Be/X 線連星A0535+262 において 2009年に起きたgiant outburst 時のBe星ガス円盤の構造

森谷友由希(1)、野上大作(1),、岡崎敦男(2)、今田明(3)、神戸栄治(3)、本田敏志(1)、橋本修(4)、市川幸平(1)
1) 京都大学　2) 北海学園大学　3) 岡山天体物理観測所　4) ぐんま天文台

We report on high-dispersion optical spectroscopic observations of the Be/X-ray binary A0535+262/V725 Tau during a giant outburst in November/December 2009, and after it. The observed emission line profiles, reflecting the structure of the geometrically thin circumstellar envelope of the Be star (Be disc), show drastic variabilities, and indicate the existence of a warped component. The enhanced blue shoulder seen after periastron passage implies a gas stream from a dense part of the Be disk to the neutron star.
(Moritani et al. 2011, PASJ, 64, L15)

1.Be/X-ray binaries

- Be star + compact object (NS)
- One of the main subgroups of HMXRBs
- 3 states:
  1. Quiescent $L_X \lesssim 10^{36}$ erg/s
  2. Normal (type I) outburst $L_X \sim 10^{36\text{-}37}$ 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)
  * geometrically thin circumstellar envelope: Be disc

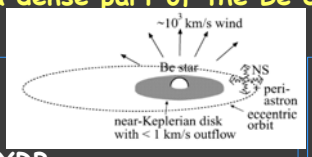


Fig. 1: Be/X ray binaries (Okazaki+ 2002, MNRAS, 337, 967)

2.A0535+262/ V725 Tau

- O9.7IIIe + NS, m_V:8.9 mag (Giangrande+ 1980, A&AS, 40, 289)
- P_{orb} = 110.24 days (Moritani+ 2010, MNRAS, 405,467)
- e ~ 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, 2009 and 2011
- Giant outburst in Nov./ Dec. 2009
  * Precursors in Oct. (Sugizaki+ 2009, Atel. #2277)
  * Rapid brightening at 30 Nov. (JD 2455166)
  * > 3 Crab at the peak in 15-50 keV (Krimm+ 2009, Atel. #2336)
- Normal outbursts after the giant outburst
  * precursor … outburst in March and July in 2010
  * no precursor … outburst in October 2010
  * X-ray peak shift in October 2010
- Giant outburst in Feb. 2011
  * ~ 500 days after the giant outburst in 2009

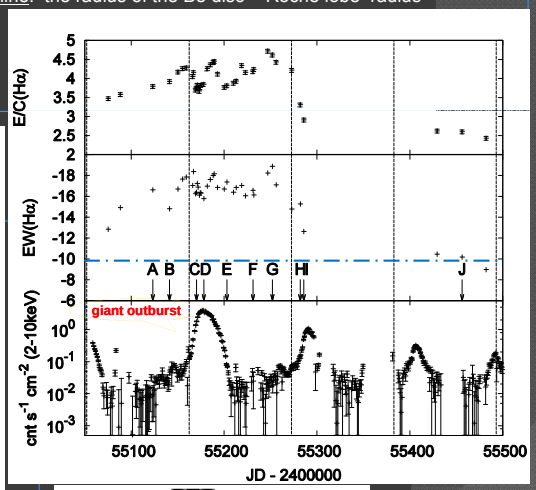


Fig. 2: X-ray light curve by MAXI/GSC (2-10 keV, bottom), and equivalent width (middle) and normalized intensity of the peak (top) of the Hα lines .
Vertical dotted lines: estimated periastron (Moritani+ 2010, MNRAS, 405, 467)
Short arrows: HJD of representative spectra in Fig.3
Horizontal blue line: the radius of the Be disc ~ Roche lobe radius

3.Observations

-OAO/HIDES, GAO/GAOES
…optical Echelle spectrograph (R ~ 50,000, S/N ~ 100)
-Wavelength and Lines;
*OAO/HIDES:3800 - 6700 Å
*GAO/GAOES:4800 - 6700 Å
-First optical (high-dispersion) spectroscopic observation covering the giant outburst!!

4.Results & Discussion

-Equivalent width is highest in the last 5 years
Grundstrom+ 2007, ApJ, 660, 1398:
*Relationship between EW(Hα) and the radius of the Be disc
Roche lobe radius (~ 5R) … - 10Å
⇒Warping component! in the Be disc?
-Observed line profiles (Fig.3) show drastic variabilities
Blue hump:
*A bright hump seen in the blue wing
*Radial velocity and intensity changed
Redshifted enhanced component:
*Triple peak
*Already seen in Aug. 2009 (after two peak outburst)
⇒Warping component in the Be disc?
Blue shoulder:
*Only seen after periastron (Fig. 4) during the giant outburst in 2009 and the normal outburst in Mar. 2010
*Radial velocity: ± 0 km/s
⇒Gas stream from Be disc to the NS (accretion disc)?
-High E/C (normalized intensity of the peak) via enhanced component

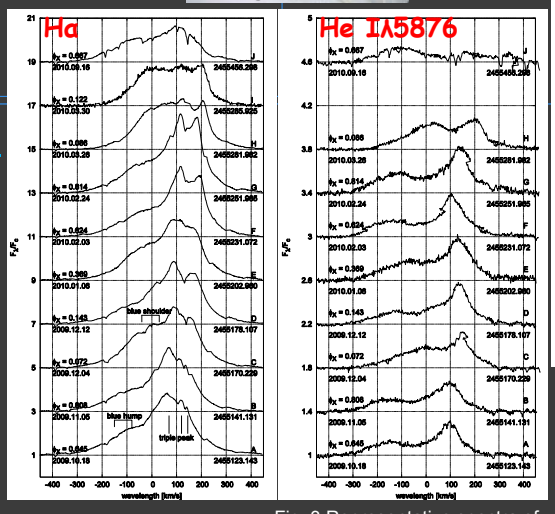
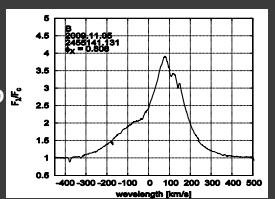


Fig. 3:Representative spectra of Hα and He I λ5876



φ_X = 0.808

Orbital phase when the blue shoulder can be seen. Blue shoulder suggests the gas stream from Be disc to the NS (orange arrow)

Fig. 4:Line profiles with blue shoulder during the giant outburst in 2009

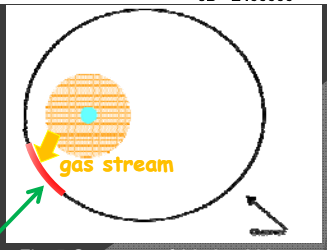
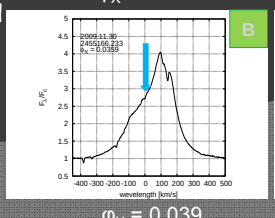
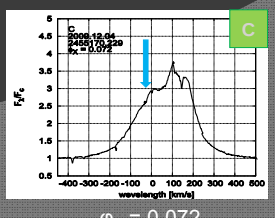


Fig. 5:Geometry of A0535+262.
Cyan circle: Be photosphere
Orange ring: Be disc with the Roche lobe radius)

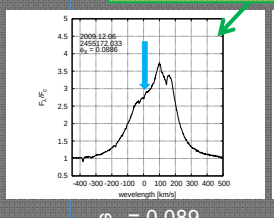
Blue shoulder can be seen only after periastron passage



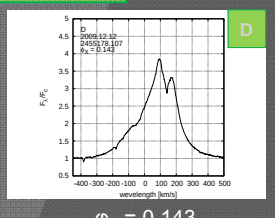
φ_X = 0.039
Giant outburst rise



φ_X = 0.072



φ_X = 0.089
Giant outburst peak



φ_X = 0.143