The Toruń Observatory Semi-Automatic Variability Search (SAVS)

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1 Introduction

For last decade many massive survey projects have been started due to availability of large CCD detectors and increase of computing power needed for data reduction. The way the projects are realized depends on goals of their scientific programs. The main topics of these researches are: microlensing events, new variable stars, optical counterparts of gamma-ray bursts, supernovae, near-Earth, asteroids or comets searches.

Even a simple telescope equipped with a commercial CCD detector and a telephoto lens can realize many interesting scientific programs (Paczyński 1997). The All Sky Automated Survey (Pojmański 1997) is an excellent example of such a low-end project. Since 1997 it has discovered thousands of new variable stars, exploring objects brighter then 14 mag (Pojmański 1998, Pojmański 2000, Pojmański 2002).

In this poster we present a short description of a new observational project called Semi-Automatic Variability Search (SAVS). SAVS is a photometric CCD sky survey aimed at discovering of new variable stars in the northern hemisphere. It is located at the Astronomical Observatory of the Mikołaj Kopernik University in Piwnice near Toruń, Poland. The survey started in spring of 2002 with a two-month test run. Since July 2002 observations have been made systematically.

Till now 16 new variables have been discovered: 8 eclipsing systems, 3 periodic pulsating stars and 5 irregulars.

2 Instrument

SAVS uses teh already existing infrastructure of the Observatory (dome, LAN). Its hardware is composed of: CCD camera, simple optics, camera mount and a control computer.

CCD Camera System. The SBIG ST-7 commercial CCD camera with Kodak KAF-0400E chip is used as a detector. It has 765 $\times$ 510 pixels of 9 micron size. The CCD matrix is cooled thermoelectrically 30 degrees below the case temperature. In practice it allows to achieve a working temperature of -10°C in summer and -30°C in winter. The camera is connected to a PC *via* a parallel port and controlled by CCDOPS software of SBIG.

Optics. An achromatic telephoto MC APO Telezenitar-M 135/2.8 is used as a optical system. It gives a field of view of 3 $\times$ 2 deg with a scale of 13.8 arcsec/pixel. The optics allows one to acquire sharp stellar images with typical FWHM of 2 pixels.

The same SBIG CFW-8 filter wheel containing 5 filters. Currently observations are performed mostly in near-Johnson V band and sporadically in B, however.

Camera Mount. The Meade LX200 telescope is used as a mount for positioning our camera on required coordinates and tracking the sky rotation. The CCD camera is attached at the top of the telescope's tube. This setup allows to achieve good quality images with exposure times up to 10 minutes. A dedicated software was written to control the camera mount and the dome's slit. The mount communicates with a PC *via* a serial port. The dome is controlled by a dedicated ISA-bus controller card.

Control Computer. The control computer is located in the control room in the dome building. It is a PC with Pentium 200 MHz CPU, 32 MB RAM, 3 GB hard disk space and an ethernet card. The observation are stored during a night on the local hard disk and then copied *via* LAN to a work station for further reduction.

3 Software pipeline

The Semi-Automatic Variability Search Pipeline (SAVS.PL) was developed for the SAVS sky survey purposes. It is an easy-to-use and intuitive software which was created for semi-automatic reduction and analysis of a large amount of CCD images and detecting new variable stars. The package consists of two main programs: DAPhot and JAMP.

The SAVS pipeline - SAVS.PL - is a freeware and can be downloaded from survey's web site:

http://www.astri.uni.torun.pl/˜gm/SAVS.

The **DAPhot** code (Fig. 1) performs standard reduction process of raw CCD frames by removing instrumental effects such as dark current and flat-field (both optional).

In an automatic way it also detects stars in each frame and conducts precise astrometry for them by transforming instrumental coordinates into equatorial ones and performs aperture photometry for all detected sources. The astrometric calibration of CCD frames bases on stars brighter than 10 mag, for which positions, precession and proper motions are calculated from TYCHO-2 Catalogue (Høg *et al.* 2000). The typical rms error of the transformation is 0.1 pixel. The typical astrometric uncertainty is 1 arc second. This precision makes identification of objects unique in practice.

DAPhot measures magnitudes of stars with differential aperture photometry against selected comparisons. Typical brightness measurement uncertainty represented by standard deviation depends on teh stellar brightness and ranges between 0.03 mag and 0.2 for bright (V=8 mag) and faint (V=13 mag) stars, respectively. The same uncertainty calculated for comparison stars does not exceed 0.03 mag.

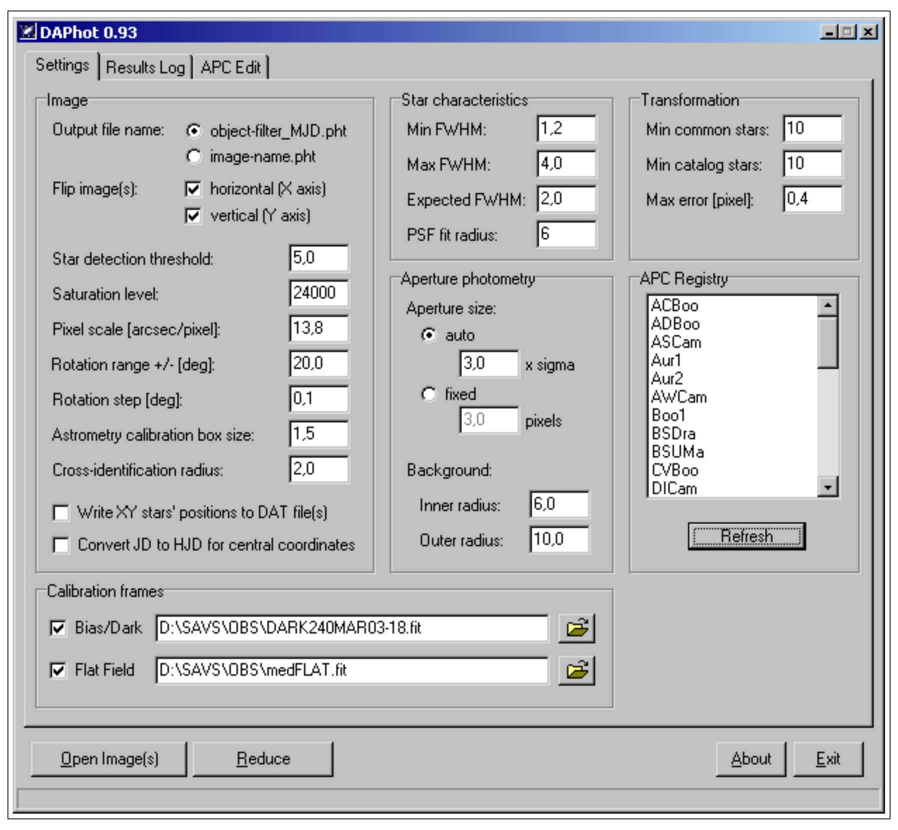

Figure 1: DAPhot interface screen-shot.

The **JAMP** interface (Fig. 2) is used for managing and analyzing the collected data. In a fully automatic way it joins data from single observations into databases which are separately created for every observed field. The candidates for variable stars are selected by the analysis of variance (ANOVA) method (Schwarzenberg-Czerny 1996). The application is also used as a viewer of the content of databases (Fig. 3).

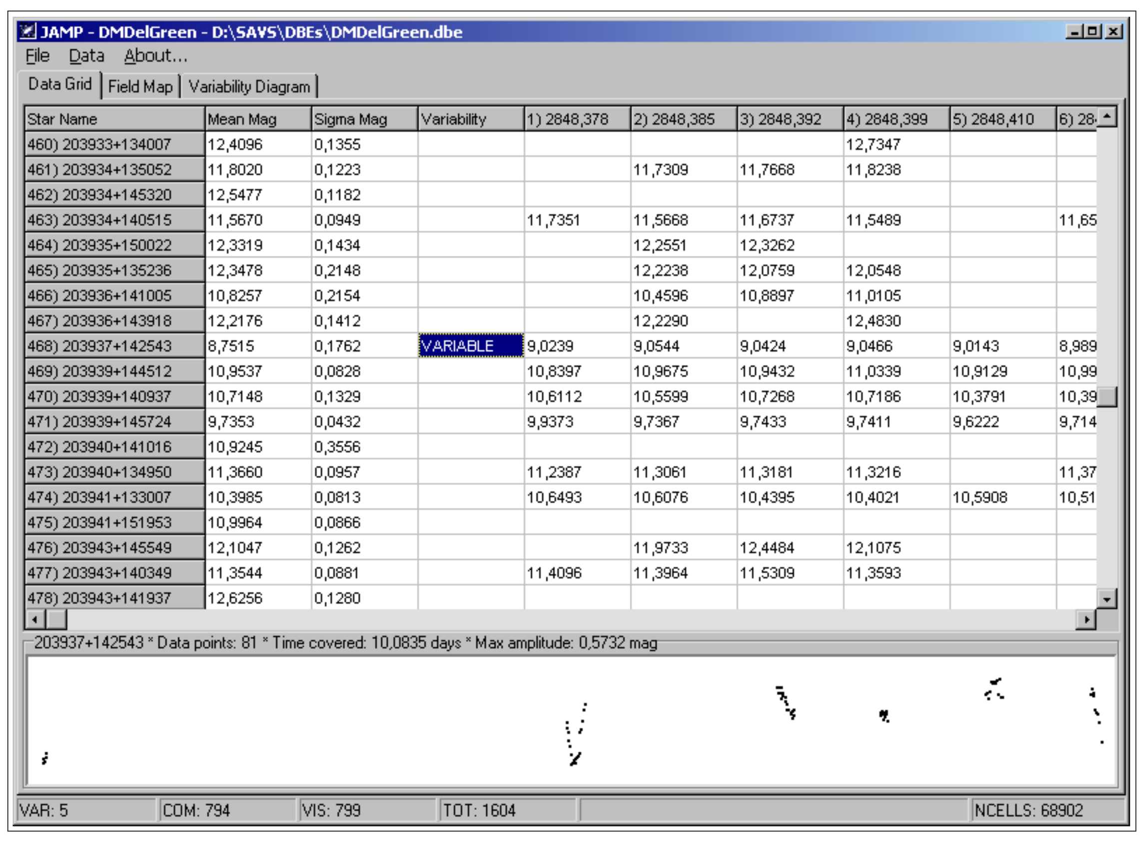

Figure 2: JAMP interface. Brightness measurements are displayed in a table. A light curve of an active star is plotted in the preview diagram.

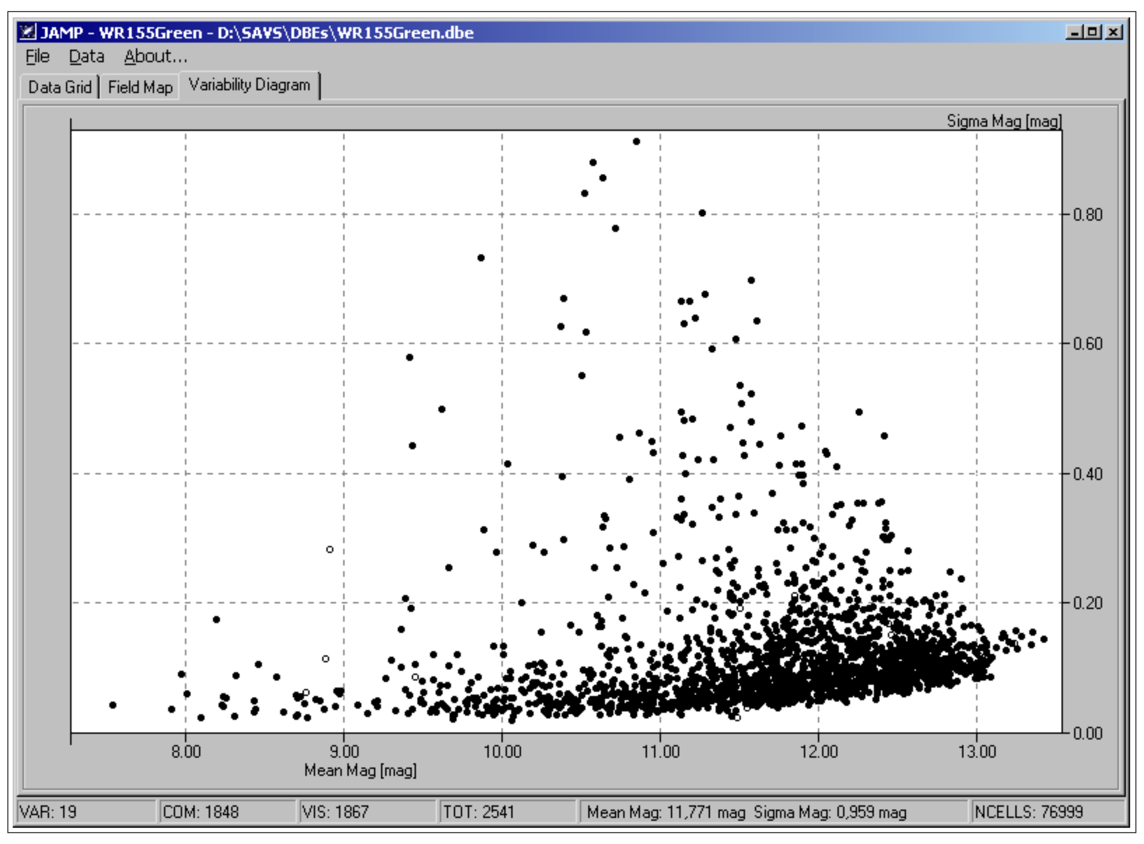

Figure 3: JAMP also visualizes data in the standard deviation *versus* magnitude diagram.

To perform a detailed period analysis for selected variable candidates we also developed a tool called **PerSea** (Fig. 4). It is based on the analysis of variance (ANOVA) algorithm (Schwarzenberg-Czerny 1996), which was adopted from ISIS package (Alard & Lupton 1998).

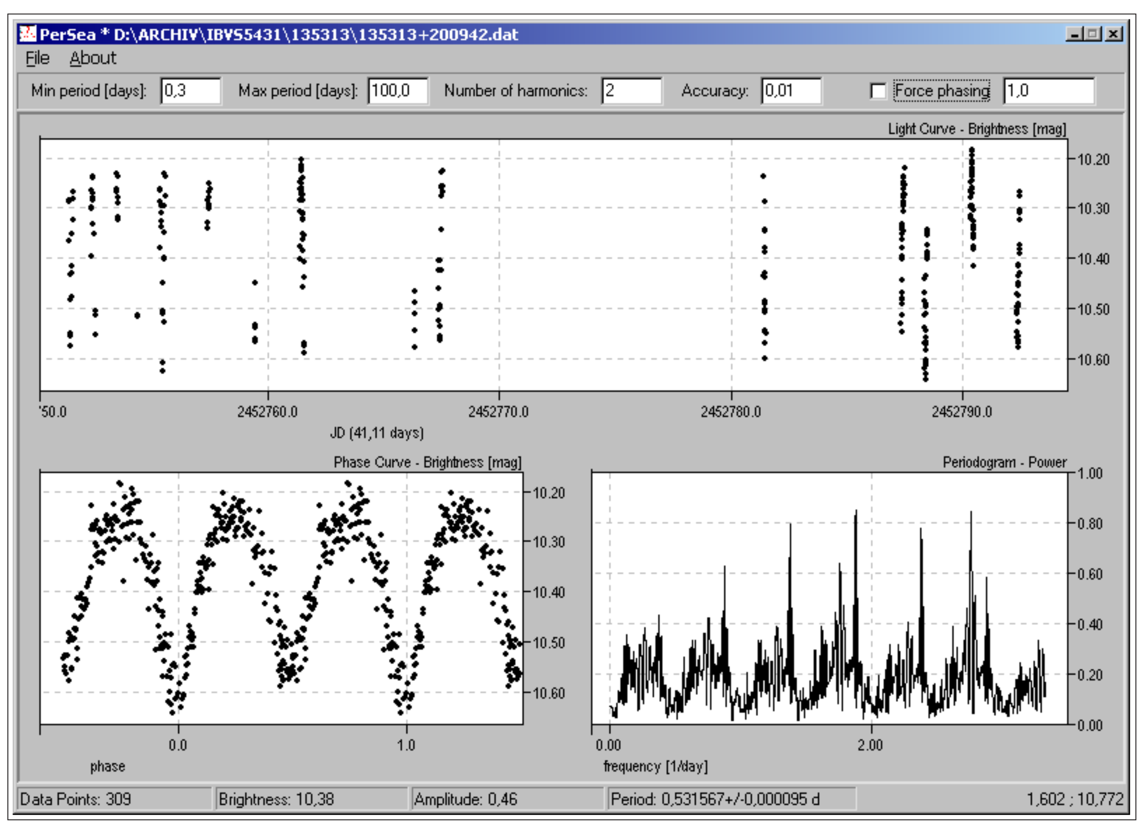

Figure 4: PerSea - a tool for searching periodicity in photometric data.

4 Observations and Results

In the first operational season (2002/2003) observations were collected during 85 nights. 3 GB of raw data or 4500 single exposures were collected in total. Over 12000 stars brighter than 13 mag in V band were observed in 25 selected fields covering 150 square degrees. 16 new variable stars were discovered: 8 eclipsing systems, 3 periodic pulsating stars and 5 red irregulars. For most of them the results have been already published (Maciejewski & Niedzielski 2002, Maciejewski *et al.* 2002, Maciejewski *et al.* 2003a, Maciejewski *et al.* 2003b, Niedzielski *et al.* 2003). A sample of new variables is shown in Fig. 5.

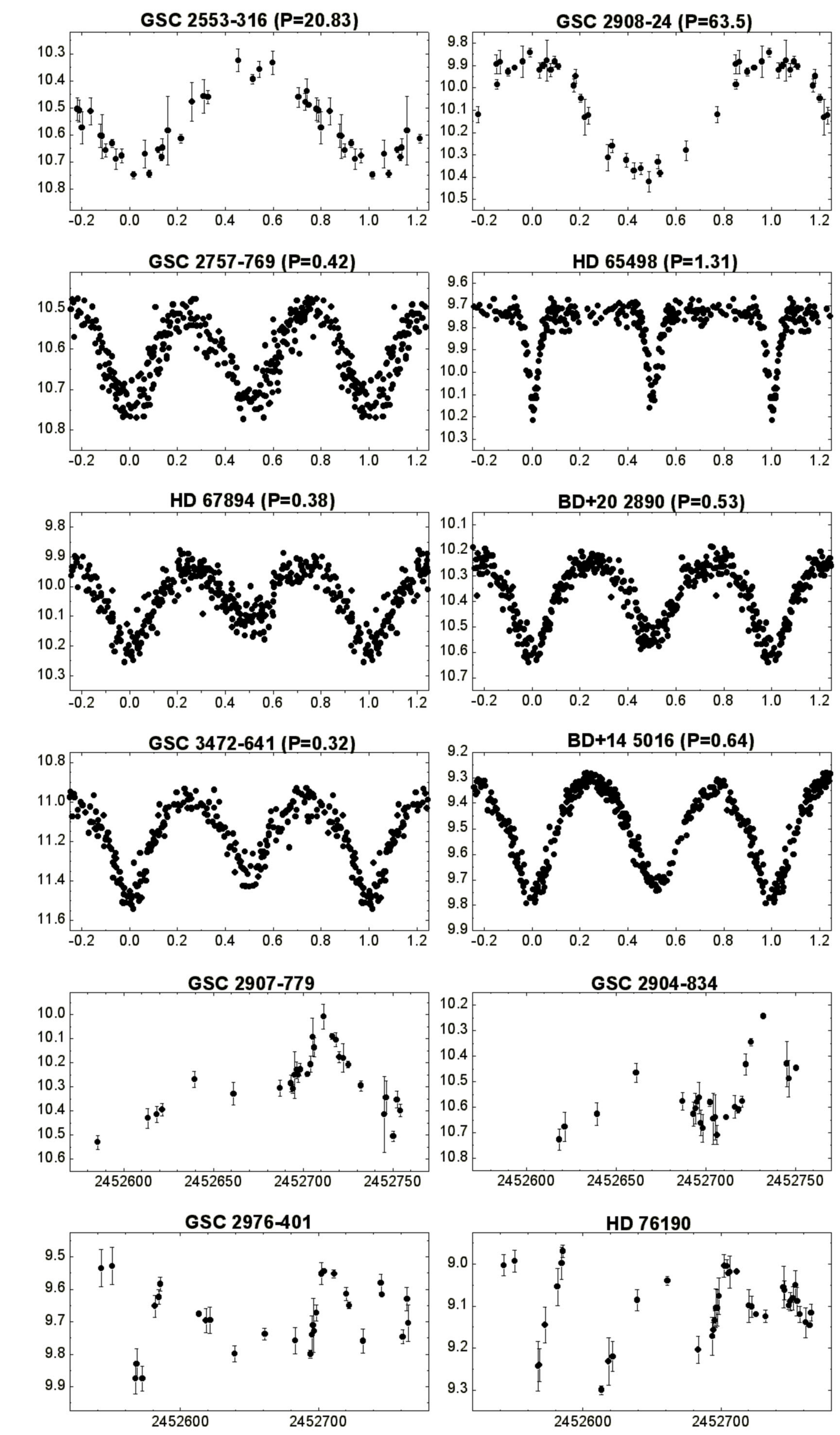

Figure 5: A sample of new variables.

The collected data allowed also to determine over 50 new times of minima for known eclipsing binary stars (Karska & Maciejewski 2003) and a few new times of maxima for pulsating stars.

The detailed list of the detected new variable stars, new releases presenting newest discoveries, hardware specification and software pipeline are available over the Internet:

http://www.astri.uni.torun.pl/˜gm/SAVS.

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References

[1] Alard, C., Lupton, R., H. 1998, ApJ, **503**, 325

[2] Høg, E., Fabricius, C., Makarov, V. V., Urban, S., Corbin, T., Wycoff, G., Bastian, U., Schwekendiek, P., Wicenec, A. 2000, A&A, **355**, L27

[3] Karska, A., Maciejewski, G. 2003, IBVS 5380

[4] Maciejewski, G., Niedzielski, A. 2002, IBVS 5308

[5] Maciejewski, G., Karska, A., Niedzielski, A. 2002, IBVS 5343

[6] Maciejewski, G., Karska, A., Niedzielski, A. 2003a, IBVS 5370

[7] Maciejewski, G., Czart, K., Niedzielski, A., Karska, A. 2003b, IBVS 5431

[8] Niedzielski, A., Maciejewski, G., Czart, K. 2003, AcA, submitted

[9] Paczyński, B. 1997, *The Future of Massive Variability Searches*, In Proc. of 12th IAP Coll., Paris, p. 357

[10] Pojmański, G. 1997, AcA, **47**, 467

[11] Pojmański, G. 1998, AcA, **48**, 35

[12] Pojmański, G. 2000, AcA, **50**, 177

[13] Pojmański, G. 2002, AcA, **52**, 397

[14] Schwarzenberg-Czerny, A., 1996, ApJ, **460**, L107