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The Optical Gravitational Lensing Experiment. The OGLE-III Catalog of Variable Stars. XV. Long-Period Variables in the Galactic Bulge*

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ABSTRACT

The fifteenth part of the OGLE-III Catalog of Variable Stars (OIII-CVS) contains 232 406 long-period variables (LPVs) detected in the OGLE-II and OGLE-III fields toward the Galactic bulge. The sample consists of 6528 Mira stars, 33 235 semiregular variables and 192 643 OGLE small amplitude red giants. The catalog data and data resources that are being published include observational parameters of stars, finding charts, and time-series *I*- and *V*-band photometry obtained between 1997 and 2009.

We discuss statistical features of the sample and compare it with collections of LPVs in the Magellanic Clouds. The vast majority of red giant stars in the Galactic bulge have an oxygen-rich chemistry. Mira variables form a separate group in the period–amplitude diagram, which was not noticed for oxygen-rich Miras in the Magellanic Clouds. We find a clear deficit of long-secondary period stars toward the Galactic center compared to the sample of Magellanic Clouds' LPVs.

Key words: *Stars: AGB and post-AGB – Stars: late-type – Stars: oscillations (including pulsations) – Galaxy: center*

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

1. Introduction

Long-period variables (LPVs) constitute a very numerous class of variable stars, because practically all the stars on the red giant branch (RGB) and asymptotic giant branch (AGB) that are brighter than a given magnitude limit show intrinsic variability. Generally, the brighter is a giant star, the larger is the amplitude of the light variations, so this limiting magnitude depends on the accuracy of our luminosity measurements. Studies of LPVs allow us to address advanced questions regarding stellar structures, evolution and pulsation theory. Variable red giants are also promising distance indicators, giving the opportunity to study structures of stellar environments where they appear.

The first significant sample of over 200 LPVs in the central region of the Milky Way was found by Shapley and Swope (1934) and Swope (1935, 1938, 1940). The spatial distribution and mean magnitudes of this sample was used to study the interstellar extinction toward the Galactic center. Baade (1946) reported a discovery of about 100 LPVs (a detailed list of these objects was given by Gaposchkin 1955) in the relatively low-extinction region centered upon the globular cluster NGC 6522 and known today as Baade's Window. Then, Ponsen (1957), Hoffleit (1957) and Lloyd Evans (1976) increased the number of known LPVs in the Galactic bulge to about a half thousand. Wood and Bessell (1983) studied 51 of LPVs in the Galactic center and showed that variables with periods longer than 250 days are significantly redder than LPVs in the solar vicinity as well as in the Magellanic Clouds. This was interpreted as a result of higher metallicity of stars in the Galactic center. Whitelock and Catchpole (1992) used Mira stars to show that the bulge has a bar-like structure. A near-infrared (near-IR) survey for LPVs in the inner bulge, within about 30 pc of the Galactic center, was conducted by Glass *et al.* (2001), who reported the discovery of 409 large-amplitude LPVs. Matsunaga *et al.* (2009) surveyed the same region with deeper near-IR photometry and identified 1364 variables which were used to estimate the extinction and distance to the Galactic center.

Large-scale variability surveys, like MACHO and Optical Gravitational Lensing Experiment (OGLE), greatly improved our knowledge of the properties of pulsating red giants. Minniti *et al.* (1998) presented preliminary results of the search for semiregular variables (SRVs) in the bulge using the photometric data collected by the MACHO project. They reported the discovery of about 2000 SRVs which followed two parallel sequences in the period–color diagram. Alard *et al.* (2001) used MACHO photometry to study the mass loss in about 300 AGB stars in the Galactic bulge. Glass and Schultheis (2003) extended this sample to more than 1000 objects and showed a series of four sequences in the $\log P - K$ magnitude plane – similar to those discovered by Wood *et al.* (1999) in the Large Magellanic Cloud (LMC).

Photometric data collected during the second phase of the OGLE project (OGLE-II) were used by Wray, Eyer and Paczyński (2004) to identify and study over 15 000 OGLE small amplitude red giants (OSARGs) in the Galactic bulge. Wray *et al.*

(2004), among others, showed that these stars also trace the Galactic bar. Woźniak, McGowan and Vestrand (2004) searched for rapid variability events in the Galactic bulge Mira stars observed by the OGLE-II survey and reported no such behavior. Groenewegen and Blommaert (2005) extracted from the OGLE-II databases 2691 Mira light curves and used them to discuss the structure and distance of the Galactic center. Matsunaga, Fukushi and Nakada (2005) compared the properties of 1968 Miras detected in the OGLE-II bulge fields with LPVs observed in the Magellanic Clouds.

In this paper we present a catalog which dramatically increases the number of known LPVs in the Galactic bulge – from thousands to hundreds of thousands. This catalog is a part of the OGLE-III Catalog of Variable Stars (OIII-CVS). To date in this series we published, among others, the catalogs of RR Lyr stars (Soszyński *et al.* 2011a) and Cepheids (Soszyński *et al.* 2011c) in the Galactic bulge, and the catalogs of LPVs in the Large (Soszyński *et al.* 2009) and Small Magellanic Cloud (SMC, Soszyński *et al.* 2011b). The long-term time-series photometry of all stars in the Catalog is available from the OGLE Internet Archive.

2. Observational Data

The OGLE-III survey toward the Galactic center lasted from 2001 to 2009. Observations were obtained with the 1.3 m Warsaw Telescope, located at the Las Campanas Observatory in Chile. The observatory is operated by the Carnegie Institution for Science. The telescope was equipped with the mosaic camera consisting of eight 2048×4096 detectors, with a combined field of view of $35' \times 35.'5$ yielding a scale of approximately 0.26 arcsec/pixel. Details of the instrumentation setup can be found in the paper by Udalski (2003). In this catalog we used also observations collected between 1997 and 2000 in the course of the OGLE-II project. By that time the Warsaw Telescope was equipped with the "first generation" camera with a SITe 2048×2048 CCD detector working in drift-scan mode (Udalski, Kubiak and Szymański 1997).

In this study we analyzed exactly the same area as in the catalogs of RR Lyr stars and Cepheids in the Galactic bulge (Soszyński *et al.* 2011ac) with the total field of 68.7 square degrees. Most of the observations were obtained with the Cousins *I* photometric band. From a few to several dozen points were collected in the Johnson *V*-band. The number of *I*-band observations and the time coverage significantly varies from field to field – from about 100 points collected over two years to more than 3000 observations obtained between 1997 and 2009 (OGLE-II + OGLE-III). Additionally, for the purpose of the period determination, we supplemented the light curves of some LPVs by adding the OGLE-IV observations collected in 2011 and 2012, but this photometry is not published in this catalog. Some stars were identified twice or more times, because they were located in the overlapping regions between adjacent fields. In such cases we selected for publication the light curve from only one of these fields – usually this one that consists of a larger number of points.

The OGLE project routinely uses the technique of Different Image Analysis (DIA, Alard and Lupton 1998, Woźniak 2000) to obtain accurate photometry of monitored stars. The DIA reference frames for each field are constructed from a stack of the ≈ 10 best images (with low seeing and low background). Most of the stars brighter than about $I = 12.5$ mag are saturated. The saturation limit for the OGLE-II data is slightly brighter, about $I = 11.5$ mag. For about 1600 LPVs that are overexposed in the DIA reference frames we provide the DOPHOT *I*-band photometry (Schechter, Mateo and Saha 1993) and flag these stars in the Remarks of the catalog. Note that only a small fraction of overexposed LPVs in the Galactic bulge were included in our catalog. More information on the photometric reduction pipeline, photometric calibrations and astrometric transformations can be found in Udalski *et al.* (2008).

For the classification purposes we cross-matched our sample with the 2MASS All-Sky Catalog of Point Sources (Cutri *et al.* 2003) obtaining near-IR J and K_s magnitudes. Following Dutra, Santiago and Bica (2002) we assumed the relation between extinction and reddening for the 2MASS magnitudes as

$$A_{K_s} = 0.670E(J-K_s)$$

and we defined the reddening-free near-IR Wesenheit index as

$$W_{JK} = K_s - 0.670(J-K_s).$$

3. Selection and Classification of Long-Period Variables

LPVs in the Galactic bulge were identified with procedures similar to those used in the Magellanic Clouds (Soszyński *et al.* 2009, 2011b). First, we calculated periodograms for each of the 3×10^8 *I*-band light curves obtained by the OGLE-II and OGLE-III projects in the Galactic bulge. We searched the frequency space from 0.0005 to 0.2 day^{-1} (periods from 5 to 2000 days) with a resolution of 10^{-6} day^{-1} using the FNPEAKS code (Z. Kołaczkowski, private communication). For each star we found five periods, iteratively fitting and subtracting third-order Fourier series from light curves folded with consecutive periods. For each period we also determined and recorded an amplitude, defined as a difference between maximum and minimum value of the third-order Fourier series fitted to the residual light curve.

The selection and classification of LPVs was primarily based on the light curve shapes. We visually inspected light curves of all stars brighter than $I = 13$ mag and for fainter objects we limited our sample to the light curves with larger amplitudes of variability, larger scatter of the observing points, or ratios of periods typical for OSARG variables. In the selection procedure we also took into account the $(V-I)_0$ color index of each star, dereddened with the reddening maps of Nataf *et al.* (2013).

Following the OGLE-III catalogs of LPVs in the Magellanic Clouds (Soszyński *et al.* 2009, 2011b) we divided our sample into three classes: Miras, SRVs and OSARGs. Stars with peak-to-peak amplitudes of the *I*-band light curves larger than 0.8 mag were classified as Miras. Separation of SRVs and OSARG variables is more difficult, in particular in the Galactic bulge, where period–luminosity sequences are significantly broadened by the depth along the line of sight. We took into account characteristic ratios of periods of OSARG stars, amplitudes, and positions in the near-IR period–luminosity diagrams. However, we cannot exclude the possibility that some of the LPVs in our catalog are incorrectly classified, especially for objects with a small number of observing points.

Similarly, our catalog may contain a limited number of objects other than LPVs. For example, during our search we detected tens of thousands rotating spotted stars. In Fig. 1 we show three example light curves of SRVs and three light curves of spotted variables. Although phased light curves may look similar in both classes of variable stars, because SRVs and spotted variables exhibit similar periods and variable amplitudes, the difference is visible in the unfolded light curves. LPVs generally have multi-periodic light curves and their amplitudes change from cycle to cycle, while spotted variables usually show only one (rotation) period and the variations of amplitudes are much slower. Nevertheless, distinguishing between LPVs and spotted variables may not be trivial for small-amplitude stars or for objects with a small number of observations. Thus, we cannot exclude that there is a number of spotted variables rather than pulsating red giants among the smallest amplitude variables in our catalog. Also, our sample may still contain a small number of young stellar objects, foreground red dwarfs and background quasars.

In the catalogs of LPVs in the Magellanic Clouds (Soszyński *et al.* 2009, 2011b) we divided our samples into oxygen-rich and carbon-rich stars using their position in the optical Wesenheit index *vs.* near-IR Wesenheit index diagram. In this catalog we cannot use the same method, because of the considerable depth of the Galactic bulge along the line of sight. However, in the Magellanic Clouds we noticed that both spectroscopic types of AGB stars show different morphology of their light curves (Soszyński *et al.* 2011b). C-rich Miras and SRVs usually exhibit irregular changes of their mean luminosity, while O-rich LPVs show much more stable light curves with one or more pulsating modes. The vast majority of the LPVs in the Galactic bulge show the latter behavior, so we recognize them as O-rich giants. This confirms earlier spectroscopic findings of an extremely low ratio of C-rich to O-rich giants in the Galactic bulge (Blanco, McCarthy and Blanco 1984), which is expected in high-metallicity environments. We found several SRVs and Miras with light curves similar to C-rich giants in the Magellanic Clouds and we flagged them as "possible C-rich stars" in the Remarks of the catalog. Their status has to be confirmed spectroscopically. One of the candidates from this list, namely OGLE-BLG-LPV-149402, has recently been found as the first C-rich Mira in the

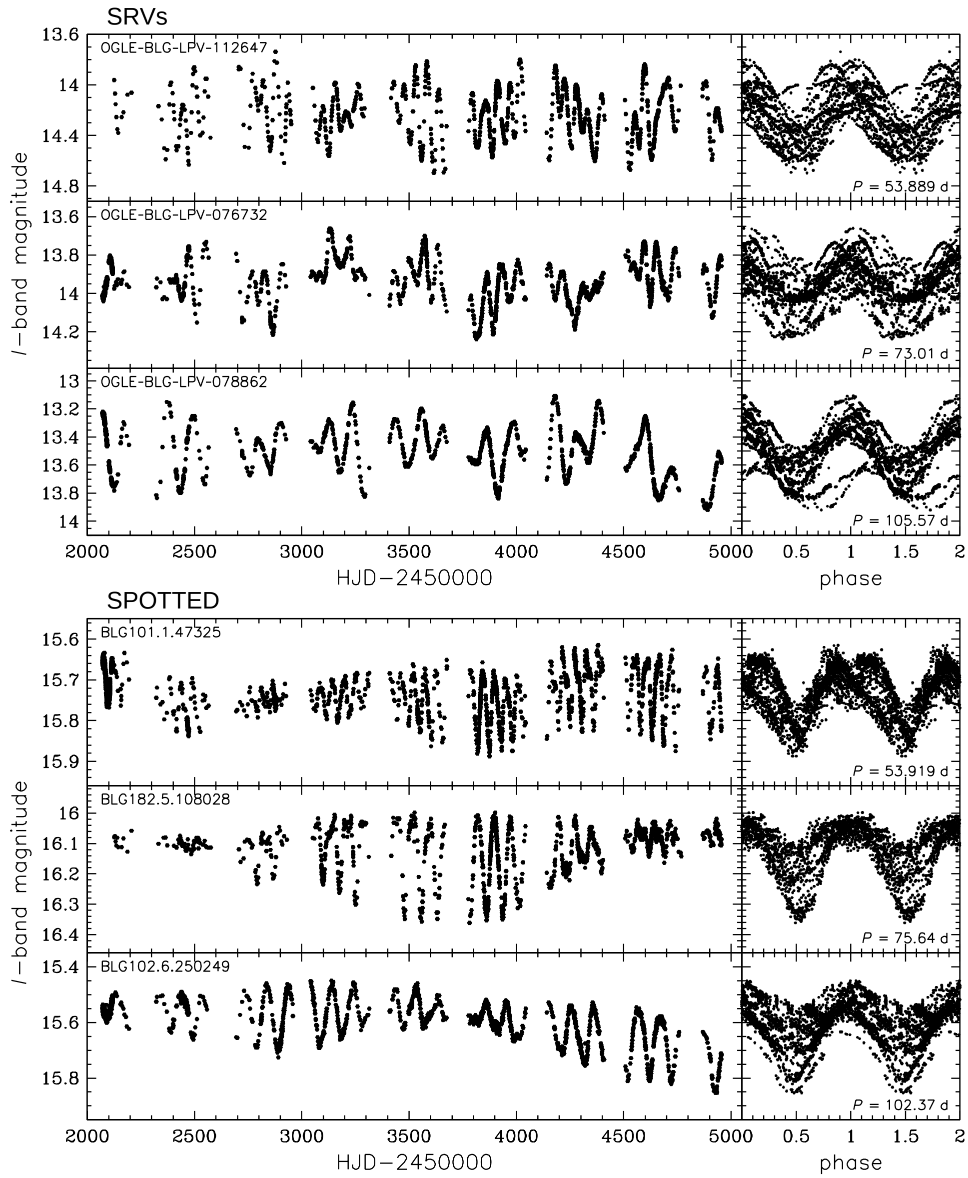

Fig. 1. Example light curves of three SRVs (*upper panels*) and three spotted stars (*lower panels*). *Left panels* show unfolded light curves, and *right panels* show the same light curves folded with the pulsation (SRVs) or rotation (spotted stars) periods. Note the difference in amplitude variations visible in the unfolded light curves.

Galactic bulge by the spectroscopic survey of the symbiotic star candidates (Miszalski, Mikołajewska and Udalski (2013).

The catalog contains some red giants which exhibit eclipsing or ellipsoidal modulation of their light curves, *i.e.,* which are members of close binary systems. We left these objects on our list only when they simultaneously showed pulsa-

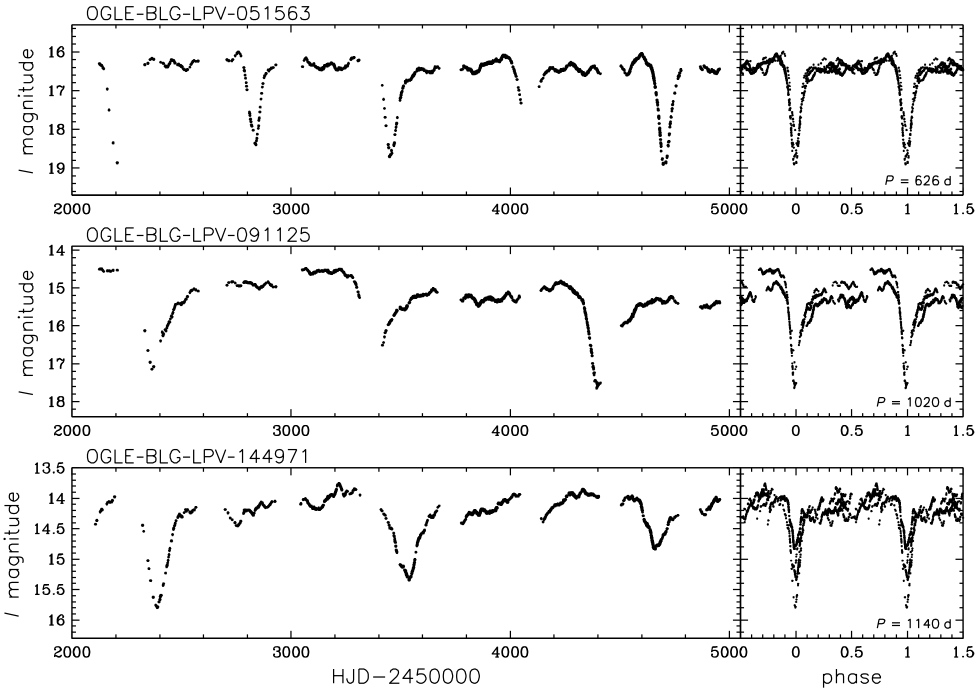

Fig. 2. Example light curves of LPVs with very deep, regular, eclipsing-like minima in their light curves. *Left panels* show unfolded light curves, while *right panels* show the same light curves phased with the periods of the eclipsing-like minima.

tions as OSARGs or SRVs. The primary periods of these stars given in the catalog usually correspond to half of the orbital periods, because such periods were automatically found by our period-searching code. About 800 distinct eclipsing or ellipsoidal red giants are flagged in the Remarks. Besides close binary systems, our catalog contains several SRVs and OSARGs that show eclipsing-like relatively narrow minima often of a very large depth (>1 mag). Three example light curves of such objects are shown in Fig. 2. It is worth noting that some of these objects may belong to the symbiotic stars class. Miszalski *et al.* (2013) recently presented a spectroscopically selected sample of symbiotic star candidates containing many objects listed in our catalog.

During the search for LPVs in the Galactic bulge several gravitational microlensing events with LPV Galactic bulge targets were serendipitously found. This is not surprising as with the OGLE discovery rate of microlensing phenomena of non-variable stars toward the Galactic center (OGLE EWS System, Udalski 2003) one can expect significant sample of microlensing events of variable sources as well. All microlensing events found during our search are marked in the Remarks. Fig. 3 shows two spectacular examples of microlensing phenomena that occurred on OSARG variables.

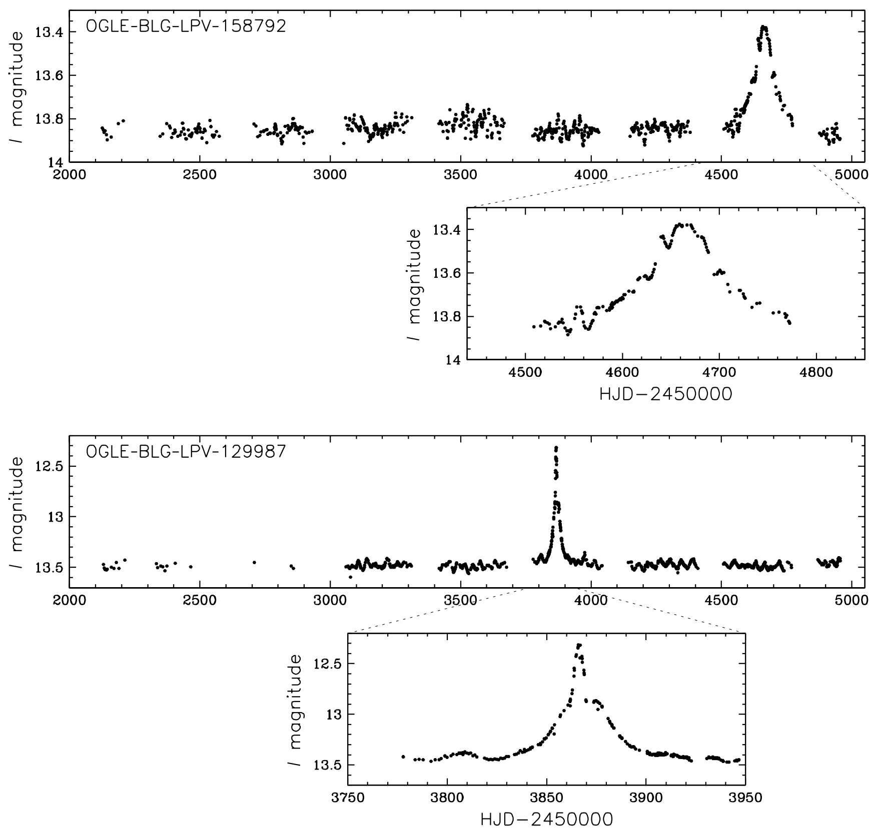

Fig. 3. Light curves of two gravitational microlensing phenomena on OSARG variables: OGLE-BLG-LPV-158792 and OGLE-BLG-LPV-129987

4. Catalog of Long-Period Variables in the Galactic Bulge

The catalog of LPVs in the Galactic bulge contains 232 406 objects, of which 6528 have been classified as Miras, 33 235 as SRVs and 192 643 as OSARGs. The proportion of different types of LPVs is similar to those in the Magellanic Clouds, with somewhat larger fraction of Miras (2.8% of the total sample in the Galactic bulge *vs.* 1.8% in the Magellanic Clouds), and slightly larger fraction of SRVs (14% *vs.* 12%). These differences may reflect the difficulties in classification of stars with the smallest amplitudes (OSARGs) in the regions of high interstellar extinction or in the fields with a relatively small number of observations (fields in the Magellanic Clouds were monitored much more homogeneously).

The catalog and data on particular objects are accessible through the anonymous FTP site or *via* the WWW interface:

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

The FTP site is organized as follows. The lists of LPVs with their J2000 equatorial coordinates, classification, identifications in the OGLE-II and OGLE-III databases and in the General Catalogue of Variable Stars (Samus *et al.* 2011) are given in the ident.dat file. The stars are arranged in order of increasing right ascension and designated OGLE-BLG-LPV-NNNNNN, where NNNNNN is a six-digit consecutive number.

The observational parameters of each star – mean magnitudes in the *I*- and *V*-bands, periods, and amplitudes – are given in the files Miras.dat, SRVs.dat and OSARGs.dat, separately for each type of LPVs. The files contain three periods per star found with the FNPEAKS code. Only for larger-amplitude variables and only the first period was visually verified and corrected, if necessary. In most LPVs the first given period corresponds to the pulsation period, or half of the orbital period (for binary systems), or the long secondary period. The second and the third periods provided in the catalog files were calculated fully automatically and may be spurious in some cases. For the in-depth analysis of the periodicity of LPVs from our catalog we recommend the reader to perform an independent frequency search using multi-epoch OGLE photometry.

The time-series *I*- and *V*-band photometry is given in separate files in the subdirectory phot/. The subdirectory fcharts/ contains finding charts for all objects. These are $60'' \times 60''$ subframes of the *I*-band DIA reference images, oriented with North up, and East to the left. The file remarks.txt contains additional information about some objects.

The completeness of our catalog strongly depends on the brightness of stars, their amplitude of light variability, interstellar extinction toward a given star, the number and time span of observations of a given field, etc. We checked the general efficiency of our variable star selection by comparing objects located in the overlapping parts of adjacent fields. Assuming that the minimum number of observing points must be larger than 100, in total 10 788 LPVs from our catalog were recorded in the OGLE databases twice – in the neighboring fields, so we had an opportunity to independently detect 21 576 counterparts. During the search we found 19 285 of them which corresponds to the 89% completeness of the total sample. We carefully looked through the light curves that had been missed during the search and we found that most of these objects had very small amplitudes, usually at the detection limits of the OGLE photometry. The same method applied only to SRVs and Miras gave much larger completeness – above 98%. However, one should keep in mind that these values concern only those stars that can be detected by OGLE, with luminosities below the saturation limit and with amplitudes above a few milimagnitudes.

Upper panel of Fig. 4 shows how the LPVs in our catalog are distributed in the sky. This is a Gaussian-smoothed stellar density map. As can be seen, the number of LPVs rises toward the Galactic center, with the exception of the regions that are closest to the center, where the large extinction prevents detection of LPVs with

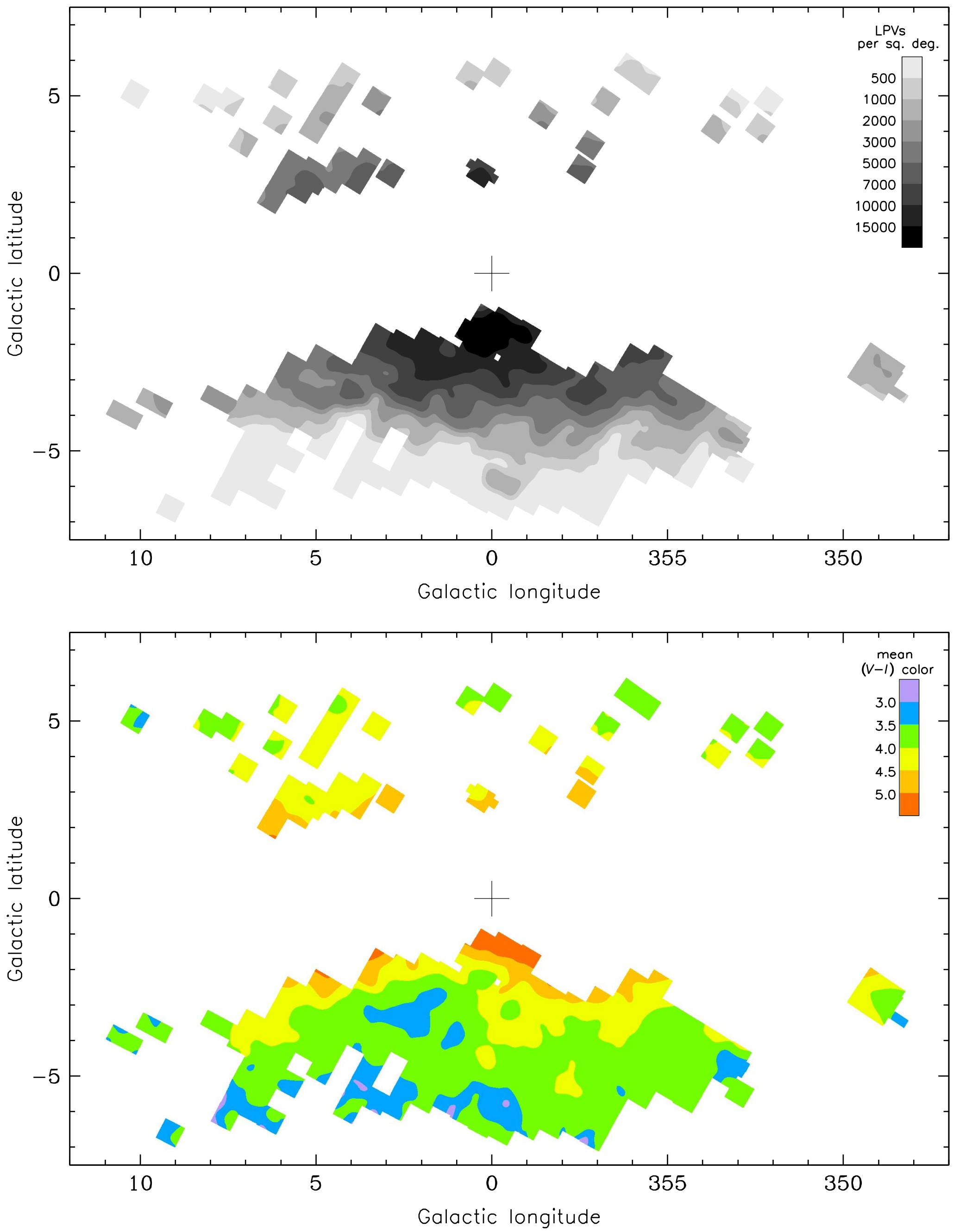

Fig. 4. *Upper panel*: surface density map of LPVs in the Galactic bulge. The map was obtained by blurring the spatial distribution of LPVs with a Gaussian filter. *Lower panel*: spatial distribution of the mean apparent $(V-I)$ colors of LPVs in the Galactic bulge.

small amplitudes. In the lower panel of Fig. 4 we present a map of the mean apparent $(V-I)$ colors of our red giants. This map illustrates the spatial distribution of the interstellar extinction toward the Galactic center.

5. Discussion

The OGLE-III catalog of LPVs in the Galactic bulge is probably the largest single collection of variable stars ever published. Together with the already published parts of the OIII-CVS our catalog contains in total over 400 000 variable stars in the Galactic bulge and Magellanic Clouds. This huge sample of variable stars may be used for various studies of the features and evolution of the stars themselves, as well as the structure and history of the stellar environments in which they are observed.

Distribution of variable red giant stars in the period–luminosity (PL) plane reveals a rather complex picture. Wood *et al.* (1999) discovered five sequences in the PL diagram for LPVs and since that time the number of known PL relationships obeyed by LPVs grows continuously (*cf.* Soszyński and Wood 2013). Red giants are often affected by significant circumstellar extinction and the PL relations are the narrowest in the near-IR band-passes, in particular in the reddening-independent Wesenheit index W_{JK}. In Fig. 5 we plot the PL diagrams for LPVs in the Galactic bulge using the 2MASS K_s band and W_{JK}. Each star is represented by only one (the primary) period. The well-known series of PL sequences observed in the Magellanic Clouds is blurred by the larger depth along the line of sight, however one can easily distinguish sequence C occupied by Miras and SRVs, sequence C$'$ populated by SRVs and sequence D formed by still unexplained long secondary periods (LSPs). The PL relations of OSARG variables overlap each other, but they may be to some extent separated by means of the characteristic period ratios of these multi-periodic oscillators. LPVs are promising distance indicators, however all previous distance estimations to the Galactic center from LPVs (Glass and Feast 1982, Glass *et al.* 1995, Groenewegen and Blommaert 2005, Matsunaga *et al.* 2009) used solely Mira stars, while SRVs and OSARGs also may be used for this purpose. Low-amplitude LPVs are much more numerous than Miras and follow a series of well defined PL relations.

Histograms showing the distribution of primary periods of OSARGs in the Galactic bulge and in the Magellanic Clouds (Soszyński *et al.* 2009, 2011b) are plotted in Fig. 6. The striking difference between OSARGs in the Galactic center and in the Magellanic Clouds appears for stars with LSPs ($2.2 < \log P < 3.1$). In the Galactic bulge, giants exhibiting this mysterious phenomenon are much less frequent than in the Magellanic Clouds. We tested if this could be an effect of shorter monitoring times of the subset of fields toward the Galactic bulge. To do this we have constructed period distribution for OSARG variables which had 5 years or longer light curves. We noted virtually no difference between this distribution and the full sample.

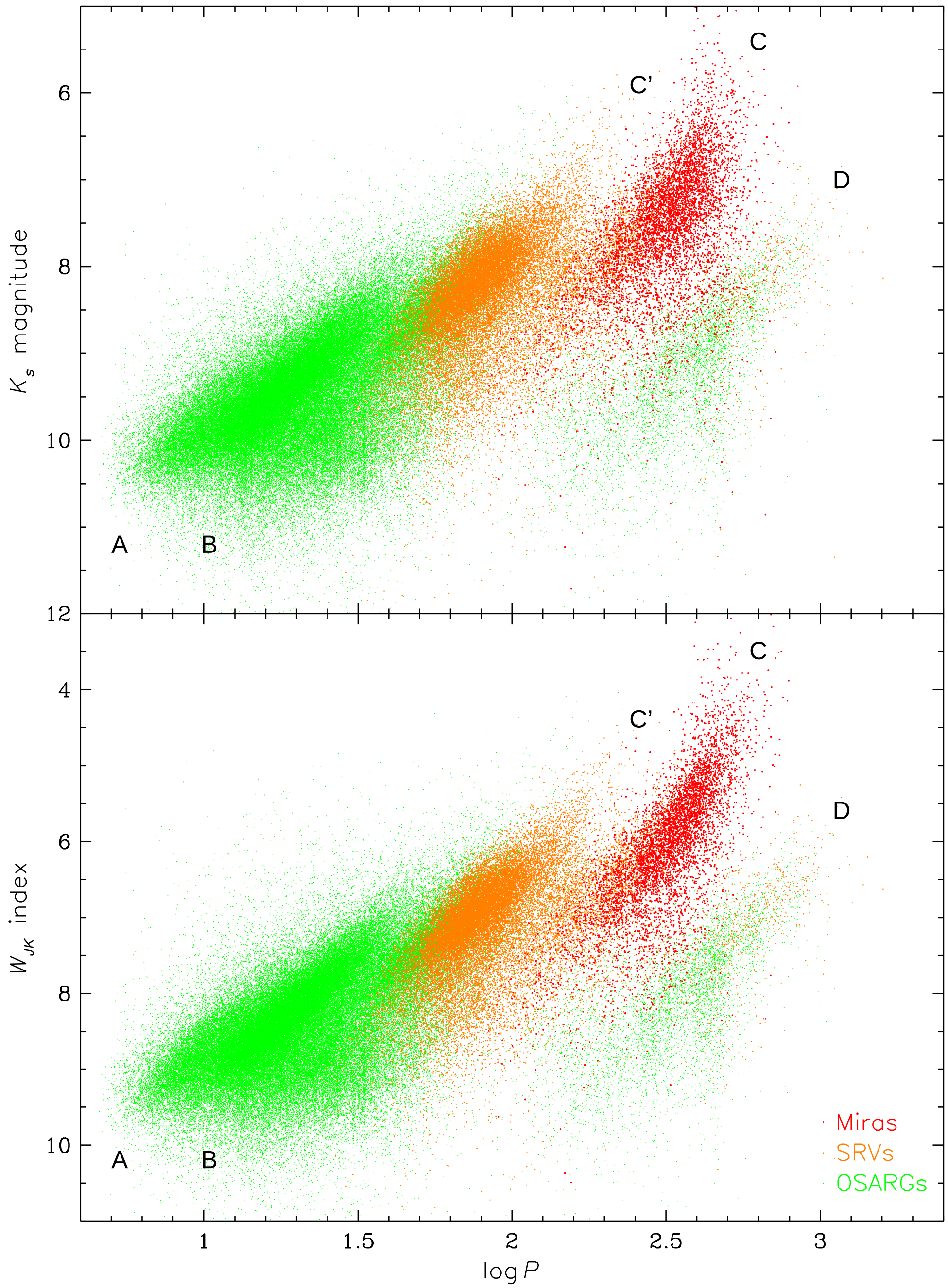

Fig. 5. Period–luminosity diagrams for LPVs in the Galactic bulge. *Upper panel* shows $\log P - K_s$ diagram, while *bottom panel* presents $\log P - W_{JK}$ diagram, where W_{JK} is the reddening-free Wesenheit index. Red points mark Mira stars, orange – SRVs, and green – OSARG variables. Each star is represented by one (the primary) period.

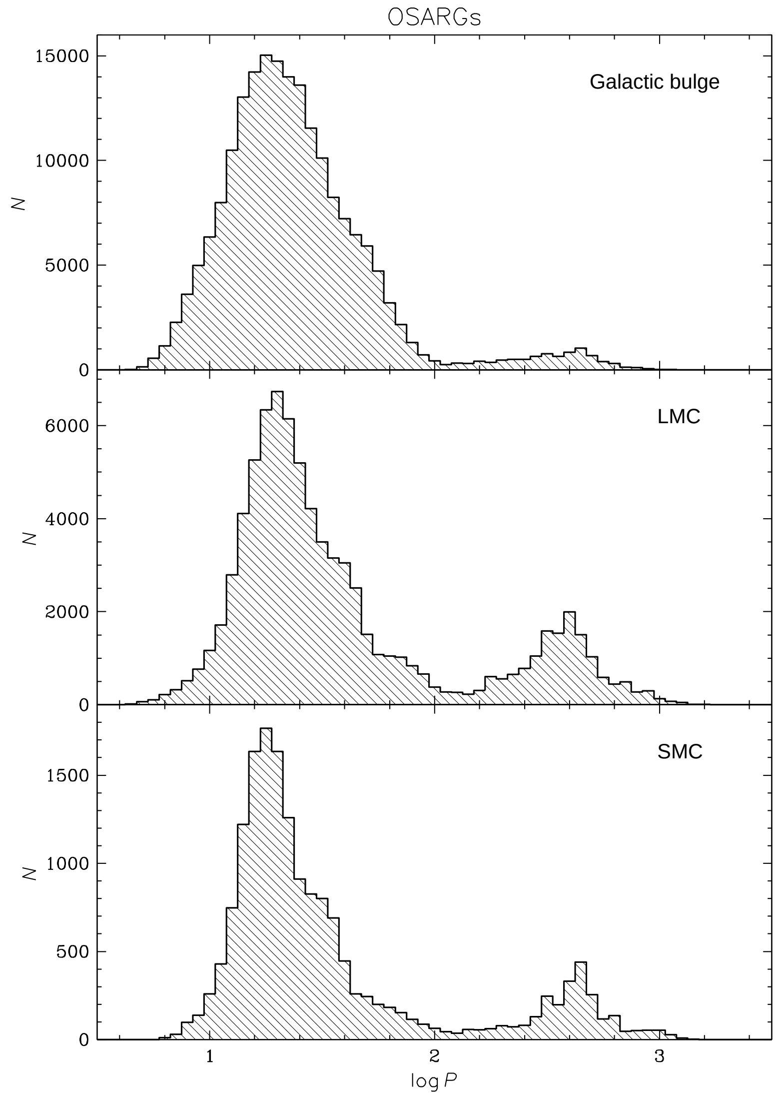

Fig. 6. Distribution of the primary periods of OSARG variables in the Galactic bulge (*upper panel*), LMC (*middle panel*) and SMC (*bottom panel*).

The period distribution of Mira stars (Fig. 7) has a similar shape in the Galactic bulge and Magellanic Clouds. Note that these three environments host completely different proportion of O-rich and C-rich Miras which is a result of different metallicity, but this feature does not influence significantly the periods of pulsations in the last stages of stellar evolution on the AGB. On the other hand, the period distribution of SRVs distinctly tends to be more concentrated with increasing metallicity. More SRVs in the Galactic bulge have primary periods falling on sequence C$'$ (first-overtone mode of pulsations), however one must remember that most of them show multi-periodic behavior, and one of the secondary periods usually falls on sequence C (fundamental mode). It cannot be ruled out that differences in primary

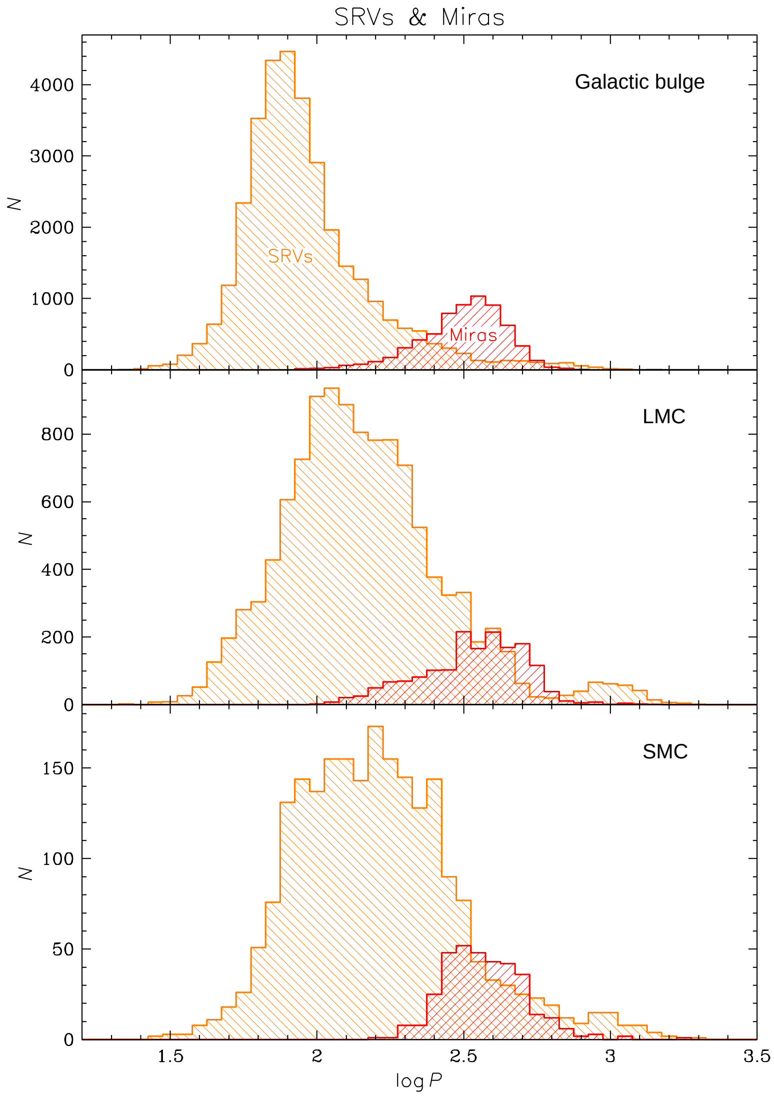

Fig. 7. Distribution of the primary periods of SRVs (orange) and Miras (red) in the Galactic bulge (*upper panel*), LMC (*middle panel*) and SMC (*bottom panel*).

period distributions of SRVs in the Galactic bulge and Magellanic Clouds result from different time span of observation of fields in these objects.

In the period–amplitude diagram (Fig. 8) OSARG variables concentrate on two sequences noticed by Minniti *et al.* (1998) and Wray *et al.* (2004). SRVs partly overlap with OSARGs, while Mira stars clearly show a separate group with *I*-band peak-to-peak amplitudes between 1.4 mag and 3 mag. We noticed such a natural distinction between Miras and SRVs in the Magellanic Clouds (Soszyński *et al.* 2009, 2011b), but only for C-rich variables, while in the Galactic bulge most of the SRVs and Miras are O-rich giants.

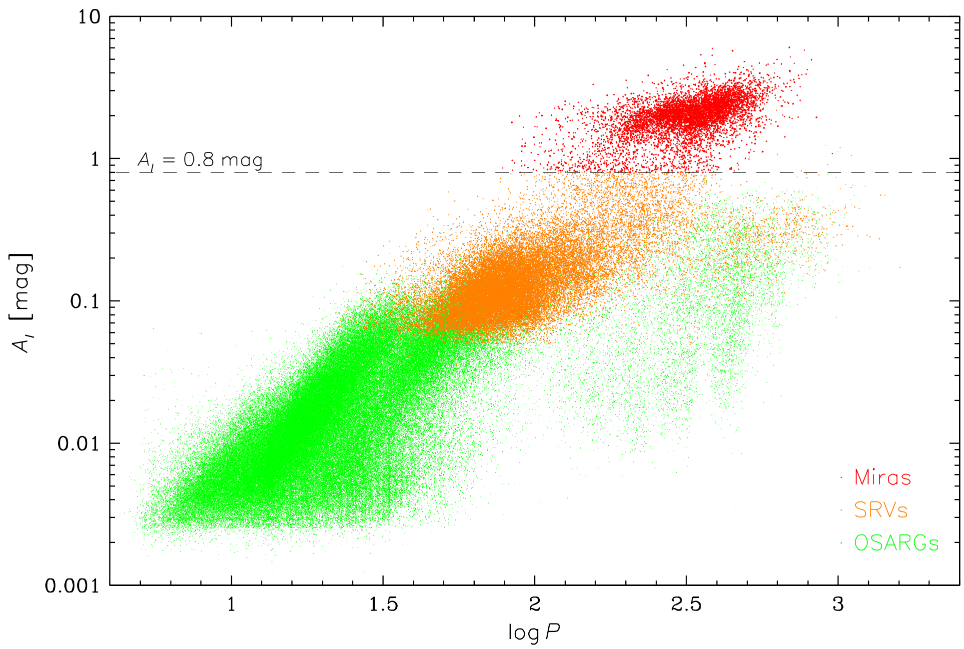

Fig. 8. Period–amplitude diagram for LPVs in the Galactic bulge. Red points mark Mira stars, orange – SRVs, and green – OSARG variables. Each star is represented by one (the primary) period.

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REFERENCES

Alard, C., and Lupton, R.H. 1998, *ApJ*, **503**, 325.
Alard, C., *et al.* 2001, *ApJ*, **552**, 289.
Baade, W. 1946, *PASP*, **58**, 249.
Blanco, V.M., McCarthy, M.F., and Blanco, B.M. 1984, *ApJ*, **89**, 636.
Cutri, R.M., *et al.* 2003, "2MASS All-Sky Catalog of Point Sources".
Dutra, C.M., Santiago, B.X., and Bica, E. 2002, *A&A*, **381**, 219.
Gaposchkin, S. 1955, *Peremennye Zvezdy*, **10**, 337.
Glass, I.S., and Feast, M.W. 1982, *MNRAS*, **198**, 199.
Glass, I.S., Whitelock, P.A., Catchpole, R.M., and Feast, M.W. 1995, *MNRAS*, **273**, 383.
Glass, I.S., Matsumoto, S., Carter, B.S., and Sekiguchi, K. 2001, *MNRAS*, **321**, 77.
Glass, I.S., and Schultheis, M. 2003, *MNRAS*, **345**, 39.
Groenewegen, M.A.T. and Blommaert, J.A.D.L. 2005, *A&A*, **443**, 143.
Hoffleit, D. 1957, *AJ*, **62**, 120.
Lloyd Evans, T. 1976, *MNRAS*, **174**, 169.

Matsunaga, N., Fukushi, H., and Nakada, Y. 2005, *MNRAS*, **364**, 117.
Matsunaga, N., Kawadu, T., Nishiyama, S., Nagayama, T., Hatano, H., Tamura, M., Glass, I.S., and Nagata, T. 2009, *MNRAS*, **399**, 1709.
Minniti, D., *et al.* 1998, in: *Proc. IAU JD 24*, "Pulsating Stars : Recent Developments in Theory and Observation, Ed. D. Sasselov and M. Takeuti (Tokyo: Universal Academy Press), p. 5.
Miszalski, B., Mikołajewska, J., and Udalski, A. 2103, *MNRAS*, in press.
Nataf, D.M., *et al.* 2013, *ApJ*, in press; arXiv:1208.1263.
Ponsen, J. 1957, *Ann. Sterrew. Leiden*, **20**, 431.
Samus N.N., *et al.* 2011, "General Catalog of Variable Stars" (Version 2011Jan).
Schechter, P.L., Mateo, M., and Saha, A. 1993, *PASP*, **105**, 1342.
Shapley, H. and Swope, H.H. 1934, *Ann. Harv. Col. Obs.*, **90**, 177.
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.
Soszyński, I., Dziembowski, W.A., Udalski, A., Poleski, R., Szymański, M.K., Kubiak, M., Pietrzyński, G., Wyrzykowski, Ł., Ulaczyk, K., Kozłowski, S., and Pietrukowicz, P. 2011a, *Acta Astron.*, **61**, 1.
Soszyński, I., Udalski, A., Szymański, M.K., Kubiak, M., Pietrzyński, G., Wyrzykowski, Ł., Ulaczyk, K., Poleski, R., Kozłowski, S., and Pietrukowicz, P. 2011b, *Acta Astron.*, **61**, 217.
Soszyński, I., Udalski, A., Pietrukowicz, P., Szymański, M.K., Kubiak, M., Pietrzyński, G., Wyrzykowski, Ł., Ulaczyk, K., Poleski, R., and Kozłowski, S. 2011c, *Acta Astron.*, **61**, 285.
Soszyński, I., and Wood, P.R. 2013, *ApJ*, **763**, 103.
Swope, H.H. 1935, *Ann. Harv. Col. Obs.*, **90**, 207.
Swope, H.H. 1938, *Ann. Harv. Col. Obs.*, **90**, 231.
Swope, H.H. 1940, *Ann. Harv. Col. Obs.*, **109**, 1.
Udalski, A., Kubiak, M., and Szymański, M. 1997, *Acta Astron.*, **47**, 319.
Udalski, A. 2003, *Acta Astron.*, **53**, 291.
Udalski, A., Szymański, M.K., Soszyński, I., and Poleski, R. 2008, *Acta Astron.*, **58**, 69.
Whitelock, P., and Catchpole, R. 1992, *in Ap&SS Library, Vol. 180, The Center, Bulge, and Disk of the Milky Way, ed. L. Blitz (Dordrecht: Kluwer)*, 103.
Wood, P.R., and Bessell, M.S. 1983, *ApJ*, **265**, 748.
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.
Woźniak, P.R., McGowan, K.E., and Vestrand, W.T. 2004, *ApJ*, **610**, 1038.
Wray, J.J., Eyer, L., and Paczyński, B. 2004, *MNRAS*, **349**, 1059.