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VARIABLE STARS IN THE FIELD OF THE OPEN CLUSTER KING 7

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King 7 (C 0355+516) was discovered by King (1949) who described the cluster as a moderately rich group of stars fainter than 16 mag and spread in the area of 8' × 4'. Durgapal et al. (1996) collected $UBVRI$ CCD photometry for the central ($6' \times 6'$) part of the cluster and obtained fundamental parameters such as the age of 600 Myr, the interstellar extinction $E(B-V) = 1.37$ mag, and the distance of 1.9 kpc. These authors also studied the mass function of the cluster. Durgapal et al. (1997) redetermined cluster's parameters and obtained the age of $600-800$ Myr, the interstellar extinction $E(B-V) = 1.25$ mag, and the distance of 2.20 ± 0.34 kpc. Durgapal & Pandey (2001) reported the limiting radius of the cluster $r_{\rm lim} = 3'$. Sandhu et al. (2003) estimated the photometric binary content in the cluster for about 20%. In this report we present results of a dedicated CCD search for variable stars in the field of King 7.

The observations were gathered in B and V bands between January and April, 2008 with the 90/180 cm Schmidt-Cassegrain Telescope of the Nicolaus Copernicus University Astronomical Observatory in Piwnice near Toruń, Poland. The telescope was used in the imaging mode with a 60 cm correction plate and a field-flattening lens mounted near the focal plane. SBIG STL-11000 CCD camera (4008 × 2672 pixels × 9 μm) was used as a detector. The field of view was 72 arcmin in declination and 48 arcmin in right ascension with the scale of 1.08 arcsec per pixel. The 2×2 binning was used to increase the signal-to-noise ratio. The exposure time was set to 20 s and 600 s. The typical seeing (FWHM) was 5–6". During about 31 hours of observations in total 277 images in V and 90 in B were obtained. About 5700 stars brighter than 18.5 mag in V were monitored. The collected observations were reduced with the software pipeline developed for the Semi-Automatic Variability Search sky survey (Niedzielski et al. 2003, Maciejewski & Niedzielski 2005). The BV magnitudes were obtained for the crowded cluster's core ($r < 8'$) with the DAOPHOT package using the profile-fitting photometry. The calibration coefficients that transform instrumental magnitudes into standard ones were determined using 270 stars located in the field of the cluster for which photometry was taken from Durgapal et al. (1997). The $(B-V)$ coverage was in range between 0.85 and 2.45 mag. The comparison of the observed $(B-V)$ with the literature one is presented in Fig. 1. The instrumental coordinates of stars were transformed into equatorial ones based on positions of stars brighter than 16 mag and extracted from the Guide Star Catalog. The candidates for

new variable stars were selected from the V-band database using the analysis of variance method (ANOVA, Schwarzenberg-Czerny 1996).

The collected BV photometry allowed us to redetermine cluster's basic parameters. The procedure described in Maciejewski & Niedzielski (2007) in detail was applied. As a result the following parameters were derived: the central coordinates $RA = 03^{\rm h}59^{\rm m}09^{\rm s}$, $DEC = 51°47'48''$, the limiting radius of 11.6 ± 0.7 arcmin, $\log(age) = 9.00 \pm 0.05$, $E(B-V) = 1.07 \pm 0.05$ mag, the apparent distance modulus of 14.7 ± 0.1 mag, and the distance of 1.90 ± 0.25 kpc. The radial density profile with the best-fit King's formula (King 1966) is plotted in Fig. 2. The central density $f_0 = 9.27 \pm 0.22$, the core radius $r_{\rm core} = 1.39 \pm 0.05$, and the density of the background stellar field $f_{\rm bg} = 1.08 \pm 0.04$ were derived. The cleaned colour-magnitude diagram (CMD) was constructed for the central part ($r < 3r_{\rm core}$) of King 7 and was plotted with the best-fit isochrone of solar metallicity in Fig. 3.

As a result of our survey 16 variable stars were detected in the field of King 7. They are listed in Table 1 and their light curves are presented in Fig. 4. V13 is known as V721 Per – a semi-regular pulsating star. The remaining 15 stars are previously unknown variables. Only 5 variables – V1, V2, V3, V4, and V5 – are located within or near to the limiting radius of the cluster and their membership can be discussed considering their location in the cluster's CMD. The remaining stars are treated as variables of the Galactic background.

V1 was classified as a pulsating variable of δ Cephei type. The star is situated near to the isochrone (Fig. 1). Assuming it belongs to the cluster, its absolute magnitude is $M_{\rm V} = +1.8$ mag and dereddened $(B-V)_0 = 0.30$. That locates the star in δ Scuti or γ Doradus area in the Hertzsprung-Russell diagram. However, the relatively long period of variance and the large amplitude in V are in disagreement with characteristics of both types. Therefore the membership of V1 is unlikely and the star seems to be a background Cepheid. V2 is a faint eclipsing system of EA type. The collected data did not allow to determine the period of variability because only one incomplete eclipse was observed. Its location in the CMD clearly indicates that it is a Galactic background star. V3 is a faint variable revealing long-time changes in the light curve. It was not detected in exposures in B filter that indicates the star is very red with $(B-V)$ greater than 2.0 mag. Its location in the CMD clearly shows that the star is not a member of King 7. V4 was classified as a short-period EB system with unequal brightness in both maxima ($\Delta V_{\rm max} = 0.05$ mag). The system is situated far from cluster's isochrone and is located in the outskirts of the cluster. That makes its membership unlikely. V5 is another variable star belonging to cluster's halo and it is situated just beyond the limiting radius. It was classified as a pulsating star of RR Lyrae type. The location of the variable in the CMD makes its membership unlikely.

To summarize, none of 5 variables detected in the field of King 7 can be treated as a likely cluster's member. This observation can be justified considering a relatively small number of stars that constitute the cluster. We estimate that only 150 the brightest stars of the cluster were monitored in our survey.

The original photometric data are available in electronic form on survey's web site[1] and will be also available at WEBDA[2].

[1] http://www.astri.uni.torun.pl/~gm/OCS
[2] http://www.univie.ac.at/webda/

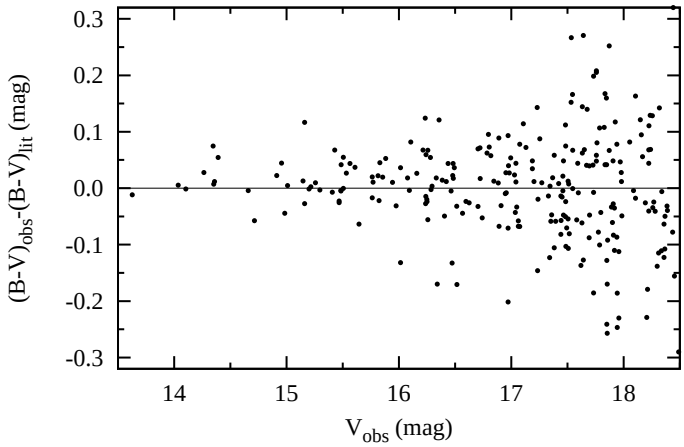

Figure 1. The comparison of the observed photometry with the literature one.

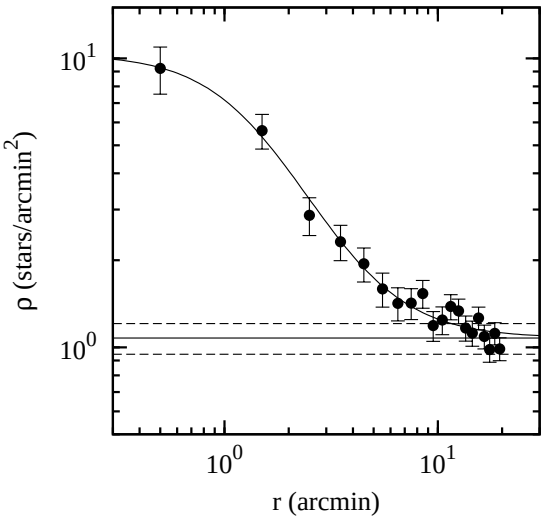

Figure 2. The radial density profile with the best-fit King's formula. The horizontal continuous line marks the background-star-density level and the dashed ones – 3-sigma error.

Table 1. The list of variable stars detected in the field of King 7. d denotes the distance from the cluster center, $V_{\max}$ – the maximal brightness in V band, ΔV – the amplitude of variation in V, $(B-V)$ – the color index at the maximum of brightness, P – the period of variation, T_0 – the epoch of minimum brightness for eclipsing systems or maximum for pulsating stars, types of variability: EA – a detached binary, EB – a semidetached binary, EW – a contact system, RR – a pulsating star of RR Lyrae type, DCEP – a pulsating star of δ Cephei type, MISC – a miscellaneous variable of unresolved type.

ID	Coordinates J2000.0	d (arcmin)	$V_{\max}$ (mag)	ΔV (mag)	$(B-V)$ (mag)	P (days)	T_0 HJD–2450000	Type
V1	035848+514259	5.8	16.54	0.35	1.37	4.3253	505.4001	DCEP
V2	035931+515446	7.7	17.39	0.58	1.26	–	–	EA
V3	035957+515700	11.8	17.46	0.32	>2	–	–	MISC
V4	035857+513540	12.3	15.76	0.14	1.02	0.28785	499.8975	EB
V5	040006+513902	12.5	17.52	0.47	1.10	0.57644	501.1083	RR:
V6	035939+513337	14.9	15.18	0.16	1.32	–	–	MISC
V7	035911+520433	16.8	11.49	0.08	1.88	–	–	MISC
V8	040041+515659	16.9	17.93	1.33	>2	–	–	MISC
V9	035700+514409	20.3	13.92	0.17	1.11	1.8667	503.1155	DCEP
V10	035652+514850	21.2	15.68	0.58	1.54	–	–	MISC
V11	035652+515156	21.5	12.63	0.18	0.84	3.9231	502.6295	EA
V12	035751+520550	21.6	16.20	1.18	2.26	–	–	MISC
V13	040039+512101	30.2	14.62	2.62	2.26	–	–	MISC
V14	040105+512140	31.8	16.05	0.14	1.18	0.36105	499.6698	EW
V15	035920+511424	33.4	14.91	0.80	0.93	0.57001	500.1683	EB
V16	040048+511144	39.3	16.53	0.26	1.18	0.28910	500.1716	EW

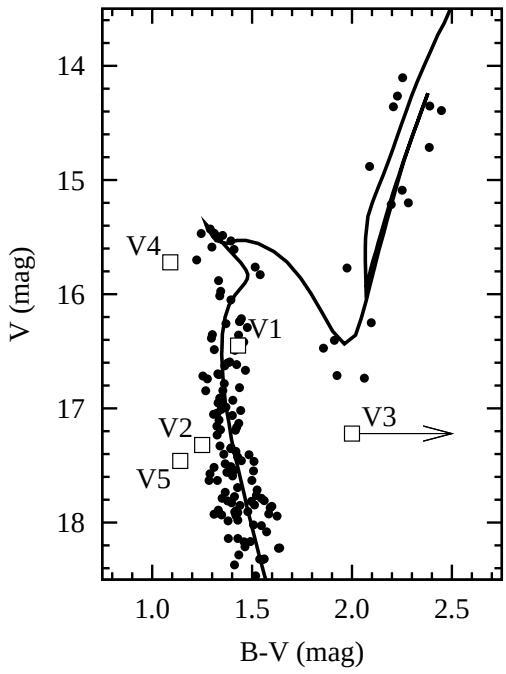

Figure 3. The colour-magnitude diagram for King 7 with best-fit isochrone of solar metallicity. The open symbols denote variables stars located within the cluster's limiting radius. See text for discussion.

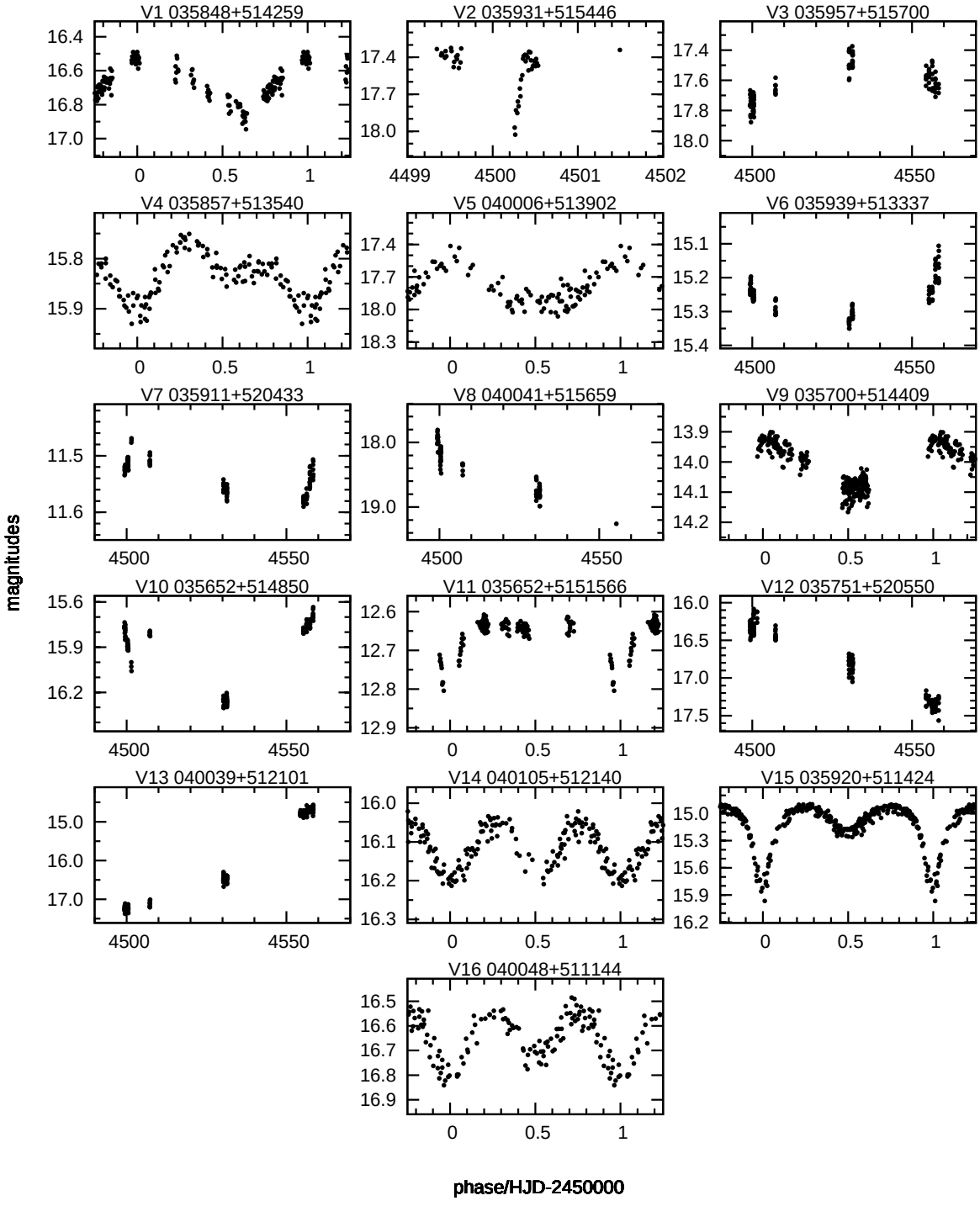

Figure 4. V-band light curves of variable stars discovered in the field of King 7.

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