ACTA ASTRONOMICA
Vol. **61** (2011) pp. 1–1

The Optical Gravitational Lensing Experiment. The OGLE-III Catalog of Variable Stars. XIII. Long-Period Variables in the Small Magellanic Cloud*

I. Soszyński[1], A. Udalski[1], M.K. Szymański[1], M. Kubiak[1], G. Pietrzyński[1,2], Ł. Wyrzykowski[1,3], K. Ulaczyk[1], R. Poleski[1], S. Kozłowski[1] and P. Pietrukowicz[1]

[1] Warsaw University Observatory, Al. Ujazdowskie 4, 00-478 Warszawa, Poland
e-mail:
(soszynsk,udalski,msz,mk,pietrzyn,kulaczyk,rpoleski,simkoz,pietruk)@astrouw.edu.pl
[2] Universidad de Concepción, Departamento de Astronomia, Casilla 160–C, Concepción, Chile
[3] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK
e-mail: wyrzykow@ast.cam.ac.uk

Received September 6, 2011

ABSTRACT

The thirteenth part of the OGLE-III Catalog of Variable Stars (OIII-CVS) contains 19 384 long-period variables (LPVs) detected in the Small Magellanic Cloud. The sample is composed of 352 Mira stars, 2222 semiregular variables (SRVs) and 16 810 OGLE Small Amplitude Red Giants (OSARGs). Sources are divided into oxygen-rich and carbon-rich stars. The catalog includes time-series *VI* photometry obtained between 1997 and 2009.

Methods used to select and classify variable stars are described. We show some statistical properties of the sample, and compare it with LPVs in the Large Magellanic Cloud. Additionally, we present objects of particular interest, *e.g.*, a SRV with outbursts, and a Mira star with the longest known pulsation period $P = 1860$ days.

Key words: *Stars: AGB and post-AGB – Stars: late-type – Stars: oscillations – Magellanic Clouds*

1. Introduction

When low to intermediate mass stars climb the red giant branch (RGB) or the asymptotic giant branch (AGB), they exhibit various forms of intrinsic variability. In the first phase of the evolution as red giants the stochastically excited solar-like oscillations are excited. The amplitudes of these variations increase with the brightness of stars and near the tip of the RGB (for both, RGB and AGB stars) solar-like

*Based on observations obtained with the 1.3-m Warsaw telescope at the Las Campanas Observatory of the Carnegie Institution for Science.

oscillations can be observed from the ground as OGLE Small Amplitude Red Giants (OSARGs, Dziembowski and Soszyński 2010). When stars are close to end of their evolution on the AGB, they start pulsations as semiregular variables (SRVs) or Miras. All these kinds of such objects are called long-period variables (LPVs). LPVs are common in various stellar systems, they are among the brightest stars and obey multiple period-luminosity (PL) relations, which makes them potentially important as distance indicators. Variability of red giants also provides information about the physical structure of these stars and probe their mass loss rates. Evolutionary advanced AGB stars are very effective contributors of re-cycled material to the interstellar medium.

The Large (LMC) and Small Magellanic Clouds (SMC) offer an opportunity to compare huge samples of red giant stars in the environments that exhibit different metallicities. In the fourth paper of this series (Soszyński *et al.* 2009, hereafter Paper I) we described the catalog of nearly 92 000 LPVs in the LMC compiled from the observations collected during the third phase of the Optical Gravitational Lensing Experiment (OGLE-III). Here we present the OGLE-III catalog of 19 384 LPVs in the SMC – the largest such catalog published to date.

First several variable red giants in the SMC were identified as a by-product of the Harvard survey for Cepheids in this galaxy (Shapley *et al.* 1925, Hoffleit 1935, McKibben Nail 1942). In those days these objects were thought to be Galactic foreground LPVs. Only Shapley and McKibben Nail (1951) showed that the concentration of LPVs toward the SMC center rules out the possibility that all these objects lay in the foreground. They provided a list of 42 Miras, semiregular and irregular variables in the SMC. Then, several LPVs in the SMC were found during the surveys of Dartayet and Landi Dessy (1952) and Thackeray (1958). The lists of 24 long-period and 61 irregular variables were provided in the catalog of variable stars in the SMC by Payne-Gaposchkin and Gaposchkin (1966). A survey devoted solely to the search for variable red giants in the Magellanic Clouds were initiated by Lloyd Evans (1971). As a result several dozen new LPVs in the SMC were discovered and analyzed (Lloyd Evans 1978ab, Lloyd Evans *et al.* 1988).

Long-term observations from microlensing sky surveys, especially MACHO and OGLE, provided unprecedented resources for variable red giant research. LPVs in the SMC were studied by Cioni *et al.* (2003), Groenewegen (2004), Ita *et al.* (2004ab), Kiss and Bedding (2004), Schultheis *et al.* (2004), Soszyński *et al.* (2004, 2007), Raimondo *et al.* (2005), Lah *et al.* (2005), usually in comparison with the larger sample of LPVs in the LMC. No catalog of LPVs in the SMC was published so far on the basis of photometric data provided by the microlensing projects.

In this paper we describe the thirteenth part of the OGLE-III Catalog of Variable Stars. The previous parts of the Catalog comprise over 173 000 variables stars of various types in the Magellanic Clouds and Galactic bulge. In this study, like in Paper I, we divide LPVs into three groups: OSARGs (Wray *et al.* 2004), SRVs and Miras. Soszyński *et al.* (2004) showed that OSARGs and SRVs constitute a separate classes of LPVs, with different series of PL relations and probably with different pulsation mechanism.

2. Observational Data

The OGLE project provides a database of *I*- and *V*-band time-series photometry of about 6 million stars in the SMC. The photometry in the central parts of the SMC was collected over a period of nearly 13 years (OGLE-II + OGLE-III), from January 1997 to May 2009. The outer parts of the SMC were monitored over a shorter time span – from June 2001. Observations were obtained with the 1.3-m Warsaw telescope at Las Campanas Observatory (operated by the Carnegie Institution for Science) in Chile. During the OGLE-III survey the telescope was equipped with the eight-chip CCD mosaic camera of the total resolution 8192×8192 pixels and the field of view of about $35' \times 35\rlap{.}'5$. Details of the instrumentation setup can be found in Udalski (2003).

The OGLE-III survey in the SMC covered an area of about 14 square degrees (41 fields). Typically about 700 observing points were collected in the Cousins *I* photometric band, and 50-70 measurements in the Johnson *V* band. For stars for which the OGLE-II photometry is available the number of observations is about 1000 and 100 in the *I* and *V* bands, respectively. When a star was located in the overlapping part of adjacent fields, the number of points may be larger, because we merged observations from both fields.

The *VI* photometry was obtained with the standard OGLE data reduction pipeline (Udalski et al. 2008) based on the Difference Image Analysis (DIA, Alard and Lupton 1998, Woźniak 2000). For 22 bright stars, which saturate in the DIA reference images, we provide the DoPhot *I*-band photometry (Schechter *et al.* 1993). These stars are flagged in the remarks of the catalog.

We matched OGLE stars against the near-infrared 2MASS All-Sky Catalog of Point Sources (Cutri *et al.* 2003) and the IRSF Magellanic Clouds Point Source Catalog (Kato *et al.* 2007) using a search radius of 1 arcsec. In this analysis we use reddening-free Wesenheit magnitudes, defined as:

$$W_{JK} = K_s - 0.686(J - K_s)$$

$$W_I = I - 1.55(V - I)$$

In these formulas J and K_s are single-epoch near-infrared measurements taken from the 2MASS or IRSF catalogs, while W_I was derived independently for each pair of measurements in V and I bands, and the mean value of W_I was derived for a given star.

3. Selection and Classification of LPVs

The selection of LPVs in the SMC began with the massive period search performed for all stars monitored by the OGLE-III project in this galaxy. We search a frequency space of 0 to 0.5 day^{-1} with a frequency spacing of 0.000001 day^{-1} using the FNPEAKS code (Kołaczkowski, private communication). Fifteen periods with the corresponding amplitudes were recorded for each star with an iterative procedure of determining periods and prewhitening the light curves with these periods.

LPVs in the SMC were selected in the same way as in the LMC (Paper I). Large- and medium-amplitude light curves (SRVs and Miras) were visually inspected and the classification was done based on the light curve morphology, position of a star in the PL, color-magnitude and period-amplitude diagrams. Like in the catalog of LPVs in the LMC, we inspected light curves of very faint objects ($I \approx 20$ mag) and detected a number of Miras and SRVs surrounded by circumstellar matter. Most of the small-amplitude LPVs (OSARGs) were identified automatically using the method described by Soszyński *et al.* (2007). The method utilizes the positions of OSARGs in the reddening-free PL diagrams and the characteristic period-ratios exhibited by these multi-periodic objects.

In some stars the automatically determined primary periods were found to be spurious and they were replaced by one of the secondary periods, usually corresponding to one of the PL sequences discovered by Wood *et al.* (1999). Note that only the primary period for each star has been verified. The second and the third periods, also given in this catalog, may be false. For detailed analyses of the periodicity we recommend use original photometry provided with the catalog. The red giants in eclipsing and ellipsoidal binary systems, which form sequence E in the PL plane, were included in this catalog only if they simultaneously showed pulsations as OSARGs or SRVs. Main periods of these stars listed in our catalog usually correspond to half of the orbital periods.

With the aim of excluding foreground Galactic objects from our catalog, we checked the astrometric measurements of the initially selected sources, and removed stars with detectable proper motions. Only in the field SMC140, centered on the Galactic globular cluster 47 Tuc, SMC stars showed proper motions relative to the cluster members (of course, we observed the motion of 47 Tuc, but the coordinate grid was established on the cluster stars, which dominate in the field SMC140). LPVs that are members of 47 Tuc are saturated in the OGLE data, so they are not included in our catalog.

LPVs were divided into carbon- (C-) and oxygen-rich (O-rich) stars using several methods. The primary criterion was the position of the star in the W_I–W_{JK} diagram (Fig. 1). The same method was used to distinguish between O-rich and C-rich giants in the LMC (Paper I), however the extension of the SMC along the line of sight is larger than the LMC, which forced us to look also for other solutions. As the secondary tests we used position of SRVs and Miras in the period–W_I diagram

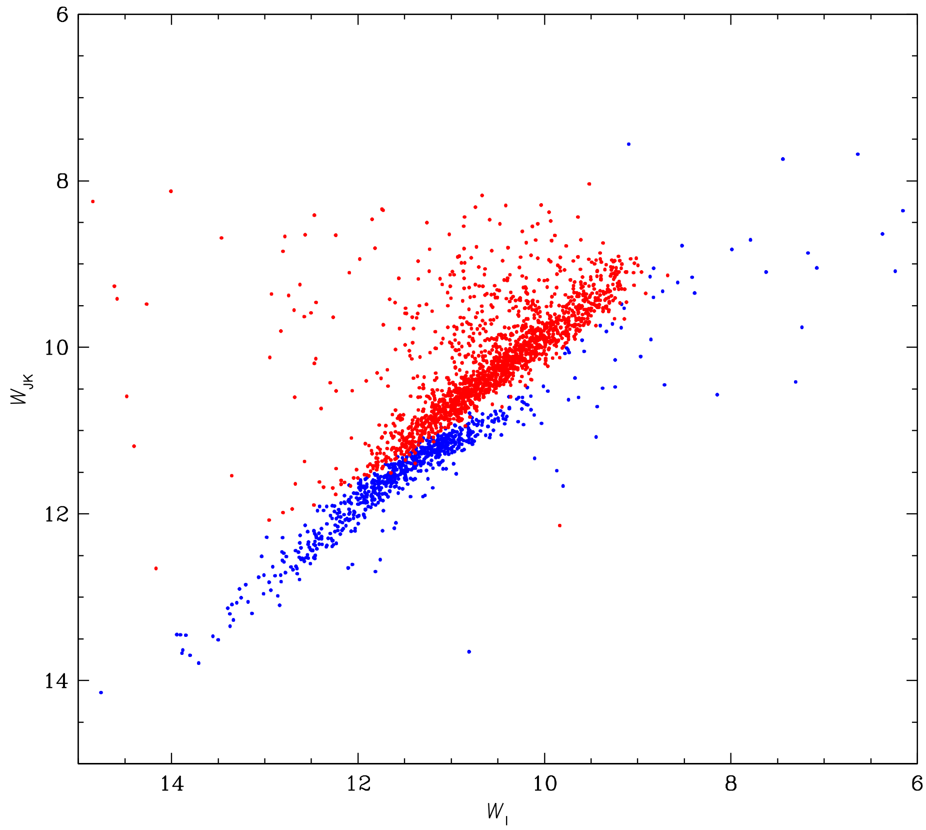

Fig. 1. $W_I - W_{JK}$ diagram for Miras and SRVs in the SMC. Blue points show O-rich, while red points represent C-rich stars.

(Soszyński *et al.* 2005), $(J - K_s)$ colors, and the morphology of light curves. Fig. 2 shows examples of typical light curves of O-rich and C-rich Miras. It is evident that C-rich LPVs exhibit significantly larger changes of the mean luminosity, which is likely connected with episodes of intensive mass loss. For stars included in the SIMBAD astronomical database[†] we compared our photometric solution with the spectroscopic determinations of the stellar types, and obtained a good agreement of both results.

To derive the amplitudes of the periodic variations we applied an iterative procedure of detrending light curves from slow irregular variations, common in C-rich variables. The period–amplitude diagram (Fig. 3) confirms a conclusion presented in Paper I that for C-rich stars there is a natural boundary between Miras and SRVs. In this work we use the same definition of Mira stars as in the catalog of LPVs in the LMC: Miras are pulsating stars which lie in the PL sequence C and have *I*-band peak-to-peak amplitudes larger than 0.8 mag. It is important to note that some stars with periods in sequence D satisfy the amplitude criterion, however their light

[†]http://simbad.u-strasbg.fr/simbad/

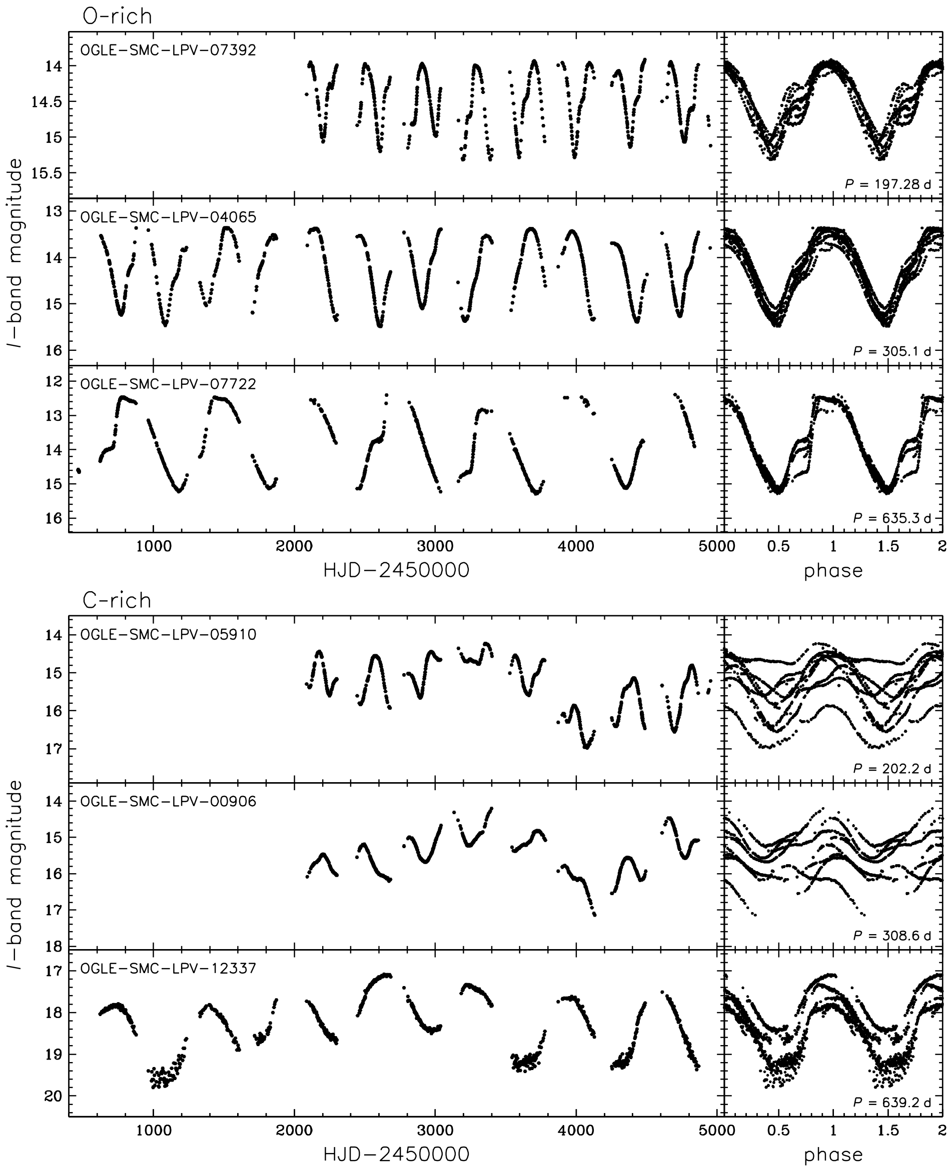

Fig. 2. OGLE-II (if available) and OGLE-III light curves of three typical O-rich Miras (three *upper panels*) and three C-rich Miras (three *lower panels*). Note different light curves of both spectral classes. *Left panels* show unfolded light curves, and *right panels* show the same light curves folded with the primary periods.

curves have very different shapes than Mira stars. Sequence D is populated by still unexplained long secondary periods observed in a large fraction of SRVs and OSARGs.

In contrast to the catalog of LPVs in the LMC (Paper I), we have not divided our sample into RGB and AGB stars. Obviously, the OSARGs brighter than the

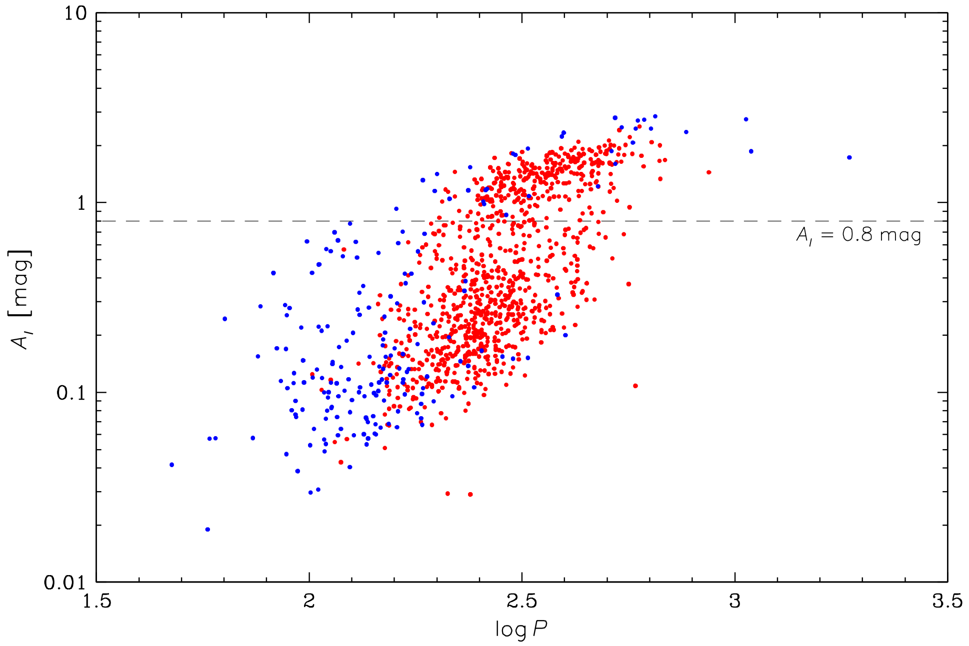

Fig. 3. Period–amplitude diagram for the sequence C stars (Miras and SRVs). Blue points show O-rich, while red points represent C-rich stars. Black dashed line mark the limiting amplitude ($A_I =$ 0.8 mag) used to separate Miras and SRVs in this paper.

tip of the RGB ($K_s \approx 12.7$ mag), and all SRVs and Miras are stars evolving along the AGB. The OSARG variables below the tip of the RGB are a mixture of RGB and AGB stars. Our method of distinguishing between RGB and AGB OSARGs described by Soszyński *et al.* (2004) worked well (at least in the statistical sense) for the LMC variables, where the PL relations are relatively well separated (however note the discussion about this method by Tabur *et al.* 2010). The significant extension of the SMC along the line of sight blurs the PL pattern and limits the application of our method.

4. Catalog of LPVs in the SMC

The catalog of LPVs in the SMC contains 19 384 objects, of which 16 810 have been classified as OSARGs, 2222 as SRVs and 352 as Miras. The proportion of different types of LPVs is more or less the same as in the LMC (Paper I). Both galaxies significantly differ in the relative number of O-rich and C-rich stars. In the SMC about 30% of SRVs and Miras are O-rich stars and 70% are C-rich giants. In the LMC SRVs and Miras divide roughly equally to the O-rich and C-rich stars. Among the SMC OSARG variables only a few percent of objects have been categorized as C-rich giants.

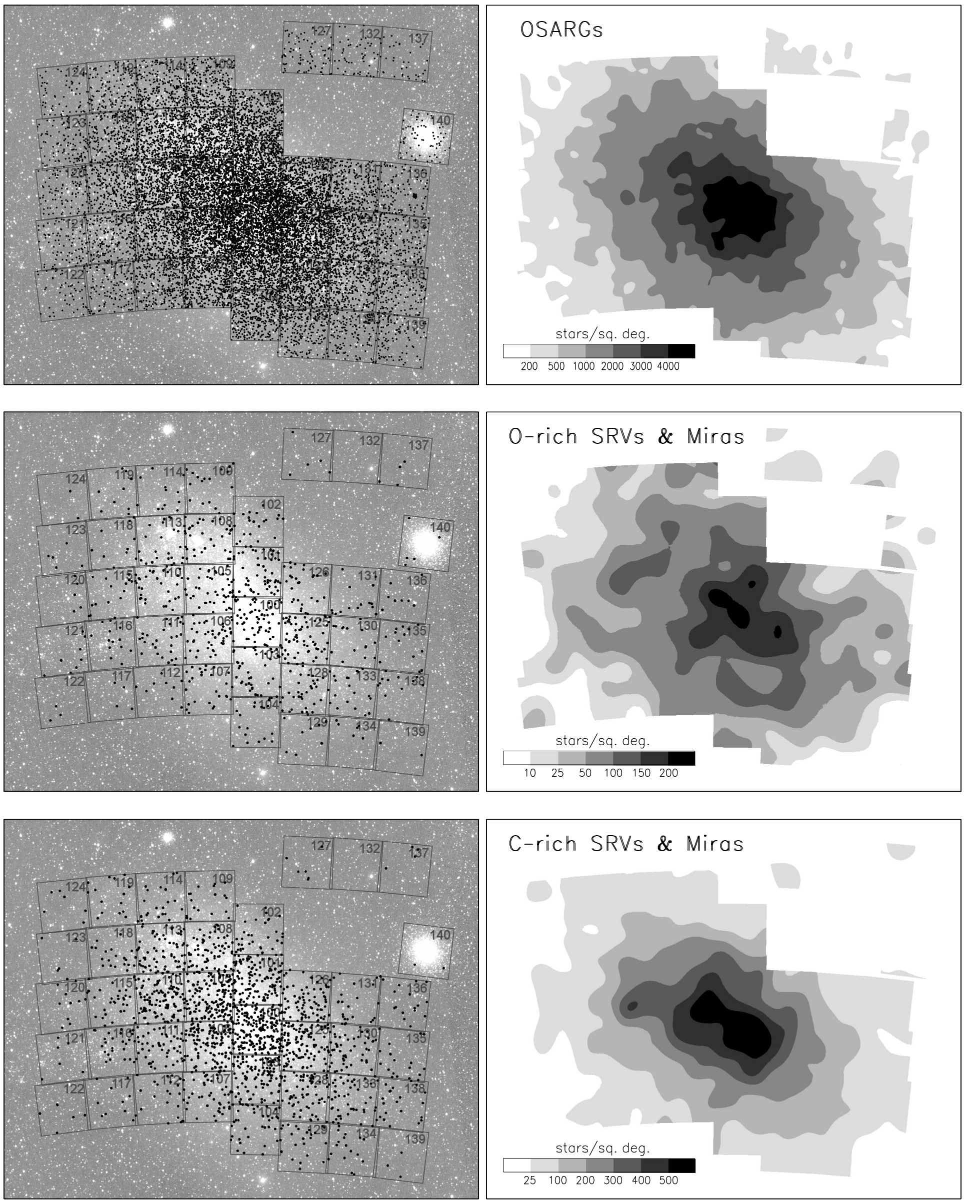

Fig. 4. Spatial distribution of LPVs in the SMC. *Left panels* show positions of stars overplotted on the SMC image originated from the ASAS sky survey (Pojmański 1997). Right panels present surface density maps obtained by the smoothing of the distributions with the Gaussian filter. *Upper panels* show OSARG variables, *middle panels* – O-rich SRVs and Miras and *bottom panels* – C-rich SRVs and Miras.

The catalog data are accessible through the anonymous FTP site or via the web interface:

ftp://ftp.astrouw.edu.pl/ogle/ogle3/OIII-CVS/smc/lpv/
http://ogle.astrouw.edu.pl/

The FTP site is organized as follows. The file named ident.dat contains the full list of LPVs with their classification and identification in other databases. The stars are organized in order of increasing right ascension and designated with symbols OGLE-SMC-LPV-NNNNN, where NNNNN is a five-digit consecutive number. The ident.dat file contains the following columns: the object designation, the OGLE-III field and the internal database number of the object, classification (Mira, SRV, OSARG), spectral type (O-rich, C-rich), equinox J2000.0 right ascension and declination, cross-identifications with the OGLE-II database (Szymański 2005), the MACHO photometric database, and the extragalactic part of the GCVS (Artyukhina et al. 1995). Files OSARGs.dat, SRVs.dat, and Miras.dat contain observational parameters of the relevant types of LPVs: mean magnitudes in the I and V bands, and three dominant periods with peak-to-peak I-band amplitudes for each star.

The files containing time-series photometry in the I and V bands are stored in the directory phot. Finding charts are in the directory fcharts. These are $60'' \times 60''$ subframes of the I-band DIA reference images, oriented with North to the top and East to the left. Additional information on some objects (long secondary periods, eclipsing or ellipsoidal variability, uncertain classification, etc.) are given in the file remarks.txt.

Fig. 4 presents the spatial distribution of LSPs in the SMC, separately for OSARGs, O-rich and C-rich SRV and Miras. The left panels show position of individual objects superimposed on the SMC image obtained from the ASAS project (Pojmański 1997), while the right panels display the same distribution smoothed with the Gaussian filter. Due to the low statistics it is difficult to clearly identify the differences between the distributions of O- and C-rich variables, as it was possible in the LMC (Paper I). However, it seems that the distribution of the C-rich SRVs and Miras in the sky is more elongated then the O-rich LPVs, as it was found in the LMC.

We judge the level of completeness of this catalog to be the same as in the catalog of LPVs in the LMC (Paper I). The comparison with the GCVS and the list of LPVs published by Raimondo *et al.* (2005) shows that we have found virtually all large and medium-amplitude variables in the OGLE-III fields, with the exception of several brightest stars, which are saturated in our database. The completeness decreases for OSARG variables with the smallest amplitudes ($A_I \lesssim 0.005$ mag), *i.e.*, the faintest ones. The solar-like oscillations with amplitudes much below the OGLE detection limits were observed in red giants by CoRoT and Kepler space telescopes (De Ridder *et al.* 2009, Gilliland, R.L., *et al.* 2010). Tabur *et al.* (2010) demonstrated a continuous transitions between these very low-amplitude oscillations and OSARGs. Thus our catalog comprise variables of the same class but with larger amplitudes and luminosities (Dziembowski and Soszyński 2010).

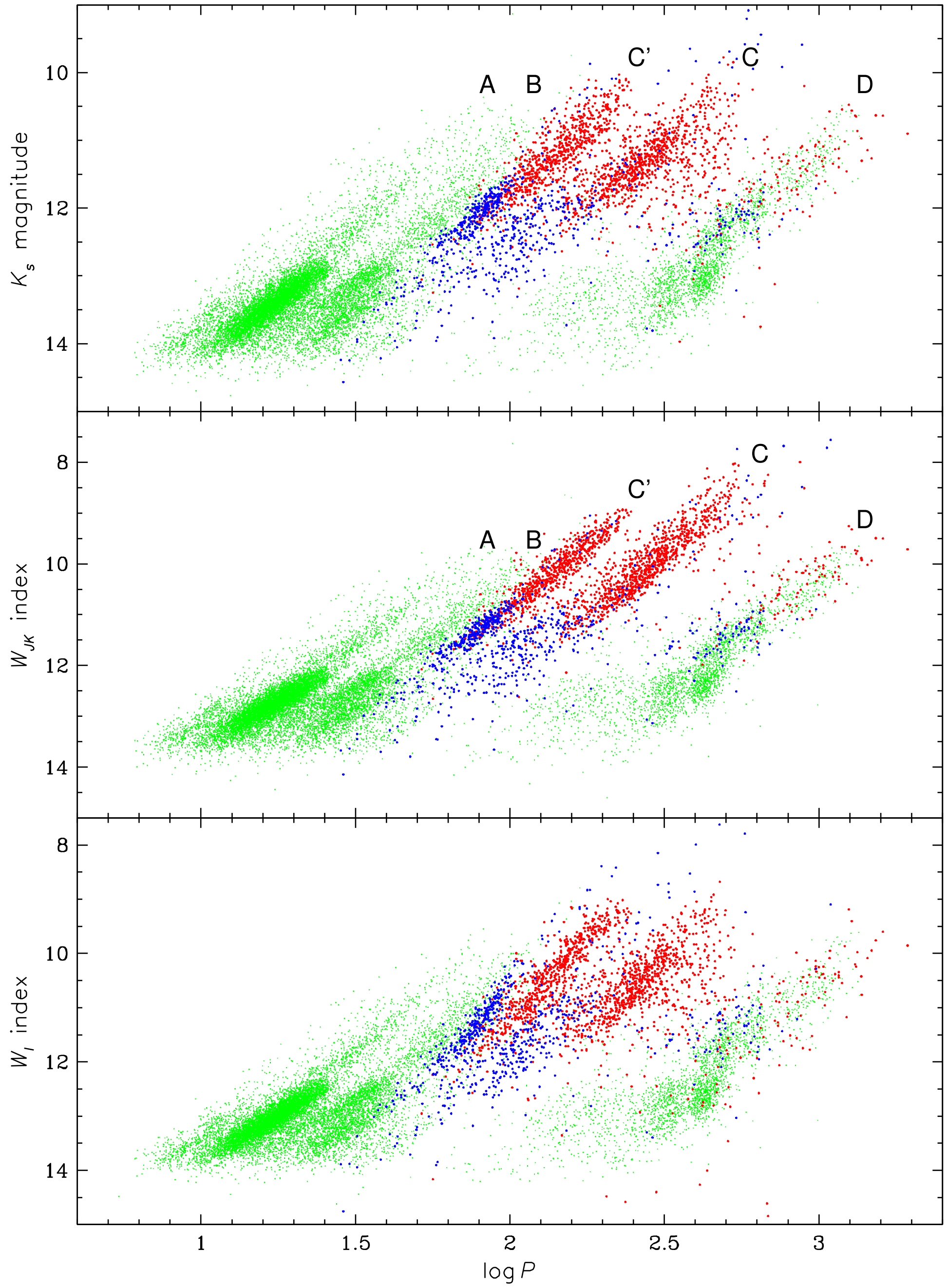

Fig. 5. Period–luminosity diagrams for LPVs in the SMC. *Upper, middle* and *bottom panels* show $\log P{-}K_s$, $\log P{-}W_{JK}$ and $\log P{-}W_I$ diagrams, respectively. Green points mark OSARG variables, blue points indicate O-rich Miras and SRVs, and red points show positions of C-rich Miras and SRVs. Each star is represented by one (the primary) period.

5. Discussion

Our catalog contains the largest sample of LPVs in the SMC ever published. It is natural to compare the red giant population in both Magellanic Clouds using the OGLE-III catalog of LPVs in the LMC (Paper I). Fig. 5 shows the relation between logarithm of the period and K_s, W_{JK} and W_I magnitudes. Variable stars are distributed on a series of different parallel relations. These relations were first discovered by Wood *et al.* (1999) from the analysis of LPVs in the LMC. The PL sequence C is populated by Miras and SRVs. Note that in the $\log P$–K_s plane some the longest-period stars in sequence C spread to low magnitudes, while this is not seen in the reddening free $\log P$–W_{JK} diagram. These faint sources, mainly Mira stars, are surrounded by thick circumstellar dust shells. Their magnitudes in the *I*-band are close to the detection limit of the OGLE project (20-21 mag).

The distribution of SMC SRVs in the PL diagrams, in particular in the $\log P$–W_{JK} plane (the middle panel of Fig. 5) confirms the existence of an additional PL ridge between sequences C and C$'$. The status of this sequence is unclear (additional mode of pulsation, different population of AGB stars?).

The most striking difference between LPVs in both Magellanic Clouds is the proportion of O-rich and C-rich stars. In Fig. 6 we present the distribution of W_{JK} magnitudes of SRVs and Miras in both systems. C-rich stars, which generally dominate among brighter Miras and SRVs, extend to fainter magnitudes in the SMC than in the LMC. A larger ratio of C-rich to O-rich stars in the SMC has been known for a long time (Blanco *et al.* 1980, Lloyd Evans 1988). This effect is related to the lower metallicity of the SMC (Iben and Renzini 1983). It is worth noting that the total distribution of magnitudes for SRVs and Miras is similar in both galaxies (taking into account different distance moduli). It means that AGB stars in the SMC become C-rich earlier than in the LMC, but this fact does not significantly affect the distribution of their reddening-free near-infrared brightness.

The huge OGLE catalog of LPVs is a source of particularly interesting, very rarely observed objects and phenomena. The light curves of three such exceptional stars are shown in Fig. 7. The upper panel presents OGLE-SMC-LPV-00861 – a SRV star with two outbursts with amplitudes 0.38 and 0.65 mag. Such a behavior is common in blue variables (Be stars), but very rare in red giants. It is possible that we observed a process of swallowing a planet by an expanding red giant (Retter *et al.* 2006). This object will be monitored by the OGLE survey in its fourth phase (OGLE-IV).

The middle panel of Fig. 7 shows the longest-period Mira star in our catalog – OGLE-SMC-LPV-08137 (IRAS00483-7347) – with the pulsation period exceeding 5 years. Actually, this is probably the longest-period Mira known in any environment. During 14 years of observations by the OGLE survey we covered only three maxima of this object. Groenewegen *et al.* (2009) considered this object as a good candidate for a super-AGB star, *i.e.*, an 8-11 $M_\odot$ counterpart of AGB stars.

Finally, the lower panel of Fig. 7 presents the light curve of a sequence D star,

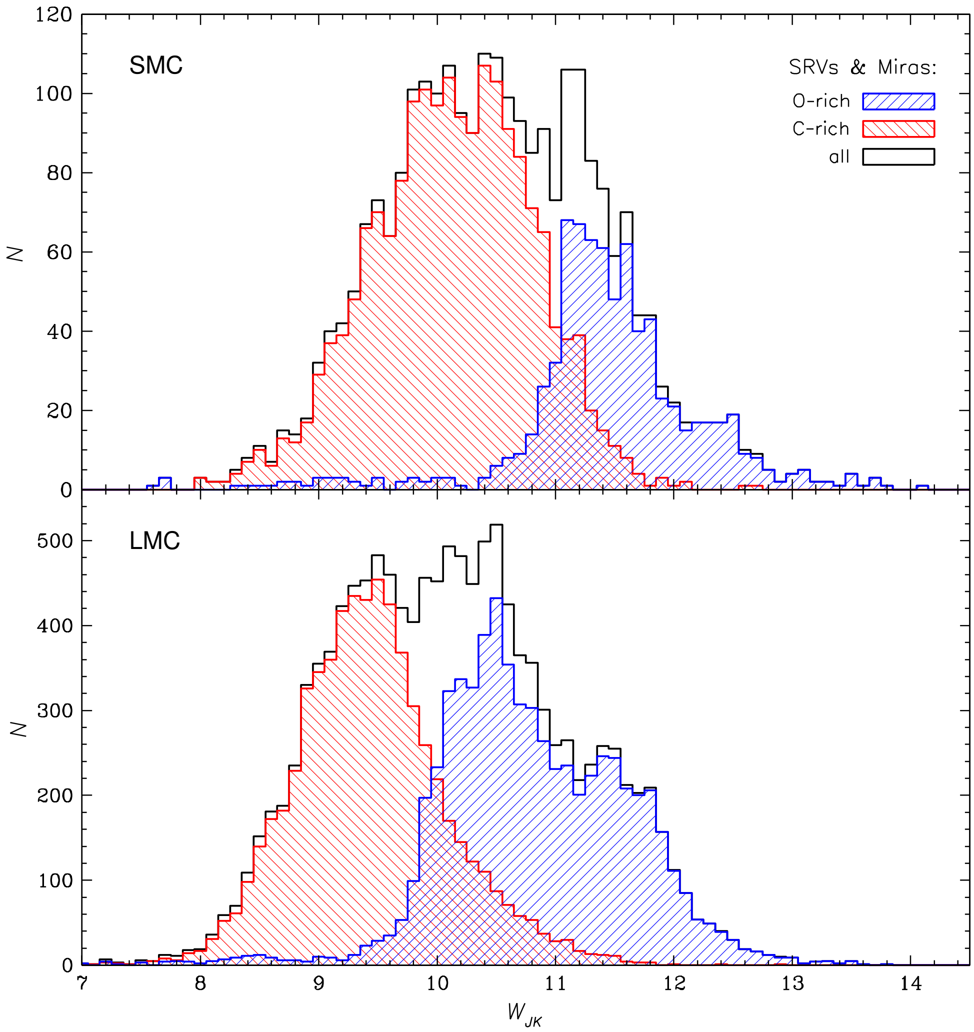

Fig. 6. Distribution of the reddening-free W_{JK} magnitudes for SRVs and Miras in the SMC (*upper panel*) and in the LMC (*lower panel*). Blue histograms show O-rich giants, red – C-rich stars and black – both spectral classes.

OGLE-SMC-LPV-14045. Our catalog contains at least two thousand OSARGs and SRVs with the primary periods corresponding to sequence D. Many more stars have secondary periods that appear in this sequence. The nature of these long-period variations is not yet understood, and the large samples of the sequence D stars detected in both Magellanic Clouds may give a clue to solve this puzzle. OGLE-SMC-LPV-14045 is an example of a sequence D star with a variable amplitude of the long-period variations. When the amplitude exceeded a certain value, the luminosity of this star decreased also in the maximum light. Such a behavior may be expected, if we assume that the sequence D variations are caused by a cloud of matter orbiting the star. During the episodes of intensified mass loss from the giant,

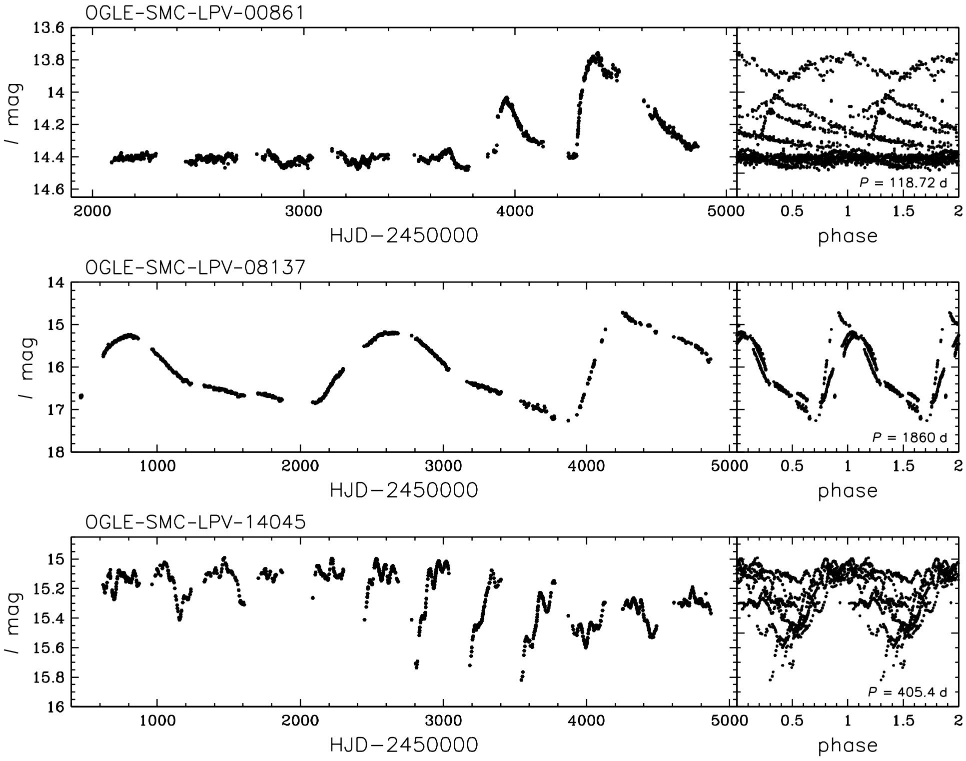

Fig. 7. Light curves of three interesting objects in our catalog. *Left panels* show unfolded light curves, and *right panels* show the same light curves folded with the primary periods. *Upper panels* present a SRV with outbursts. *Middle panels* show the longest-period Mira OGLE-SMC-LPV-08137. *Lower panels* contain a sequence D star with the changes of the mean luminosity which are correlated with the amplitude variations.

the cloud becomes denser and larger, which increases the amplitude of variations, and finally the whole star is obscured by dust, which decreases its mean luminosity.

Acknowledgements. We wish to thank W. Dziembowski for reading the manuscript and providing very useful suggestions. We are grateful to Z. Kołaczkowski, G. Pojmański and J. Skowron for providing software and data which enabled us to prepare this study.

The research leading to these results has received funding from the European Research Council under the European Community's Seventh Framework Programme (FP7/2007-2013)/ERC grant agreement no. 246678. This study made use of the SIMBAD database, operated at CDS, Strasbourg, France.

REFERENCES

Alard, C., and Lupton, R.H. 1998, *ApJ*, **503**, 325.
Artyukhina, N.M. *et al.* 1995, "General Catalogue of Variable Stars", 4rd Ed., vol. V. Extragalactic

Variable Stars, “Kosmosinform”, Moscow.
Blanco, V.M., McCarthy, M.F., and Blanco, B.M. 1980, *ApJ*, **242**, 938.
Cioni, M.-R.L., Blommaert, J.A.D.L., Groenewegen, M.A.T., Habing, H.J., Hron, J., Kerschbaum, F., Loup, C., Omont, A., van Loon, J.T., Whitelock, P.A., and Zijlstra, A.A. 2003, *A&A*, **406**, 51.
Cutri, R.M., *et al.* 2003, “2MASS All-Sky Catalog of Point Sources”.
Dartayet, M., and Landi Dessy, J. 1952, *ApJ*, **115**, 279.
De Ridder, J., Barban, C., Baudin, F., Carrier, F., Hatzes, A.P., Hekker, S., Kallinger, T., Weiss, W.W., Baglin, A., Auvergne, M., Samadi, R., Barge, P., and Deleuil, M. 2009, *Nature*, **459**, 398.
Dziembowski, W.A., and Soszyński, I. 2010, *A&A*, **524**, 88.
Gilliland, R.L., *et al.* 2010, *PASP*, **122**, 131.
Groenewegen, M.A.T. 2004, *A&A*, **425**, 595.
Groenewegen, M.A.T., Sloan, G.C., Soszyński, I., and Petersen, E.A. 2009, *A&A*, **506**, 1277.
Hoffleit, D. 1935, *Harv. Coll. Obs. Bull.*, **900**, 3.
Iben, I., Jr., and Renzini, A. 1983, *ARA&A*, **21**, 271.
Ita, Y., Tanabé, T., Matsunaga, N., Nakajima, Y., Nagashima, C., Nagayama, T., Kato, D., Kurita, M., Nagata, T., Sato, S., Tamura, M., Nakaya, H., and Nakada, Y. 2004a, *MNRAS*, **347**, 720.
Ita, Y., Tanabé, T., Matsunaga, N., Nakajima, Y., Nagashima, C., Nagayama, T., Kato, D., Kurita, M., Nagata, T., Sato, S., Tamura, M., Nakaya, H., and Nakada, Y. 2004b, *MNRAS*, **353**, 705.
Kato, D., *et al.* 2007, *PASJ*, **59**, 615.
Kiss, L.L., and Bedding, T.R. 2004, *MNRAS*, **347**, L83.
Lah, P., Kiss, L.L., and Bedding, T.R. 2005, *MNRAS*, **359**, L42.
Lloyd Evans, T. 1971, in: “The Magellanic Clouds”, ed. A.B. Muller (Reidel, Dordrecht), p. 74.
Lloyd Evans, T. 1978a, *MNRAS*, **183**, 305.
Lloyd Evans, T. 1978b, *MNRAS*, **183**, 319.
Lloyd Evans, T., Glass, I.S., and Catchpole, R.M. 1988, *MNRAS*, **231**, 773.
McKibben Nail, V. 1942, *Ann. Harv. Coll. Obs.*, **109**, 27.
Payne-Gaposchkin, C., and Gaposchkin, S. 1966, *Smithsonian Contrib. Astrophys.*, **9**, 1.
Pojmański, G. 1997, *Acta Astron.*, **47**, 467.
Raimondo, G., Cioni, M.-R.L., Rejkuba, M., and Silva, D.R. 2005, *A&A*, **438**, 521.
Retter, A., Zhang, B., Siess, L., and Levinson, A. 2006, *MNRAS*, **370**, 1573.
Schechter, P.L., Mateo, M., and Saha, A. 1993, *PASP*, **105**, 1342.
Schultheis, M., Glass, I.S., and Cioni, M.-R. 2004, *A&A*, **427**, 945.
Shapley, H., Yamamoto, I., and Wilson, H.H. 1925, *Harv. Coll. Obs. Circ.*, **280**, 1.
Shapley, H., and McKibben Nail, V. 1951, *Proc. Nat. Acad. Sci.*, **37**, 138.
Soszyński, I., Udalski, A., Kubiak, M., Szymański, M., Pietrzyński, G., Żebruń, K., Szewczyk, O., and Wyrzykowski, Ł. 2004, *Acta Astron.*, **54**, 129.
Soszyński, I., Udalski, A., Kubiak, M., Szymański, M., Pietrzyński, G., Żebruń, K., Szewczyk, O., Wyrzykowski, Ł., and Ulaczyk, K. 2005, *Acta Astron.*, **55**, 331.
Soszyński, I., Dziembowski, W.A., Udalski, A., Kubiak, M., Szymański, M.K., Pietrzyński, G., Wyrzykowski, Ł., Szewczyk, O., and Ulaczyk, K. 2007, *Acta Astron.*, **57**, 201.
Soszyński, I., Udalski, A., Szymański, M.K., Kubiak, M., Pietrzyński, G., Wyrzykowski, Ł., Szewczyk, O., Ulaczyk, K., and Poleski, R. 2009, *Acta Astron.*, **59**, 239 (Paper I).
Szymański, M.K. 2005, *Acta Astron.*, **55**, 43.
Tabur, V., Bedding, T.R., Kiss, L.L., Giles, T., Derekas, A., and Moon, T.T. 2010, *MNRAS*, **409**, 777.
Thackeray, A.D. 1958, *MNRAS*, **118**, 117.
Udalski, A. 2003, *Acta Astron.*, **53**, 291.
Udalski, A., Szymański, M.K., Soszyński, I., and Poleski, R. 2008, *Acta Astron.*, **58**, 69.
Wood, P.R., *et al.* (MACHO team) 1999, in: *IAU Symp.* 191, “Asymptotic Giant Branch Stars”, Ed. T. Le Bertre, A. Lébre, and C. Waelkens (San Francisco: ASP), p. 151.
Woźniak, P.R. 2000, *Acta Astron.*, **50**, 421.
Wray, J.J., Eyer, L., and Paczyński, B. 2004, *MNRAS*, **349**, 1059.