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 will be reported. The giant outburst occurred in A0535+262 in November 2009 for the first time since 2005. We carried out the spectroscopic monitoring from November 2009. In the brightening phase of the giant outburst, the observation performed densely (almost at every night). Obtained H-alpha, H-beta and He I emission line, exhibiting dramatical profile variability during the giant outburst, has highly redshifted (100km/s) bright component, which had weakened before the normal outburst in March 2010. We discuss profile variability of these emission lines.

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)
  - * geometrically thin circumstellar envelope: Be disc

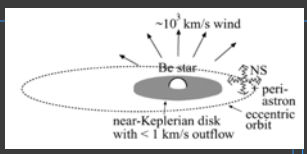
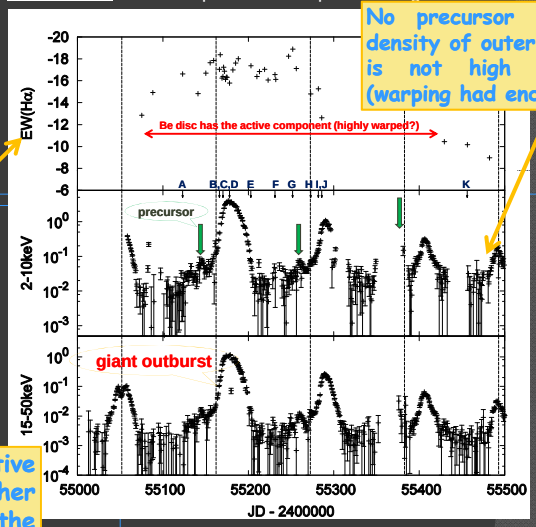


Fig. 1: Be/X ray binaries (Okazaki+ 2002, MNRAS, 337, 967)

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 and 2009
- Giant outburst in Nov./ Dec. 2009
  - * Precursors in 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)
- 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

Fig. 2: X-ray light curve by Swift/BAT (15-50 keV, bottom) & MAXI/GSC (2-10 keV, middle), and equivalent width of the Hα lines (top).
Dotted lines: estimated periastron passage (Moritani+ 2010, MNRAS, 405, 467)
Short arrows: HJD of representative spectra in Fig.3



No precursor … the density of outer region is not high enough (warping had ended?)

EW(Ha) reflects the density of outer region in the Be disc

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

4.Results

Line profiles show drastic variabilities

A:before the giant outburst:
*Hα; red dominated
*He Iλ5876; double peaked (V<R)

B:around the precursor:
*The E/C gradually increased
*He Iλ5876; the violet component brighter
*Hα; the violet shoulder brightened, the component ~120 km/s disappeared

C:rising phase and around the peak:
*Hα; the E/C decreased, bright "bump" appeared ~0 km/s
*He Iλ5876; the center part (~±50 km/s) brightened

Be disc has the active component with higher density and/or the temperature (warping!?)

D & E:pading phase:
*Hα; the "bump" faded once and reappeared, the E/C increased and decreased again
*He Iλ5876; the E/C increased and slightly decreased again
the violet component shifted violet-ward and then red-ward

F:after the giant outburst: … after the apastron (φ_X=0.624)
*Hα; the component ~120 & 200 km/s brightened
the violet "bump" weakened and/or broadened
*He Iλ5876; the violet component shifted to ~-200 km/s
the "valley" of the profile became clear

G:prior to the normal outburst in March 2010:
*Hα; the component ~200 km/s brightened
*He Iλ5876; the E/C slightly brightened

H, I & J:around the normal outburst:
*Hα; the violet wing ~-200 km/s faded at periastron
the profile turned wider and flattened ("red" two peaks remained)
*He Iλ5876; the bright component appeared ~0 km/s
the red component weakened

K:current:
*the profile become different between the Hα and the He Iλ5876 lines
* Hα; V<R, became broader, the E/C decreased
* He Iλ5876; V>R, two peaks are seen ~ 120 & 320 km/s.

The density and/or the temperature of the inner region became lower?!

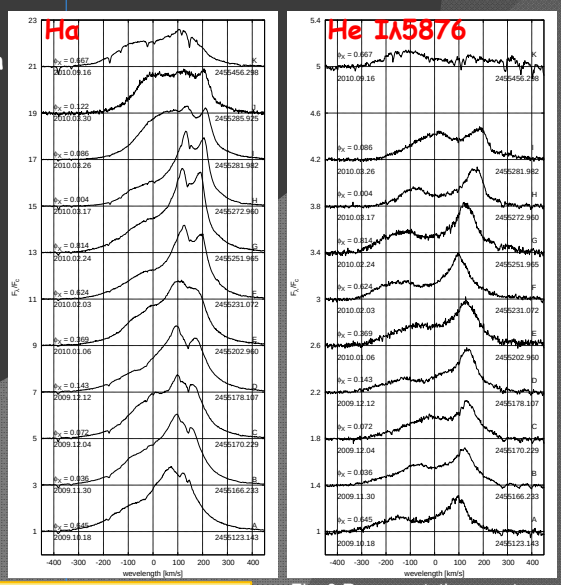


Fig. 3:Representative spectra