HIGH–FREQUENCY OPTICAL OSCILLATIONS ON THE FLARE STAR EV LACERTAE

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Due to many-site multicolor synchronous monitoring of the flare star EV Lac and the careful treatment of the data obtained, we have confirmed the reality of rapid optical brightness oscillations during a significant part of a flare lifetime as was discovered by Rodonó in 1974 [3]. Our findings, based on three flare events in EV Lac, allow us to conclude that high frequency optical oscillations are coherent, with periods of 13 and 26 s and amplitudes of 0.025 mag in the B band and larger by a factor of 5 in the U band. As found, UBV color indices of the mean flare light curve differ significantly from those of the oscillations.

OBSERVATIONS, METHODS AND RESULTS

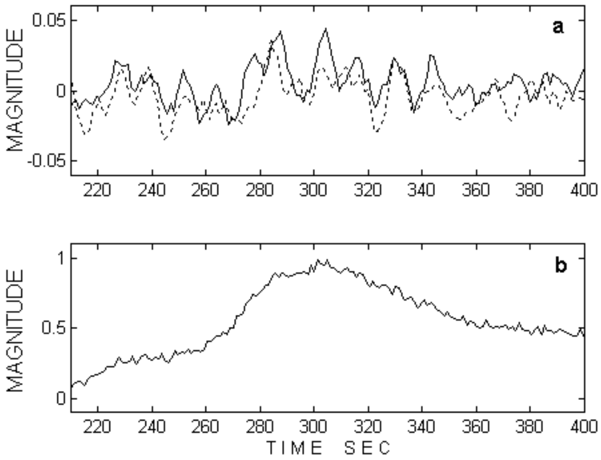
Amongst the vast variety of stellar flare light curves, a special place is occupied by the flare in the Hyades flare star HII 2411, which occured on November 20, 1972 and was detected by Rodonó [3]. During this rather intense flare, he registered highly oscillatory phenomena with the oscillation period varying from 13.7 to 12.4 s throughout the recording time of about 12 min; the oscillation amplitude appeared to be constant and was equal to about 25% of the mean intensity in the quiescent phase in white light. Here, for the first time, we describe similar optical brightness pulsations in the EV Lac flares which we detected with a more accurate technique including many-site multichannel monitoring and which we analyzed with much more sophisticated methods.

The observational data for the flare star EV Lac reported here were obtained from four separate sites over 19 nights in September– October 1998. The instruments which were used were the following: the 2-m Ritchey-Chretien and the 60-cm Cassegrain telescopes at Peak Terskol; the 30-inch telescope at the Stephanion Observatory in Greece; the 1.25-m reflector AZT-11 at the Crimean Observatory; the 60-cm Cassegrain telescope at the Belogradchik Observatory. The typical integration time was 0.1 s. The UBV data were converted to a relative intensity scale with respect to the mean values of quiescent fluxes.

To detect small oscillations, large intrinsic intensity variations must first be removed. To achieve this, we apply high-pass filtering. The near-ideal Kaiser filter was used [2]. The filter coefficients are

$$h(k) = h(-k) = \frac{\sin(\pi \nu_c k)}{\pi\ k} \cdot \frac{I_0(\eta\sqrt{1-(k/l)^2})}{I_0(\eta)}, \tag{1}$$

where $I(x)$ is the modified Bessel function of the zero order, η is the parameter that enters the filter model, l is the number of filter coefficient pairs. Three basic input parameters, *i.e.*, the filter passband ν_c given in units of the Nyquist frequency, the width of transition band and the stopband loss in the decibel scale, completely determine quantities η, l and the filter as a whole (for more details see [1]). In our cases the cutoff frequency value of 0.033 Hz was employed. This removes any variations in time scales greater than 30 s.



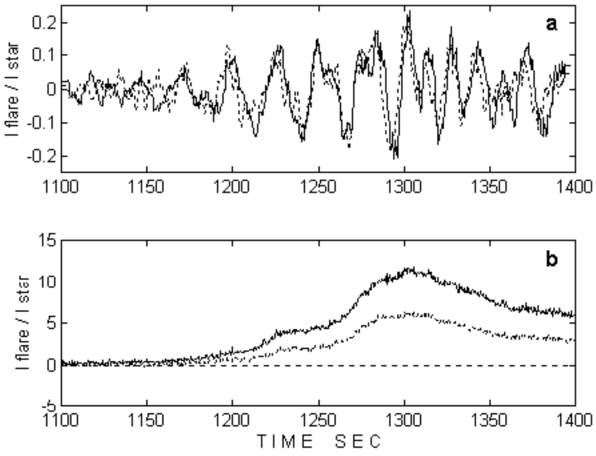


Figure 1: (left) Portions of the high-frequency B-band remains (upper panel) and of the main light curve (lower panel) from the sets of EV Lac data obtained with the Crimean (solid line) and Greek (dotted line) telescopes on September 11, 1998, 21:55:02 UT (max)

Figure 2: (right) Time variations in high-frequency oscillations in the U (solid) and B (dotted) bands from the same sets of EV Lac data obtained at Crimea (upper panel). The lower panel represents the raw main U and B light curves. Both B curves are magnified by a factor of 5

Figure 1a shows the simultaneous observations of the oscillations on EV Lac at the Crimean and at the Stephanion observatories. Figure 1b shows the main flare curve in B band with 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) was obtained from the times of maxima and a mean amplitude of 0.025 mag was calculated. From these facts we can be assured that both an atmospheric and an instrumental origin for the high-frequency oscillations can be ruled out with a high degree of confidence. Figure 2 gives some insight into the way in which high-frequency oscillations arise and develop during the progress of a flare. An illustrative example of a strong excitation of oscillations is furnished by Figure 2a. These oscillations first arise at the earliest stage of the flare development, with a frequency of 0.039 Hz (the period = 25.7 $\pm$ 1.8 s). Some time later they transform into a wave of a twofold frequency. Their amplitudes may reach 10% of the quiescent intensity in the U band and about five times lower in the B.

As the data of Figure 2 suggest, the UB color indices of the mean flare light curve differ significantly from those of the oscillations. They are as follows: U–B = -0.99 ± 0.06 , B–V = -0.46 ± 0.07 and U–B = -0.42, B–V = 0.07, respectively. The color indices do not show variations with time in the vicinity of the brightness maximum and on the portion of the descending light curve to an accuracy of 0.07 mag.

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