Identifying Previously Uncatalogued Mira Variable Stars in the Optical Gravitational Lensing Experiment (OGLE) Database

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Abstract Candidate variable stars in the publicly available data of the Optical Gravitational Lensing Experiment (OGLE) project were identified by data mining the galactic disk photometry database for entries that matched the following criteria: mean *i*-magnitude between 8 and 14 and standard deviation of *i*-magnitude between 0.5 and 1.0. Ten previously uncatalogued Mira variable stars have been identified, with only stars not listed in the International Variable Star Index (VSX) at the time of submission being included.

1. Introduction

The second phase of the Optical Gravitational Lensing Experiment (Udalski *et al.* 1997) was conducted from the Las Campanas Observatory in Chile using a 1.3-meter telescope operating at an effective focal ratio of *f* / 9.2. This gave an image scale of 0.417 arcsec/pixel. All observations were made in driftscan mode with the majority of observations made using an *i*-band filter with a passband near to Cousins *I*.

The pulsating long period red variable stars forming the subject of this survey are asymptotic giant branch (AGB) stars of spectral types K and M. They fall into one of three categories: Mira (M), semiregular (SR), and slow irregular (L) variables. Both the M and SR category variable stars obey a period-luminosity relationship and so can be used as indicators of distance and as targets for studies of galactic kinematics. A discussion of the importance of these variable stars was written by Wożniak *et al.* (2004).

Mira variable stars have periods between 80 and 1,000 days and light amplitudes between magnitudes 2.5 and 11 in the *V*-band, although infrared amplitudes are far less than this. Results from Lockwood and Wing (1971) and Reid and Goldston (2002) suggest that $\Delta V = \Delta\ i\ (5 \pm 1)$. This is important in the current study where the measurements contributing to the light curve and to the reported amplitudes are all in the infrared.

The 1,000-day duration of phase 2 of the OGLE project means that, though it was easy to conclude that a star was variable, it was sometimes difficult to determine either the period or the full amplitude of variation of the star.

2. Object selection

The primary aim of this experiment was to devise a system for rapidly identifying previously uncatalogued Mira type variable stars, but it was not the intention at this stage to publish details of every uncatalogued Mira variable in the database. For this reason results for just ten stars are presented and there is no significance to the fact that they are all in Norma rather than Carina, Centaurus, or Scorpius.

The OGLE database contained over 10^{10} measurements of more than 40 million objects in the OGLE-II fields, so it was important to use a range of selection criteria that would facilitate the identification without also including large numbers of stars without any reliable photometry, or stars where the amplitude was too small for the stars to be classified as Mira type variables.

For this reason candidates were identified by data mining the galactic disk photometry database (Szymański 2005) for entries that matched the following criteria: mean *i*-magnitude between 8 and 14 and standard deviation of *i*-magnitude between 0.5 and 1.0. Only 166 stars matched both criteria.

Subsequent trials showed that only five stars had a standard deviation greater than 1.0. Of these, two had no photometry and three were already present in the International Variable Star Index (VSX; Watson *et al.* 2007). Reducing the lower cutoff for the standard deviation rapidly increased the number of candidate variable stars requiring study while simultaneously reducing the percentage of stars that could be classified as Mira type variables. However there is no doubt that more Mira type variables can be identified by studying fainter stars and stars with a lower standard deviation in the *i*-magnitude results.

3. Data

Identification and classification of these long period variable stars required time-resolved photometry and examination of the resultant light curve.

The OGLE photometry was examined using the SQL interface available from the OGLE website (http://ogledb.astrouw.edu.pl/~ogle/photdb/phot_query.html). Identifying candidate variable stars was a five-stage process:

- Option “Select OGLE target:”—select Galactic Disk
- Option “Select parameters database:”—select PSF photometry
- From range of parameters—select and use “Mean *I*-magnitude” with values 8 to 14
- From range of parameters—select and use “Standard deviation of *I*-magnitude” with values 0.5 to 1.0
- Select “Sexag. RA/Dec output”

A total of 166 candidate variable stars were identified using this technique. It was then possible to examine the light curve for each star by clicking on the relevant StarID in the table of results generated via the sql interface.

4. Periods and amplitudes

The intention was to determine the period, amplitude, type, and epoch of the new discoveries using the software package PERANSO (Vanmunster 2007), but there were some difficulties partly due to the *General Catalogue of Variable Stars* (GCVS; Kholopov *et al.* 1985) classification scheme for these red long period variable stars being based only on the amplitude and regularity of the visual-band variation.

Although the period and shape of the light curves obtained is typical of long period variable stars, the observed amplitude is less in the infrared band used by OGLE than it would have been in the more frequently used Johnson *V*-band. This is because infrared magnitudes are not subject to the effect of absorption by titanium oxide (TiO) that contribute significantly to the observed variation in *V*-band magnitudes.

Also, the time span of the survey, plus the seasonal nature of the observations, means that only partial coverage of a small number of cycles was obtained. This meant that in some cases neither the maxima nor minima magnitudes were reported, and so it was not always possible to determine either the full amplitude of variation or the epoch of maximum light (Greaves 2008).

In addition, many of the candidate variable stars showed substantial variation in both the shape of the light curve and in the peak magnitude reached in consecutive cycles. This was reflected in the phase plots.

5. Reliability and completeness

In the case of this survey, every entry was subject to a clerical and then to an astronomical check. The clerical check was used to ensure that the associated data files were complete and free from error, and the astronomical check was to ensure that the star was “clearly variable” based on the OGLE data and that at the time that VSX was checked—December 2008 to January 2009—that the variability of each new entry had not previously been reported.

6. Data access and light curves

All data, including phase plots, relating to the new discoveries discussed in this paper can be downloaded from http://www.martin-nicholson.info/ogle.xls.

Figures 1 through 10 illustrate the light curves of the ten Mira variable stars discovered during the course of this project, and Table 1 presents the key features of these stars. In all cases a provisional classification of M seems justified, although the previously mentioned caveats should not be ignored.

7. Summary

Ten previously uncatalogued Mira variable stars in the constellation of Norma have been identified using the publicly available data of the Optical Gravitational Lensing Experiment (OGLE) project.

8. Acknowledgements

This publication makes use of data products from *The Two Micron All Sky Survey* (Skrutskie *et al.* 2006), which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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Table 1. Details of ten previously uncatalogued Mira variable stars.

Name	*R. A. (2000)* *h m s*	*Dec. (2000)* *° ' "*	*Max*	*Min*	*P(d)*	*Epoch*
NOR_SC1 135123	16 13 12.80	–54 21 44.1	11.7	14.2	398	2451015
NOR_SC1 194064	16 13 22.75	–54 25 05.5	12.3	15.0	463	2450919
NOR_SC3 43905	16 15 21.26	–53 46 46.8	12.9	14.5	273	2451256
NOR_SC3 71397	16 15 53.58	–54 21 24.9	12.0	14.6	338	2451685
NOR_SC3 100580	16 15 51.86	–53 59 31.7	11.8	>14.2	331	2451597
NOR_SC4 48534	16 16 46.75	–53 41 10.4	<12.0	>14.2	359	
NOR_SC4 121227	16 17 13.57	–53 38 02.6	11.0	14.4	301	2451229
NOR_SC4 129604	16 17 06.95	–53 32 08.4	11.8	14.8	377	2451632
NOR_SC4 189185	16 17 39.19	–53 33 36.4	11.8	13.9	288	2450859
NOR_SC7 113114	16 26 06.43	–52 05 31.8	11.9	14.5	284	2450902

Notes NOR_SC1 135123 may be identical to NSV 7525, which is nominally 0.54 arc minute away.

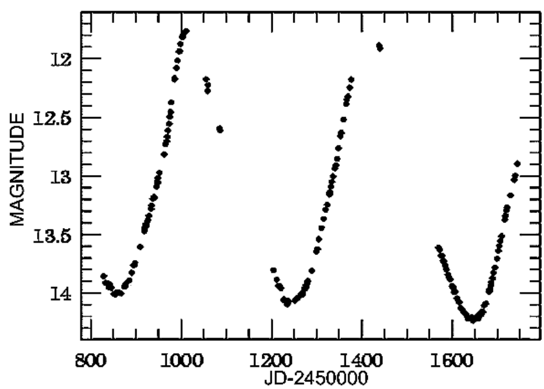

Figure 1. Light curve of NOR_SC1 135123, 2MASS J16131280-5421434.

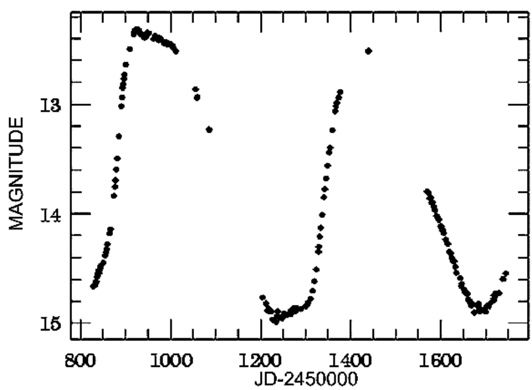

Figure 2. Light curve of NOR_SC1 194064, 2MASS J16132274-5425047.

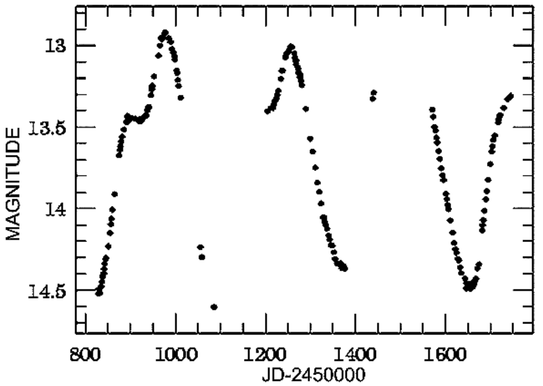

Figure 3. Light curve of NOR_SC3 43905, 2MASS J 16152132-5346459.

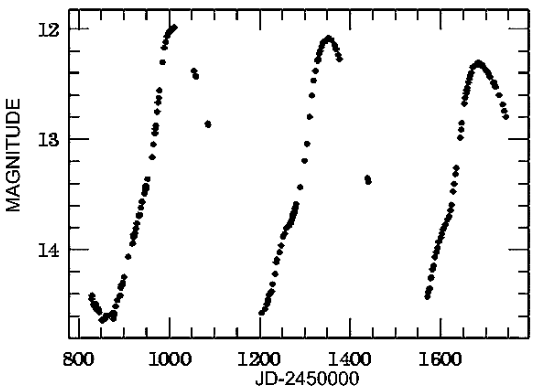

Figure 4. Light curve of NOR_SC3 71397, 2MASS J 16155358-5421244.

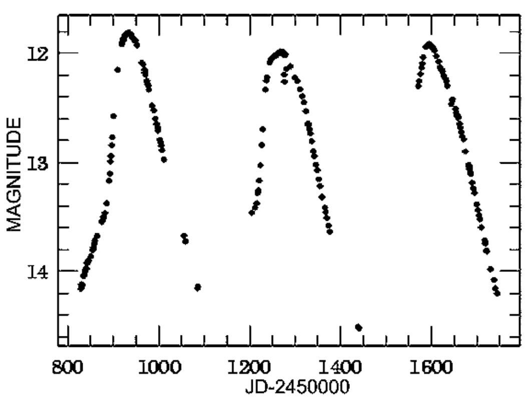

Figure 5. Light curve of NOR_SC3 100580, 2MASS J16155191-5359310.

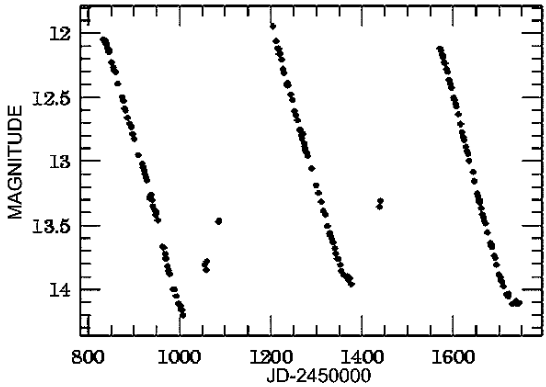

Figure 6. Light curve of NOR_SC4 48534, 2MASS J 16164682-5341095.

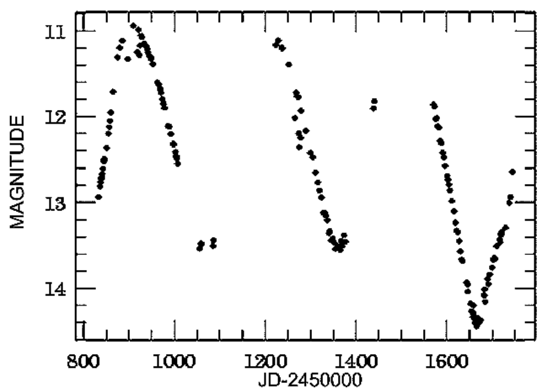

Figure 7. Light curve of NOR_SC4 121227, 2MASS J 16171367-5338016.

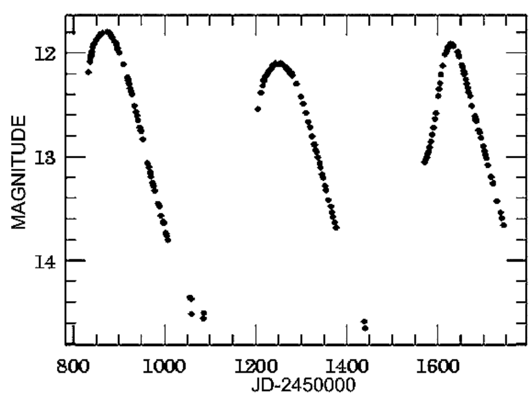

Figure 8. Light curve of NOR_SC4 129604, 2MASS J 16170706-5332073.

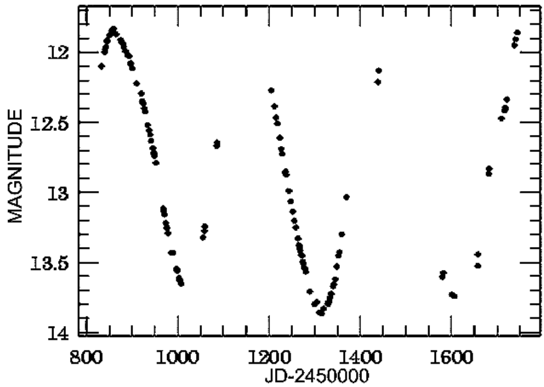

Figure 9. Light curve of NOR_SC4 189185, 2MASS J 16173928-5333355.

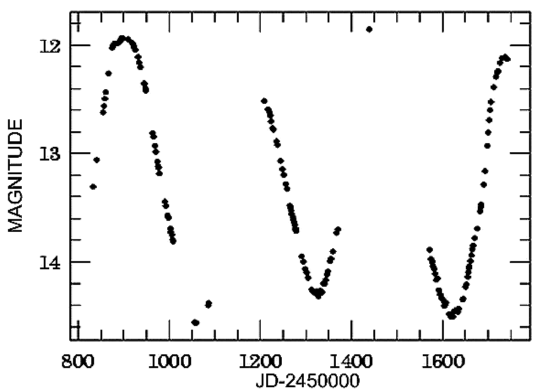

Figure 10. Light curve of NOR_SC7 113114, 2MASS J 16260650-5205316.