (Dias et al. 2002[1]), but still about 800 of them were never studied in details. Although large photometric survey offer the advantage of covering most of the cluster areas, the pipeline reduction processes often cause intrinsic inhomogeneities.

In order to analyse the membership probabilities of stars within cluster fields, one needs precise kinematic data such as proper motions. However, the two currently available sources for this data type, the PPMXL (Röser et al. 2010) and UCAC3 (Zacharias et al. 2010) show systematic offsets between each other at least for declinations north of −20°. Thus, the current situation in this respect is rather unsatisfactory.

The motivation to study open clusters is multifaceted. They are perfectly suited not only to investigate distinct "local stellar populations", but also to trace the formation and evolution of the Milky Way in a very precise way.

The analysis of an individual open cluster crucial depends on its clear distinction from the fore- and background field which is especially difficult for very dense fields in the galactic bulge. In addition, it can be confused with an open cluster remnant which is defined as a low spatial density concentration of stars, but with sufficient members to show an evolutionary (main) sequence in the colour–magnitude diagrams (Carraro 2002). These aggregates are results of the dynamical evolution of open clusters during their lifetimes within the tidal field of the Milky Way. Furthermore, it is rather difficult to distinguish them from moving groups and stellar associations (Pavani & Bica 2007).

In this paper, we present Johnson-Cousins *BVRI* photometry, of three northern unstudied open clusters, namely NGC 3231, NGC 7055, and NGC 7127. In addition, we analysed the available proper motion data of the corresponding fields to shed more light on their true nature. NGC 3231 and NGC 7055 are listed as "non-existent NGC" according to Sulentic & Tifft (1979) whereas NGC 7127 is classified as "object not found in the DSS images inspection (wrong coordinates?)" by Dias et al. (2002). To our knowledge, no studies of these three clusters are, so far, available in the literature.

2. Observations, reduction, and calibration

The observations were performed at the Sandvreten Observatory (Uppsala, Sweden) using the 0.444 m $f/4.4$ Newton telescope

★ The complete tables with the photometric measurements are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/542/A68

[1] http://www.astro.iag.usp.br/~wilton

Table 1. Basic data of the three target clusters, the number of observed stars in the fields and the parameters from (solar abundant) isochrone (Schaller et al. 1992) fitting.

Cluster	α(2000)	δ(2000)	l	b	Diameter [′]	$N_{\rm Stars}$	$(M-m)_{\rm V}$ [mag]	$E(B-V)$ [mag]	log t [dex]
NGC 3231	10 27 29	+66 47 54	141.924	+44.653	9	39	15.5	0.10	(7.5)
NGC 7055	21 19 30	+57 36 00	97.470	+5.617	3	251	14.0	0.45	(8.0)
NGC 7127	21 43 41	+54 37 48	97.907	+1.150	5	288	15.0	0.40	(7.0)

Notes. The uncertainties are $\Delta(M-m)_0 = 0.2$ mag and $\Delta E(B-V) = 0.1$ mag. The ages are only rough estimates using the listed values of the reddening and distance modulus to fit the photometric sequences.

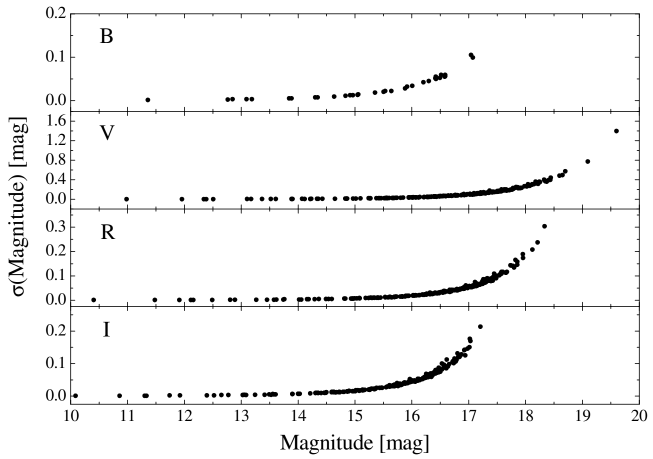

Fig. 1. Error distributions of our *BVRI* measurements for NGC 7055.

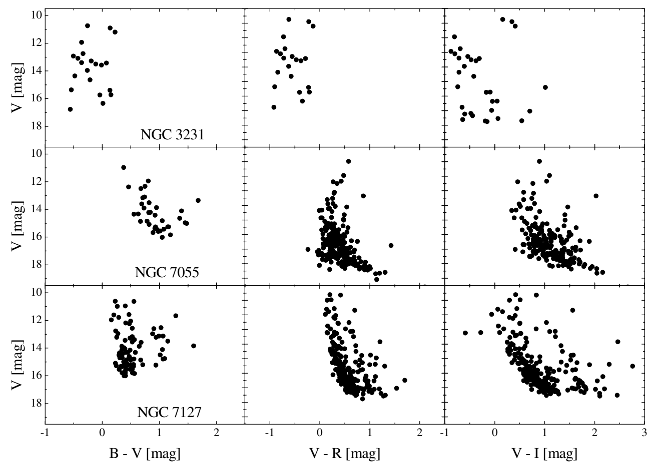

Fig. 2. Colour–magnitude diagrams of the three observed cluster fields.

equipped with a SBIG ST-7E Dual CCD and Schüler photometric Johnson-Cousins *BVRI* filters. The configuration yields a field-of-view of 8′ × 12′ and a scaling of 0.9′′ per pixel.

The target clusters were observed in the nights of 03./04.11.2009 (NGC 7055), 18./19.12.2009 (NGC 7127), and 10./11./12.02.2010 (NGC 3231). To check our calibration procedure and the stability of the instrument, also NGC 7654, one of the "standard" open clusters (Stetson 2000), was observed. For each filter, three individual, five and ten minute exposures, were stacked.

After the basic CCD reductions (bias-subtraction, dark-correction, and flat-fielding), we applied for all frames aperture photometry within IRAF[2]. To account for different seeing conditions and crowding of the fields, apertures with diameters of 12 and 24 pixels were used.

For the calibration of our instrumental to the standard system, the following sources of photometry were taken:

– APASS (Henden et al. 2011): *BV*;
– PPMXL (Röser et al. 2010): *BVRI*;
– Tycho-2 (Bessell 2000): *BV*;
– UCAC3 (Zacharias et al. 2010): *BRI*.

If there are more than one measurement per star and filter available, an unweighted mean was calculated. As last step, the instrumental measurements were linearly transformed to the standard system. We also checked all transformations if additional colour terms are necessary, but find no significant ones to include. The described procedure was verified by using the data of NGC 7654 and the measurements listed by Stetson (2000). For 116 objects of this clusters, the zero points are determined with an error between 4 and 13 mmag.

Figure 1 shows the error distributions of our *BVRI* measurements for NGC 7055. It also illustrates the limiting magnitudes reached for each filter.

The number of observed stars for each cluster is listed in Table 1. The complete tables with the photometric measurements will be available in WEBDA[3] and via ADS/CDS/Simbad.

3. Analysis and conclusions

The classical photometric analysis of open clusters and their colour–magnitude diagrams always included observations in the far blue optical region (for example Becker and Johnson U as well as Strömgren u). A $(B-V)$ versus $(U-B)$ diagram can easily sort out members from field stars within a cluster area (Purgathofer 1961). With the widespread usage of CCD detectors, and their, generally, non-sensitivity in the far blue region, such observations are, nowadays, more difficult to perform and analyse.

We are also facing a similar situation. Figure 2 shows the different colour–magnitude diagrams in the Johnson-Cousins *BVRI* filter system. Due to the sensitivity of the CCD, the B measurements are limited to $V \lesssim 16.5$ mag.

The isochrones of Schaller et al. (1992) were used for fitting a distance modulus and reddening. The metallicity was set as solar, i.e. isochrones with $[Z] = 0.02$ dex were applied. For the reddening of the different colour indices we used the standard correlation $A_{\rm V} = 3.1E(B-V) = 5.12E(V-R) = 2.48E(V-I)$. As last step, we made a rough estimate of the apparent cluster/field sequences (ages). The complete results are summarized in Table 1. In the following, we discuss the individual cluster colour–magnitude diagrams in more details.

[2] http://iraf.noao.edu/

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

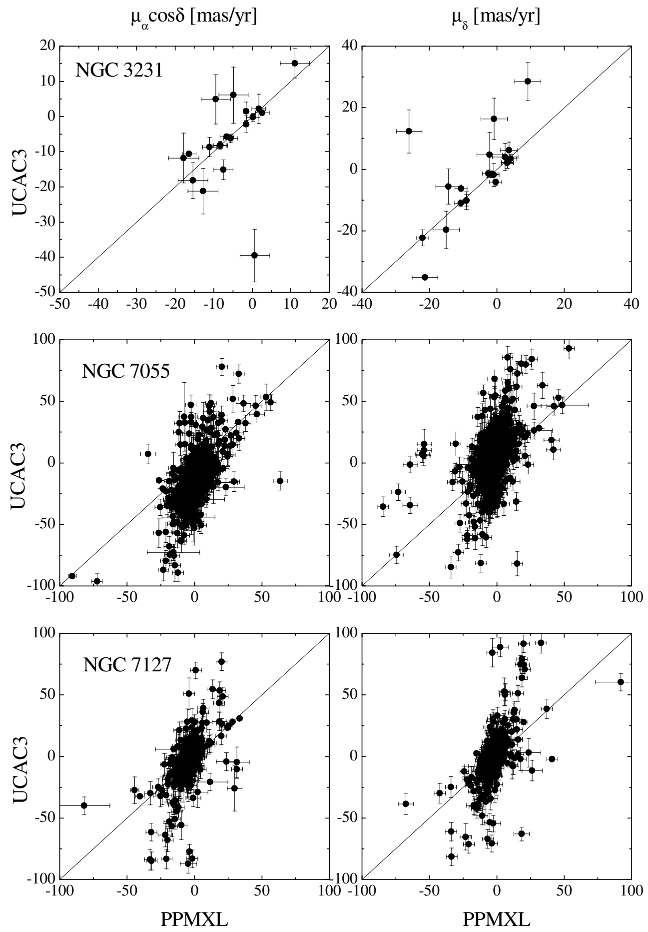

Fig. 3. Systematic differences of the proper motions taken from the UCAC3 and PPMXL for the target fields.

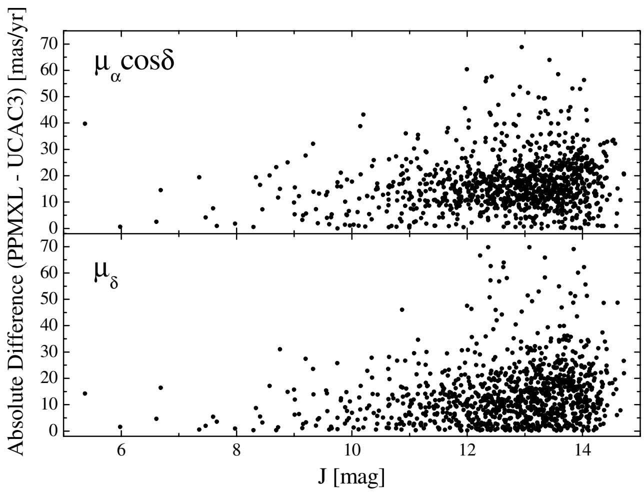

Fig. 4. Absolute differences of the proper motions in correlation with the 2MASS *J* magnitudes for NGC 7055.

NGC 3231: This field is only sparsely populated at a galactic latitude of about +45°. The three brightest objects in the field seem to be giants according to their $(V - I)$ colours. However, the $(B - V)$ and $(V - R)$ colours are only marginally in accordance. If those stars are members, an isochrone with $\log t = 7.5$ fits all observations very well. As expected, the reddening is almost negligible at such high galactic latitudes.

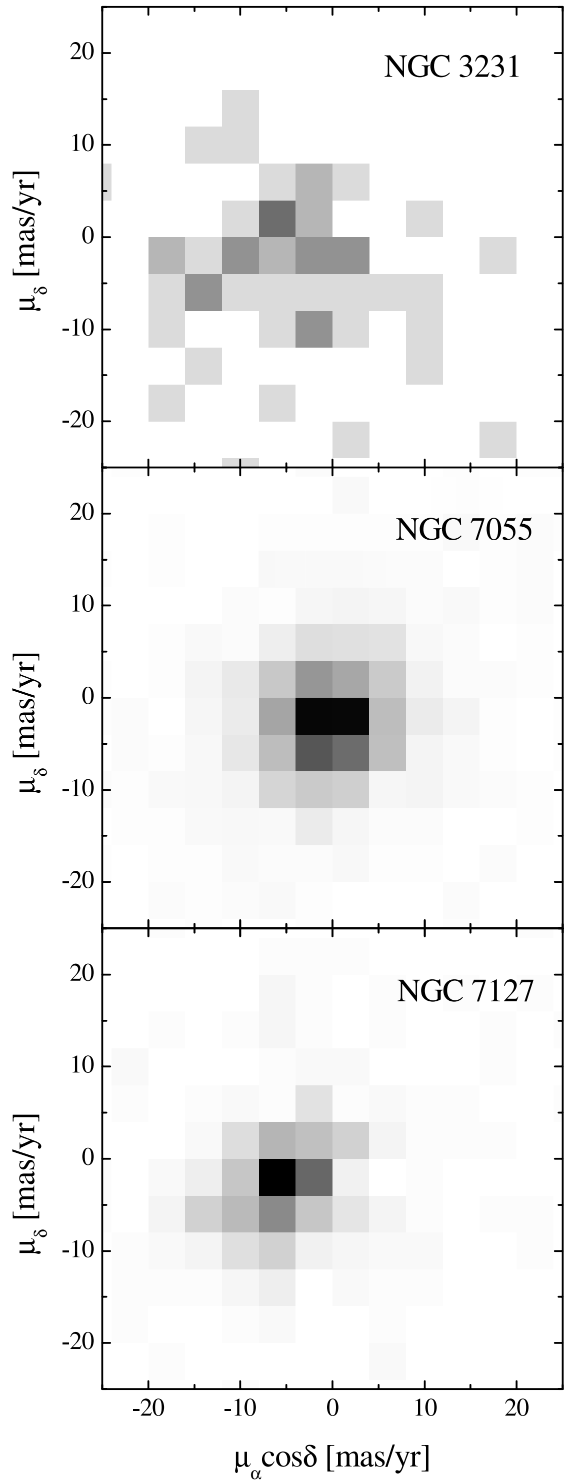

Fig. 5. Distribution of the proper motions of the PPMXL catalogue binned to 4″ boxes.

NGC 7055: The inspection of the cluster field clearly shows a main sequence which already exhibits a turn-off sequence. The lower main sequence is very broad reaching down to $V \approx 19$ mag.

NGC 7127: The most prominent feature is a "secondary" main sequence shifted by about 0.4 mag in $(V - R)$. We checked the location of these stars within the frame and found an uniform distribution over the complete field. So we are able to assume that these objects represent the background field population because they have a higher reddening than the "primary" main sequence. We are confident that this is a real open cluster.

To shed more light on the true nature of the three fields, we extracted the corresponding proper motions from the UCAC3 (Zacharias et al. 2010) and PPMXL (Röser et al. 2010). The limiting magnitudes for these catalogues are $V \approx 16$ and 20 mag. Röser et al. (2010) reported severe plate-dependent distortions of the UCAC3 in its proper motion system north of $-20°$ declination. Figure 3 shows the systematic differences of the proper motions of these two catalogues. There are three different effects: 1.) the inclination is not equal one; 2.) the offsets are not zero and 3.) several outliers are present. In addition we found double entries and several objects in the PPMXL with unrealistic high proper motions (> 500 mas yr^{-1}). These entries are very probably false identifications while generating the catalogue.

We checked the data sets, if we are able to find a hint of a magnitude limitation as a possible reason for these effects. As a most homogeneous source, 2MASS J magnitudes were taken. Figure 4 shows the absolute differences of the proper motions in correlation with the magnitudes for NGC 7055. As expected, the differences become larger with fainter magnitudes. However, even for the brighter objects in the field with $J < 10$ mag, large differences are present. We, therefore, conclude that on the basis of magnitudes, no improvement of the data sets can be achieved.

In the following, we used the values from the PPMXL only, discarding the unusual large proper motion objects and double entries. First of all, we investigated the error distributions of all proper motions. We emphasize that the errors for $\mu_\alpha \cos\delta$ and μ_δ are always identical. The means and medians of the errors range between 3.6 and 4.2 mas yr^{-1} for all three fields. The data sets were binned in 4×4 mas yr^{-1} boxes and a two dimensional distribution calculated. Figure 5 shows the results for the three star fields. The region of NGC 3231 is not very dense (see also Fig. 3) which is also reflected in the "irregular" patches. The other two fields show a Gaussian distribution around a well defined zero point. For NGC 7127, the peak of the distribution is slightly shifted towards negative $\mu_\alpha \cos\delta$ values. From a kinematic point of view, the stellar fields around NGC 7055 and NGC 7127 consist of a homogeneous stellar populations which resemble open clusters. For the sparsely populated field of NGC 3231, no distinct kinematic concentration of stars can be found. We conclude, that NGC 3231 is probable not an open cluster, but could be classified as an open cluster remnant (Carraro 2002) at a high galactic latitude.

Still a significant effort is needed to fill the observational gaps for open clusters. Preferable, such studies should include observations in the far blue optical region to distinguish non-members.

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