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SDSS J080434.20+510349.2: cataclysmic variable witnessing the instability strip?

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Abstract. Among the accreting pulsators that have experienced a dwarf novae outburst, SDSS J080434.20+510349.2 has the most dramatic history of events within a short time scale: the 2006 outburst with 11 rebrightenings, series of December 2006 – January 2007 mini-outbursts, the 2010 outburst with 6 rebrightenings. Over 2006–2011, in addition to positive 0.060-d superhumps during the superoutburst and 1-month post-outburst stage, 0.059005-d orbital humps in quiescence, it displayed the periods of $P1 = 12.6$ min, $P2 = 21.7$min, $P3 = 14.1$ min and $P4 = 4.28$ min. The 12.6-min non-radial pulsations of the WD first appeared 7 months after the 2006 outburst and was the most prominent one during the following ~ 900 days. They varied within a range of 36 s, and amplitude changed from 0.013^m to 0.03^m. Simultaneously there were the less significant 21.7-min and 14.3-min periodicities. During the minioutbursts the 21.7-min periodicity became the most powerful while the 12.6-min one was less powerful. After the 2011 outburst the most prominent short-term periodicity appeared ~ 7 months after the outburst, but at 4.28 min. We identified that variability with periods P2, P3 and P4 could be additional pulsation modes.

Key words. Stars: binaries – Stars: cataclysmic variables – dwarf nova, Individual: – Stars: SDSS J080434.20+510349.2

1. Introduction

SDSS J080434.20+510349.2 (hereafter SDSS J0804) was first discovered as a CV and was

Send offprint requests to: E. Pavlenko considered as a potential dwarf nova with an underlying white dwarf (WD) in quiescence prior to the 2006 outburst (Szkody et al. 2006) and it was first found in outburst by Pavlenko et al. (2007). Its 0.060-d superhump period (Pavlenko et al. 2007; Kato et al. 2011) and 0.059005-d orbital period (Pavlenko 2009; Zharikov et al. 2008; Kato et al. 2009) suggested SDSS J0804 as a period bouncer, passed the period minimum (Zharikov et al. 2008). Pavlenko (2007) first discovered the non-radial pulsations of the WD that appeared 8 months after the 2006 outburst and lasted for ~ 2 years. Now there are thirteen accreting pulsating WDs belonging to the SU UMa stars (Mukadam et al. 2010). Among the accreting pulsators that have experienced a dwarf novae outburst, SDSS J0804 has the most dramatic history of events in a short time scale. During 2006 – 2010 interval SDSS J0804 underwent two outbursts in 2006 and 2010, accompanied by 11 and 6 rebrightenings consequently (Pavlenko et al. 2007; Kato et al. 2011). Additionally a series of mini-outbursts have been observed in December, 2006 – January, 2007 (Zharikov et al. 2008). This CV gives a unique opportunity to study the evolution of the WD pulsations under such rare conditions.

2. Data set

Here we present an analysis using already published data (Pavlenko et al. 2007; Zharikov et al. 2008; Pavlenko 2009; Pavlenko & Malanushenko 2009; Kato et al. 2009; Pavlenko et al. 2010; Kato et al. 2011) and unfiltered data newly obtained on April 4, September 5 and September 6 at the 2.6-m Shajn telescope of the Crimean astrophysical observatory with 20-s exposure time.

3. 2006 and 2010 outbursts

Despite there was some reason to believe that SDSS J0804 is similar to WZ Sge, possessing the outburst activity once per tens of years (Pavlenko et al. 2007), it displayed the second outburst four years after the 2006 outburst. The overall light curve is shown in Fig.1.

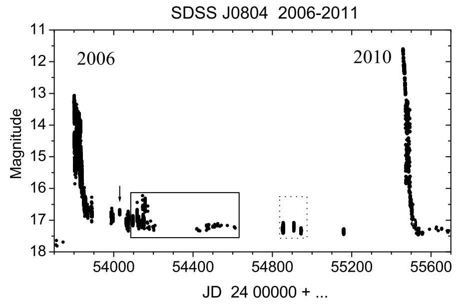

Fig. 1. The light curve of SDSS J0804 in 2006–2010. The arrow points to the first detection of pulsations. The first prolonged box designates the time interval where pulsations were observed. The second small box indicates the period of unstable appearance of observed pulsations.

The increased scattering around JD = 2454150 is attributed to minioutbursts. Note that the first appearance of pulsations was detected before and close to the start of minioutbursts.

The 2010 outburst differed from the previous one at least in a sequence of rebrightenings. The comparison of rebrightenings is given in Fig. 2. Besides their different number during the first and second outbursts, rebrightenings in 2010 have a larger amplitude. Also the system became fainter much more quickly in 2010 than in 2006 at the same epoch following the end of the main outburst. In ~ one month since the end of the main outburst, SDSS J0804 was one magnitude fainter in the 2010 than in the 2006.

4. WD pulsations

During 50–60 days after both the 2006 and the 2010 outbursts the most powerful signal of variation was the 0.060 d superhump period with amplitudes of 0.15^m – 0.25^m. Later it was replaced by the orbital signal. The profile of the orbital light curve before and after the 2010 outburst is similar. It was two-humped curve with eclipses (Kato et al. 2009) and with slight (~ 0.02^m) and occasional brightness depression in every hump. An example of peri-

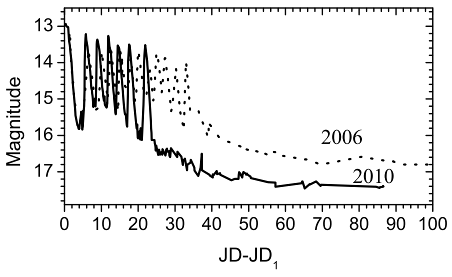

Fig. 2. The comparison of the rebrightenings occured after the 2006 outburst (dotted line) and the 2010 outburst (solid line). The zero-point of the X-axis starts at the rapid decline after the main outburst plateau. Data are combined, using T0 = JD 2453801 for the 2006 outburst and T0 = JD 2455470 for the 2010 outburst.

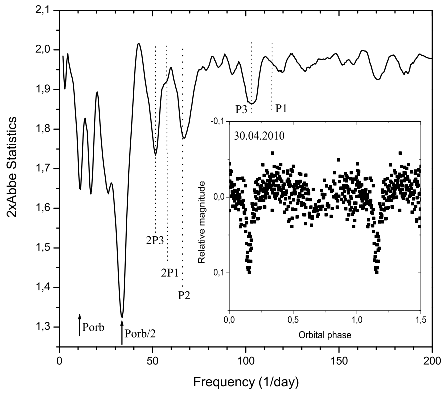

Fig. 3. Periodogram for the original data of April 30, 2011. In the inset the data folded on the orbital period are shown. The peak corresponding to the 12.6-min pulsation is designated as P1. The positions of periods corresponding to $P2$ = 21.7 min and $P3$ = 14.1 min (see later sections in the text for detail) are also pointed.

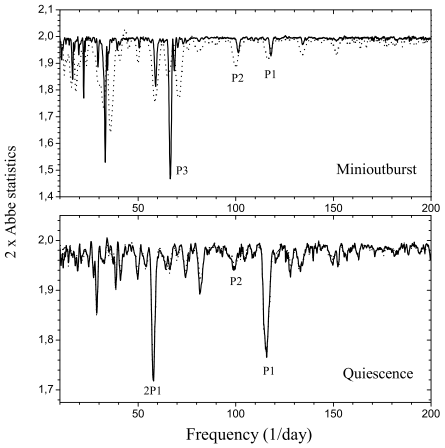

Fig. 4. Above: the two periodograms for the data in the minioutburst (JD 2454117 and 2454118). Below: the two periodograms for the data in quiescence (JD 2454123 and 2454124). For each pair of periodogram the original ones are denoted by the solid and dotted lines. The orbital signal has been removed before making the periodograms.

odogram and data for 2011, April 30 folded on the orbital period is shown in Fig. 3. The periodogram analysis has been carried out using the Stellingwerf method (Pelt 1980). Note that there are no evidence of 12.6-min pulsations that have been before the 2010 outburst. The period P3 roughly coincides with Porb/6. Period P2 will be discussed below.

The periodograms in a region of frequencies 10 – 200 d^{-1} during the 2007 minioutbursts and apart of them differ drastically (Fig. 4).

During the two nights in the minioutburst (JD 2454117 and 2454118) the 12.6-min pulsations have been detected but at a much lower significance than the most prominent periodicity at 21.7 min (designated as P2 in Fig. 3.) The 21.7-min period is not related to harmonics of orbital period and we interpreted that it could be an independent nonradial pulsation of the white dwarf. Meanwhile the periodograms for the data after termination of this minioutburst (JD 2454123 and 2454124) display the biggest peaks related to $P1$ = 12.6-min pulsations and 2P1. The peak related to P1 is more significant than those in the periodograms for the minioutburst. The 21.7-min peak is difficult to distinguish from the noise of periodograms in quiescence.

On every nigh when the 12.6-min period was recorded, we estimated its current value. The drift of this period in a region of 732

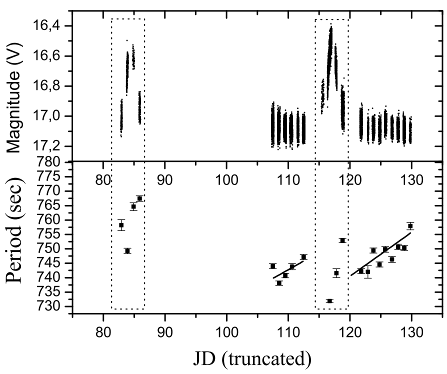

Fig. 5. The light curve including two minioutbursts (above) an corresponding drift of 12.6-min pulsation (below). The zero-point of the time scale is JD 2454000

s – 768 s is obvious. This region is ~ 10 times wider than those found by Mukadam et al. (2010) for SDSS J161033.64-010223.3. Note that variations of the period presented by Mukadam et al. (2010) referred to a time scale ~ 100 times shorter then ours. In Fig. 5 we presented the details of period drift around the minioutbursts.

It is seen that during the minioutbursts themselves there is a larger scatter of periods, while after the every of minioutburst the periods lengthened. In a whole during the ~ 900 days this period varied in the same region regardless of the presence of minioutbursts. The drift of this period together with amplitude of pulsations is shown in Fig. 6. The amplitudes varied from 0.013^m to 0.030^m. The last data at JD 600 – 960 showed a decrease in period together with a decrease in amplitude. There was, however, no correlation between periods and amplitudes for the entire data.

As already pointed out, the duration of the stable appearance of 12.6-min pulsations was ~ 900 days. After the 2010 outburst these pulsations did not appear at least during the following ~ 11 months. However in the 7 months the 4.28-min (257 s) periodicity was detected. We can't immediately claim that this periodicity reflects a new pulsation mode. In Fig. 7 the periodograms for the data of three nights (April 30, September 5 and 6, 2011) are shown.

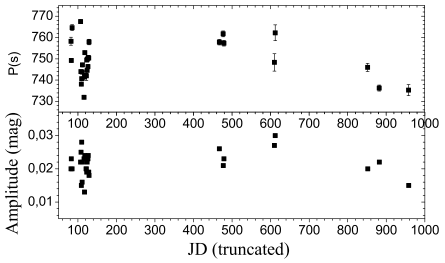

Fig. 6. The drift of periods and amplitudes of the 12.6-min pulsations of SDSS J0804 during ~ 900 days since the appearance of pulsations. Zero-point of the time scale is JD 245400.

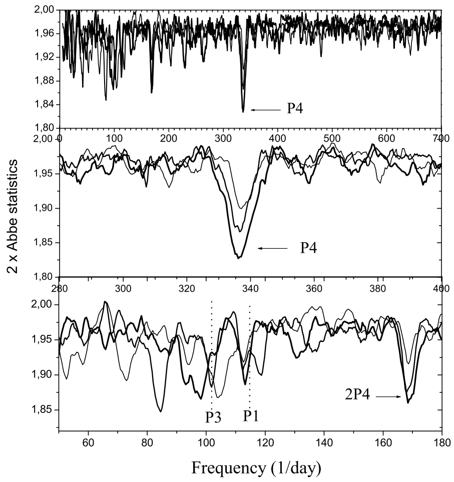

Fig. 7. Above: The periodograms for the data of April 30 (thin line), September 5 (thick line) and September 6 (thickest line) in a region of frequencies 5–700 d^{-1}. Middle: The central part of the periodograms. Below: The cut of the periodograms in a region of peaks clustered at a long-period part of periodograms. The position of periods P2 and P3 is shown by dotted lines. The orbital signal was removed before making the periodograms.

One could see that a frequency, corresponding to the 4.28-min period is the most prominent one in a region of frequencies of 5–700 d^{-1} for all periodograms (there is also less significant peak at 8.56-min that corresponds to its double value). Its amplitude is 0.015^m. It is impossible to conclude immediately if this period is caused by the WD nonradial pulsations or by the WD rotation (in the last case the expected rotational period will be 8.56-min).

One could see also a group of a less significant peaks near the long-period edge of the periodograms, clustering around frequency, corresponded to period P3. From these three nights the periodogram for the April, 30 and September, 5 indeed contained a peak which coincides with P3 within the limit of accuracy. Note that there are no peaks at the 12.6-min period.

5. Conclusions

SDSS J0804 experienced many accretion events over last four years, that could affect the WD, resulting in the appearance and disappearance of WD nonradial pulsations. In present work we investigated the behavior of the most prominent 12.6-min pulsations (P1), which was stable over $\sim$ 900 days. The nature of other periods is unknown. Future observations are needed in order to clarify whether or not the P2 = 21.7 min and P3 = 14.1 min have a transient nature, these periods have relation to the WD pulsations, and if the 4.28-min periodicity is a new pulsation mode or related to the WD rotation.

6. Discussion

PAULA SZKODY: It seems quite unusial to me 1-mag minioutbursts in a WZ Sge star (they usually only have SOBs).

ELENA PAVLENKO: SDSS J0804 indeed is unusual WZ Sge type star. It has common features with WZ Sge stars such as a short orbital period 0.0590048 d, large 6-mag amplitude of the superoutburst, 11 rebrightenings after the 2006 outburst and 6 rebrightenings after the 2010 outburst, the two-humped orbital profile. But occurrence of mini-outbursts is known only for this system.

DMITRY BISIKALO: Do you have any explanations of these pulsations?

ELENA PAVLENKO: Not yet! This question is rather difficult. Probably these pulsations are more strong during the mini-outburst and after them the amplitude of pulsations became less then the amplitude of the 12.6-min pulsations.

DMITRY KONONOV: What is the photometric precision of the instrument you use and what mathematical methods do you use to pick out these pulsation periods?

ELENA PAVLENKO: All observations were done with the 2.6-m Shajn telescope of the Crimean astrophysical observatory in primary focus with best accuracy of the 0.005–0.007 magnitudes. The analysis we used was method of Stellingwerf developed by Jaan Pelt in his package ”ISDA”.

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