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Evidence of SS 433 Rapid Evolution

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Abstract. From 37-year-long photometry of the relativistic binary SS 433, we reveal secular changes in its light curve. Observations suggest that the expanding A-type component of this system passes to a dynamical mode of mass transfer filling and episodically overfilling the Roche lobe of the neutron star.

SS 433 is a unique binary with moving emission lines in the spectrum. The moving components of the Balmer and He I lines are formed by a pair of oppositely directed, highly collimated and precessing relativistic jets of the very hot matter moving with a velocity of 0.26 c. The system is eclipsing with the period of 13.082 days. The 162-day precession period is presented both in photometric and spectroscopic data. The star is located in the center of the radio structure W50 interpreted as a 10000-year old supernova remnant. On the base of *UBVRI* photometry and X-ray observations in the eclipses, we have established the fact that the compact component in this system is a neutron star (Goranskij 2011). The optical companion is an A4–A7 I star (8.3–11.0 $M_\odot$) evolving to the red giants with the envelope cut off by its Roche lobe.

We analyze the collection containing 4304 observations in the *V*-band taken on 2277 nights between 1979 and 2016. Additionally, we use a dense set of synoptic monitoring containing 2437 eye estimates made with the 25 cm telescope and an electronic image tube with a microchannel plate. This set was obtained for 386 nights between 2003 and 2016, with a few nights overlapping with CCD observations. The system of this device is close to the Cousins *R* one, the correction of $-0\overset{\mathrm{m}}{.}4$ was accepted relative to the simultaneous CCD R_C measurements. On the base of this analysis, we noted some evidences of the A-type star expansion, filling and overfilling the neutron star's Roche lobe by the accreting matter, when the neutron star episodically immerses in the envelope of the donor star forming a common envelope (CE). These evidences are the following.

- The amplitude of the orbital and precession brightness variations including the brightness in the eclipse depth in the *V*-band decreased by about 40 per cent during 37 years of monitoring.

- The widths and depths of the eclipses vary. Sometimes we note the total lack of the eclipses predicted from ephemeris, when the neutron star is immersed in the CE, and there is nothing to eclipse (cases C in Fig. 1).

- Near the T1 and T2 precession phases, the star is as bright as at the T3 phase, because the CE radius is large, and the star is covered by the external circumbinary disk less (assumed by Barnes et al. (2002)) (cases B in Fig. 1).

- At some CE episodes, the jets are blocked, and the moving lines are not observed in the spectra. In the critical moments, they penetrate through the CE and recover with an explosion and an ejection a large amount of the matter (case A in Fig. 1).

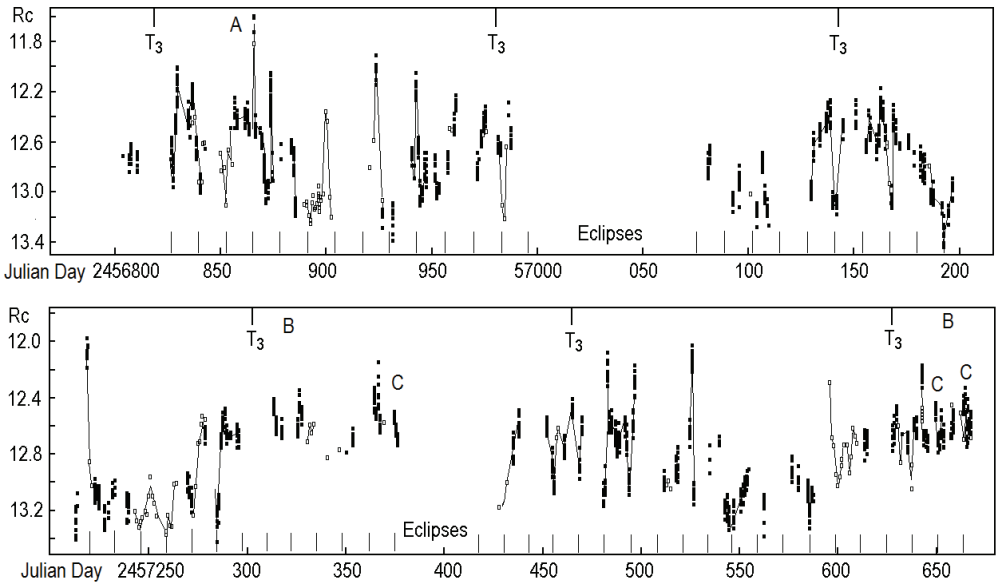

Figure 1. Light curves of SS 433 in the *R* band. The T_3 epochs are calculated with the precession period of 162.278 day and T_0 = JD 2450003; the eclipse moments are calculated with the ephemeris Min I = JD 2450023.78 + $13^d.08223 \cdot E$. Black signs are eye estimates with the 25 cm telescope and an image tube, light signs are CCD observations with different telescopes.

To explain these phenomena, we follow Podsiadlowski (2014): "when the donor star is a giant or supergiant with a convective envelope, since a star with a convective envelope tends to expand rather than shrink when it loses mass very rapidly (adiabatically), while the Roche-lobe radius shrinks when mass is transferred from a massive star to a less massive star; this makes the donor overfill its Roche lobe by an ever larger amount and causes runaway mass transfer on a dynamical timescale (so-called dynamical mass transfer)." Hence, the jet phenomenon in SS 433 may be of a short duration comparable with a human life.

When the Roche lobe of a neutron star is filled or overfilled, the primary component represents a rapidly rotating star with the neutron star in the center, i.e. a Thorne & Zytkov (1977) object. In the future, the neutron star will be engulfed by the expanding massive component finally forming a single more massive Thorne-Zhytkov star with the neutron core.

References

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