

Synchronous network of distant telescopes

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Abstract. The Synchronous Network of distant Telescopes (SNT) represents an innovative approach in observational astrophysics. The authors present a unique existing realization of the SNT-conception. It was founded within the international collaboration between astronomical observatories of Ukraine, Russia, Bulgaria and Greece. All telescopes of the Network are equipped with standardized photometric systems (based on photo-multipliers). The unified timing systems (based on GPS-receivers) synchronize all the apertures to UTC with an accuracy of 1 microsecond and better. The essential parts of the SNT are the original software for operating and data processing. The described international Network successfully works for more than 10 years. The obtained unique observational data made it possible to discover new fine-scale features and flare-triggered phenomena in flaring red dwarfs, as well as the recently found high-frequency variability in some chromospherically active stars.

Key words: stars: flare - stars: individual: EV Lac, SAO 52355 - stars: activity

1 Introduction

The basic idea of the SNT-conception is to consider a number of optical telescopes as a single instrument. Such an instrument provides an elegant solution of wide scope of problems, which remain unresolvable for single-site observations. Synchronous tracking the same source with different distant telescopes enables the user to obtain data sets with the same true signal and independent uncorrelated noise. These obvious advantages enable state-of-the-art experiments, providing observational information of high quality.

Authors discuss the following questions: (a) a new observational technology with the Synchronous Network of distant Telescopes and new methodology of data processing; (b) description of the optical High Frequency Oscillations (HFO) in EV Lac flares; (c) the technique and results of spectroscopic monitoring of transient events with low-resolution grism spectrometer; etc.

2 Observations

The Synchronous Network of Telescopes, involving telescopes at four observatories in Ukraine, Russia, Greece and Bulgaria allows studying small-scale activity of stars with a high time resolution (Zhilyaev et al. 2003). The

instruments used are the following: the 2 m Ritchey-Chretien and the 60-cm Cassegrain telescopes at Terskol Peak (North Caucasus, 3100 m a.s.l.) with a high-speed two-channel UBV photometer (Zhilyaev et al. 1992); the 30 inch telescope at Stephanion Observatory in Greece, equipped with a single-channel photometer with digitized readings in the U band (Mavridis et al. 1982); the 1.25 m reflector AZT-11 at the Crimean Observatory with a UBVRI photometer-polarimeter (Kalmin & Shakhovskoy 1995); the 2 m Ritchey-Chretien telescope at the Rozhen Observatory and the 60-cm Cassegrain telescope at the Belogradchik Observatory with a single-channel UVB photon-counting photometer (Antov & Konstantinova-Antova 1995).

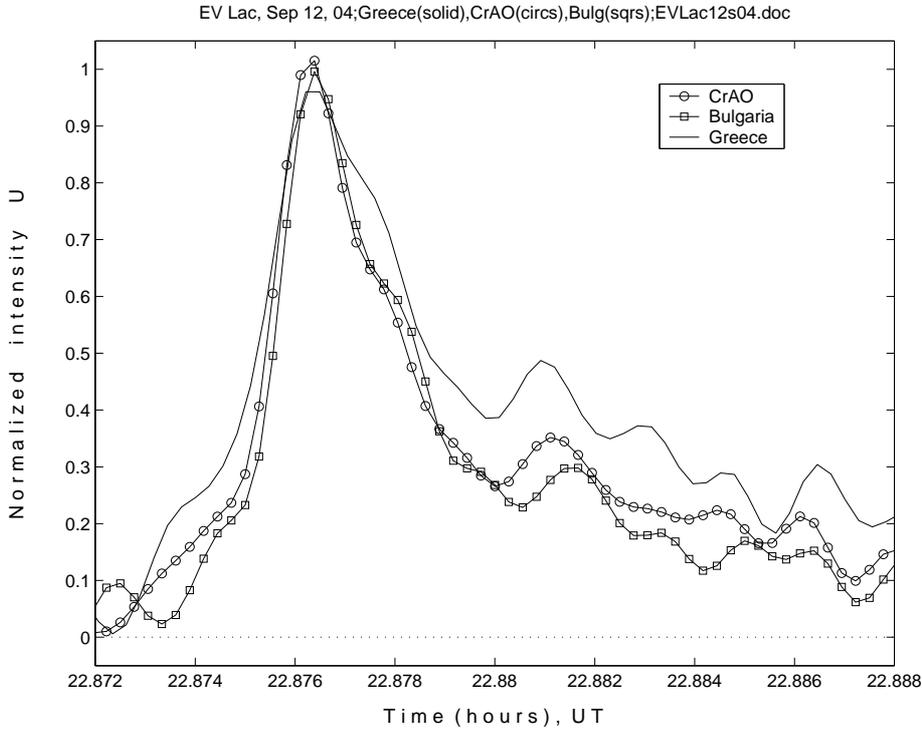


Fig. 1. Multi-site photometry of the flare from September 12, 2004, 22:53 UT (max), as simultaneously seen by the three instruments: Ukraine (circles), Greece (solid), and Bulgaria (squares).

All the telescopes of SNT are equipped with standardized photometric systems based on photomultipliers. The unified timing systems based on GPS technology synchronize all the apertures to UTC with an accuracy of 1 microsecond and better. For operating and processing of the SNT data an original software was developed. The typical integration time is 0.1 s. To increase the signal-to-noise ratio we perform digital filtering of the available photometric data. We use the Kaiser convolution to obtain a low-frequency

outburst light curve from the sets of flaring stars data and a moving-average to suppress high-frequency noises (see details in Zhilyaev et al. 2000).

The SNT team carries out usually two observing campaigns yearly, in winter and in autumn. Figure 1 represents the light curves of the flare detected on Sept. 12, 2004. All sites in Ukraine, Russia, Greece, and Bulgaria had registered this flare event. Figure 1 demonstrates the remarkable consistency of the U-band light curves simultaneously obtained by three instruments of the Crimean, the Stephanion, and the Belogradchik observatories. The smoothed data show clear presence of high-frequency oscillations (HFO) in the descending part of the flare. The application of new observational technology and new methodology of data processing - a high-speed, multi-site monitoring and digital filtering - provided new results: we confirmed HFO in stellar flares and discovered fast color variations of the flares radiation (Zhilyaev et al. 2007). The color-indices and time tracks in the UBVR color-color diagrams are based on the data obtained with the Crimean 1.25 m reflector AZT-11. An example of such color time tracks can be seen in Figure 2.

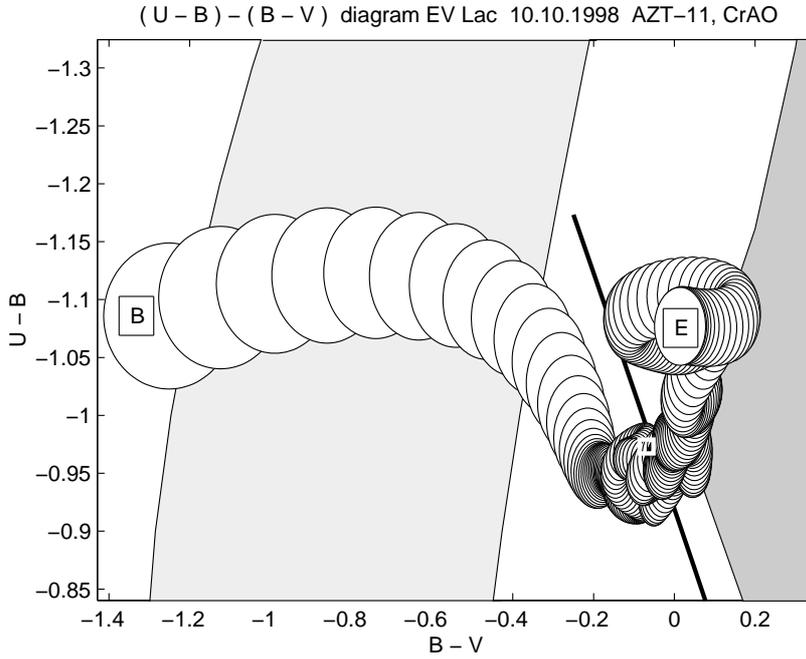


Fig. 2. Color tracks of the flare from Oct. 10, 1998, as observed from the Crimean 1.25 m reflector AZT-11. The 95% error ellipses are shown. The onset and end of the flare are marked by letters B and E, respectively. The light density area denotes color characteristics of plasma optically thin in the Balmer continuum, with $T_e \simeq 15000$ K and N_e from 10^{14} to 10^{10} cm^{-3} , the gray density area covers the region corresponding to plasma optically thick in the Balmer continuum, with T_e from 15000 to 8000 K. Blackbody radiation follows the thick line (Chalenko 1999).

Figure 2 shows the color tracks of the flare of October 10, 1998. According to the theoretical color-color diagrams (Chalenko 1999), the flare's onset (and 95% error ellipse) falls in the region corresponding to the radiation of hydrogen plasma optically thin in the Balmer continuum. The flare in its onset shows extremely blue colors $U-B = -1.1$, $B-V = -1.3$. Using the blackbody model for the photosphere of EV Lac in a quiet state and the observed flare amplitudes in the U-band, one may estimate the size of the flare (Alekseev & Gershberg 1997). For EV Lac in quiescence one may adopt $T_{eff} = 3300K$ (Pettersen 1980). Changes in the color-color diagram prove that the flare in its maximum is similar to a blackbody source with a most probable temperature of 16 000 K.

3 The grism spectroscopy of transient events

The slitless UBVR grism spectrometer is mounted at the Zeiss-600 telescope at Peak Terskol in North Caucasus (Zhilyaev et al. 2010). It allows to carry out parallel recording of the spectrum with subsecond temporal resolution while working in SNT mode. A blazed transmission grating is included in the converging beam in the telescope filter wheel. The wavelength scale after calibration is accurate to about 3 nm. The grating spectrum has a resolution of about 100 at 480 nm. The grism spectrometer can provide moderate signal-to-noise ratio for stars up to 16 magnitude. It allows measuring the equivalent widths of the non blended lines down to 0.07 nm. The grism tools can be used to study temporal variations in the spectra of variable stars. We use customized software that relies on the theory of count statistics to identify intrinsic activity in spectra. This allows us to detect the relative power of fluctuations down to $(10^{-5} - 10^{-6})$ in the visible range.

The obtained unique observational data made it possible to discover new fine-scale features and flare-triggered phenomena in flaring red dwarfs, as well as low-amplitude rapid variability of spectra in chromospherically active stars. Detailed colorimetric analysis based on the fast grism spectroscopic data allowed estimating important characteristics of flares on some red dwarf flaring stars: the temperature at brightness maximum and size. The high temporal resolution monitoring of some chromospherically active stars revealed variations in the Balmer and CaII H, K lines at time span of seconds to minutes with amplitudes of a few percents. This allows us first to assert the existence of intense microflaring activity in these stars (Zhilyaev et al. 2011).

4 Some results

4.1 The flare star EV Lac

100 spectra of strong flare of EV Lac with a time resolution of 7.5 sec are shown in Figure 3. One can easily see a dramatic change in the short wavelength during a flare. By mathematical convolution of spectra with the transmission curves of filters one can obtain estimates of the UBVR magnitudes. The U band light curve of strong flare of EV Lac on Aug 10, 2010 is shown in Figure 4. The synchronous registration of the flare with the 2 m telescope

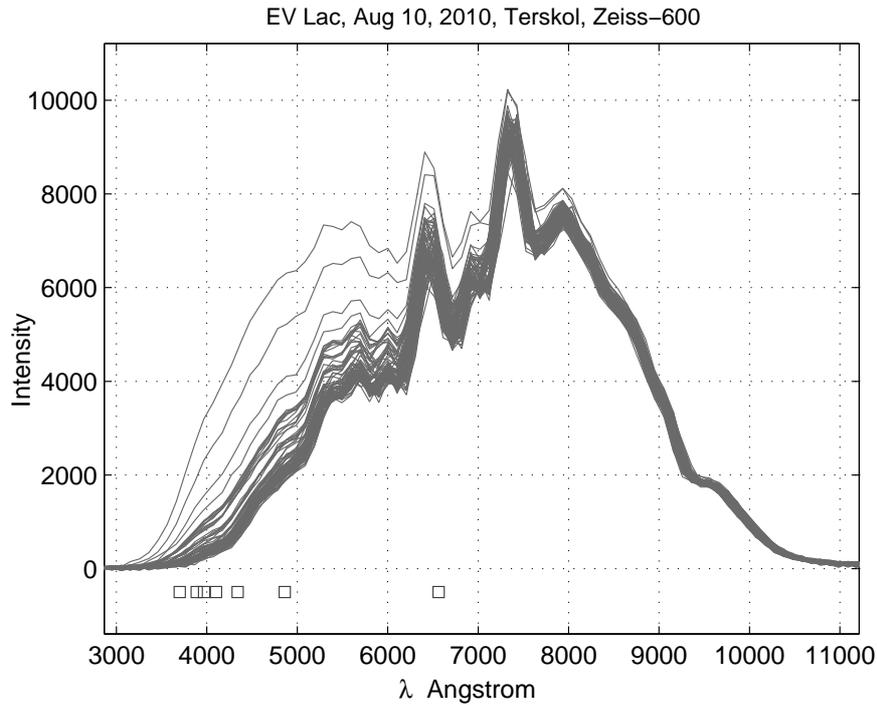


Fig. 3. 100 grism spectra of strong flare of EV Lac on August 10, 2010, obtained with the grism spectrometer on the 60 cm Zeiss telescope.

is also presented on Figure 4. Detailed colorimetric analysis allowed for estimating the temperature at maximum brightness and its size. The two-color (U-B) - (B-V) diagram in Figure 5 confirms that the flare at maximum light radiates as a black body with a temperature of about 13 400 K. The linear size of the flare at the maximum luminosity is about 3.9% of the stellar radius.

4.2 The chromospherically active star SAO 52355

We have carried out low-resolution spectroscopy of SAO 52355 with the Zeiss-600 telescopes at Peak Terskol. SAO 52355 is a field star of the spectral type K0 III. We came out on this star in search of reference stars for the variable EV Lac. The X-ray observations taken by Ginga and ROSAT indicate in SAO 52355 coronae plasma temperatures as high as 10^7 K. This star is supposed to have high-powered chromosphere.

On May 30, 2010, we obtained 200 low-resolution grating spectrograms of SAO 52355. For SAO 52355 we used GSC 3226 640 as the reference star,

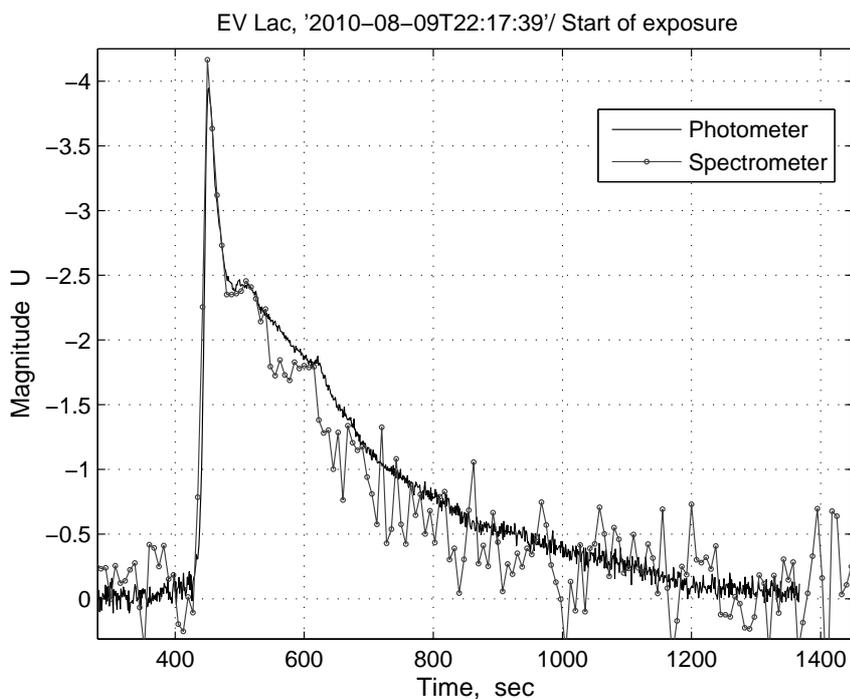


Fig. 4. The U-band light curves of a flare event on EV Lac, August 10, 2010, based on the synchronous observations with the Terskol 2-m telescope (two channel photometer), and the 60 cm Zeiss telescopes (grism spectrometer).

Johnson V magnitude: 10.69. Data inferred from the Tycho catalog: BT magnitude 11.018 ± 0.032 , VT magnitude 10.726 ± 0.036 . Johnson B-V color, computed from BT and VT: 0.270.

In Figure 6 the relative power of variations in grating spectra of SAO 52355 and its reference star GSC 3226 640 are shown. Note the "smooth" spectral energy distribution in the power spectra of the reference star and the "emission" features at wavelengths of the Balmer lines and the CaII H, K lines, as well as at the wavelength of the Balmer jump (370-380 nm) in SAO 52355. From the power spectrum data one can find that variations in the intensities of the CaII H, K and H_γ lines are 3.2% and 1.5%, respectively.

It is found that chromospherically active stars show strong Hydrogen and Ca II emission lines as well as high X-ray luminosity. As mentioned by Gondoin (2003), the high X-ray flux from chromospherically active stars detected by space observatories could be explained by assuming that the heating of its corona results from a large number of small flares. It is well-known that the stellar coronae are heated by the two most favored agents involving magnetic fields, namely MHD waves and transients, such as flares, and microflares (see

Narain & Pandey 2006, and references therein). It is thought that flares are associated with conversion of magnetic energy of plasma to thermal energy via magnetic reconnection. The reconnect heating by foot-point motions was proposed first by Parker (1991).

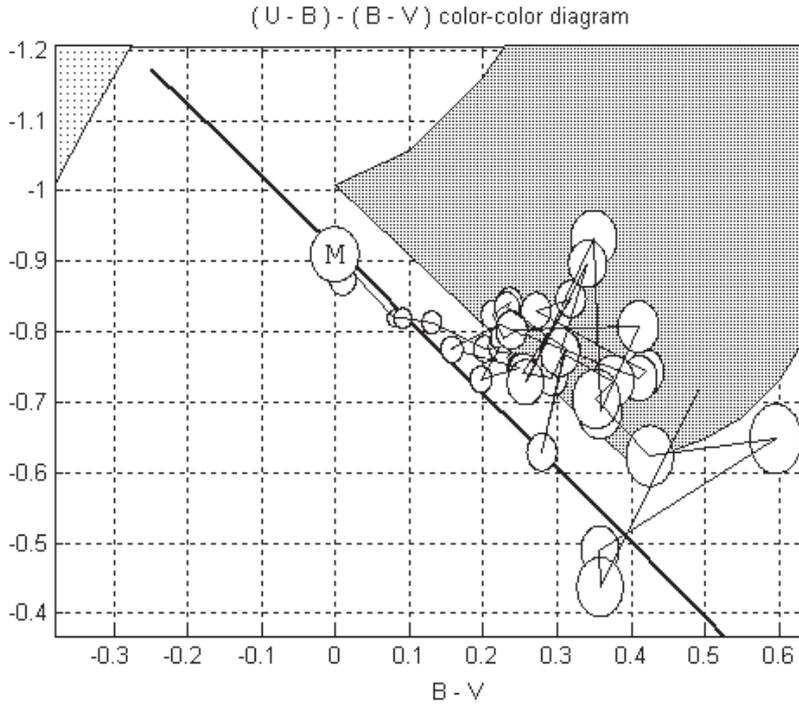


Fig. 5. Color tracks of a flare in the diagram $(U - B) - (B - V)$ from the grism data. Ellipse with the letter M marks the position of the flare maximum. At maximum light a flare emits as a blackbody with a temperature of 13400 ± 500 K. The size of the flare is 3.9% of the radius of the star, or about 0.15% of the visible disk of the star.

A forest of closed magnetic loops has foot points ankered in photospheric regions. The mechanical energy flux is generated by foot point motions. These motions increase the energy stored in the entwined magnetic field. This system can return to a minimum energy configuration only after a reconnection (or a cascade of reconnections). It is thought that these small and frequent reconnection events give rise to the microflare heating (Narain & Ulmschneider 1996).

Thus, our observations allows us to assert the existence of intense microflaring activity in the chromospherically active star SAO 52355.

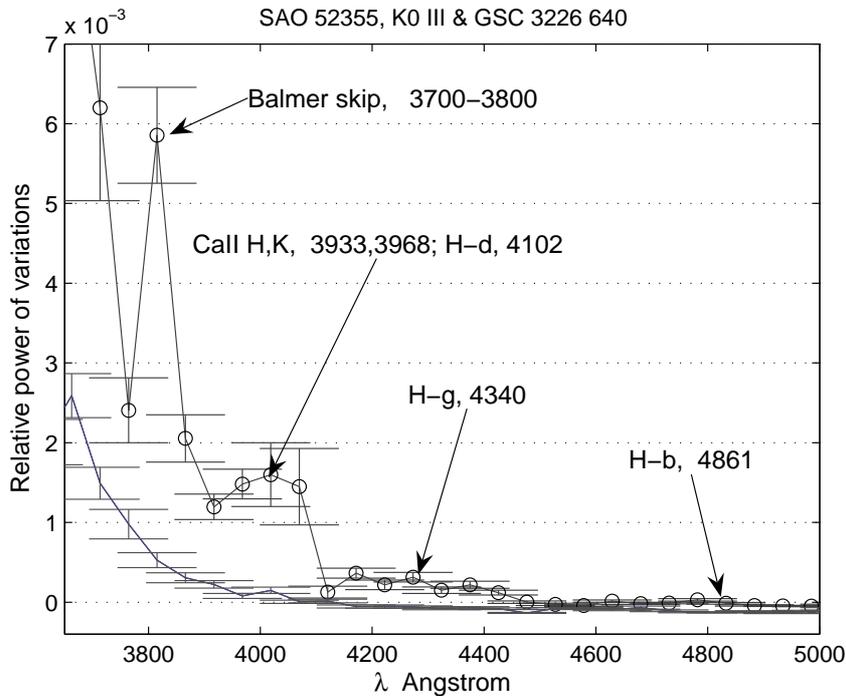


Fig. 6. The relative power of variations in grating spectra of SAO 52355 (circles) and its reference star GSC 3226 640 (solid curve). 1 sigma error bars are shown.

5 Conclusion

The application of new observational technology with the Synchronous Network of distant Telescopes and new methodology of data processing provided new results: we confirmed High-Frequency optical brightness Oscillations (HFO) in stellar flares and discovered fast color variations of the flare radiation.

Our first description of the optical HFO in the EV Lac flares (Zhilyaev et al. 2000) was interpreted by Kouprianova et al. (2004) and Stepanov et al. (2005). They concluded that a source of such an HFO is located at a magnetic loop footpoint, the pulsations are determined by modulation of the flux of energetic particles descending along a loop with fast magnetoacoustic oscillations.

Spectroscopic monitoring of the chromospherically active star SAO 52355 showed variations of intensity in the Balmer lines and in the CaII H, K lines at time intervals ranging from seconds to minutes. From the power spectrum data one can find that variations in the intensities of the CaII H, K and H_{γ} lines are 3.2% and 1.5%, respectively. Satellite surveys at X-ray indicate high

temperature coronae plasma in many chromospherically active stars. High-frequency changes, which were found in SAO 52355, suggest the existence of intense microflaring activity in this star.

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