XROM and RCOM:  
Two New OGLE-III Real Time Data Analysis Systems

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ABSTRACT

We describe two new OGLE-III real time data analysis systems: XROM and RCOM. The XROM system has been designed to provide continuous real time photometric monitoring of the optical counterparts of X-ray sources while RCOM system provides real time photometry of R Coronae Borealis variable stars located in the OGLE-III fields. Both systems can be used for triggering follow-up observations in crucial phases of variability episodes of monitored objects.

Surveys – Techniques: photometric – X-rays: stars – Stars: AGB and post-AGB

1 Introduction

The Optical Gravitational Lensing Experiment (OGLE) is a long term large scale sky survey regularly monitoring the most dense stellar fields in the sky (Udalski et al. 1992, Udalski, Kubiak and Szymański 1997, Udalski 2003). The OGLE project started originally in 1992 as a first generation microlensing survey and contributed in its subsequent phases to many fields of modern astrophysics like stellar astrophysics, extrasolar planet searches, gravitational lensing and others. Huge databases of photometric measurements of hundreds of millions stars spanning several years provide a unique opportunity for data mining, performing statistical analyzes of huge samples of particular objects or conducting analysis of long term behavior of selected classes of stars.

One of the most important results of the OGLE survey was the implementation of real time data analysis systems that allow monitoring of selected variable objects in almost real time. Advantages of this approach are obvious, especially in the case of transient or non-periodic variable objects. For instance, one can carefully prepare different kind of follow-up observations, knowing current photometric behavior of a selected object. Microlensing field is the best example here. The OGLE project was the first to implement the so called Early Warning System (EWS, Udalski et al. 1994) – the system that detected on-going microlensing events in their early phases. Information on such events was made public. Several microlensing follow-up teams were formed in the several past years to observe intensively the already discovered ongoing microlensing phenomena. This strategy turned out to be very successful leading to the important discoveries like microlensing extrasolar planets (Udalski et al. 2005, Beaulieu et al. 2006, Gould et al. 2006, Gaudi et al. 2008) or Magellanic Cloud microlensings (Afonso et al. 2000, Dong et al. 2007).

OGLE-III phase of the OGLE project, that started on June 12, 2001 and has been conducted up to now, was a significant extension of the OGLE survey. Much larger observing capabilities made it possible to cover practically entire area of the LMC and SMC and large fraction of the Galactic bulge. Also new data analysis systems were implemented during this phase (Udalski 2003). Beside the EWS system allowing the discovery of about 600 microlensing events every year, two new systems were developed after the first four seasons of the OGLE-III phase: EEWS and NOOS.
The EEWS system was designed to detect in the real time anomalies of microlensing events from a single mass microlensing. The implementation of this system became an important step – thanks to it the vast majority of non-standard microlensing events, including many planetary microlensings, were detected in almost real time and the information was passed to other microlensing groups. EEWS system also allowed to switch the OGLE observing mode from the standard survey mode to follow up mode where the observations of a particular object were done with much higher cadence – dependent on the variability rate.

The second real time system NOOS (Udalski 2003) was designed to detect in real time the transient stellar objects that brighten strongly enough to be seen in the OGLE images for some time. This class of objects include supernovae (SNe), long term variable stars, microlensing of very faint stars (non-detectable in the regular OGLE photometry range) etc. A few new SNe were detected soon after the implementation of this system (Udalski 2004).

Finally, the real time monitoring of the Einstein Cross gravitational lens (QSO 2237+0305) provides the real time photometry of four images of the quasar. This object is one of the most important gravitational lenses and unique OGLE photometric dataset (Woźniak et al. 2000, Udalski et al. 2006) was often used for its modeling. Continuous monitoring of the quasar images allows early detection of potential caustic crossings or cusp approaches in this lens. These events are crucial for proper modeling and understanding the gravitational lenses and provide an opportunity to estimate the quasar size.

In this note we present two new real time OGLE-III data analysis systems implemented recently: XROM and RCOM. They allow real time monitoring of selected classes of highly variable optical objects. The photometry provided by these systems is available to the astronomical community from the OGLE Internet archive.

2 XROM: X-Ray Variables OGLE Monitoring System

X-ray astronomy is one of the most rapidly developing branches of modern astrophysics. New space missions provide more and more exciting data in this wavelength range and the data flow accelerates. Nevertheless in the majority of cases the proper interpretation of observed X-ray behavior of detected objects requires observations in other wavelengths as well, including the optical range.

The dense OGLE-III fields like the Magellanic Clouds or Galactic bulge include many X-ray sources. Part of them has been successfully identified with the optical counterparts. For example, the SMC contains a large sample of X-ray pulsars discovered during the past few years (Coe et al. 2005). OGLE data has already been used for interpretation of some of these objects (Coe et al. 2005, McGowan et al. 2008).

Continuous optical monitoring of counterparts of X-ray sources is very important, as many of them undergo large optical variations, eruptions etc. likely related to the X-ray activity. Therefore, many planned X-ray follow-up observations may be much better tuned-up when the current optical state and behavior of these objects is known.

The OGLE-III XROM system provides continuous photometric coverage of a selected sample of known optical counterparts of X-ray sources located in the OGLE-III fields. The initial sample contains 52 objects. It can be easily extended with other or newly detected objects. Photometry of the XROM objects is typically updated after each clear night. Fig. 1 presents the OGLE-III light curve of one of such objects: SXP 756.

The interactive access to the XROM objects is provided via the main OGLE WWW page:
The structure of the page is similar to other OGLE real time system pages. After selecting an object, the object page is invoked providing the basic information: its OGLE identification, RA/DEC coordinates, finding chart and two light curve plots: one showing the entire light curve and the second one showing the last 60 days. The photometry is obtained through the $I$-filter and it is only roughly calibrated with accuracy of the zero points of $\pm 0.1 - 0.2$ mag.

The photometry can be download from the OGLE archive:

[ftp://ftp.astrouw.edu.pl/ogle3/xrom]

### 3 RCOM: OGLE Real Time Monitoring of R CrB Variable Stars

R CrB stars form a group of stars that reveal dramatic variability episodes. Their brightness can fade by a few magnitudes in the time scale of several days. These fading episodes are unpredictable and can last for months. After that period the brightness of these stars gradually recovers to the original state.

It is believed that fading is related to the formation of dust clouds over the surface of these stars. When they disperse the brightness returns to the unobscured level. Some such clouds were directly observed. R CrB variables are very small group of stars – only about 50 is known in the Galaxy (Tisserand et al. 2008) and about 20 in the Magellanic Clouds (Alcock et al. 2001, Tisserand et al. 2004).

R CrB stars provide an opportunity of studying the late stages of stellar evolution. To clarify their evolutionary status extensive follow-up observations are needed in the most dramatic fading or rising phases of the variability episodes. As the episodes are unpredictable only continuous observations of R CrB variables may trigger such follow-up programs.
Fig. 2. Light curve of the R CrB type star, MACHO-051551.8-691008, monitored by the OGLE-III CROM system.

OGLE-III fields are ideal for the real time data analysis system monitoring R CrB variables. They contain many R CrB stars, both in the Magellanic Clouds and the Galactic bulge. The RCOM system was designed to continuously monitor a sample of R CrB stars from the OGLE-III fields. Initially the sample consists of 23 objects but it can be extended when the new objects are detected. Unfortunately most of the known R CrB stars in the Galactic bulge are saturated in the OGLE-III reference images, therefore their photometry is not available. Fig. 2 shows an example of the light curve of one of the R CrB objects monitored by the CROM system, MACHO-051551.8-691008.

The interactive access to the RCOM objects is provided via the main OGLE WWW page:

http://ogle.astrouw.edu.pl

The structure of the page and provided information are identical as for the XROM system.

The photometry can be download from the OGLE archive:

ftp://ftp.astrouw.edu.pl/ogle3/rcom

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REFERENCES
Afonso, C. et al. 2000, Astrophys. J., 532, 340.
Alcock, C., Allsman, R. A., Alves, D. R. et al. 2001, Astrophys. J., 554, 298.
Beaulieu, J.-P. et al. 2006, Nature, 439, 437.
Coe, M.J., Edge, W.R.T., Galache, J.L., and McBride, V.A. 2005, MNRAS, 356, 502.
Dong, S., Udalski, A., Gould, A. et al. 2007, Astrophys. J., 664, 862.
Gaudi, B.S., Bennett, D.P., Udalski, A. et al. 2008, Science, 319, 927.
Gould, A., Udalski, A., An, D. et al. 2006, Astrophys. J., 644, L37.
McGovan, K.E., Coe, M.J., Schurch, M.P.E.; Corbet, R.H.D., Galache, J.L., and Udalski, A. 2008, MNRAS, 384, 821.
Tisserand, P. et al. 2004, Astron. Astrophys., 424, 245.
Tisserand, P. et al. 2008, Astron. Astrophys., 481, 673.
Udalski, A., Szymański, M.; Kałużny, J., Kubiak, M., Mateo, M. 1992, Acta Astron., 42, 253.
Udalski, A., Szymański, M., Kałużny, J., Kubiak, M., Mateo, M., Krzeminski, W., and Paczyński, B. 1994, Acta Astron., 44, 227.
Udalski, A., Kubiak, M., and Szymański, M. 1997, Acta Astron., 47, 319.
Udalski, A. 2003, Acta Astron., 53, 291.
Udalski, A. 2004, IAUC, 8276.
Udalski, A., Jaroszyński, M., Paczyński, B. et al. 2005, Astrophys. J., 628, 109.
Udalski, A. et al. 2006, Acta Astron., 56, 293.
Woźniak, P.R., Alard, C., Udalski, A., Szymański, M., Kubiak, M., Pietrzyński, G., and Zebruń, K. 2000, Astrophys. J., 529, 88.