THE SYNCHRONOUS NETWORK OF OPTICAL TELESCOPES: A NEW INSTRUMENT FOR STELLAR PHOTOMETRY

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Abstract

We describe a new multimirror instrument for time-series photometry of variable stars, organized to research a rapid variability on time scales down to millisecond. We use existing telescopes at four astronomical sites equipped with high-speed photometers. Submitted preliminary results are much promising.

1 Introduction

In the history of astronomy, implementation of new techniques gives from time to time unexpected results. Successful results have being obtaining by international collaboration of astrophysicists well known as the Whole Earth Telescope (Nather et al. 1990). The WET project started its operations in 1988. New time domain was explored and new results were obtained in the field of asteroseismology.

Groups of astronomers were united around the research problem of the red dwarf flare star EV Lacertae. Coordinated observations of photometric, spectral and radio studies of the flares were carried out from the 1989 (Alekseev et al. 1994; Abdul-Aziz et al. 1995; Abranin et al. 1998; Alekseev et al. 2001 etc).

Our team has participated in these campaigns since 1996. We proposed to reduce of integration time for photometric count in order to obtain new results. Using a statistical technique with the synchronous high speed UBVRI photometric data we find some new futures in the EV Lacertae flares (Zhilyaev et al. 1998). One of recent paper (Zhilyaev et al. 2000) informed on the confirmation of the rapid optical brightness oscillations during a significant part of a flare lifetime as was discovered by Rodono (1974).

The idea of synchronous photometric observations has been started on several occasions in our Observatory. We can practice this technique thanks to our two High Speed Photometric Systems which are mounted at the: Observatory Terskol, North Caucasus and Crimean Astrophysical Observatory. Colleagues from Greece and Bulgaria joined us and we set up Coordinated Network of the Telescopes (CNT).

We would like to set up Synchronous Network of Telescopes (SNT) now. What can SNT really achieve? The point of SNT and its unique power - is a synchronous operation of several distant telescopes. To integrate the some small apertures we need to synchronize our distant telescopes to UTC within the sampling time. How to increase detection probability of the weak signals? Because the inherent signal varies correlatively in the different SNT time series, whereas noises remain non-correlated variables, a potential achieved precision may be significantly increased. Using the method of Fisher the joint probability curve can be obtained from the statistical transformations. The SNT instrument can makes a unique contribution to high-resolution fast photometry.

We see that modern observations of a micro-variability may be considered in the context of the statistical photometry, which is based on the theory of detection and estimation of a signal hidden behind the atmospheric and photon noises.

2 CNT Today

2.1 Organization

For today our network is grounded on the agreements about joint research projects between our observatory and the International Research Center for Astronomy, Medicine and Ecology with the Crimean Astrophysical Observatory (CrAO), the Institute of Astronomy of the Bulgarian Academy of Sciences and the Aristoteleion University of Thessaloniki.

Each of research group is equipped with photometers by individual peculiarities. It does not let us to have unified devices. Therefore comparisons of data and their joint processing need preliminary preparations. The equipping of all observational sites with the identical photometers requires volume money investments. Therefore, at the first stage, it is necessary to standardize the filing software so as to have one format for the data.

Usually we manage to organize one or two observation campaign a year with a duration of 1-2 weeks.

2.2 Equipment

Let us review the state of instrumentation estate at our observing sites.

In the Crimean Astrophysical Observatory we cooperate together with the Laboratory Physics of Stars and Galaxies leaded by Prof. Gershberg. They can use UBVRI photometer-polarimeter described by Piirola (1984) installed to the 1.25 m reflector AZT-11. Spectral monitoring can be executed with the Shajn 2.6 m reflector. Our group mounted Two Channel High Speed Photometer with the 50-inch telescope. This reflector was made in 1908 and is under renovation during the last couple years.

At the Observatory Terskol our Kyiv team has the possibility to install a photometric system with the 2 m or 0.6 m Carl Zeiss telescopes.

Both these observational sites are equipped with the similar photometric systems based on the Two Channel High Speed Photometer (Zhilyaev et al. 1992).

We equipped our photometric systems with the GPS Smart Antenna ACUTIME 2000 for precise timing and synchronization. Once power is applied, the Acutime 2000 automatically tracks satellites and surveys its position to within meters. It then switches to a predetermined time mode and generates a pulse-per-second (PPS) output synchronized to UTC within 50 nanoseconds (one sigma). An external event capture is available with the resolution 320 nanoseconds.

The Colleagues from the Institute of Astronomy of the Bulgarian Academy of Sciences have made a new Bulgarian Ukrainian Photometer (Antov et al. 2000) with the help of Kyiv team. It can be mounted to the 2 m Carl Zeiss RCC telescope of the Rozhen Observatory or with the 0.6 m telescope of the Belogradchik Observatory.

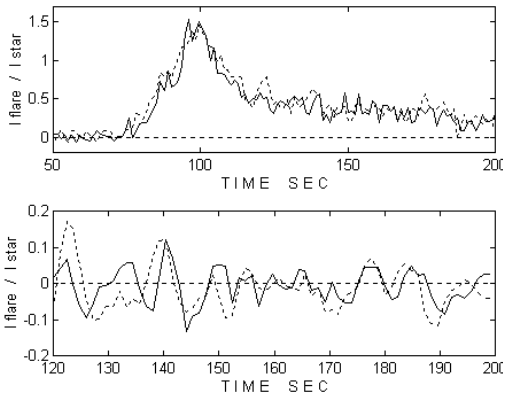
The Colleagues from the Aristoteleion University of Thessaloniki at the Stephanion Observatory used observational technique, which were described by Mavridis and Avgoloupis (1986) with 30-inch telescope.

We should point out that up to this year we had low-level synchronization for our network of the telescopes, because its accuracy was about 1 sec. The mathematical methods have been used to synchronize the time series, which contained flares.

2.3 Science

Forasmuch as CNT begun its operations under the frame cooperative monitoring of the flare red dwarf star EV Lac, most attention was paid to files obtained during our campaigns. Some of our early results have been confirmed via the next observational results obtained with the 1.25 m telescope AZT-11 in Crimea (Zhilyaev et al. 1998). We may conclude that multicolor high-speed observations combined with synchronous monitoring at two distant telescopes, allow one to detect new fine-structure futures in the flare activity.

The detection of intrinsic small-scale light fluctuations in stars is hampered by atmospheric disturbances and instrumental imperfections. To remove large intrinsic intensity variations from the 1998's time series we apply high-pass filtering. We have used both the moving-average and Kaiser convolutions to eliminate the main outburst light curve from the sets of EV Lac data. Fig 1b shows a portion of the high-pass filtered flare light curve obtained at Peak Terskol with the 2 m telescope. Readings in the U band were taken every 0.2 sec.



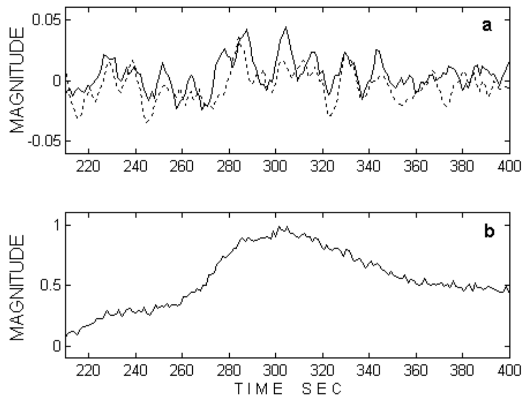


Figure 1. The magnified B-band and raw U-band light curves of the EV Lac flare on September 15, 1998, 22:30:26 UT (max) (upper panel) as seen simultaneously by the Stephanion 30 inch telescope (dotted line) and the Belogradchik 60 cm telescope (solid line). The lower panel shows time variations in high-frequency oscillations; both curves are strongly correlated at a more than 99 % confidence level.

Figure 2. Portions of the high-frequency B-band remains (upper panel) and of the main light curve (lower panel) from the sets of EV Lac data obtained with the Crimean (solid line) and Greek (dotted line) telescopes on September 11, 1998, 21:55:02 UT (max).

The above inferences about high frequencies oscillations were tested by means of the results of many-site synchronous observations. A further example of a highly blue oscillation color is given in Fig. 1. The high frequency B-band residual magnified by a factor of six coincide practically with the U ones.

Fig. 2b shows the main flare curve in B band with a sampling time of 1.2 s. A comparison between these two measurements obtained from synchronous observations at different sites showed obvious correlations significant at greater than 99 % confidence level. A period of $12.8 \pm 0.7 s (0.078 Hz)$ and a mean amplitude of 0.025 mag were calculated from data.

3 SNT for tomorrow

3.1 Science

"Periodic phenomena, by definition, repeat themselves over and over, so the sampling we are forced to rely upon still works. But astrophysical events that take only a short time to complete, and do not recur periodically, are largely beyond our current instrumental ability to recognize reliably, particularly if instrumental artifacts could explain them. Overlapping coverage of the same target object from two separate locations might open up a whole new field of study". This idea has been stressed by Nather et al. (1990).

Our research of parts of the light curves of the EV Lac in quiescence state and other objects shows interesting preliminary results too. Increasing the temporal resolution to milliseconds one should encounter successively more rapid events, on timescales of some tenth seconds and milliseconds. It can be phenomena like: -

optical oscillations during a flare lifetime - small-scale and short-lived non-periodic astronomical events - small-scale instabilities in the accretion discs around compact objects - optical emission from millisecond pulsars etc.

3.2 Equipment

To undertake joint research projects in astrophysics with good competence level we propose to develop instrumentations for SNT. The ideal Earth-based telescopes for SNT and for WET are the same. Their aperture size might be perhaps 3 m (Nather et al. 1990). We have very good potential to organize the telescopes of 2 m class for SNT goal. They spaced in longitude in the Europe and have close latitudes.

We can use of the 2 m telescope at the Observatory Terskol (Russia), the Shajn 2.6 m telescope at the CrAO (Ukraine), and the 2 m telescope of the Rozhen Observatory (Bulgaria). And we propose the same for the new 2.3 m ARISTARCHOS telescope. We think that for some projects, it will be possible to use telescopes with mirrors of a smaller size as we used before now.

We have to develop our high-speed photometers to instrumental uniformity, or at least we need to obtain same formatted files of data.

An optimal design for a new photometer is that which allow the using of new detectors, specially CCDs for high-speed photometry. We have to equip our photometric systems with GPS antenna for precise synchronisation of all SNT telescopes.

3.3 Organisation

To make possible the aforesaid, we have to discus every detail and especially the operating policies of the Synchronous Network of Telescopes for the future.

In conclusion we propose this technique and our capabilities for joint observational projects.

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