

Optical Spectroscopic observations of the Be/X-Ray binary A0535+262/V725 Tau during the giant outburst in 2009

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Optical high dispersion spectroscopic observations of the Be/X-ray binary A0535+262/V725 Tau during the giant outburst in November 2009 are reported. This giant outburst lasted approximately 30 days, and Swift/BAT team reported that A0535+262 brightened up to more than 3 times of the Crab in the 15 - 50 keV band. We carried out the spectroscopic monitoring at OAO and GAO from November 2009 to March 2010, before the giant outburst to the rising phase of the normal outburst which occurred after the next periastron. Obtained H-alpha, H-beta and He I emission line exhibited drastic profile variability during the observations.

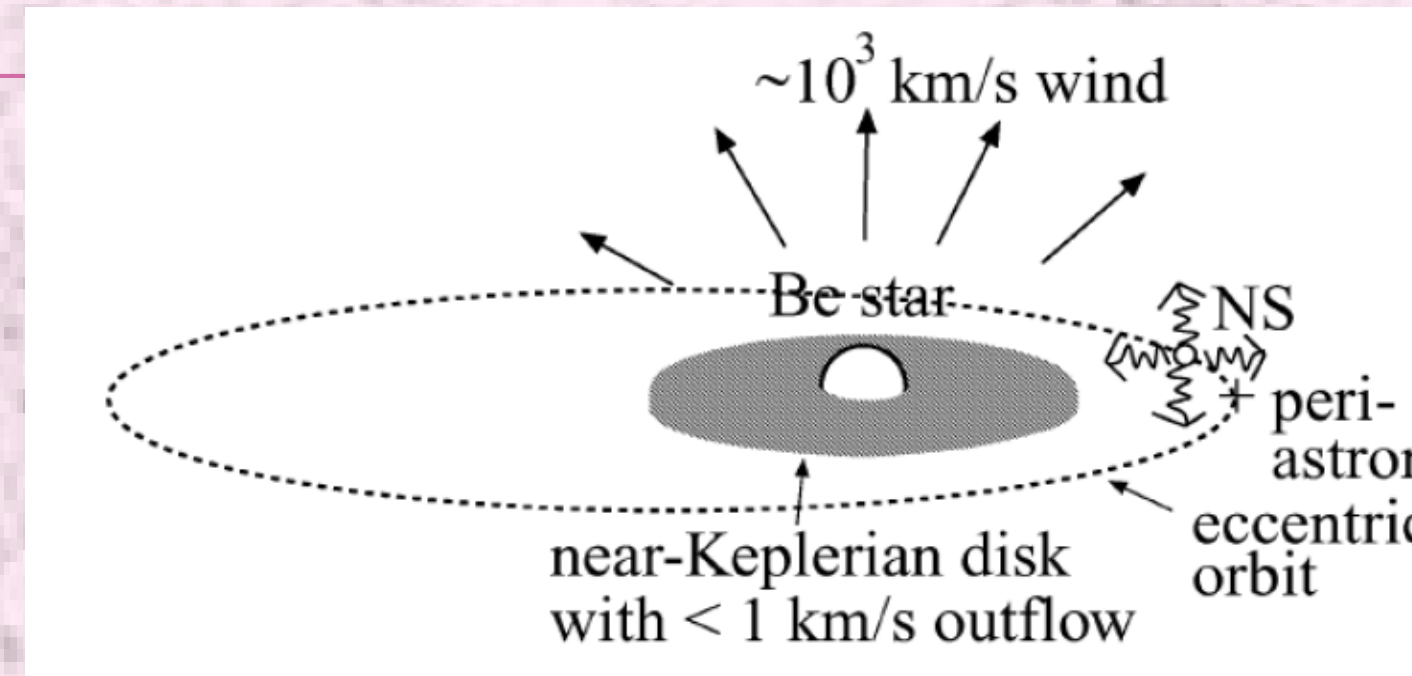


Fig. 1: Be/X ray binaries (Okazaki+ 2002, MNRAS, 337, 967)

2. A0535+262/V725 Tau

- O9.7IIIe + NS, $m_v \sim 8.9$ mag (Giangrande+ 1980, A&AS, 40, 289)
- $P_{\text{orb}} = 110.24$ days (Moritani+ 2010, MNRAS, 405, 467)
- $e \sim 0.47$ (Finger+ 1994, AIPC, 308, 459)
- NS...103-sec. pulsar (Caballero+ 2007, A&A, 465, L21)
- 6 giant outburst have been observed; in 1975, 1980, 1991, 1996, 2005 and 2009
- Giant outburst in Nov./ Dec. 2009
 - Gradual brightening from Oct. (Sugizaki+ 2009, Atel. #2277)
 - Rapid brightening at 30 Nov. (JD 2455166)
 - 3.1 Crab at the peak in 15-50 keV (Krimm + 2009, Atel. #2336)
 - Periastron passage in Mar. 2010... a normal outburst

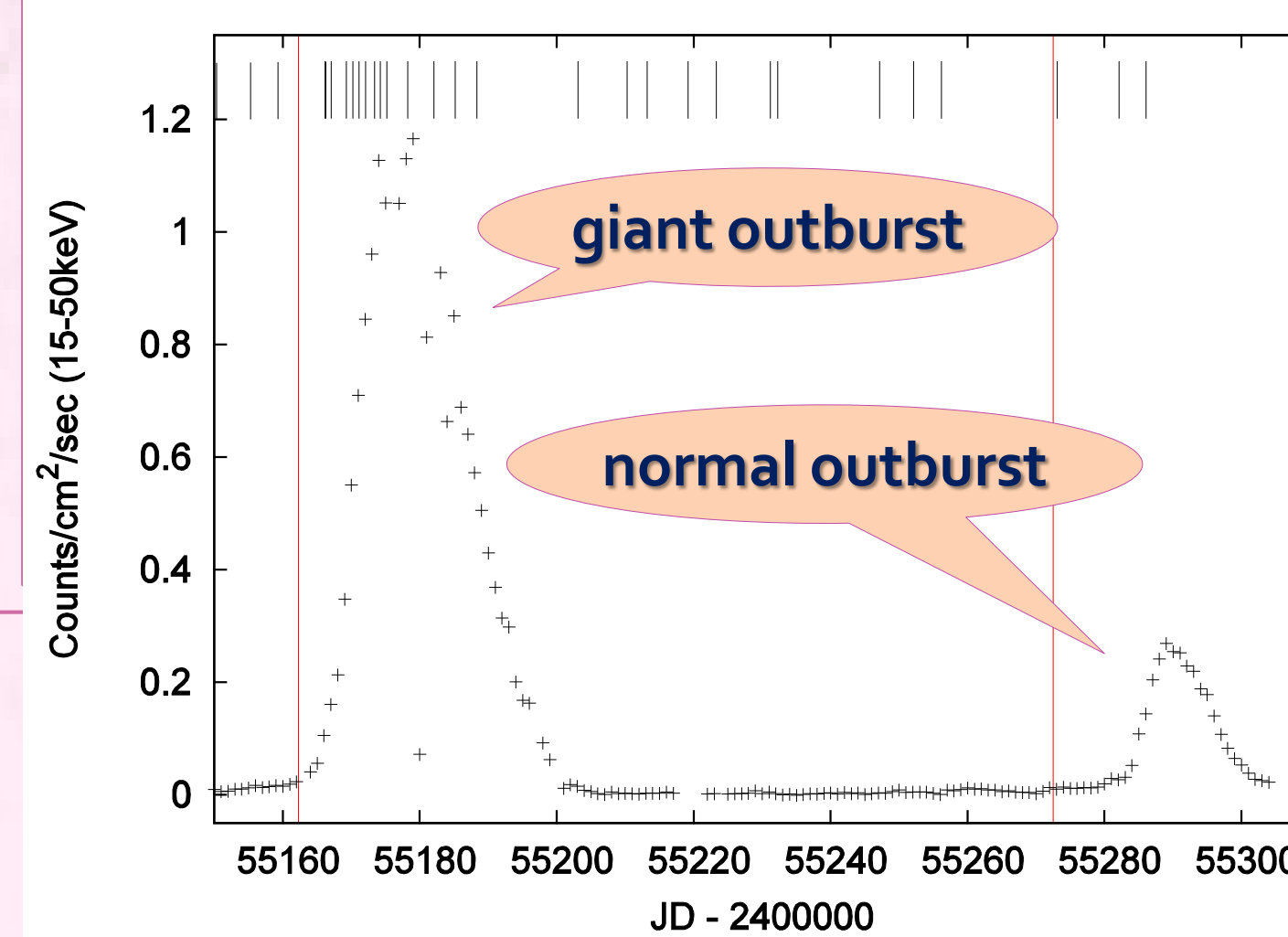


Fig. 2: Light curve by Swift/BAT (15-50 keV) Short black lines: date of our observations Red lines: estimated periastron passage using Moritani+ 2010, MNRAS, 405, 467.



1. Be/X-ray Binary

- **Be star + compact object (NS)**
- Majority of HMXRBs
- 3 states:
 1. **Quiescent** $L_X \lesssim 10^{36}$ erg/s
 2. **Normal (type I) outburst** $L_X \sim 10^{36-37}$ erg/s
 - Orbital modulation
 3. **Giant (type II) outburst** $L_X \gtrsim 10^{37}$ erg/s
 - Less frequently than normal outbursts
- **Be stars** (B emission stars):
 - B stars which have exhibited Balmer lines in emission at least once (Luminosity class ; III-V)
 - Equatorial region ... weak outflow ($\lesssim 1$ km/s), balance between the surface gravity and the centrifugal force due to rapid rotation (\lesssim several 100 km/s) \Rightarrow geometrically thin circumstellar envelope (**Be disc**)

3. Observations

- OAO/HIDES, GAO/GAOES ... optical Echelle spectrograph
- $R \sim 50,000$, $S/N \sim 100$
- Wavelength and Lines;
 - OAO/HIDES: 3800 - 6700 Å ... H α , H β , H γ , He I λ 6678, He I λ 5876, He I λ 4471
 - GAO/GAOES: 4800 - 6700 Å ... H α , H β , He I λ 5876

4. Observed Line Profiles

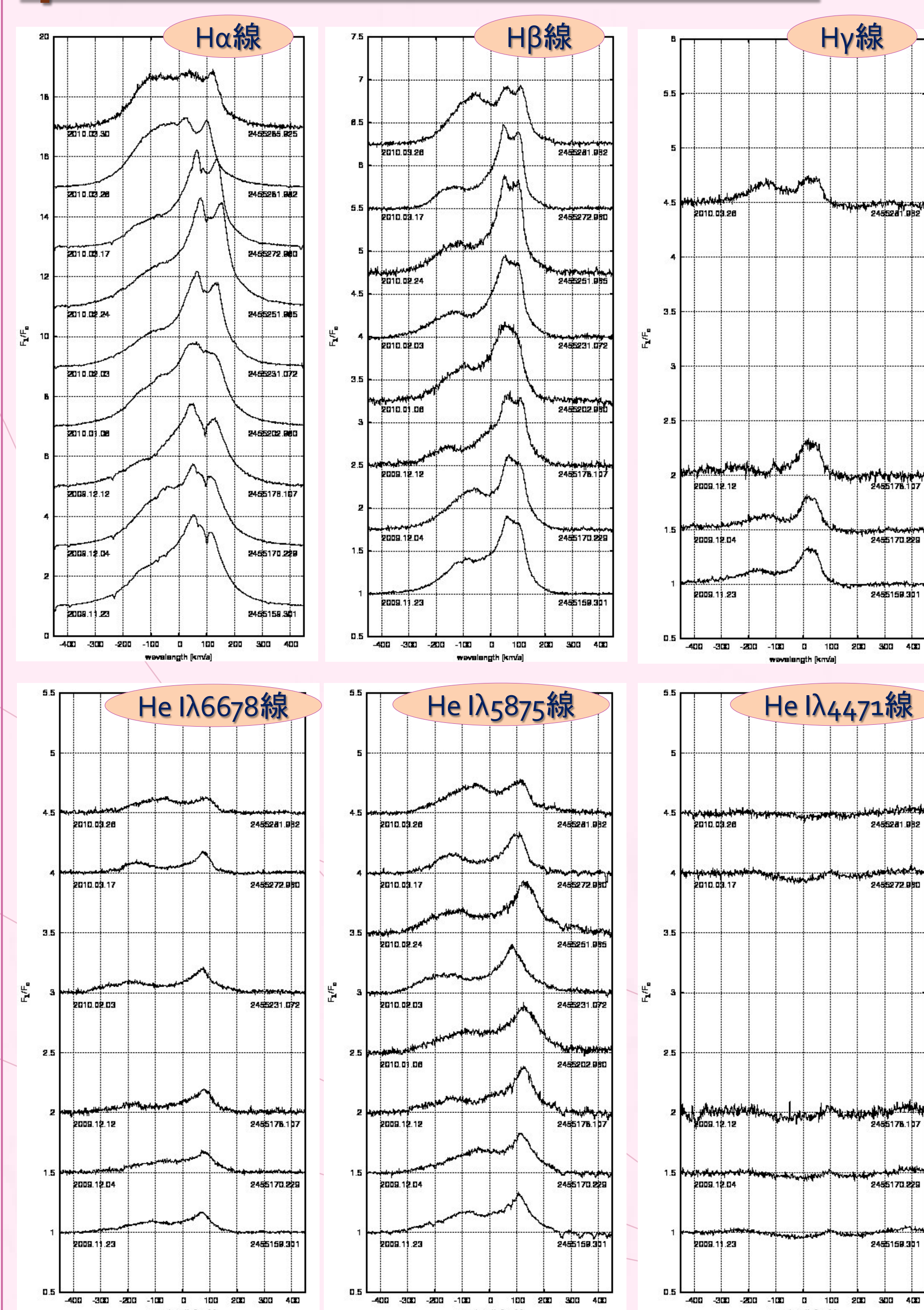


Fig. 3: Representative spectral lines. Top: from left, H α lines, H β lines and H γ lines. Bottom: from left, He I λ 6678 lines, He I λ 5875 lines and He I λ 4471 lines.

- **Remarkable profile variability** ... correlation between Balmer lines and He I lines.
- **Redshifted (~ 100 km/s) red enhanced component** ... double peaked in H α line
- This component had weakened before the normal outburst.

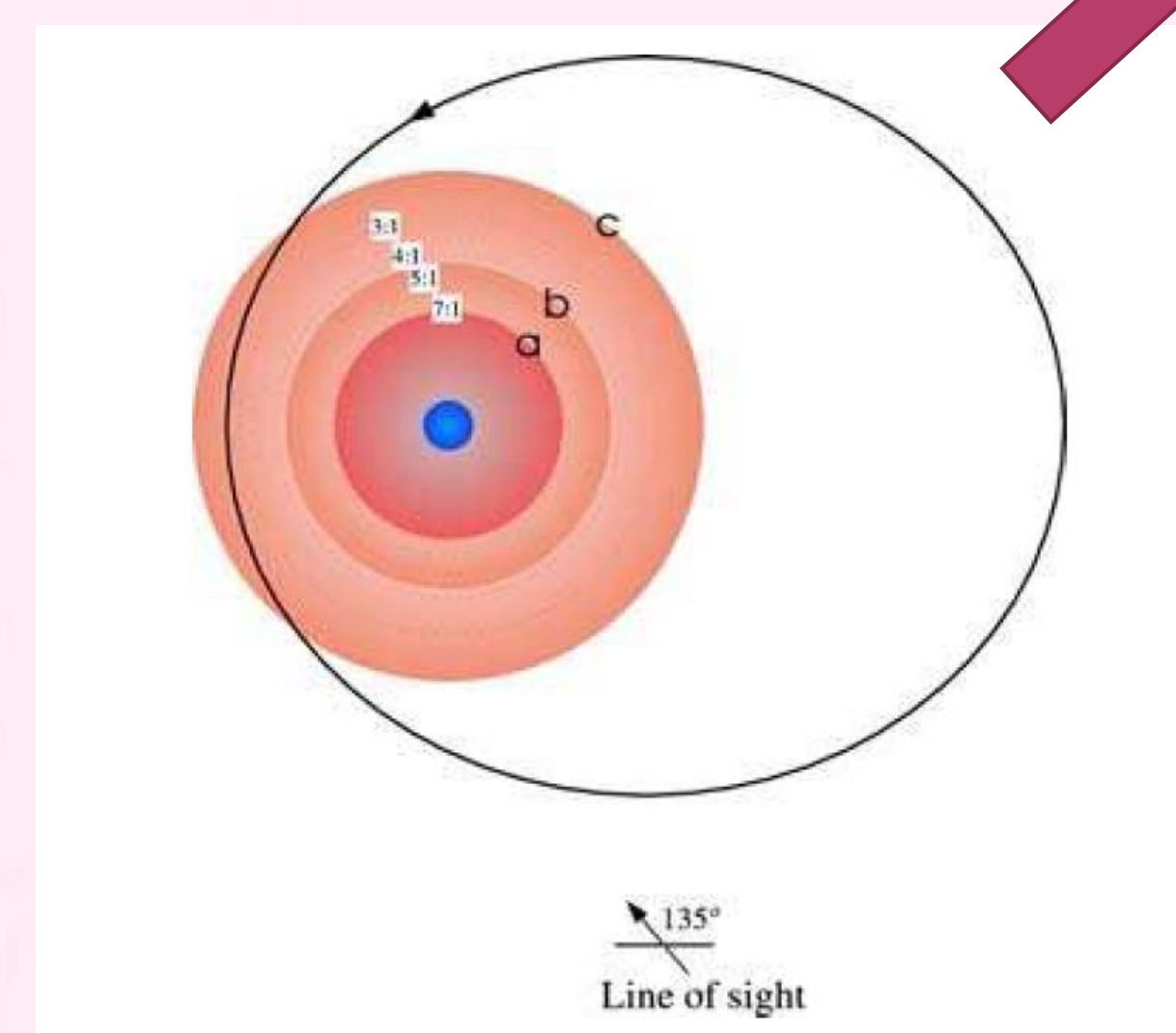


Fig. 4 : The geometry of A0535+262 (Coe + 2006, MNRAS, 368, 447)

5. Redshifted Enhanced Component

Q. The enhanced component is emitted from the Be disc or from the accretion disc around the NS?

- The radial velocity of the component...
 - 1) varies in a range several tens km/s
 - 2) decrease around the periastron passage \Rightarrow It is possible that the source is **Be disc**.

- Peak Separation of the enhanced component in H α line profile increased from the apastron. \Rightarrow **Be disc shrank** due to ... The tidal interaction with the NS? ... The gas transferred to the NS?

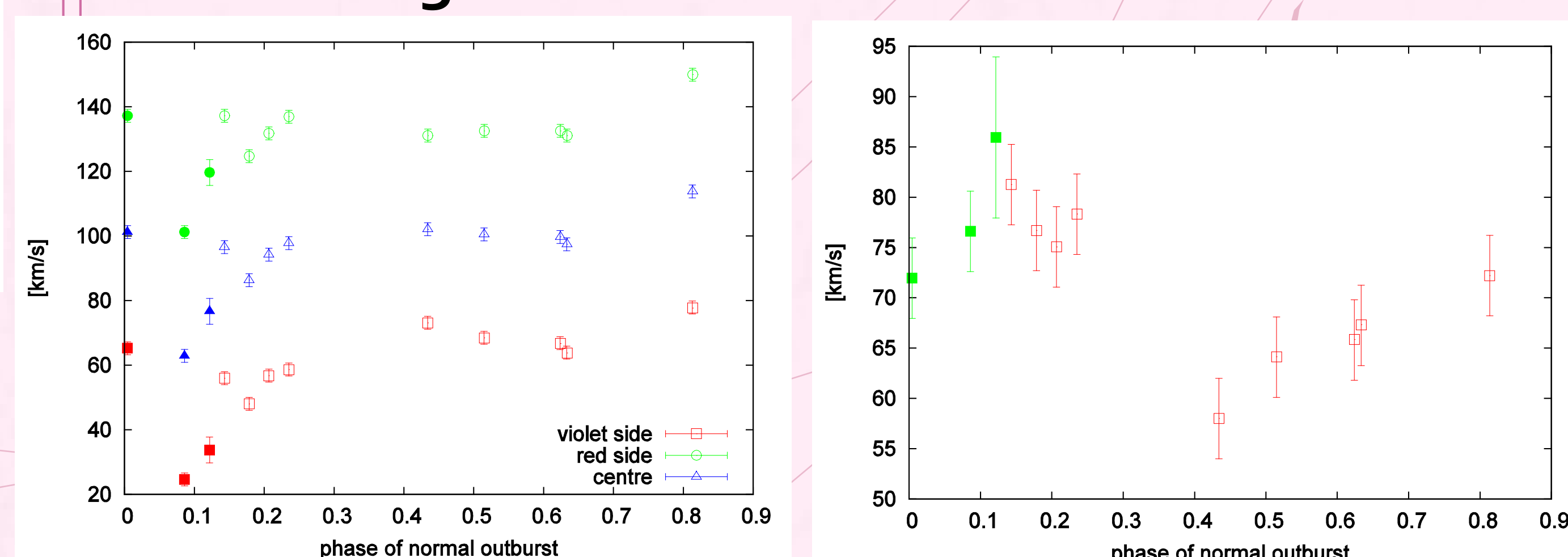


Fig. 5: Radial velocity (left) and peak separation (right) of the redshifted, enhanced component in H α line profiles along with the orbital phase.