Short-term variability of dwarf nova SS Cyg during outbursts

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Abstract. Here we report the results of CCD observations of classical dwarf nova SS Cyg carried out with the two 60-cm telescopes in Crimea during the last years. These observations cover a few outbursts in 2006, 2007 and 2008. Power spectrum analysis of our CCD data clearly shows the existence of rapid periodic oscillations in the light curve of SS Cyg at the stage of decline after maximum. CCD observations of SS Cyg in autumn 2006 outburst revealed oscillations with the two periods 10 s and 76 s, in November 2007 – with 41 s period and in January 2008 with 98 s. We interpret detected variations as quasi-periodic oscillations.

1. Introduction
Dwarf nova SS Cyg belongs to U Gem sub-type (classical dwarf novae with quick brightening of large amplitude). SS Cyg undergoes outbursts once every 50 days. During an outburst the magnitude of SS Cyg increases up to 8 m. After outburst it returns to the previous brightness 12 m and remains in quiescent state a few weeks. Three types of outbursts are observed in this system depending of outburst amplitude and duration: normal, long and anomalous ones. SS Cyg system consists from white dwarf and a cool late type optical star that fills its Roche lobe and transfers mass to the white dwarf, forming an accretion disk around it. The orbital period is 0 d.275130 and masses of the components M rd ~ 0.46 M ⊙ and M wd ~ 0.66 M ⊙, orbital inclination of the system is about 50° Voloshina and Khruzina (2000).

2. Observations
Observations of dwarf nova SS Cyg were performed during different outbursts in 2006, 2007 and 2008. Photoelectric observations of SS Cyg in August and October 2007 were made with UBV photometer on the 60-cm and 50 cm telescopes of Sternberg Astronomical Institute in Crimea. CCD observations of SS Cyg during outburst in October 2006 and November-December 2007 were taken with Apogee 47 device on the 60 cm telescope also with 1 s and 2 s time resolution (V band). Observations of SS Cyg in January 2008 were made on the 60-cm telescope with UBV photometer. In figure 1 we illustrate the overall light curves of SS Cyg for 2 outbursts when our observations were carried out. The visual data for them were kindly given to us by American Association of Variable

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Star Observers (AAVSO). Figure 2 shows some of the daily light curves of SS Cyg obtained in maximum, decline and quiescence.

Figure 1. The latest outbursts of SS Cyg in 2007 and 2008.

Figure 2. Some of SS Cyg daily light curves obtained during two recent outbursts: in autumn 2007 (quiescence, maximum and decline, left) and in anomalous outburst in January 2008 (maximum and decline, right).
3. Short-term variability
Different types of short-term variations occur in dwarf novae (Hack and La Dous 1993). They are:
- **the flickering** – random light variations on the time-scales of minutes with amplitudes of tenths of a magnitude;
- **the coherent oscillations** (DNO) with periods of a few tens of seconds and amplitudes on the order of 0\(^m\).002;
- **quasi-periodic oscillations** (QPO) with periods from some 20 s to several hundred s and amplitudes larger than the coherent oscillations. Quasi-periodic oscillations are not strictly periodic. Very different values of periods are possible in one object during different outbursts. They may or may not appear simultaneously with coherent oscillations.

Three groups of short-term oscillations were found during the outburst of SS Cyg:
rapid variations first were detected in October 1976 with \(P=9.735\pm0.002\) s and amplitude 0\(^m\).0002 (Patterson 1978) and later oscillations with periods 8.5-10.9 s and 32-36 s with amplitude up to 0\(^m\).001 were found in the light curve of this dwarf nova (Horne and Gomer 1980). In 1982 the third group of quasi-periodic oscillations with \(P=86\) s and full amplitude of 1.5 % have been detected for SS Cyg by Voloshina and Lyuty (1988). Quasi-periodic oscillations of this group early were detected in other cataclysmic variables.

4. Data analysis
We use Fourier method for our data analysis. Periodograms obtained from this analysis which demonstrate our findings are shown in Figure 3. We find oscillations with periods 10 s and 76 s in 2006 outburst. Close examination of the power density spectra (PDS) related to the 2007 outburst light curves reveals a few peaks. The most prominent PDS peak corresponds to persistent coherent oscillation of period about 41 s for all nights of our observations. For the first time we detect this oscillation in November 18 light curve. The amplitudes of these oscillations increased from \(A=0.004\) (on November 20, the maximum of the outburst) to \(A=0.007\) (on December 3, decline stage). Oscillations of \(P=35\) s, \(P=72\) s take place in the light curves on November 18 and December 3 respectively. In the latter case the period is very close to that in 2006. One can also see a prominent peak of period 98 s in PDS of the 2008 outburst (lowest panel in figure 3). Note the other period (21 s) is not real. Observations of SS Cyg folded with periods of 98 s and 41 s are shown in figure 4. Each point on these curves represent the mean value of all data points in the 0.1 phase range.

5. Summary
The following rapid periodic oscillations were detected in SS Cyg light curves:
- **outburst in October 2006** - 10 s and 76 s
- **outburst in November 2007** - 41.5 s, 35 s and 72 s.
- **outburst in January 2008** - 98 s.
- according to their properties the oscillations could be interpreted as quasi-periodic oscillations.
- no oscillations were detected by UBV observations in 1996 and 2000 outbursts.
- flickering is also present in SS Cyg light curve in quiescence.
Figure 3. Power spectra of light curves of SS Cyg for different observational nights in 2007-2008 (left) obtained from analysis of CCD observations

Figure 4. Observations of SS Cyg folded with values of obtained periods.

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