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Transient high frequency optical oscillations on two weak flares of the red dwarf V390 Auri

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In this paper the presence of high-frequency oscillations on two weak flares of the G8 dwarf V390 Auri is investigated. The combined use of fractal analysis and DFT-analysis enable us to estimate proper random noise and to detect possible weak transient optical oscillations. In accordance with the results of the previous studies the results of the present study indicate that (1) transient high frequency oscillations occur during the flare event; (2) the observed frequencies, not rigorously bounded, range between 0.011 Hz (period 1.5 min) and 0.083 Hz (period 12 s). This result is in accordance with the results of the observation of transient optical oscillation on strong and medium flares.

Keywords: Flare stars; High frequency oscillations; DFT analysis

1 Introduction

Observational results on the red dwarfs EV Lac (Zhilyaev et al. 2000, 2007; Contadakis et al. 2004a,b; Contadakis et al. 2006), AD Leo (Contadakis et al. 2010, 2011), EQ PegB (Mathioudakis et el. 2006) indicate that transient high frequency oscillations occur during the flare event and during the quiet-star phase as well. This phenomenology is consistent with the generation of a fast mode magneto-acoustic wave generated at the base of the magnetic loop at the impulsive phase of the flare and travelling through the loop (Roberts et al. 1984; Nakariakov et al. 2004; Trap et al. 2011). The postulation that this is a general characteristic of active red dwarfs is a very important task. In the context of this consideration we present the results of the analysis of the U-light curve for two weak flares of the red dwarf V390 Auri. In a recent international patrol study, Konstantinova et al. (2005) concluded that the flare activity of V390 Auri is lower than that of AD Leo and comparable to the flare activity of EV Lac but no attention was paid to the presence of high-frequency oscillation.

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2 Observations

The observations were carried out with the help of the 30-inch Cassegrain telescope of the Stephanion Observatory ($\phi = 22°49'45'', \lambda = 37°45'09''$ and $h = 900$ m) which is equipped with a Johnson photometer. The digitized recording system has a recording resolution of 0.108 s. The observations on V390 Auri consist of continuous monitoring in the U-band during the flare patrol periods of 20 to 30 October 2000, and 2 to 14 February 2002. The total patrol time was 3.5 and 4 hours respectively for each period and one weak flare was observed in each observational period. Table 1 displays the characteristics of these flares and Fig. 2 displays the light curve of Flare No 2 as an example.

Table 1 Characteristics of the observed flares.

Flare No	Date	$UT_{\max}$	Duration (min)	$(I - I_0)/I_0$ (max)	σ_I	$\sigma_{\rm BW}$
1	23/10/00	00h52.87m	>14.26	0.06	0.15	0.01
2	13/02/02	18h27.53m	16.63	0.04	0.015	0.01

where $UT_{\max}$ is the Universal Time at the flare maximum, Δm the variation of stellar brightness in magnitudes at the moment of flare maximum, $((I - I_0)/I_0)_{\max}$ the normalized flare intensity at maximum, σ_I the standard deviation of the deflection random noise, estimated from the quiet state of the star and $\sigma_{\rm BW}$ the standard deviation of the deflection random noise, estimated from the particular flare deflection on the base of the Brownian Walk characteristic of random noise (see Analysis).

3 Analysis

The data consist of a sample of relative intensities, i.e., $(I - I_0)/I_0$, where I is the flare intensity and I_0 is the quiet star intensity. The extent as well as the resolution of the observational sample is suitable for a reliable Discrete Fourier Transform analysis of sufficient light-curve parts for the determination of possible transient oscillations in the frequency domain and their approximate location in the time domain. For the determination of the reliability of the results, the standard deviation of the photometry which is determined from the standard deviation of a certain part of the star deflection, plays a key role, as it is recorded by the recording facility at hand. This sample is considered, according to the observer's estimation (judgment) to reflect the noise of his photometric system and is clear from any real stellar brightness variation, which is assumed to be white noise. However the quiet star deflection is the sum of three components (a) the noisy stellar brightness assumed to be white noise (b) the inherent atmospheric noise which we assume to be random, i.e., white noise and (c) the white noise of the recording system. If the memory of the recording system is short, i.e., the system has large sampling intervals, then the quiet star deflection is white noise. If the memory of the recording system is large, i.e., the sampling interval

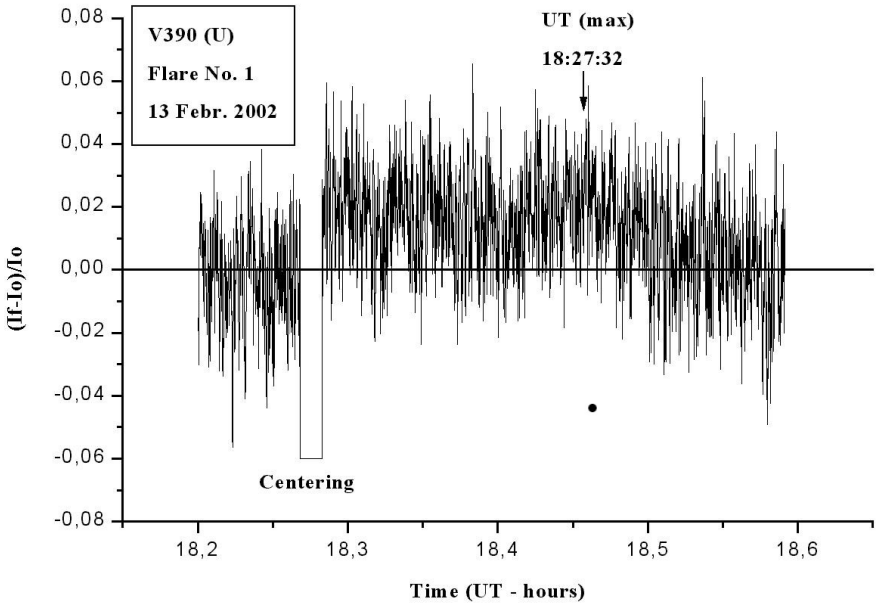


Figure 1 Flare No 2 of V 390 Auri at 13 February, 2002.

is very short the quiet star deflection is Brownian Walk (Turkotte 1997). This is the case of the most stellar recording systems today. Brownian Walk is an affine fractal and has a power low spectrum with $b = -2$ (Contadakis et al. 2006, 2011).

Our system has a sampling interval of 0.108 seconds which is very short. On the base of this property it is possible to separate the random noise of our data from the not random variations even from the signal of the active part of a star and furthermore to determine any non-random deflection variation. The standard deviation which is derived using the Brownian Walk part of the frequencies, called $\sigma_{\rm BW}$, may be up to 30% smaller than the conventional one (σ_I). The respective $\sigma_{\rm BW}$ for each flare is given in the seventh column of Table 1. This standard deviation was used for the estimation of the confidence level of the detected potential oscillations.

4 Results and discussion

White light high-frequency oscillations are mostly observed and studied on relatively large and medium size flares, although some researchers point out that it may occur during the quiet state of the flare stars (Contadakis et al. 2006, 2010). The flares under investigation are very weak and it is very interesting to see if high-frequency oscillations are also present. Figure 2 displays the logarithmic power spectrum of V390 Auri for the weakest flare, namely that of February of 2002.

It is seen that the power spectrum presents a breaking point at $\log f = -4$ which corresponds to instrumental frequency 0.0183 cycles/gap. This corresponds to 0.1696

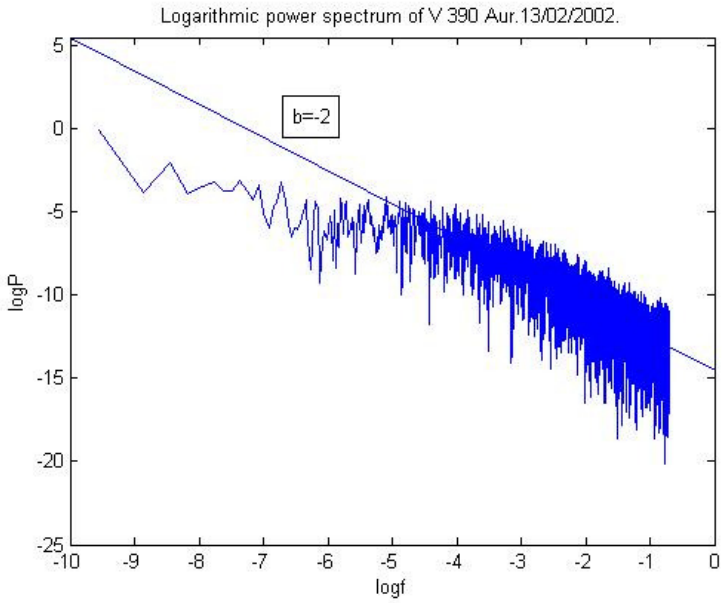


Figure 2 Logarithmic power spectrum of the flare of 13/02/2002.

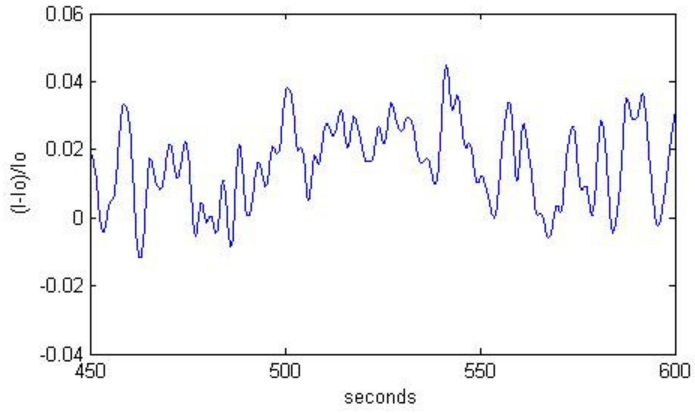


Figure 3 A part of the flare light curve. Transient oscillations with periods of 10 to 14 seconds are seen.

Hz, i.e., a period of 5.8966 seconds. This indicates that the random part of the spectrum comprises the fluctuations with frequencies higher than 0.0183 cycles/gap, i.e., the random noise while the lower frequencies part comprises non-random fluctuations. So we filter out the random part, which comprises the random noise part of the fluctuation, and de-noise the flare light curve. We now determine the accuracy of our photometry which is given by the standard deviation of the Brownian Walk part of

the deflection which is $\sigma_{\rm BW} = 0.0105$. This is displaced in the seventh column of Table 1.

Figure 3 focuses our interest in a part of this light curve. As it is shown in this figure the light-curve of the flare is dominated by transient oscillations with periods 10 to 14 s and amplitudes ≈0.02 superimposed on oscillations with period 1.5 min and amplitudes ≈0.03. Comparing the magnitudes of these transient oscillations with the standard deviation of the photometry ($\sigma_{\rm BW} = 0.0105$) we conclude that the confidence level of the identification is smaller than 2% (probability of correct identification higher than 98%). Also the power spectrum of the light-curve is marked by picks of increasing magnitudes which correspond to frequencies ranging between 0.011 Hz (period 1.5 min) and 0.083 Hz (period 12 s). The above figure indicates that these frequencies correspond to transient weak oscillations.

5 Conclusions

The combined use of fractal analysis and DFT analysis enable us to estimate the proper random noise and detect possible weak transient optical oscillations. In accordance with the results of the previous studies the results of the present study indicate that (1) transient high frequency oscillations occur during the flare event; (2) the observed frequencies, not rigorously bounded, range between 0.011 Hz (period 1.5 min) and 0.083 Hz (period 12 s). This result is in accordance with the results of the observation of transient optical oscillation on strong and medium flares.

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