ACTA ASTRONOMICA
Vol. **60** (2010) pp. 245–260

The Cluster AgeS Experiment (CASE). Variable Stars in the Globular Cluster M55

J. Kaluzny[1], I.B. Thompson[2], W. Krzeminski[3], K. Zloczewski[1]

[1] Nicolaus Copernicus Astronomical Center, ul. Bartycka 18, 00-716 Warsaw, Poland
e-mail: jka@camk.edu.pl, kzlocz@camk.edu.pl
[2] Carnegie Institution of Washington, 813 Santa Barbara Street, Pasadena, CA 91101, USA
e-mail: ian@obs.carnegiescience.edu
[3] Las Campanas Observatory, Casilla 601, La Serena, Chile
e-mail: wojtek@lcoeps1.lco.cl

Received July 12, 2010

ABSTRACT

We report time-series photometry for 55 variable stars located in the central part of the globular cluster M55. The sample includes 28 newly identified objects of which 13 are eclipsing binaries. Three of these are detached systems located in the turn-off region on the cluster color–magnitude diagram. Two of them are proper motion (PM) members of M55 and are excellent candidates for a detailed follow-up study aimed at a determination of the cluster age and distance. Other detached binaries are located along the unevolved part of the cluster main sequence. Most of the variable stars are cluster blue straggler stars. This group includes 35 SX Phe stars, two contact binaries, and one semi-detached binary. V60 is a low mass, short period Algol with the less massive and cooler component filling its Roche lobe. The more massive component is an SX Phe variable star. The orbital period of V60 increases at a rate of $\mathrm{d}P/P = 3.0\times10^{-9}$. In addition to numerous variable blue stragglers we also report the detection of two red stragglers showing periodic variability. Both of these are PM members of M55. We note and discuss the observed paucity of contact binaries among unevolved main sequence stars in M55 and NGC 6752. This apparent paucity supports an evolution model in which the formation of contact binaries is triggered by stellar evolution at the main-sequence turn off.

Key words: *Stars: dwarf novae – globular clusters: individual: M55 – binaries: eclipsing – blue stragglers*

1. Introduction

M55 = NGC 6809 is a nearby globular cluster whose low reddening and relatively high Galactic latitude ($(m-M)_V = 13.87$ mag, $E(B-V) = 0.08$ mag, $b = -23\overset{\circ}{.}3$; Harris 1996) makes it an attractive target for detailed studies. The photometric survey presented here was conducted as a part of the CASE project

(Kaluzny *et al.* 2005) conducted with telescopes at the Las Campanas Observatory. Some results of an earlier photometric study of M55 made with the 1.0-m Swope telescope were presented by Pych *et al.* (2001) and Olech *et al.* (1999). In these papers we reported the identification of several SX Phe stars and the first ever detection of non-radial oscillations in RR Lyr variable stars. An unreported result from that survey was the detection of a few detached eclipsing binaries. We have used the 2.5-m du Pont telescope for a follow-up photometric study of these binaries. In addition, we used the du Pont observations to search for variable stars in the innermost region of the cluster. The central region of the cluster was poorly resolved on images collected with the Swope telescope. In this paper we present light curves and a preliminary analysis of variable stars detected on images collected over several observing seasons with the du Pont telescope.

2. Observations and Data Analysis

All images were taken with the 2.5-m du Pont telescope. A field of 8.84×8.84 arcmin was observed with the TEK5 CCD camera at a scale of 0.259 arcsec/pixel. Two pointings were used. On most nights the cluster core was positioned $1\overset{\prime}{.}5$ South and $1\overset{\prime}{.}4$ East of the detector center. Below we call this pointing field A. On some nights the cluster core was positioned at the center of the detector. We call this pointing field B. Note that there was a substantial overlap between the two fields and so most stars were monitored on all observing nights.

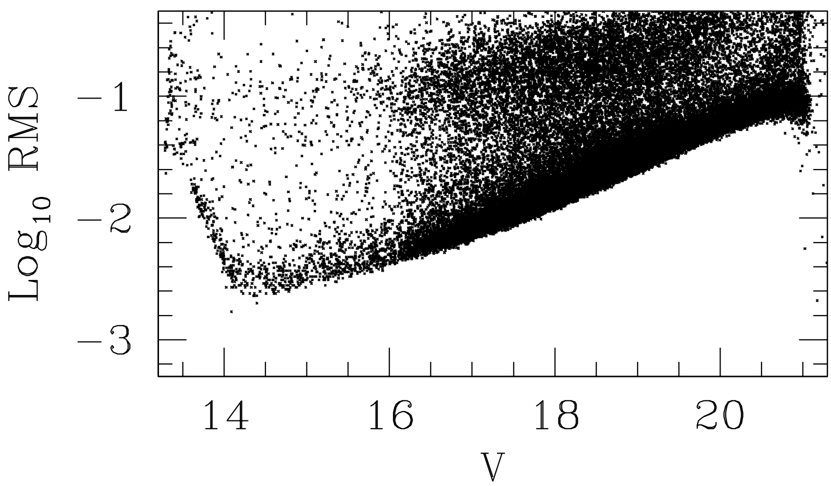

Fig. 1. Standard deviation *vs.* average *V* magnitude for light curves of stars from M55 field.

Observations were made on a total of 66 nights between 31 May 1997 and 28 June 2009. Images were taken in two bands with average exposure times of 70 s and 120 s for the *V* and *B* filters, respectively. The readout time of the detector was 68 s. In total, 3388 useful frames in *V* and 712 frames in *B* were collected.

The median seeing was 1.″09 and 1.″15 for the *V*- and *B*-bands, respectively. The stellar photometry was extracted with a modified version of the image subtraction package ISIS V2.1 (Allard and Lupton 1998, Allard 2000). DAOPHOT, ALLSTAR and DAOGROW codes (Stetson 1987, 1990) were used to extract lists of point sources and to derive aperture corrections for the reference images. For each of the two pointings the observed field was divided into a 4×4 mosaic to reduce effects caused by a spatially variable point spread function. Light curves were extracted for 47 138 point like sources detected on the *V* reference image. The instrumental photometry was tied to the standard *BV* system using linear transformations based on 328 local standard stars from Stetson (2000).

Fig. 1 shows the *rms* of individual measurements *vs.* average magnitude for *V*-band light curves. Stars with $V<14.0$ mag are overexposed on template images. The photometry has an accuracy of about 3 mmag for the brightest unsaturated stars, decreasing to 14 mmag at $V=18.0$ mag.

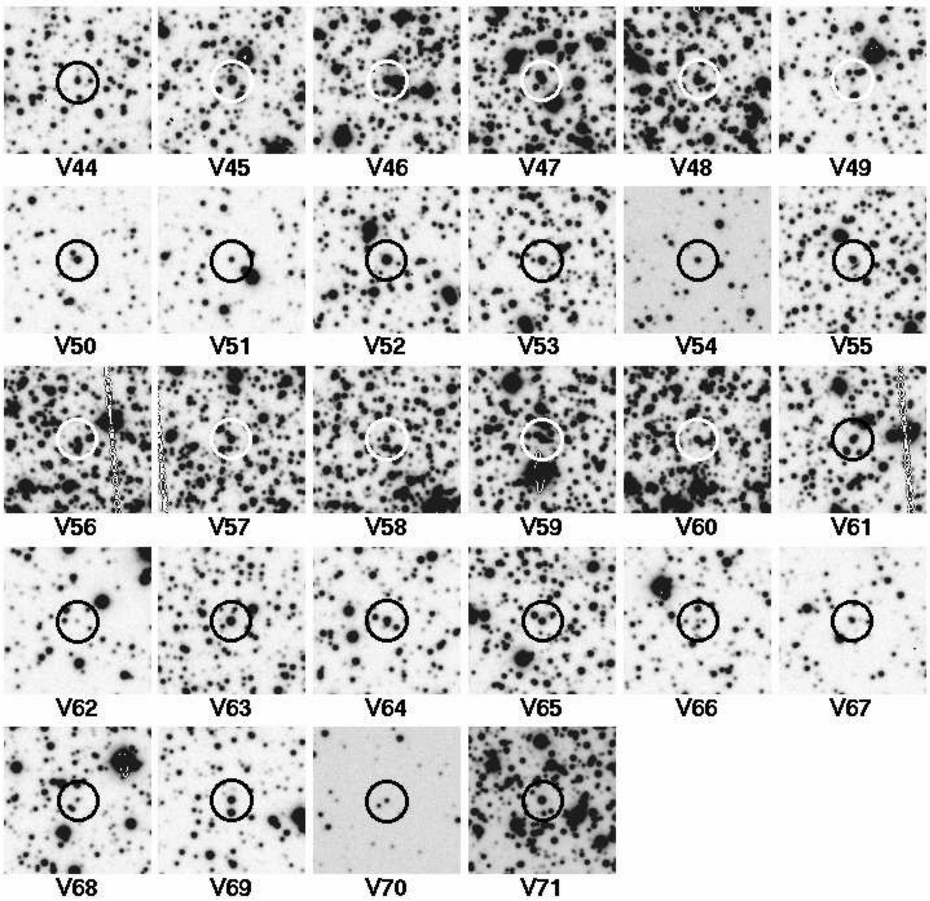

Fig. 2. Finding charts for variable stars V44–70. Each chart is 30″ on a side: North is up and East to the left.

The light curves were checked for variability with AoV and AOVTRANS algorithms running in the TATRY program (Schwarzenberg-Czerny 1996, Schwarzenberg-Czerny and Beaulieu 2006).

T a b l e 1

Equatorial coordinates for M55 variable stars

ID	RA(J2000) [°]	Dec(J2000) [°]	ID	RA(J2000) [°]	Dec(J2000) [°]
16	295.03833	−30.94527	45	295.03677	−30.95457
17	295.04724	−30.99056	46	295.02548	−30.97280
18	295.02864	−30.94251	47	295.01940	−30.96607
19	294.99030	−30.95061	48	295.01224	−30.95817
20	294.97897	−30.97283	49	295.05049	−30.97099
21	294.99278	−30.98528	50	295.05603	−30.99595
22	295.03250	−31.00376	51	295.04699	−30.91533
23	294.96592	−30.93159	52	295.02693	−30.99111
24	294.93953	−30.93433	53	295.02178	−30.98953
25	294.96479	−30.93950	54	294.90595	−30.95111
26	294.94607	−30.95970	55	295.03304	−30.94736
27	294.97521	−30.96900	56	295.00456	−30.95584
29	294.92741	−30.93312	57	294.99827	−30.94833
31	295.00412	−30.96597	58	294.99567	−30.95132
32	294.99224	−30.97601	59	295.01676	−30.97048
33	294.97731	−30.99967	60	294.99046	−30.96288
34	295.00425	−31.01080	61	295.00281	−30.99124
35	294.95985	−30.92036	62	294.95751	−30.90109
36	294.95234	−30.94610	63	294.95539	−30.94218
37	294.95777	−30.96207	64	294.94666	−30.95341
38	294.99525	−30.97104	65	294.96326	−30.98365
39	295.04998	−31.03483	66	294.94217	−30.99322
40	295.00790	−30.92753	67	294.93898	−31.00914
41	295.01230	−30.97480	68	295.00426	−31.01171
42	294.99423	−30.95691	69	294.97403	−31.01317
43	295.03599	−30.98135	70	294.88948	−30.90194
44	295.04360	−30.96861	71	295.01376	−30.98486

A total of 54 variable stars located below the horizontal branch on the cluster's color–magnitude diagram (CMD) were identified in our data[1]. Their equatorial coordinates are listed in Table 1. Astrometric solutions were obtained for fields A and B using the positions of 662 and 761 stars from the UCAC3 catalog (Zacharias *et al.* 2010), respectively. Variable stars V16–V43 were reported by Pych *et al.* (2001) and Kaluzny *et al.* (2005). The remaining 27 objects are new identifications[2]. Finding charts for these new variable stars are presented in Fig. 2.

[1]Several brighter RR Lyr stars were also detected but the *V*-band photometry was affected by saturation in some frames.

[2]Light curves of the variable stars discussed in this paper are available from the CASE archive at *http://case.camk.edu.pl*

3. SX Phe stars

The sample of variable stars includes 35 SX Phe stars. Table 2 provides some basic photometric parameters of these stars. Average magnitudes are given in columns 3 and 5 while light curves amplitudes are given in columns 4 and 6. For multi-mode pulsators the listed periods correspond to the largest amplitude mode.

Table 2

Periods, average magnitudes and amplitudes of SX Phe stars in M55

ID	P [d]	$\langle V\rangle$	A_V	$\langle B\rangle$	A_B	Mode^a
16	0.05341898(1)	16.974	0.006	17.331	0.008	s
17	0.04126184(1)	17.191	0.018	17.523	0.023	s
18	0.04655539(1)	16.999	0.011	17.317	0.013	s
19	0.03823603(2)	17.326	0.012	17.635	0.016	s
20	0.03321202(5)	17.018	0.033	17.360	0.047	m
21	0.13559137(1)	15.775	0.010	16.200	0.013	m^b
22	0.04563898(1)	16.806	0.123	17.102	0.151	s
23	0.04140053(1)	17.231	0.018	17.551	0.022	s
24	0.04181954(4)	17.062	0.002	17.380	0.003	m
25	0.09853144(1)	15.882	0.285	16.210	0.364	s
26	0.0820104(2)	16.110	0.047	16.495	0.063	s
27	0.0410321(1)	17.131	0.010	17.471	0.012	m
29	0.0343117(2)	20.681	0.090	20.842	0.104	m
31	0.03884781(5)	17.278	0.016	17.628	0.025	m
32	0.0414872(1)	16.953	0.037	17.275	0.046	m
33	0.0573482(6)	16.400	0.055	16.725	0.041	m
34	0.03701723(6)	17.238	0.011	17.542	0.015	m
35	0.0486828(2)	16.586	0.015	16.894	0.022	m
36	0.03939643(2)	16.741	0.024	17.036	0.031	m
37	0.04379779(6)	16.949	0.017	17.239	0.023	m
38	0.03817392(7)	16.709	0.018	17.108	0.027	m
39	0.0358108(1)	17.209	0.012	17.495	0.013	m
40	0.03697678(3)	17.217	0.010	17.534	0.013	m
41	0.09033409(1)	16.536	0.040	16.826	0.049	m
42	0.0366654(2)	17.180	0.018	17.423	0.025	m
45	0.03083606(5)	16.330	0.004	16.572	0.004	m
47	0.0249482(3)	16.786	0.003	17.053	0.003	m
48	0.0330509(3)	16.113	0.024	16.378	0.025	m
52	0.0276799(3)	16.153	0.003	16.359	0.003	m
55	0.0323921(1)	17.228	0.002	17.615	0.003	m
57	0.02185877(8)	16.644	0.003	16.894	0.003	m
59	0.02624428(7)	16.650	0.007	16.897	0.012	m
61	0.03490324(9)	17.305	0.008	17.620	0.012	m
63	0.05308522(9)	16.399	0.002	16.707	0.003	m
69	0.0450622(2)	17.027	0.007	17.350	0.011	m

Note: ^{a} single (s) or multi mode (m) pulsator , ^{b} period for seasons 2001–2008, for seasons 1999–2001 $P = 0.13552290(2)$.

As can be seen in Fig. 3, SX Phe variable stars constitute most of the cluster blue stragglers brighter than $V \approx 17.5$ mag. Few constant stars are located in this part of the cluster CMD. This point will be discussed further in a forthcoming proper-motion study of the cluster (Zloczewski *et al.*, in preparation). The luminosities of SX Phe stars belonging to M55 span a range of $\Delta V \approx 1.5$ mag implying a substantial range of stellar mass. The pulsational characteristics of these stars are worth detailed modeling given that they share the same metallicity and distance; this in turn puts strong constraints on models.

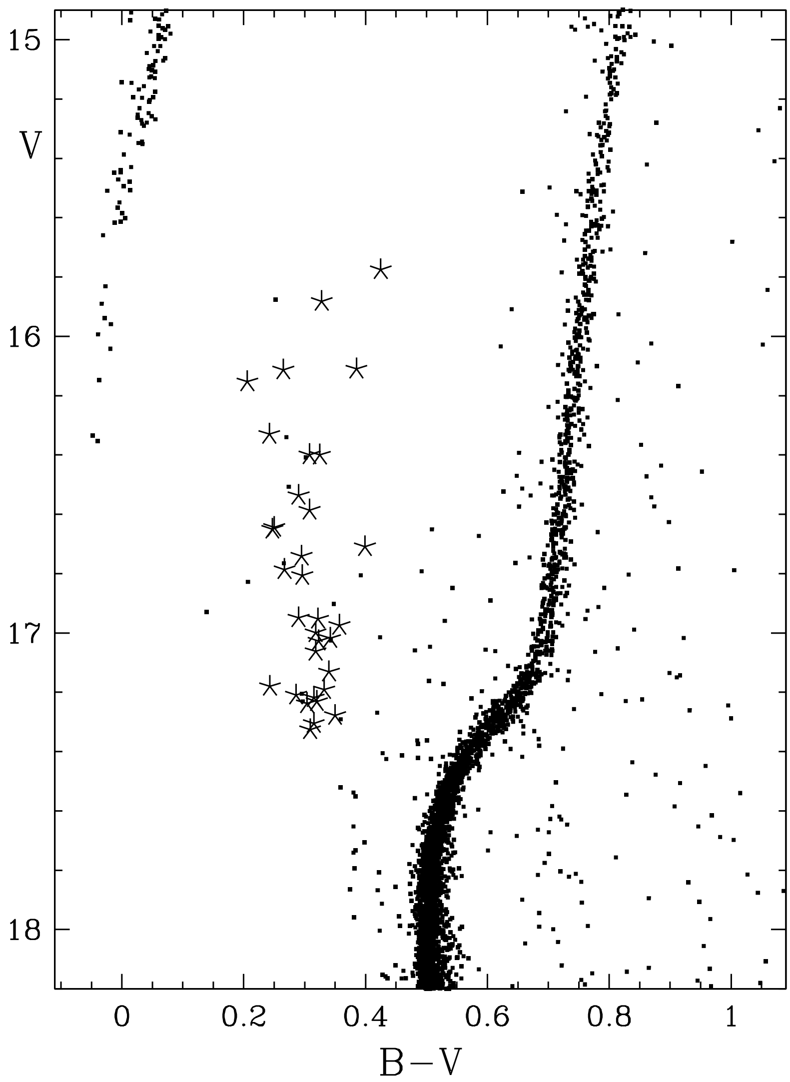

Fig. 3. Color–magnitude diagram for M55, with positions of SX Phe variable stars marked with asterisks.

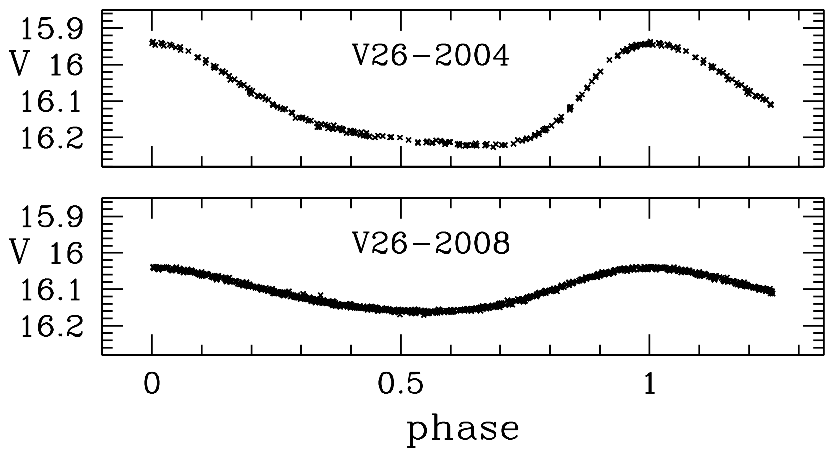

Fig. 4. Phased light curves of SX Phe variable V26 for observing seasons 2004 and 2008.

The sample includes 8 single mode pulsators. All but one of these showed coherent oscillations with constant amplitude over 12 years of observations. The exception is V26 which showed changes of the period as well as the amplitude. Light curves of V26 for seasons 1997–2001, 2003–2006 and 2007–2009 can be phased with periods of 0.082011545(4), 0.082008684(24) and 0.082011912(13) days, respectively. For the *V*-band the amplitude of the variability ranged from 0.098 in the 2004 season to 0.041 in the 2008 season. This is shown in Fig. 4. We checked that the observed changes of the period and amplitude are not due to oscillations in two very closely separated modes. An explanation of the unusual behavior of V26 is left to experts in the field of stellar pulsations. We note that also some of multi-periodic variable stars also showed noticeable instabilities of their periods and amplitudes over the 12 year interval.

4. Eclipsing Binaries and Unclassified Variable Stars

In Table 3 we list the basic properties of variable stars other than the SX Phe stars discussed above. Ephemerides are given in columns 2 and 3, followed by *V* and *B* magnitudes at maximum light, the amplitude of the variability for the *V* filter, the average $B-V$ color and the assigned variability type. The last column lists the membership status based on proper motion measurements (Zloczewski *et al.*, in preparation). Fig. 5 shows the location of the variable stars on the cluster CMD.

The sample includes eight eclipsing binaries with periods ranging from 0.54 days to 17.2 days. Phased light curves of these stars are shown in Fig. 6. All but one of these are detached systems. The exception is the semi-detached blue straggler V60, further discussion of this system is given in Section 4.1. The detached binaries V44, V54 and V58 are located near the turnoff region of the cluster. V44 and V54 are PM members of M55 while PM status of V58 remains undetermined.

Table 3

Basic data for eclipsing binaries and unclassified variable stars in M55

ID	P [d]	T_0 [HJD-2450000]	$V_{\rm max}$	$B_{\rm max}$	ΔV	$\langle B-V \rangle$	Type	M
43	–	–	19.1	19.45	–	0.68	CV[a]	Y
44	2.166123(5)	2076.8618	17.843	18.360	0.25	0.538	EA[b]	Y
46	0.31941843(1)	599.3135	16.462	16.725	0.35	0.260	EW[c]	–
49	1.95902(4)	599.5426	19.15	20.24	0.47	1.06	EA	N
50	–	–	17.08	17.98	0.30	0.90	?	N
51	0.4522456(4)	599.0813	18.445	18.71	0.07	0.269	EW	N
53	0.32524682(1)	599.2113	16.545	16.796	0.05	3 0.251	EW	Y
54	9.26917(1)	2869.7370	18.300	18.857	0.36	0.56	EA	Y
56	0.29186192(1)	599.1822	17.74	18.28	0.36	0.51	EW	–
58	8.6205:	2769.8231	18.01	18.56	0.20	0.55:	EA	–
60	1.1830214(7)	599.1814	16.83	17.24	1.78	0.41	EA	Y
62	1.2358474(5)	599.2222	20.26	21.08	0.49	0.82	EA	Y
64	12.945:	1339.5:	17.02	17.77	0.18	0.77	?	Y
65	5.587538:	3887.7:	17.22	18.10	0.19	0.88	?	Y
66	0.5496634(7)	599.4780	20.22	21.12	0.41	0.92	EA	–
67	0.121062:	3861.9:	18.31	18.84	0.12	0.53	?	Y
68	0.53857748(3)	599.2259	20:65:	20.92:	0.52:	0.24:	EA	–
70	0.22287334(4)	599.1016	19.40	20.12	0.72	0.76	EW	–
71	8.0399:	601.5:	16.87	17.57	0.69	0.13	?	Y

Note: [a] cataclysmic variable (Kaluzny *et al.* 2005), [b] detached or semi-detached binary, [c] contact binary.

These systems deserve a detailed study aimed at a determination of the absolute parameters of their components. This in turn can provide information about the age and distance of M55 (Paczyński 1997). Binaries V62 and V66 are located slightly above the lower main sequence of the cluster. The former is a PM member of M55 while there is no PM information for V66. According to its PM V49 is a field object. Its location on the cluster CMD indicates that it is a foreground binary. Its light curve shows large season-to-season changes which is not unusual given the late spectral type inferred from the observed color. We do not have PM information for V68 but its location on the CMD indicates that it is a field object located behind the cluster. Its color and magnitude are appropriate for an early F-type binary belonging to the Sagittarius dwarf. We note that Pych *et al.* (2001) detected 3 SX Phe stars in the M55 field which belong to the Sagittarius galaxy. These variable stars are located in the same part of the cluster CMD as V68 and are also expected to be stars of spectral type F.

Five objects were classified as contact binaries. Their phased light curves are shown in Fig. 7.

No PM information is available for V56 and V70. Examination of their light curves leads to the conclusion that the individual components of V56 and V70 are located on the cluster main sequence. Therefore, both systems are likely members

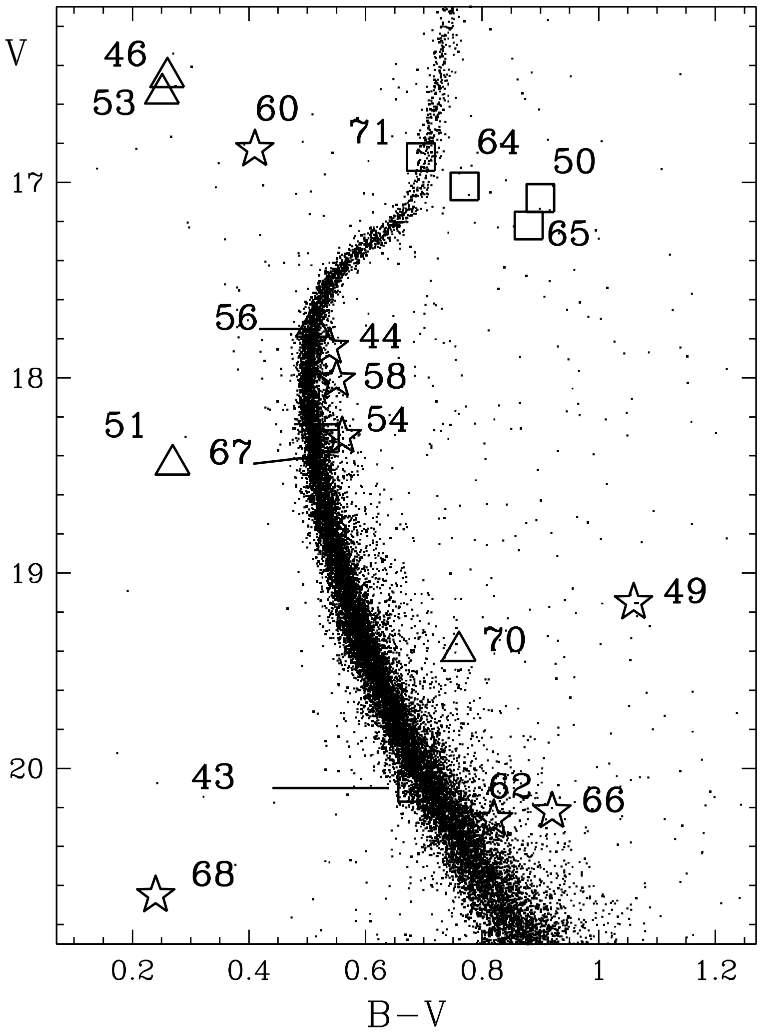

Fig. 5. Color–magnitude diagram for M55 with positions of variable stars marked. Stars – detached or semi-detached binaries; triangles – contact binaries; squares unclassified variable stars and dwarf nova V43 = CV1.

of M55. The large amplitude of the light curve of V70 indicates that it has a mass ratio close to unity.

The blue straggler V53 is a PM member of M55 while there is no PM information for the blue straggler V46. We note that light curves of both binaries show asymmetric maxima. These asymmetries were observed in all 9 observing seasons and so it is unlikely that they are caused by stellar spots. The asymmetries are more likely related to some phenomena resulting from mass transfer in V46 and V53.

The variable V51 has a small but measurable proper motion: $\mu_\alpha = 0.512 \pm 0.295$, $\mu_\delta = 4.441 \pm 0.163$. It is definitely a field object not related to the cluster.

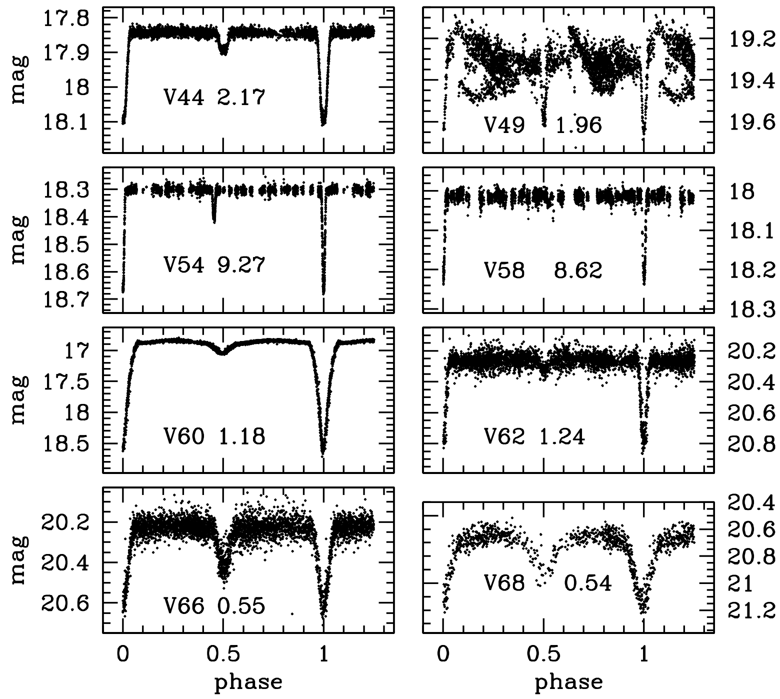

Fig. 6. Phased *V* light curves of variable stars classified as detached or semi-detached binaries. Inserted labels give names of variable stars followed by their period in days.

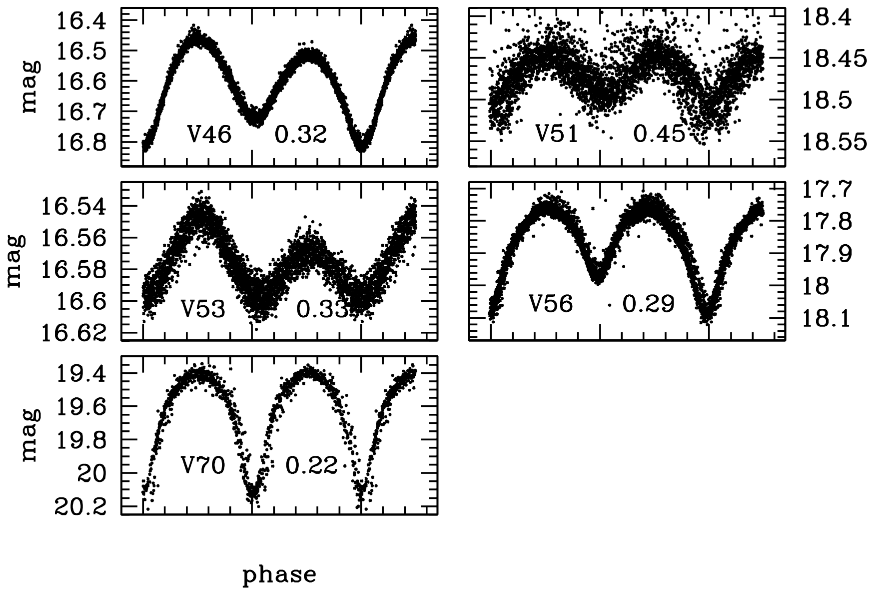

Fig. 7. Phased *V* light curves of five variable stars classified as contact binaries. Inserted labels give names of variable stars followed by their period in days.

Its light curve resembles light curves of low amplitude contact binaries. However, on the color–period diagram (Rucinski 2002) the variable is located outside of the region occupied by contact binaries. With $(B-V)_0 = 0.15$ mag and $P = 0.45$ d the star is too blue to be an ordinary contact binary[3]. Given its location on the CMD and the shape of the light curve V51 is possibly a very distant, close but non-contact binary with low orbital inclination. Alternatively it might be a binary sdB system showing orbital modulation of its light.

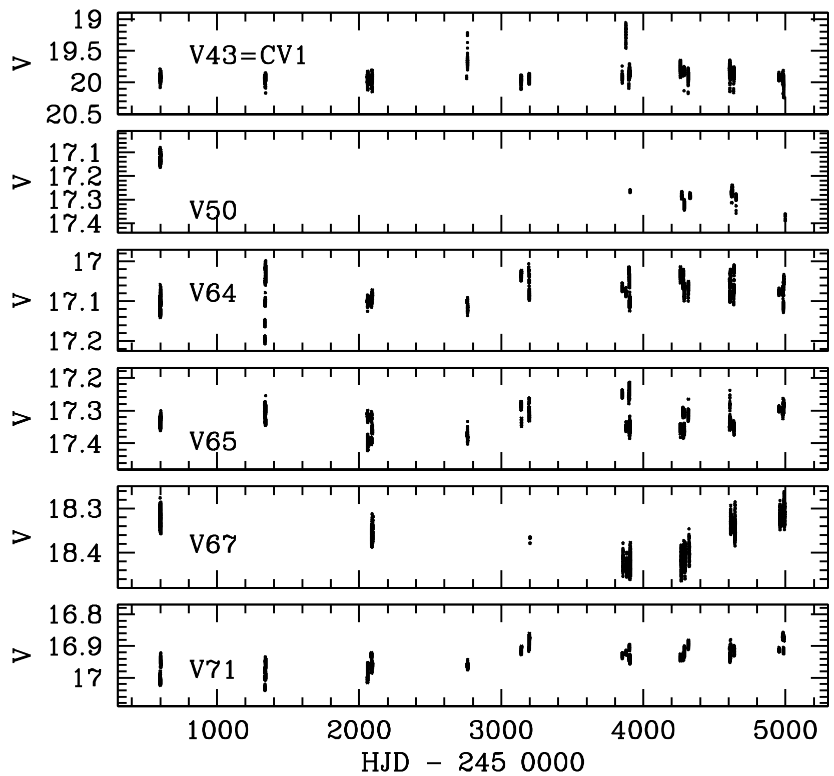

Fig. 8. Light curves of variable stars V43, V50, V64, V65 and V66.

The variable stars V64 and V65 lie slightly to the red of the subgiant branch on the cluster CMD. Both stars are PM members of M55. As can be seen in Fig. 8 they show systematic season-to-season changes of their average luminosities. At the same time their light curves show coherent periodic variability with changing amplitudes, as demonstrated in Fig. 9. This coherence of the observed periodic variations suggests that V64 and V65 are binary systems. Bassa *et al.* (2008) identified V65 as the likely optical counterpart to the X-ray source CX7. They also note that it is a candidate active magnetic binary. Time domain and phased light curves of V67 are presented in Figs. 8 and 9. The object is located right on the

[3]Throughout this paper we use $E(B-V) = 0.115$ mag following Dotter *et al.* (2010).

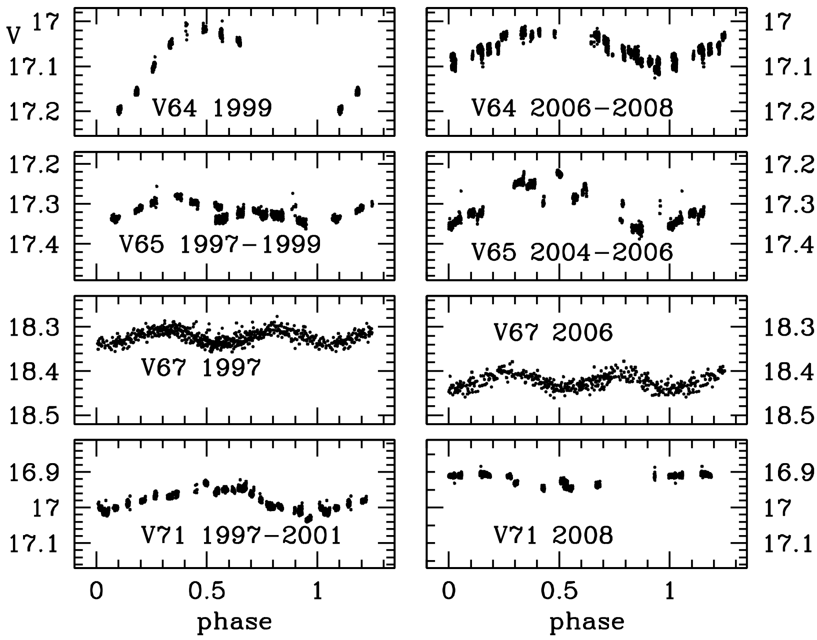

Fig. 9. Phased *V* light curves of periodic variable stars V64, V65 and V67. Inserted labels give names of variable stars and respective observing season(s).

main sequence of M55 and it is PM member of the cluster. The amplitude of the periodic light variations is small. The star is probably either a contact binary observed at low inclination or an ellipsoidal variable. In the later case the short orbital period suggests that one of the components is a degenerate star. Variable V71 is a likely optical counterpart to the X-ray source CX8 (Bassa *et al.* 2008). The star is located at the base of the subgiant branch on the cluster CMD and it is PM member of M55. As is shown in Fig. 8 the average luminosity of V71 changes on a yearly time scale. Periodic modulation of the light curve with $P \approx 8.04$ d was observed in some seasons, as is demonstrated in Fig. 9. Spectroscopic observations can help to answer questions about the nature of the four objects discussed briefly in this paragraph.

As can be seen in Fig. 8 the cataclysmic variable V43 = CV1 showed two outbursts during our observations. In quiescence the variable is relatively red and occupies a position close to the main-sequence on the cluster CMD. No periodic variability could be detected in quiescence.

The variable V50 is a field star based on PM measurements. Its light curve does not show any periodicity. However, as can be seen in Fig. 8, the average luminosity of V50 showed noticeable changes on a time scale of 10 years. The star is a likely optical counterpart to the X-ray source CX29 (Bassa *et al.* 2008).

4.1. The Blue Straggler V60

The blue straggler V60 is a PM member of M55. Fig. 10 shows phased *B* and *V* light curves for the observing seasons 2006–2009. The depth of the primary eclipse increases from about 1.78 mag in the *V*-band to about 2.17 mag in the *B*-band indicating a large difference of the effective temperatures of the components of V60. The orbital period of the system is unstable. The $O-C$ diagram presented in Fig. 11 includes moments of primary eclipses based on the du Pont observations as well as some measurements based on unpublished CASE observations collected with the Swope telescope. The relevant data are listed in Table 4.

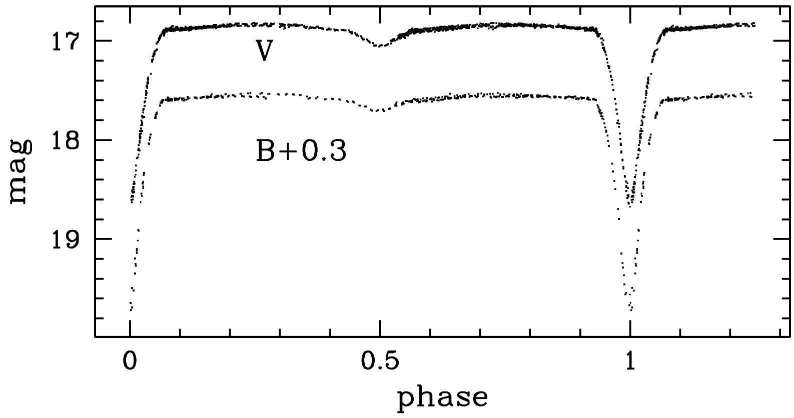

Fig. 10. Phased light curves of an eclipsing blue straggler V60. Note shift applied to *B* curve.

Table 4

Times of primary minima of V60. The $O-C$ residuals are calculated with ephemeris from Table 3.

E	HJD-245 0000	sigma	$O-C$
−3415	615.72698	0.00016	0.00405
−3092	997.84749	0.00004	0.00081
−2797	1346.84636	0.00019	−0.00551
−2180	2076.77070	0.00100	−0.00305
−1853	2463.62201	0.00016	−0.00499
−1514	2864.66824	0.00024	−0.00554
−1267	3156.87576	0.00023	−0.00573
−1225	3206.56427	0.00008	−0.00717
−1197	3239.68670	0.00100	−0.00488
−655	3880.88230	0.00020	−0.00060
−323	4273.64582	0.00024	0.00038
−264	4343.44210	0.00100	0.00261
0	4655.75744	0.00009	0.00603
37	4699.52850	0.00100	0.00691
293	5002.38290	0.00022	0.00707

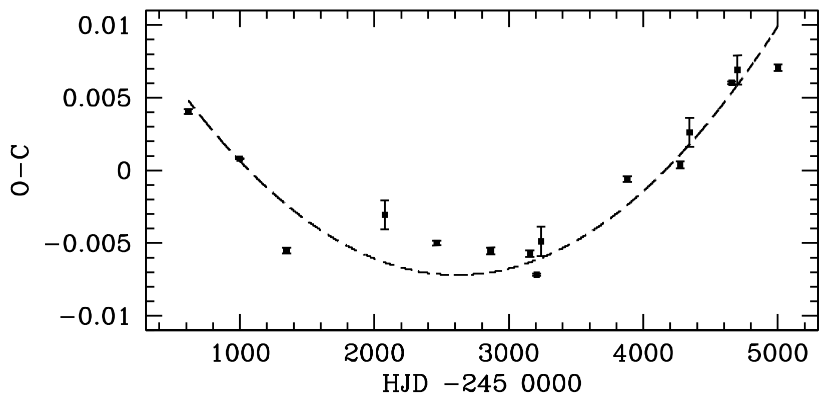

Fig. 11. The $O-C$ diagram of V60 constructed with the linear ephemeris listed in Table 3. Dashed line shows formal parabolic fit to the data.

The $O-C$ diagram indicates that orbital period of the variable increases at the rate of $\mathrm{d}P/\mathrm{d}t \approx 3.0 \times 10^{-9}$. This can be interpreted as the result of conservative mass transfer in the system and is consistent with a semi-detached configuration reported below. An accurate determination of the parameters of the binary is hampered by the lack of spectroscopic information about the mass ratio. Nonetheless, we obtained a preliminary solution of the light curves shown in Fig. 10 using the Wilson-Devinney code (Wilson and Devinney 1971) working under control of the Phoebe utility (Prŝa and Zwitter 2005). We used portions of the data from observing seasons 2006–2009. Light curves were phased separately for each of these seasons using the values of T_0 listed in Table 4. The mass ratio $q = m_s/m_p$ was treated as an adjustable parameter. Several trials were made starting with different values of q assuming a detached configuration. The solution indicates a semi-detached configuration with a mass ratio $q = 0.20$, inclination $i = 87\overset{\circ}{.}1$ and $R_p/R_s = 0.81$. Thus the binary is a classical Algol with the less massive and cooler component filling its Roche lobe. The luminosity ratio at quadratures is $(L_p/L_s)_V = 3.46$ and $(L_p/L_s)_B = 5.95$. The resulting apparent (reddened) colors of the components are $(B-V)_p = 0.31$ mag and $(B-V)_s = 0.90$ mag. With $V_p = 17.11$ mag the primary of V60 is located among the SX Phe pulsating blue stragglers on the M55 CMD (see Fig. 3). Low amplitude pulsations with a period of about 0.03 d are in fact easily seen in the light curve of the binary. To check if these oscillations are coherent we used the following procedure. A second order polynomial was fitted to the out-of-eclipse sections of the nightly V light curves from the 1999 observing season. The residual light curves were then merged and searched for periodicity with TATRY. A strong signal was detected at a period of 0.03087(7). The residual light curve phased with such a period is shown in Fig. 12.

The light curve of V60 is symmetric and shows only minor season-to-season changes. The system is apparently free from significant photometric disturbances caused by mass transfer or chromospheric activity. Therefore, a reliable and accu-

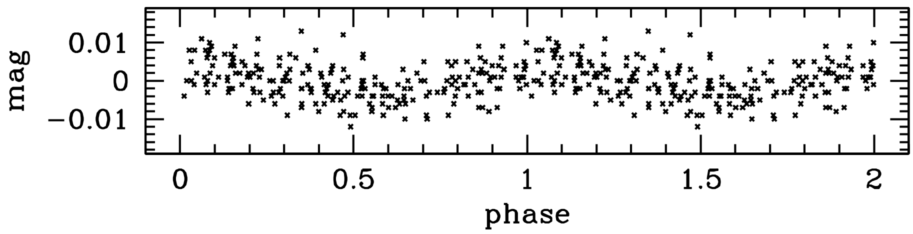

Fig. 12. Residual light curve of V60 phased with a period of 0.03087 d. See text for details.

rate determination of its geometrical parameters should be possible once the mass ratio is constrained by spectroscopy. The binary is worth a more detailed follow-up study including a determination of its absolute parameters. The primary component of V60 is a Population II star with $[\mathrm{Fe/H}] = -1.9$ and a mass noticeably exceeding masses of turnoff stars in globular clusters. As such it may provide an interesting benchmark for models of low metallicity stars.

5. Summary and Discussion

According to a proper motion study conducted by Zloczewski *et al.* (2010, in preparation) most of the variable stars reported in this paper are members of M55. As we have already noted several of them deserve a spectroscopic study. In the case of eclipsing binaries such a study should lead to a determination of their absolute parameters and distances. At this time the absolute parameters are known for very few Population II stars. Six stars of different masses constituting three detached binaries from the cluster turnoff should lay on the same isochrone. Hence, knowing their absolute parameters one may conduct an interesting test of stellar models at low metallicity. Spectroscopic observations of several other variable stars would also be valuable, confirming with high confidence the membership status of objects that are candidate PM members of the cluster. The systemic velocity of M55 is $V_r = 174.8$ km/s.

We note the apparent paucity of contact binaries among stars on the cluster main-sequence. Two systems were detected among the blue stragglers and one at the turnoff at $V = 17.7$ mag. Two of these three are PM members of M55 and the PM status for third one is unknown. In contrast just one contact binary was found below the turnoff. This is variable V70 with $V = 19.4$ mag and an unknown membership status. The sample of surveyed stars is strongly dominated by lower main sequence stars. We have examined the variability status of 13 775 stars with $V < 18.0$ mag and 25 530 stars with $18.0 \text{ mag} < V < 19.5$ mag, where $V \approx 18.0$ mag corresponds to the turnoff level. As can be seen in Fig. 1 the accuracy of our differential photometry is such that it would be easy to detect any potential contact binaries with $V < 19.5$ mag and $\Delta V > 0.1$ mag. A similar lack of contact binaries among main-sequence stars is also observed in NGC 6752. Our recent survey of this nearby globular cluster revealed two contact systems among the blue stragglers and none among main-sequence stars (Kaluzny and Thompson 2009). Our results indicate that the formation of W UMa stars is driven mainly by nuclear evolution of stars. Once the more massive component of a close but initially detached binary reaches the turnoff its expansion causes Roche lobe overflow and eventually leads to a contact configuration of the system. After mass reversal the binary may end up as a blue straggler with a configuration that depends on the efficiency of mass and angular momentum loos. The observed lack of contact binaries among unevolved main sequence stars in GCs supports the evolution model advocated by Gazeas and Stępień (2008).

Acknowledgements. Research of JK and KZ is supported by the grant MISTRZ from the Foundation for the Polish Science and by the grant N N203 379936 from the Ministry of Science and Higher Education. I.B.T. acknowledges the support of NSF grant AST-0507325. We thank Paweł Moskalik for help with time series analysis of variable V26.

REFERENCES

Alard, C., and Lupton, R.H. 1998, *ApJ*, **503**, 325.
Alard, C. 2000, *A&A*, **144**, 363.
Bassa, C.G., Pooley, D., Verbunt, F., Homer, L., Andersom, S.F., and Lewin, W.H.G. 2008, *A&A*, **488**, 921.
Dotter, A., *et al.* 2010, *ApJ*, **708**, 698.
Gazeas, K., and Stępień, K. 2008, *MNRAS*, **390**, 1577.
Harris, W.E. 1996, *AJ*, **112**, 1487.
Kaluzny, J. *et al.* 2005, in: *AIP Conf. Proc.*, Vol. **752**, "Stellar Astrophysiscs with the World's Largest Telescopes", Ed. J. Mikolajewska and A. Olech A., *AIP Conf. Proc.*, p. 70.
Olech, A., Kaluzny, J., Thompson, I.B., Pych, W., Krzeminski, W., and Schwarzenberg-Czerny, A. 1999, *AJ*, **118**, 442.
Paczyński, B. 1997, in: *Space Telescope Science Institute Series*, "The Extragalactic Distance Scale", Ed. M. Livio (Cambridge University Press), p. 273.
Prŝa, A., and Zwitter, T. 2005, *ApJ*, **628**, 426.
Pych, W., Kaluzny, J., Krzeminski, W., Schwarzenberg-Czerny, A., and Thompson, I.B. 2001, *A&A*, **367**, 148.
Rucinski, S.M. 2002, *PASP*, **114**, 1124.
Schwarzenberg-Czerny, A. 1996, *ApJ*, **460**, L107.
Schwarzenberg-Czerny, A., and Beaulieu, J.-P. 2006, *MNRAS*, **365**, 165.
Stetson, P.B. 1987, *PASP*, **99**, 191.
Stetson, P.B. 1990, *PASP*, **102**, 932.
Stetson, P.B. 2000, *PASP*, **112**, 925.
Wilson, R. E., and Devinney, E.J. 1971, *ApJ*, **166**, 605.
Zacharias, H.I. *et al.* 2010, *AJ*, **139**, 2184.