Evidences of rapid evolution of SS 433

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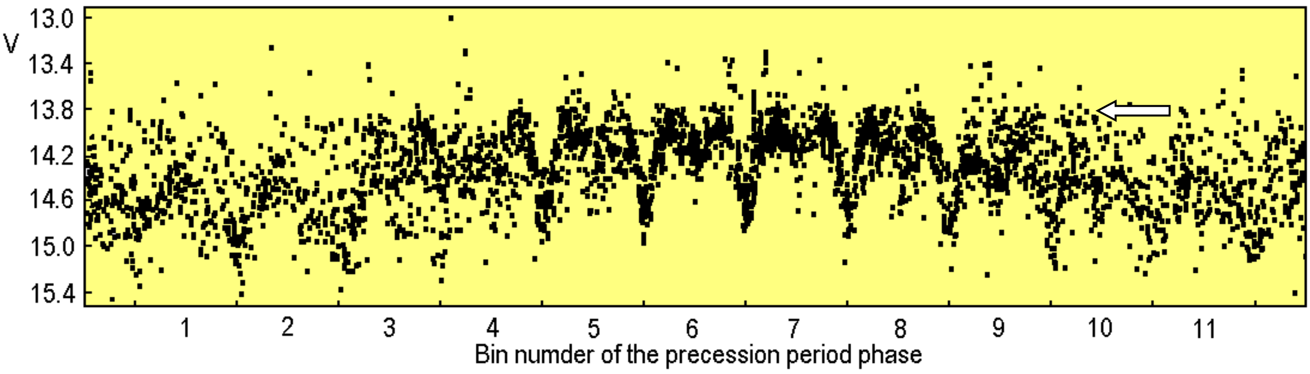
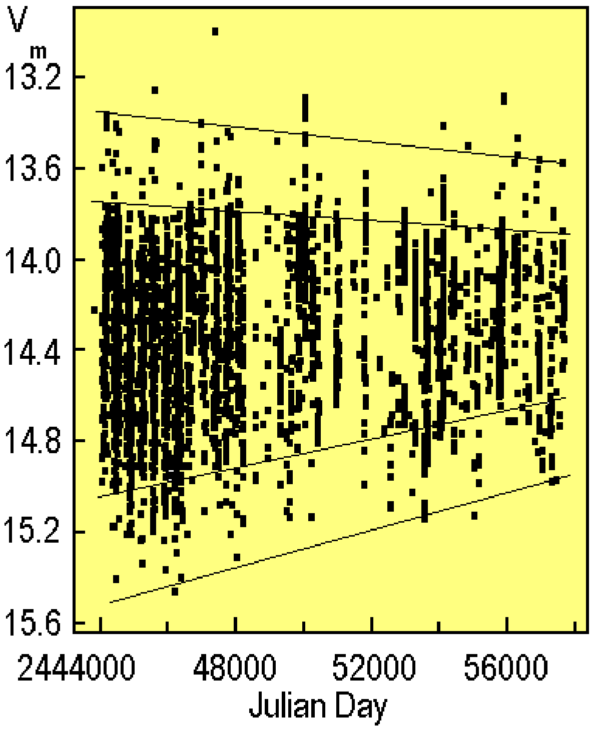
SS 433 is a unique binary with moving emission lines in the spectrum. The moving components of Balmer and He I lines are formed by a pair of oppositely directed, highly collimated and precessing relativistic beams of very hot matter moving with a velocity of 0.26 *c*. The system is eclipsing with the period of 13.082 day. The 162-day precession period presents both in photometric and spectroscopic data. The star is located in the center of radio structure W50 interpreted as a 10000-year old supernova remnant. 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 red giants.

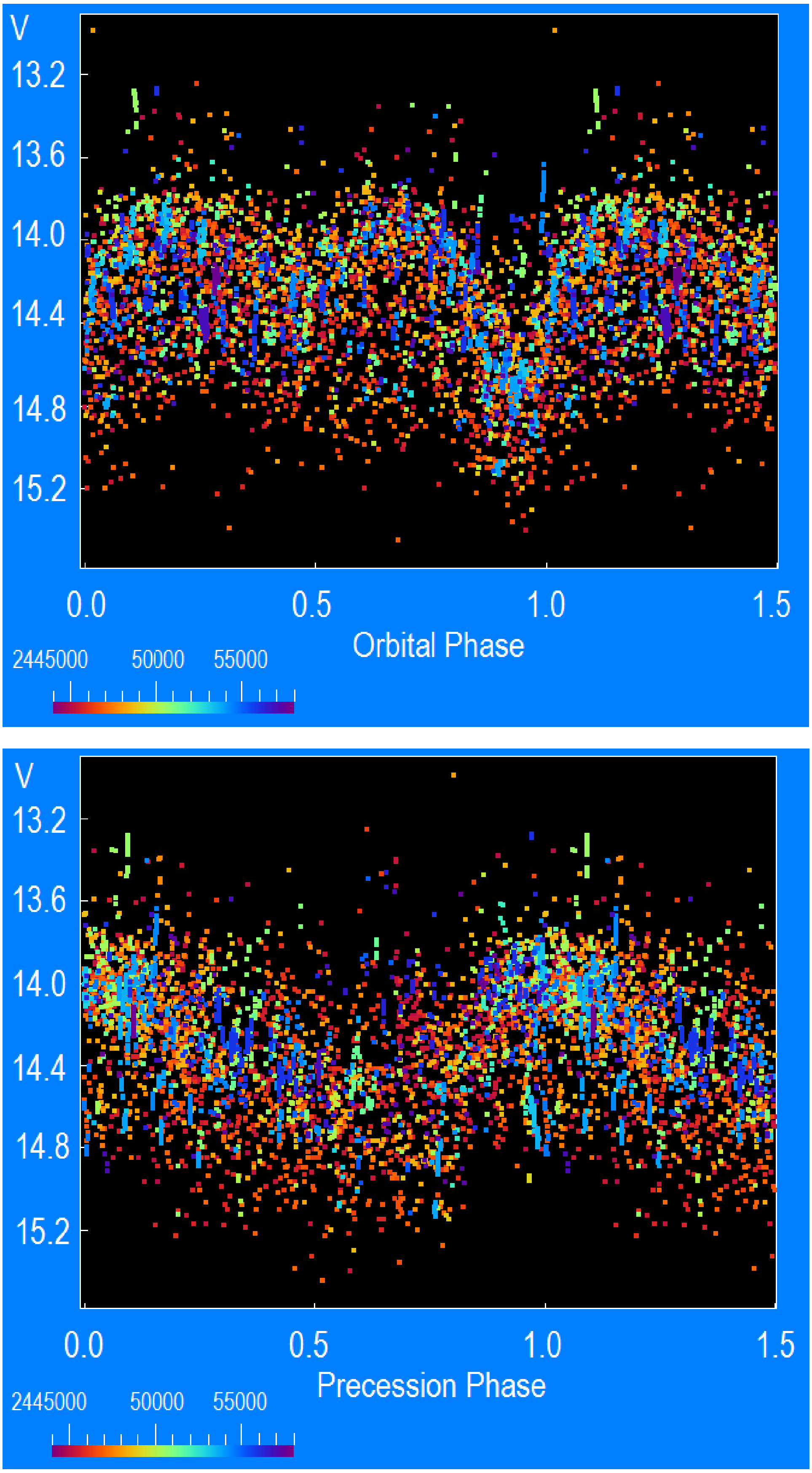
T_3



38-year long photometry of SS 433 in the V band. The orbital light curves are plotted vs the phase of the 162-day precession period. White arrow shows that now the star often gets the upper level typical of T_1 and T_2 phases.

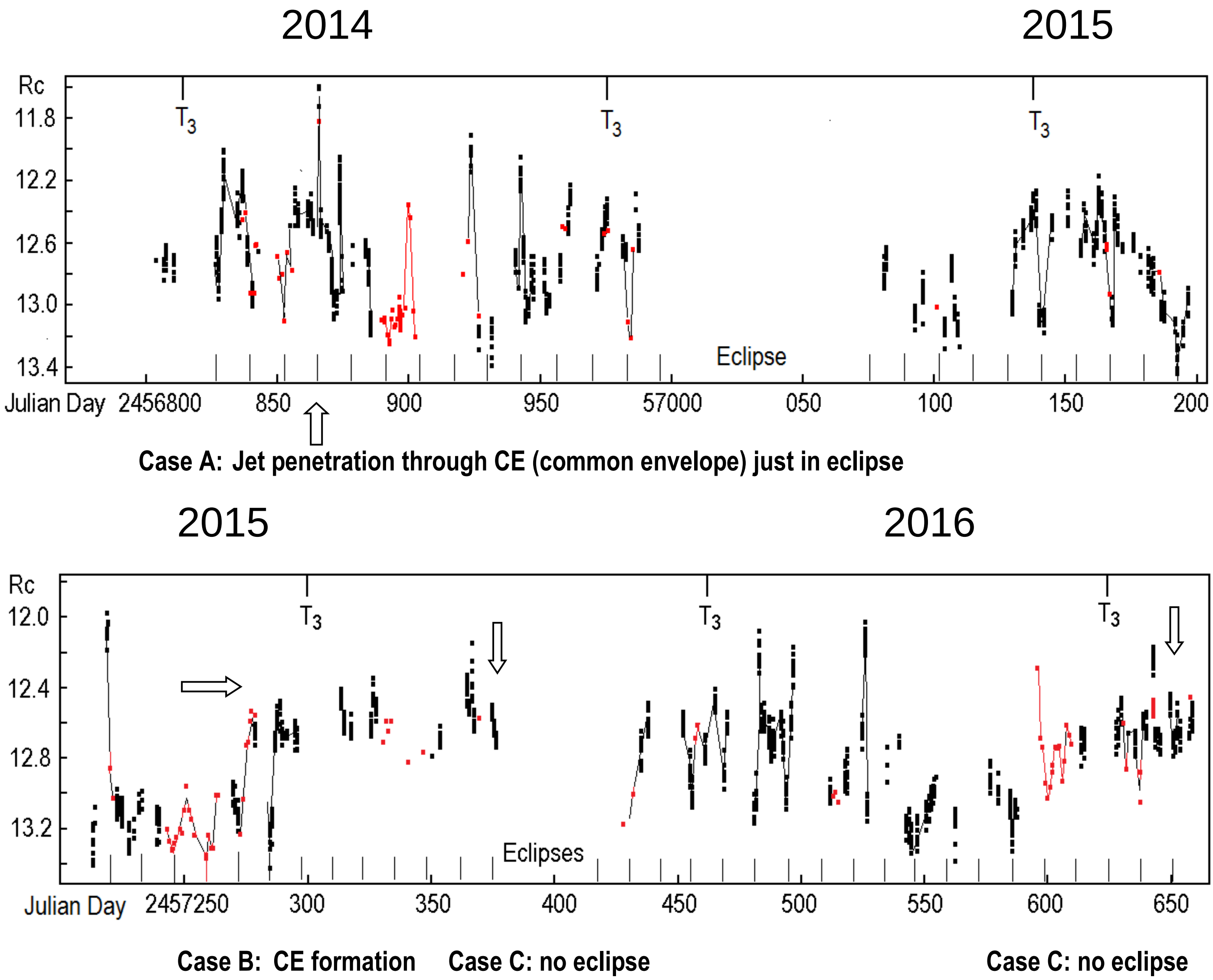
Secular variability of amplitudes of orbital and precession variations during the period of 38 years



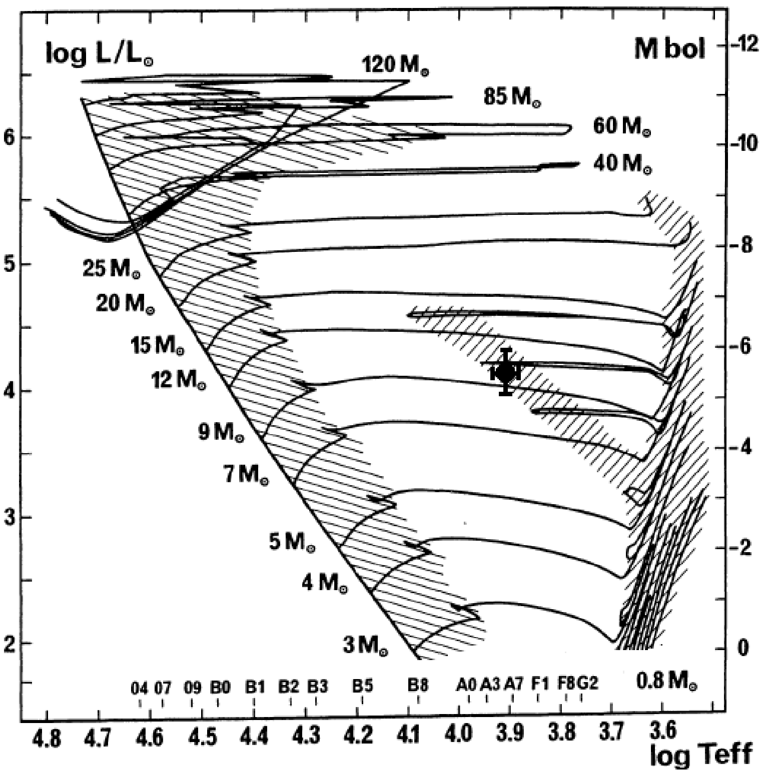


Orbital (top) and precession (bottom) light curve changes of SS 433 depending on time. Color of points varies from red to blue when time varies from 1979 to 2016.

Synoptic observations of SS 433 with the 25 cm telescope and the electronic image tube equipped with a microchannel plate.



Light curves of SS 433. Red points are CCD observations.



Location of the secondary component on the Temperature-Luminosity Diagram. This fragment with evolutionary tracks is from Schaller et al. 1992.

Mass transfer from the A-type component passes into a dynamical timescale. Overfilling a compact companion Roche lobe and sporadic events of common envelope formation braking by ejections of large volume of mass become more frequent.

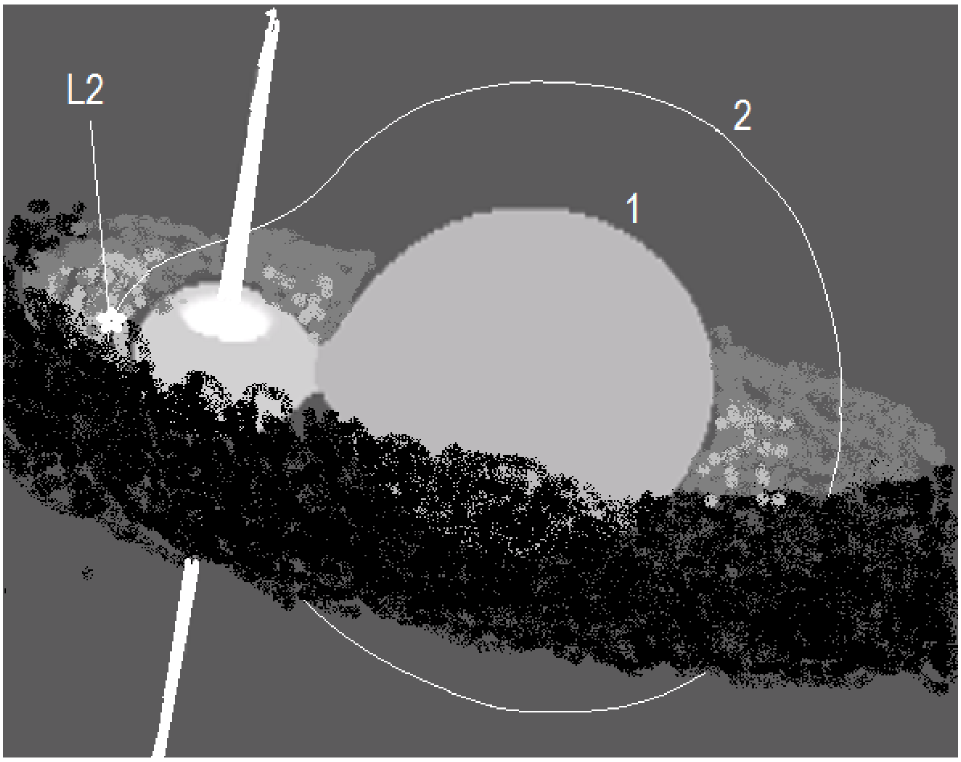
P. Podsiadlowski (2014):

Mass transfer is unstable when the accreting star cannot accrete all the material transferred from the donor star. The transferred material than piles up on the accretor and starts to expand, ultimately filling and overfilling the accretor’s Roche lobe. This leads to the formation of a common-envelope (CE) system, where the core of the donor and the companion form a binary immersed in the envelope of the donor star. This typically happens 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 more massive 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).

When the Roche lobe of the 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-Zhytkov object.

A.M. Cherepashchuk (2013):

If the interaction energy of close binary systems at the stage with a common envelope is relatively not large, the relativistic object falls by spiral on the center of the donor star, and binary system vanishes remaining a single peculiar star with the relativistic object at the center. Such objects used to be called Thorne-Zytkow (1977) objects, by names of researchers, which showed that a situation is possible when the accretion onto the center neutron star goes in a not high-temperature mode, and neutrinos do not take away the energy released in the accretion process. In this case, the accretion temp keeps at the value of about $dM/dt \sim 10^{-8}$ $M_{\odot}$/year, so that the star luminosity occurs at a level of an Eddington level, and lifetime of such an object is long enough (10^6-10^8 years). A high-temperature mode of the accretion onto a central neutron star also can be realized (Zeldovich et al, 1972), when all the energy released in accretion is taken away by neutrinos. In this case, the lifetime of a spherically symmetric envelope is very short, about dynamical time, and as a result of evolution of such an object, if the envelope is massive enough, a single black hole will arise.



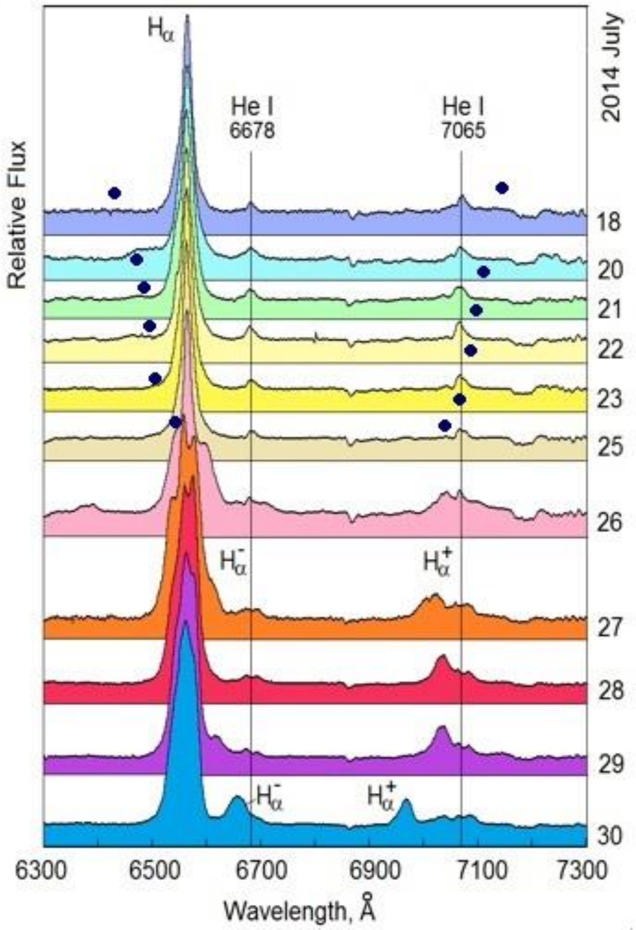
Schematic view of SS433 system submerged in the external disk. 1 – case of contact configuration with the filled Roche lobe of the compact companion, and with the nozzle and jet. 2 – case of overcontact configuration with the overfilled Roche lobe and with the flow of the matter in the external disk through Lagrange L2 point. In this case, the plain of the disk covers less relative area of the stellar disk.

Evidences of approach the components and episodes of common envelope (CE) in SS433 system.

Different widths and depths of eclipses in X-rays and in optics. Sometimes their total lack when the neutron star is inside the envelope of A-star, and nothing to eclipse (Case C).

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

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



Recovery of jets after CE episode in June 2014. Spectroscopic observations are taken by V.F. Esipov at the SAI Crimean Station. Black points are calculated positions of jets expected from ephemeris.

Explosion and matherial ejection is seen in the profile of H_α line.

The explosion was accompanied by strong outburst in continuum with an IR excess.

The results of this research suggest that the jet phenomenon in SS433 is of very short duration comparable with the duration of a human life. It is connected to the dynamical phase of envelope expansion of a rapidly evolving massive component in a binary, and its approach with a neutron star. In the future, the neutron star will be engulfed by the component to form a more massive Thorne-Zhytkov object.

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References:

Barnes et al. (2002), MNRAS **365**, 296.

Cherepashchuk A.M. (2013), in Close Binary Stars, II, FizMatLit, p.264 (Rus).

Goranskij V.P. (2011), Variable Stars **31** (5),1.

Podsiadlowsky P. (2014), in Accretion Processes in Astrophysics, Cambridge Univ. Press, p.45.

Schaller G., Schaerer D., Meynet G, Maeder A. (1992), AsAp Suppl. Ser. **96**, 269.

Thorne K.S. & Zytkov A.N. (1977), ApJ **212**, 832.

Zeldovich Ya.B., Ivanova L.N., Nadezhin D.K. (1972), Sov. Astron. **16**, 209.