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Variable stars in the globular cluster NGC 6362

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ABSTRACT

We report the results of a CCD search for short-period variables in the field of a southern globular cluster NGC 6362. We identified 19 new candidate variables, five of which are cluster RR Lyraes, four are probable SX Phe-type stars and eight are eclipsing binaries. Of the discovered binaries, three are EA-type systems, two of which are located on the cluster CMD in the turn-off region and the third 1 mag above the turn-off point, in the yellow straggler region. Five other systems are of W UMa type, three of which are foreground objects and two are likely cluster members. The remaining two candidates exhibit a modulation of the brightness level with an amplitude of 0.1–0.2 mag; further observations are needed to reveal the nature of their variability. Phased *VI* light curves for 20 variables (18 RR Lyrae stars and two blue stragglers) located in the central region of the cluster are presented.

Key words: binaries: close – binaries: eclipsing – stars: variables: other – globular clusters: individual: NGC 6362.

1 INTRODUCTION

The last decade has brought a dramatic change in our views on the binary-star population in globular clusters. A number of observational techniques have been successfully applied to identify such binaries (see reviews by Hut et al. 1992, Mateo 1996). Among them, the photometric charge-coupled device (CCD) surveys have proved to be particularly effective at detecting short-period ($P < 1$ d) systems (Mateo et al. 1990; Hodder et al. 1992; Kaluzny & Krzemiński 1993; Yan & Mateo 1994; Kaluzny et al. 1996a, 1997a, 1998; Kaluzny, Thompson & Krzemiński 1997b). Many of these systems appeared to be blue stragglers (BSs) – thus providing direct evidence that at least some BSs formed as a result of a mass transfer in close binary stars. Mateo et al. (1990) estimated that it is possible that all the non-eclipsing BSs in the sparse globular cluster NGC 5466 formed as a result of mergers of the components in close binaries; however, the uncertainties in their analysis were very large. In this situation, an additional test of the mass-transfer/coalescence hypothesis could be provided by analysis of masses of pulsating BSs (SX Phe-type stars). Although the number of SX Phe-type variables discovered in the globular clusters has increased significantly in recent years, our knowledge of their pulsational and physical properties is still fragmentary. There are numerous problems involved in establishing the P–L relation for these stars (Nemec, Nemec & Lutz 1994; McNamara 1995, 1997a; Petersen & Høg 1998). SX Phoenicis itself is the only genuine member of this class with accurate *Hipparcos* parallax (ESA 1997); the idea of incorporating the SX Phe-type members of globular clusters meets with difficulties, caused, in part, by a lack of well-calibrated photometry for other kinds of pulsating stars (e.g. RR Lyrae stars) in the clusters containing SX Phe variables. This makes the comprehensive studies giving photometry for all kinds of variable stars in a single photometric system particularly attractive [like Walker (1994) paper on the globular cluster M68].

In 1989 December, we started a CCD survey for short-period variables in the selected star clusters at Las Campanas Observatory. Our sample contains both open clusters of intermediate and old age (e.g. Cr261 – Mazur, Krzemiński & Kaluzny 1995; NGC 2243 – Kaluzny, Krzemiński & Mazur 1996b and references therein) and globulars (e.g. NGC 4372 – Kaluzny & Krzemiński 1993; NGC 288 – Kaluzny, Krzemiński & Nalezyty 1997c; 47 Tuc – Kaluzny et al. 1997d). The primary goal of the present study was to increase the number of stars of the globular clusters searched for short-period binaries and SX Phe-type pulsators. The globular cluster NGC 6362 ($\alpha_{2000} = 17^{\mathrm{h}}31^{\mathrm{m}}55^{\mathrm{s}}$, $\delta_{2000} = -67°03'$, $l = 325.^{\circ}5$, $b = -17.^{\circ}6$) was selected for our programme because of its proximity and low central concentration. The cluster did not attract much attention in the past; after a few photographic studies of the variable stars (Woods 1919; van Agt 1961; Van Hoof 1961; Fourcade, Laborde & Albarracin 1966), colour–magnitude diagrams (CMDs) of NGC 6362 were published in the early 1970s (Alcaino 1970, 1972; Fourcade 1974). The only photometry reaching below the turn-off point is that by Alcaino & Liller (1986), who presented a CCD *BVRI* study

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[★] E-mail: Beata_Mazur@camk.edu.pl (BM); jka@sirius.astrouw.edu.pl (JK); wojtek@roses.lco.cl (WK) of a 4×2.5 arcmin^2 field located at 3.3 arcmin south of the cluster nucleus.

The metallicity of NGC 6362 is high and relatively well established. Zinn & West (1984) derived for it $[\mathrm{Fe/H}] = -1.08$. Recently, Carretta & Gratton (1997) obtained $[\mathrm{Fe/H}] = -0.96$ from the analysis of echelle spectra of cluster giants.

The Third Catalogue of Variable Stars in Globular Clusters (Sawyer Hogg 1973) lists 33 variables in NGC 6362, two of which are, in fact, not variable – as noted by Clement, Dickens & Bingham (1995). 15 of the Sawyer Hogg's variables, all of RR Lyrae type, had previously published periods. Clement, Dickens & Bingham (1995) found that four of them were in error and derived periods for an additional 15 RR Lyraes.

2 OBSERVATIONS AND DATA REDUCTIONS

Most of the observations reported in this paper were obtained with the 2.5-m telescope at the Las Campanas Observatory. Sequences of frames to search for variables were collected with the I and V filters (the log of the observations is summarized in Table 1). All the 1991 data were taken with a Ford Aerospace 2048×2048 CCD, which was operated binned 2×2 to give 0.32 arcsec pixel^{-1} and a field of view of 5.5 arcmin. During 1991 May 1–2 we observed a field located 3 arcmin south of the cluster centre, while during 1991 June a location closer to the cluster centre (1.8 arcmin south of the nucleus of the cluster) was chosen. 1992 June data were taken with a Tektronix #2 1024×1024 CCD giving a field size of 3.8 arcmin with a pixel size of 0.22 arcsec, and with a Tektronix #3 2048×2048 chip, with the same scale and a field size of 7.6 arcmin. The latter camera was also used during 1992 September run. During both 1992 runs the observed field was centred on the nucleus of the cluster. The exposure times for all but a few frames were 300–360 s for the I and 400–480 s for the V band. We obtained a total of 186 frames in the I band and 71 frames in the V band. On the night of 1991 May 2, several standard stars from Landolt (1992) were observed, and they were used to determine the colour terms of the transformation of instrumental $v/v - i$ on to the standard system. The zero points were calculated based on the photometry obtained in 1996 September.

On the nights of 1996 September 26–28 we made additional observations using the Las Campanas 1-m telescope equipped with Tektronix #5 2048×2048 CCD. With the scale of the chip being 0.7 arcsec pixel^{-1}, the field size was 24 arcmin. The cluster was monitored for a total of about 6.5 h, mainly in the B and V bands. Several standard stars from Landolt (1992) list were observed as well; they were used to determine transformations to the standard BVI system.

Table 1. Journal of the observations.

Date UT	Nobs I	Nobs V	Nobs B	Δt h m	Field of view arcmin^2
1991 May 1	36	3	–	4:26	5.5×5.5
1991 May 2	45	–	–	4:46	5.5×5.5
1991 Jun 6	61	3	–	6:35	5.5×5.5
1991 Jun 8	2	48	–	6:44	5.5×5.5
1992 Jun 23	14	3	–	3:31	3.8×3.8
1992 Jun 24	28	2	–	4:32	7.6×7.6
1992 Sep 15	–	12	–	2:00	7.6×7.6
1996 Sep 26	4	3	2	0:56	24×24
1996 Sep 27	2	21	4	2:50	24×24
1996 Sep 28	2	3	24	2:57	24×24

The preliminary processing of the raw CCD data was performed under IRAF,[1] all frames were bias-subtracted and flat-fielded with median-averaged sky flats. The photometry of NGC 6362 stars was accomplished using two packages: frames included in the cluster CMD were analysed with DAOPHOT [we applied a version with variable point spread function (PSF); Stetson 1987, 1989], while the sequences of the observations aimed at searching for variables were reduced with the DOPHOT package (Schechter, Mateo & Saha 1993). DOPHOT V1.1 uses an analytic, position-independent PSF. The assumption of a constant PSF was satisfied quite well for Tektronix frames, but in the case of Ford it worked much less well. In order to minimize the influence of variable PSF on the light curves of individual stars we applied a method of local comparison stars, as described in detail in Kaluzny, Mazur & Krzemiński (1993).

3 SEARCH FOR THE VARIABLES

The search for the variables was conducted by separately analysing 1991/92 and 1996 observations. The candidates for the variables were identified following two methods described in detail by Mazur, Krzemiński & Kaluzny (1995). First, we applied the traditional 'scatter search' technique – we selected stars exhibiting excessive scatter compared with other stars of comparable brightness. The idea of the second method was taken from Stellingwerf (1978) paper on the phase dispersion minimization (PDM) method. We divided the overall variance calculated for consecutive intervals of a time-domain light curve by the global variance obtained from all data points and selected, for the further examinations, stars for which the quotient was the smallest. An additional examination was made of the light curves of stars that fall in the blue straggler region.

From the analysis of the 1991/92 data set, 31 clearly variable stars were identified. We compared our list with the Sawyer Hogg Catalogue (1973). Eight of the variables (four RR Lyrae, two variable blue stragglers and two EA-type binaries) are not listed in the catalogue at all. Of the 23 stars in common, 15 had unknown periods (these were determined only recently by Clement, Dickens & Bingham 1995). For 14 of the variables listed in Sawyer Hogg's catalogue we collected a sufficient amount of data that independent period determination became possible; hence, only these 14 of the previously known variables will be discussed in this paper.

The 1996 field covered a much larger area, but the number of collected frames was rather small. In fact, we have only two continuous sequences of observations in the V and B bands, each lasting for about 2 h. This mini-survey resulted in the discovery of 11 candidates for variables.

In Fig. 1 we present the finding charts for the newly found variables. The V frame of the 1996 field, together with the rectangular coordinates of the variables corresponding to this frame, as well as the complete photometry of the variables are available from Beata_Mazur@camk.edu.pl upon request.

Table 2 lists the equatorial coordinates and photometric properties of 22 variable stars for which we obtained photometry during 1991/92 seasons. Column (1) gives the designation of a star from the Sawyer Hogg Catalogue, new variables have got consecutive numbers starting from 34; columns (2) and (3) are

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

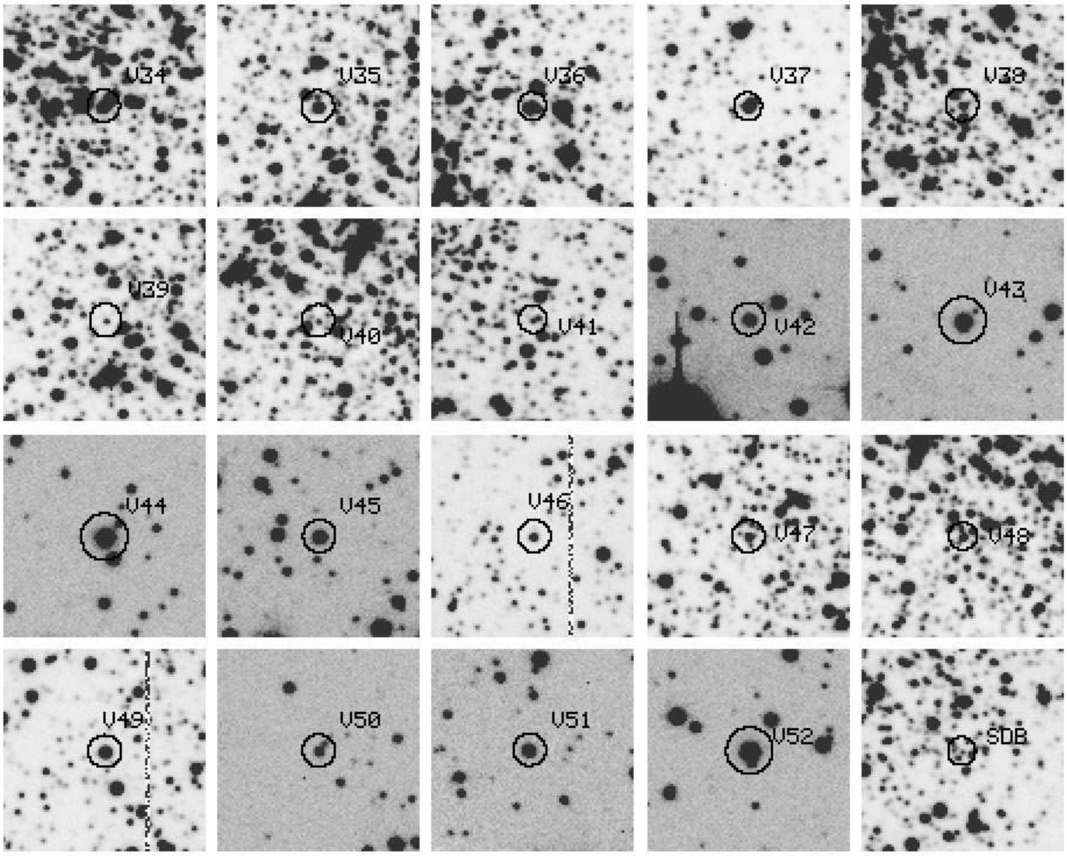

Figure 1. The *V*-band finder charts for the 19 newly discovered variables and the sdB candidate. V36 is the right part of a blend and V37 the lower left. The sides of each chart are 60 arcsec, with north up and east to the left.

Table 2. NGC 6362 variables observed during 1991 and 1992 seasons.

Var	$\alpha(2000)$ h m s	$\delta(2000)$ $^\circ$ $'$ $''$	$<V>$	$<I>$	$V-I$	A_V	A_I	Period (d)	$\Delta P\times 1000$ (0.001 d)	Type
V2	17 31 50.3	−67 04 24	15.22	14.73	0.54	1.2	0.85	0.488952	−1.774	RRab
V3	17 31 41.0	−67 04 15	15.30	14.77	0.56	0.8	0.65	0.447315	0.011	RRab
V5	17 32 08.9	−67 02 58	15.36	14.72	0.65	1.0	0.5	0.5209	0.06	RRab
V11	17 31 50.0	−67 01 57	15.18	14.79	0.4	0.5	0.28	0.288786	−0.008	RRc
V15	17 32 03.5	−67 02 44	15.23	14.77	0.46	0.45	0.3	0.279947	0.001	RRc
V19	17 32 16.0	−67 03 09	15.32	14.66	0.67	0.6	0.4	0.594492	−0.028	RRab
V20	17 32 02.7	−67 02 58	15.22	14.54	0.67	0.32	0.26	0.69833	−0.03	RRab
V21	17 32 22.6	−67 04 30	15.29	14.88	0.42	0.54	0.32	0.281392	−0.001	RRc
V23	17 32 00.2	−67 03 07	15.31	14.89	0.43	0.5	0.32	0.275107	0.003	RRc
V24	17 32 07.2	−67 03 20	15.14	14.68	0.48	0.47	0.3	0.32936	−4.389	RRc
V26	17 31 58.9	−67 03 21	15.29	14.64	0.66	0.6	0.4	0.602164	0.014	RRab
V28	17 31 59.2	−67 02 07	15.05	14.56	0.49	0.45	0.3	0.35843	0.014	RRc
V29	17 31 52.5	−67 03 19	15.22	14.58	0.64	0.38	0.28	0.64778	0.01	RRab
V32	17 32 01.9	−67 02 12	15.27	14.71	0.6	1.15	0.8	0.497246		RRab
V34	17 31 52.9	−67 03 33	15.29	14.74	0.57	0.85	0.6	0.494302		RRab
V35	17 32 08.2	−67 03 02	15.27	14.82	0.46	0.47	0.3	0.29079		RRc
V36	17 31 43.7	−67 02 16	15.09	14.57	0.52	0.4	0.24	0.31007		RRc
V37	17 31 32.2	−67 02 03	15.27	14.85	0.41	0.38	0.3	0.2550		RRc
V38	17 31 43.7	−67 02 58	16.98	16.56	0.43	0.65	0.4	0.066616		SX Phe
V39	17 32 08.5	−67 03 14	17.84	17.28	0.56	0.23	0.2	0.36325		W UMa
V40	17 32 04.1	−67 03 45	18.20	17.44	0.76	$\gtrsim$0.28				EA
V41	17 31 35.4	−67 04 02	18.73	17.95	0.78		0.28			EA

V5: shows the Blazhko effect, photometric parameters derived from 1991 June data.
V37: other possible periods: 0.2507, 0.2527 d.
V39, V40 and V41: *V* and *I* correspond to maximum brightness.

the equatorial coordinates, derived from the positions of about 100 stars from USNO-A V1.0 Catalogue of Astrometric Standards (Monet et al. 1996). The errors of coordinates are about 1 arcsec. Columns (4) and (5) are intensity-mean *V* and *I* magnitudes; for binaries V39, V40 and V41 values at brightness maximum are given. Column (6) is the magnitude-mean colour, while columns (7) and (8) are the amplitudes in the *V* and *I* bands. Column (9) gives the periods, while column (10) shows the differences between periods derived by us and those of Clement, Dickens & Bingham (1995), in units of 0.001 d. Column (11) gives the type of the variability. The mean magnitudes and colour were determined from the light curves following smoothing with cubic splines.

The periods of the variables were determined with a programme based on the PDM method. In order to minimize effects from gaps in the data, the *V* and *I* light curves were analysed simultaneously. The problem of aliases was rather severe, especially for longer-period and/or crowded variables (V20, V29, V36, V37). Hence we are pleased to find that in most cases the periods derived by us and those of Clement at al. (1995) are almost identical; only in two cases (V2, V24) do they differ by more than a thousandth of a day. We should mention that V32, claimed by Clement et al. (1995) to be constant, has been found by us to be an RR Lyrae type ab, with a *V* amplitude of 1.15 mag; its 'non-variability' has to be the result of a misidentification. We

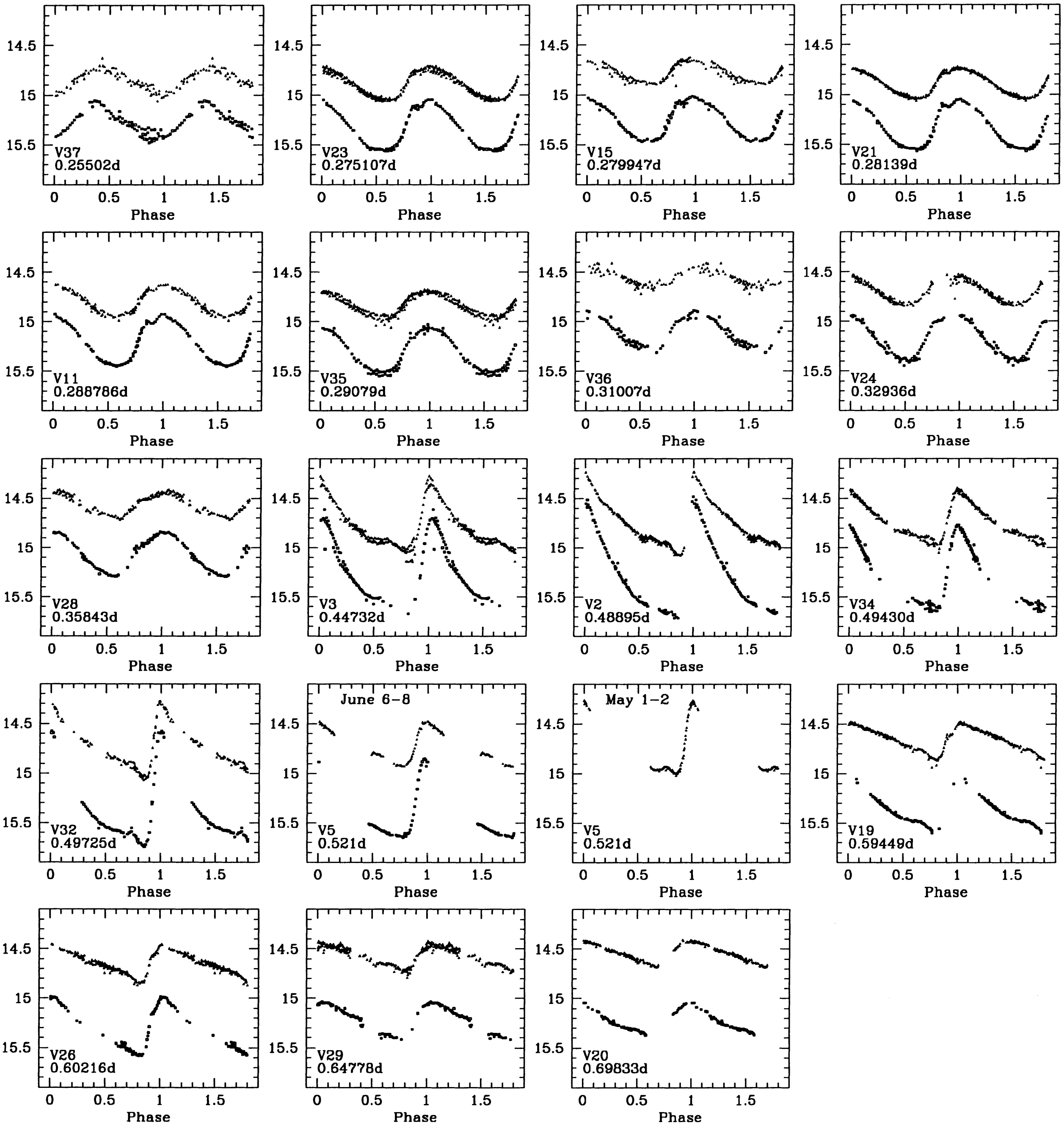

Figure 2. The *VI* light curves of 18 RR Lyraes, phased with the periods from Table 2. The plots are arranged in order of increasing period. In the case of V24, V29, V36 and V37, an excessive scatter of the light curves is caused by crowding. The variability of the light curves of V3 and V34 seems to be real, similarly in the case of V5, which shows the Blazhko (1907) effect.

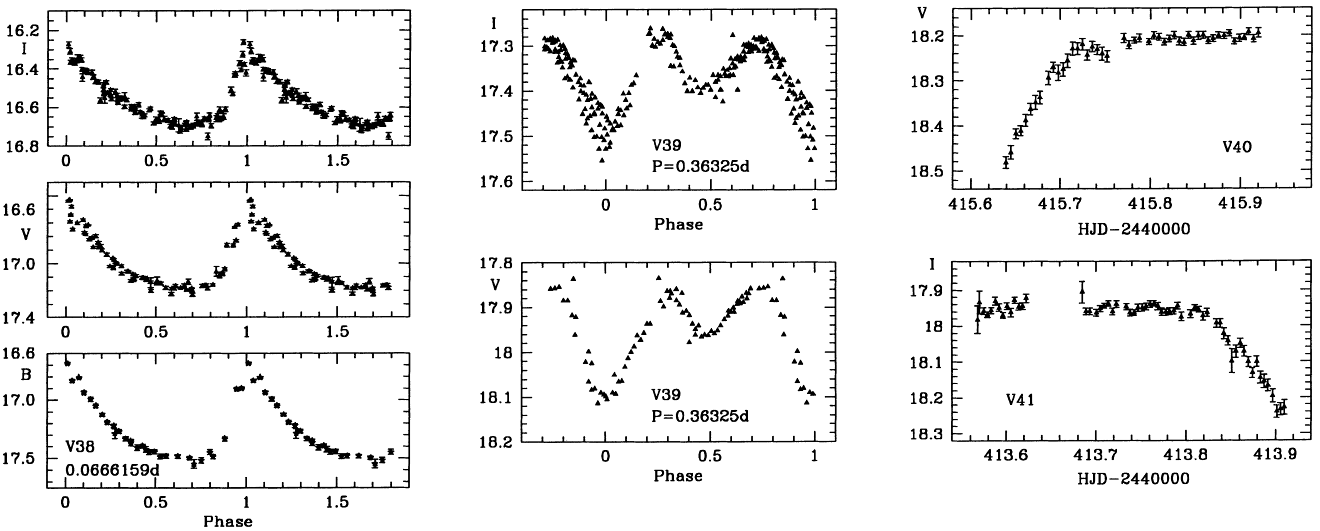

Figure 3. Phased light curves of the variable blue stragglers V38 (left) and V39 (middle) and time-domain light curves of presumed EA-type systems V40 and V41 (right).

Table 3. Variables discovered during 1996 season.

Var	α(2000) h m s	δ(2000) ° ′ ″	$V_{\max}$	$B_{\max}$	$B-V$	A_V	A_B	Period (d)	Type
V42	17 31 09.1	−66 51 39	17.49	18.1	0.6	>0.6	0.9		EA
V43	17 34 03.4	−66 52 54	16.02	16.75	0.73	0.44	0.35	0.285	EW
V44	17 33 26.0	−66 53 43	15.29	15.73	0.44	>0.13	>0.2		RRab
V45	17 32 52.7	−66 58 59	16.93	17.69	0.76	0.3	0.32	0.409	EW
V46	17 32 25.0	−67 00 31	17.48	17.85	0.37	0.05	0.05	≃0.05	SX Phe
V47	17 32 13.1	−67 02 37	17.10	17.44	0.33	0.05	0.06	≃0.05	SX Phe
V48	17 31 59.9	−67 03 49	17.01	17.37	0.36	0.05	0.06	≃0.05	SX Phe
V49	17 32 24.1	−67 04 00	15.21	16.14	0.93	0.12	0.11		mod
V50	17 34 09.6	−67 07 55	18.44	19.0	0.6	0.35	0.5		Ecl ?
V51	17 34 15.7	−67 12 06	16.87	17.7	0.8	0.17	0.18		mod
V52	17 33 10.7	−67 13 16	15.36	16.00	0.64	>0.46	0.6	0.399	EW

V46, V47 and V48: for the SX Phe-type variables, *V* and *B* correspond to mean values.

confirm that V4 is constant, at the level of 0.03 mag. Although we failed to determine the period for V1, we can confirm that it is a RRab-type variable, and its period is very close to 0.5 d. The *VI* light curves for RR Lyrae-type stars are displayed in Fig. 2. The plots are arranged in order of increasing period.

The phased light curves of the variable blue stragglers V38 and V39, as well as the time-domain light curves of the stars V40 and V41, for which we observed eclipse-like events, are shown in Fig. 3. V38 is the SX Phoenicis-type variable, with an amplitude of 0.8 mag in the *B* band. High amplitude implies that the star pulsates in a radial mode (Rodriguez et al. 1996) and the asymmetric light curve suggests that the fundamental mode is excited. V39 is the W UMa-type contact binary. The shape of the light curve – with minima of different depths – suggests that components of this binary might be in poor thermal contact. For V40 and V41, eclipse-like events were observed on the nights of 1991 June 8 and 1991 June 6, UT, respectively. Both stars are located on the cluster CMD in the turn-off region.

Basic data for the variables discovered from the 1996 survey are listed in Table 3. Column (1) gives the designation of a star, columns (2) and (3) are the equatorial coordinates, columns (4) and (5) are the *V* and *B* magnitudes at maximum (for the presumed SX Phe-type variables V46, V47 and V48 mean values are given). Column (6) is the $B-V$ colour at the maximum, while columns (7) and (8) are the amplitudes in the *V* and *B* bands. Column (9) lists the estimated period, when available. Column (10) gives the type of the variability ('mod' stands for the brightness modulation; further observations are required to establish the nature of variability). The *BV* light curves of variables discovered during the 1996 season are presented in Figs 4–6.

The shape of the light curve, together with the position on the cluster CMD in the RR Lyrae instability strip, suggest that V44 is the next RRab cluster member. V44, located 13 arcmin from the cluster centre, is the most distantly projected RR Lyr in the cluster. Stars V46, V47 and V48, located on the cluster CMD in the blue straggler region, exhibit variability on the time-scale of ≃0.05 d and an amplitude in the *V* band of ≃ 0.05 mag, which can be interpreted as variability of the SX Phe-type. Further observations are needed to confirm this finding, and to determine the periods of these presumed, low-amplitude SX Phe-type variables.

V42 is the EA-type eclipsing binary. The depth of the minimum observed on the night of 1996 September 28, 0.9 mag in the *B* band, implies that this system contains an evolved component. V42 is located 1 mag above the cluster turn-off point, in the yellow straggler region, and it might be a descendant of the former blue straggler cluster member. The large (≃12 arcmin) distance to the cluster centre may awaken suspicions that it is, in fact, a field object. Still, V42 is located closer to the cluster nucleus than V44. V49 and V51 are located close to the red giant branch, V49 at the level of horizontal branch and V51 1.5 mag below. V49 exhibits

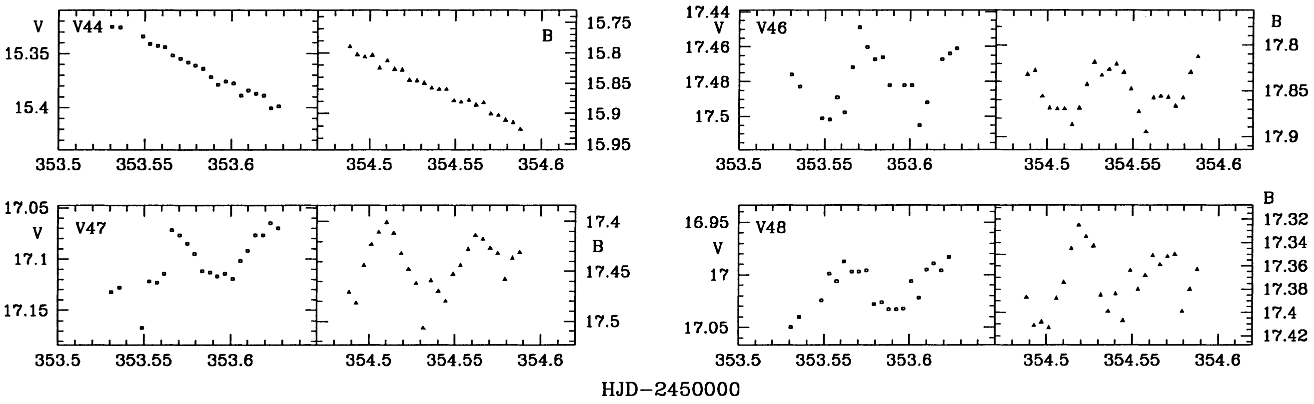

Figure 4. Time-domain light curves of the pulsating variables V44, V46, V47 and V48; left panels show *V* data, while right panels show data in the *B* band, obtained on the nights of 1996 September 27–28, UT.

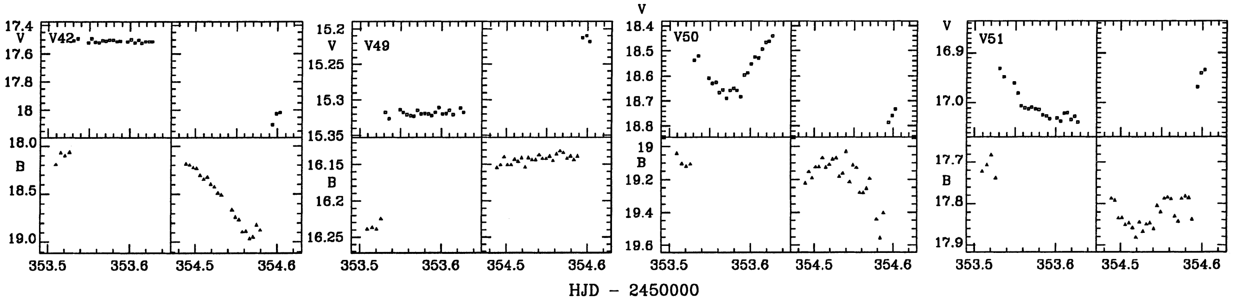

Figure 5. Time-domain light curves of the variables V42, V49, V50 and V51. Upper panels show data in *V*, and lower panels in the *B* band.

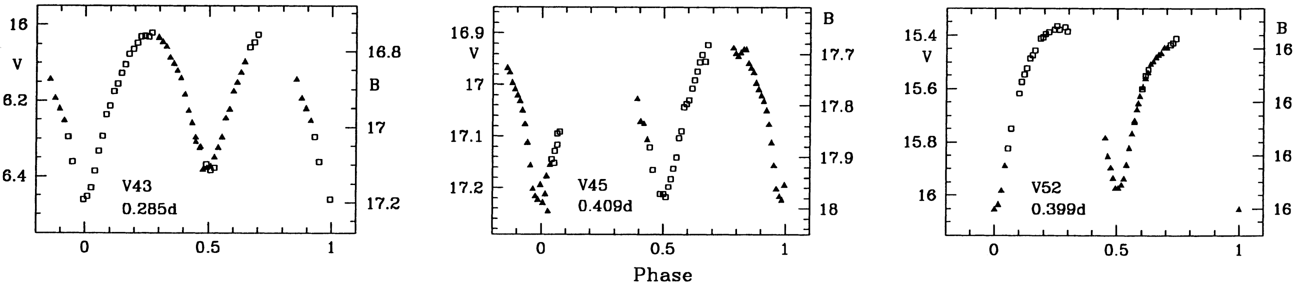

Figure 6. Phased light curves of the foreground contact systems V43, V45, V52. The squares represent *V* data; triangles represent *B* data shifted by the $B-V$ colour of the variable.

nightly changes of the brightness level, with an amplitude of several hundredths of magnitude, which could be due to light modulation caused by fast rotation connected with spot activity, or due to ellipsoidal effect. The time-scale of the variability of V51 seems to be shorter – several hours. The reason for the light variations is unclear; it might be caused by eclipses, or the ellipsoidal effect. V50, hidden on the cluster CMD among stars that populate the region of the turn-off point is, most probably, a W UMa-type contact system. We failed to determine the period of this system. V43, V45 and V52 are also W UMa-type systems.

Fig. 7 shows the locations of the variables in the colour–magnitude diagrams. The $V/V-I$ diagram is based on two exposures in V (400 s, 100 s) and two exposures in the I band (300 s, 20 s), taken with the 2.5-m telescope, on the night of 1991 May 1, UT. The field observed covered an area of $5.5\times5.5\,\mathrm{arcmin}^2$, located 3 arcmin south of the cluster centre. In the $V/V-I$ diagram, locations of the variables from Table 2 are shown. Data for the $V/B-V$ diagram were collected with the 1-m telescope, on the night of 1996 September 27, UT. We used a pair of V and B frames, each exposed for 300 s. Stars located at a distance $r<8$ arcmin from the cluster centre were plotted on this diagram. In the $V/B-V$ diagram positions of all newly discovered variables are marked. The diagrams are not intended to be complete – stars with unreliable photometry (having an atypically large error in the photometry for their magnitude) have been omitted. We note the blue object present on both diagrams ($V=19.1$, $V-I=-0.24$, $B-V=-0.28$), which might be a hot subdwarf cluster member; a finder chart is given in Fig. 1 ($\alpha_{2000}=17^{\mathrm{h}}31^{\mathrm{m}}46\overset{\mathrm{s}}{.}3$, $\delta_{2000}=-67°05'03''$).

4 CLUSTER MEMBERSHIP OF THE VARIABLES

In many cases it is difficult to judge unambiguously if a variable belongs to the cluster or not, based on photometric data alone. This is not the case for RR Lyraes. All variables of the RR Lyrae-type belong to the cluster, hence we can try to use them to estimate

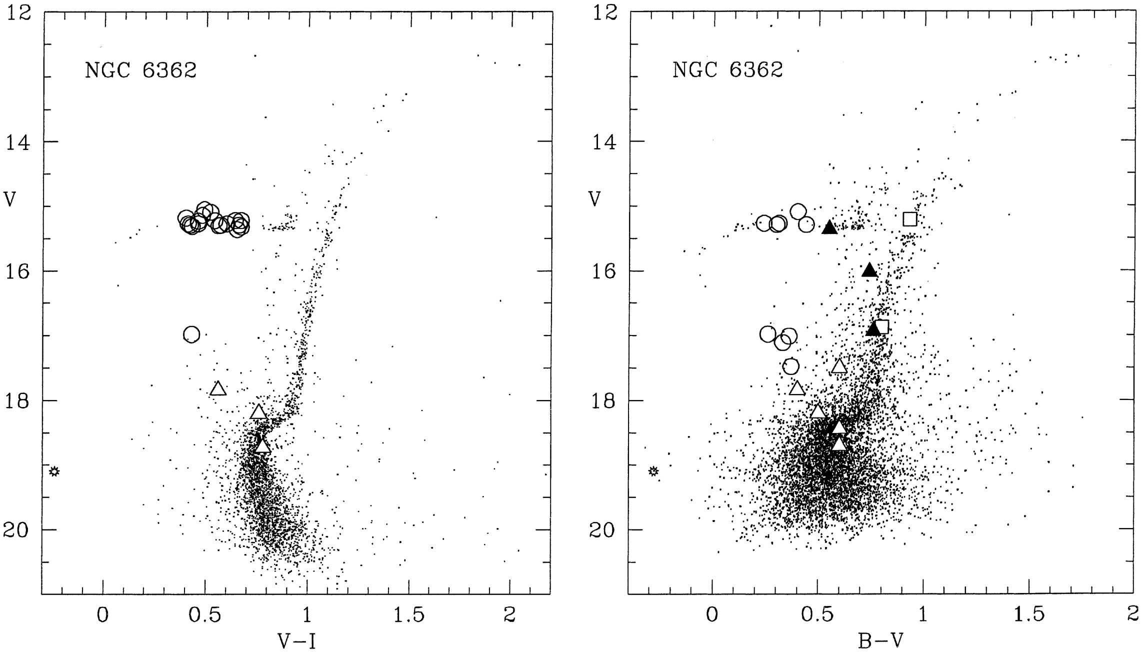

Figure 7. The $V/V-I$ (left) and $V/B-V$ (right) CMDs for NGC 6362 (see text for details). Open circles represent the positions of pulsating variables. Triangles represent eclipsing binaries (field W UMa systems are marked with filled triangles); squares correspond to other variables. The starlet denotes the presumed sdB star. For pulsating stars the positions correspond to mean colours and magnitudes; for remaining stars, colour and magnitude at maximum brightness are plotted.

the distance modulus to the cluster. Unfortunately, RR Lyraes do not seem to be as good standard candles as one would like them to be. There is a long-standing controversy about the zero point of the RR Lyrae distance scale, as well as the slope of the absolute magnitude–metallicity relation (see Walker 1995). Calibrations using the Baade–Wesselink method (Clementini et al. 1995) and by statistical parallaxes (Gould & Popowski 1998) give absolute magnitudes that are, on average, some 0.2–0.3 fainter (but see McNamara 1997b) than those obtained by pulsation analysis (Sandage 1993), horizontal-branch-evolutionary models (Caloi, D'Antona & Mazzitelli 1997), or main-sequence fitting to field subdwarfs (Reid 1997; Gratton et al. 1997). It is beyond the scope of this paper to discuss this problem. We shall rather adopt the range of absolute magnitudes and infer on this basis the corresponding range of distance moduli. At the faint end, we adopt the fainter of the two relations derived by Clementini et al. (1995), i.e. $M_V = 0.20[\mathrm{Fe/H}] + 1.06$; at $[\mathrm{Fe/H}] = -1.08$, we get $M_V = 0.85$. The mean luminosity of 16 cluster RR Lyraes $<V(\mathrm{RR})>= 15.27$ (we excluded two higher-luminosity, most likely evolved variables V28 and V36 from the average). The estimated lower limit on the apparent distance modulus $(m-M)_V = 14.42$. The brightest estimates for the absolute magnitudes of RR Lyraes are obtained from the main-sequence fitting. We adopt Gratton et al. (1997) relation $M_V = 0.29([\mathrm{Fe/H}] + 1.5) + 0.43$, which leads to $M_V = 0.55$ and $(m-M)_V = 14.72$.

In recent years it was demonstrated that Fourier decomposition of light curves is a useful technique for determining physical parameters of RR Lyrae variables. Simon & Clement (1993) showed, using the hydrodynamic pulsation models, that luminosity of RRc-type stars can be computed from the pulsation period and Fourier phase $\phi_{31} = \phi_3 - 3\phi_1$, via the relation: $\log(L/\mathrm{L}_\odot) = 1.04 \log \mathrm{P} - 0.058\phi_{31} + 2.41$. In Table 4 the Fourier parameters ϕ_{31}, $\sigma_{\phi_{31}}$, $\log(L/\mathrm{L}_\odot)$ derived from this equation are listed, as well as M_V and $(m-M)_V$ for six RRc stars, for which $\sigma_{\phi_{31}} < 0.2$. Fourier decomposition was calculated using the programme developed by Schwarzenberg–Czerny, which uses periodic orthogonal polynomials (Schwarzenberg-Czerny & Kaluzny 1998). While converting $\log(L/\mathrm{L}_\odot)$ to M_V we adopted $M_\odot^{\mathrm{bol}} = 4.79$, and $BC = 0.06[\mathrm{Fe/H}] + 0.06$ (Sandage & Cacciari 1990). Derived distance moduli fall half way between the faint and bright limits, obtained from the absolute luminosity–metallicity relations.

Table 4. Parameters for the RRc stars.

Var	ϕ_{31}	$\sigma_{\phi_{31}}$	$\log(L/\mathrm{L}_\odot)$	M_V	$(m-M)_V$
V11	3.38	0.09	1.653	0.66	14.52
V15	3.11	0.13	1.651	0.67	14.56
V21	3.27	0.07	1.648	0.68	14.61
V23	3.04	0.12	1.651	0.67	14.64
V28	4.60	0.09	1.680	0.60	14.45
V35	3.52	0.17	1.648	0.68	14.59

Recently Kovács & Jurcsik (1996, 1997) derived the linear formulae that connect the absolute magnitudes of RRab stars with their periods and Fourier parameters describing the shape of the light curves. Unfortunately, all their formulae are based on Fourier decomposition of V light curves, which in our case suffer from poor phase coverage. V26 is the only RRab star for which we managed to determine ϕ_{31} with an acceptable error. We obtained $\phi_{31} = 5.6 \pm 0.3$, $A_1 = 0.234 \pm 0.015$; via equation $M_V = 1.221 - 1.396P - 0.477A_1 + 0.103\phi_{31}$, we get $M_V = 0.85 \pm 0.12$, consistent with Baade–Wesselink determinations, which define the zero point of the Kovács & Jurcsik relations. Discussing the cluster membership of the other types of the variables, we shall assume that the apparent distance modulus of NGC 6362 falls somewhere between 14.42 and 14.72 mag.

V38 is the SX Phe-type pulsating blue straggler, which could, in principle, provide determination of the cluster distance modulus.

McNamara (1997a) and Petersen & Høg (1998) derived independently a period–luminosity relation for high-amplitude δ Scuti stars, which was based on *Hipparcos* parallaxes. Unfortunately, the number of variables with accurate parallaxes is very small (5–6), and SX Phoenicis itself is the only Population II variable in this sample. From McNamara (1997a) P–L relation we get for V38 $(m-M)_V = 14.53 \pm 0.13$, while Petersen & Høg (1998) formula gives $(m-M)_V = 14.49 \pm 0.14$; quoted errors do not include the uncertainty of $<m_V>$. Given the uncertainties of both the cluster distance modulus and P–L relation, we can conclude that V38 is the likely cluster member.

In the case of the W UMa stars, the calibration of M_V in terms of orbital period and colour index (Ruciński 1994) provides invaluable help in distinguishing cluster members. We applied the latest version of Ruciński's calibration, which is based on *Hipparcos* data (Ruciński & Duerbeck 1997). The calibration gives M_V as a function of period and unreddened colour $(B-V)_0$: $M_V = -4.44 \times \log(\mathrm{P}) + 3.02 \times (\mathrm{B}-\mathrm{V})_0 + 0.12$. There are four contact systems in our sample for which we managed to determine periods: V39, V43, V45 and V52. Photometric parameters for the three latter systems are given in Table 3; from 1996 September data, the observed $(B-V)$ of V39 is equal to 0.4. Following the prescription of Sarajedini (1994) we estimated from our $V/V-I$ CMD, that $E(V-I) = 0.11$–0.12. Next, utilizing the relation between $E(V-I)$ and $E(B-V)$ given by Dean, Warren & Cousins (1978) we derived the reddening $E(B-V) = 0.09$. We note that our estimate of the reddening is consistent with a value given by the reddening maps of Schlegel, Finkbeiner & Davis 1998, i.e. $E(B-V) = 0.076$. The apparent distance modulus of V39, calculated as a difference between V_{max} and M_V derived from Ruciński's formula, equals to 14.83. The obtained distance modulus is larger than any of the previous estimates; in fact, this is what we should expect for this system, given the shape of the light curve – with unequal minima – which suggests poor thermal contact configuration. For binaries V43, V45 and V52 we obtained distance moduli: 11.55, 13.06 and 11.81 , respectively; none of them belongs to the cluster.

For other variables it is impossible to exclude or confirm membership based on photometric data alone; we need spectroscopy to resolve this problem. Stars V40 and V41 deserve special attention, as they are potential members of the important category of detached eclipsing double-lined binaries – which are a primary source of information on stellar masses, radii and luminosities (Andersen 1991 and references therein). When properly calibrated they can provide direct distances with 1 per cent accuracy (Paczyński 1997).

5 SUMMARY

We surveyed a southern globular cluster NGC 6362 in a search for short-period variables. We identified 19 new candidate variables, three of which are the foreground contact systems of the W UMa-type. Of the remaining 16, five are cluster RR Lyraes, four are probable SX Phe-type stars, five are eclipsing binaries, and two exhibit a modulation of brightness level, with an amplitude of several hundredths of magnitude, which could be due to ellipsoidal effect or fast rotation connected with spot activity. Of the discovered binaries, two are detached systems located near the turn-off point of the cluster CMD; spectroscopic observations are required to confirm their cluster membership. If they are cluster members, they could be used to determine masses and radii of the stars at the turn-off of the cluster, as well as the distance to NGC 6362. The third of the EA-type systems (V42) is located in the yellow straggler region. The depth of the observed minimum, 0.9 mag in the B band, suggests that the binary contains an evolved component; it might be the descendant of the former blue straggler cluster member. We demonstrated that two variable blue stragglers (EW/EB-type binary and the high-amplitude SX Phe-type star) are likely cluster members. We present the phased VI light curves for 20 cluster variables (18 RR Lyrae stars and two blue stragglers) from the central part of NGC 6362.

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