Optical spectroscopic monitoring of the Be/X-ray binary A0535+262/V725 Tau during the giant outburst in December 2009

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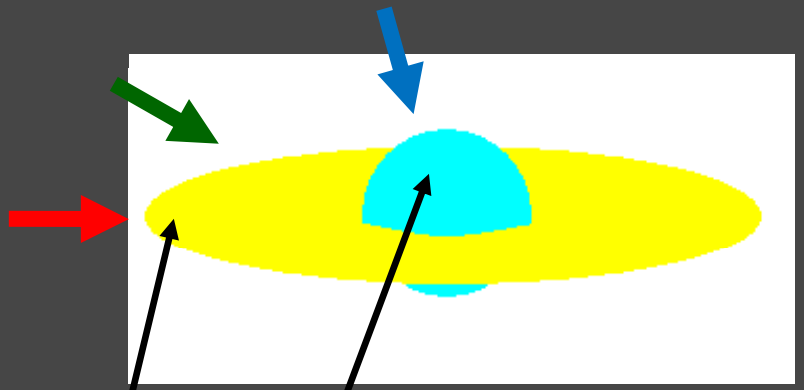
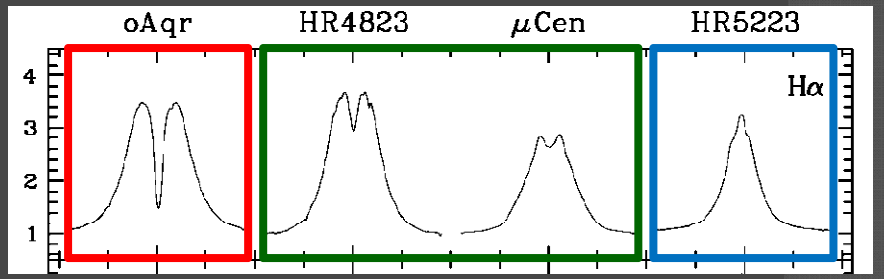
Be/X-ray Binaries (1)

- Classical Be star + Compact Object (NS)
  - (Classical) Be star: a B star which has exhibited Balmer lines in emission even once (Luminosity class: III -- V)
  - These emission lines originate from geometrically thin circumstellar envelope called “Be disc”



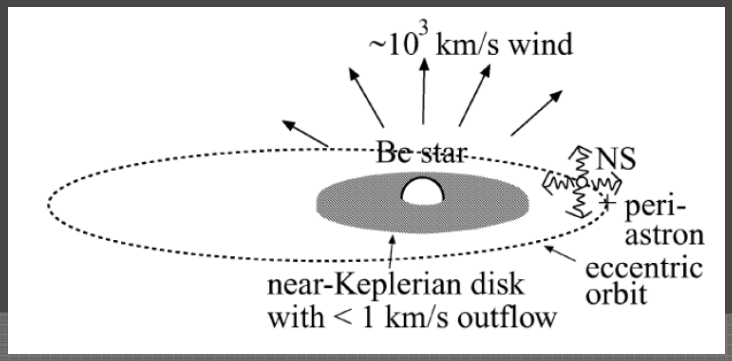


Hα emission profile of Be stars;
Porter & Rivinius (2003)

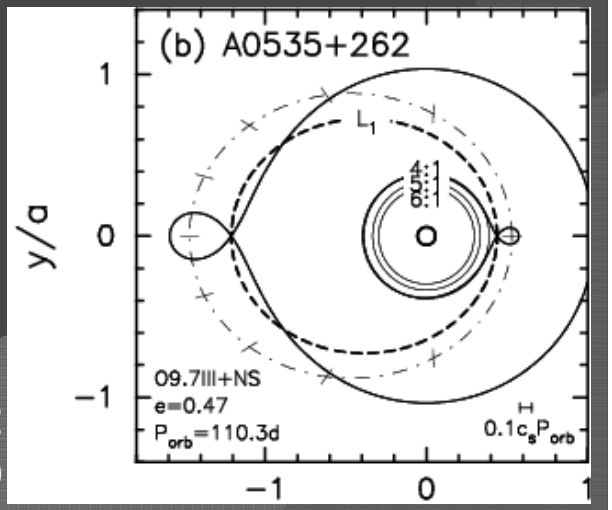
Rapid rotation (V/V_{crit} ~ 0.7—0.8), weak outflow (<1km/s) in the equatorial region and viscosity play an important role in the formation of the Be disc

Be/X-ray Binaries

- 2 discs: the Be disc and accretion disc
- The orbital eccentricity is not small (> 0.3): transient
  - normal (type I) outbursts ($10^{36\text{-}37}$ *erg/s* at 2 -10 keV)
    …occur around periastron passage, frequent
  - giant (type II) outbursts (> 10^{37} *erg/s* at 2 -10 keV)
    …occur anytime of the orbital phase, rare
- Mass transferred from the Be star (the Be disc) to the NS cause outbursts:
  - normal: Roche lobe overflow



<= Be/X-ray binary
(Okazaki+ 2002)



=> Roche lobe of A0535+262
(Okazaki & Negueruela 2001)

Motivation

- To understand the mechanism of Be phenomena
  - especially in binary systems;
    - under the interaction with the compact object
- Long-term monitoring the Be/X-ray binaries including intensive observations:
  - aiming at both short-term and long-term variabilities
  - short-term variability (< 1 week -- 1 orbital period):
    - related with normal/giant outbursts
  - long-term variability (> 100 days):
    - related with the Be disc variation
- These systematic observations of Be/X-ray binaries are our unique approach!!

Target: A0535+262/V725 Tau

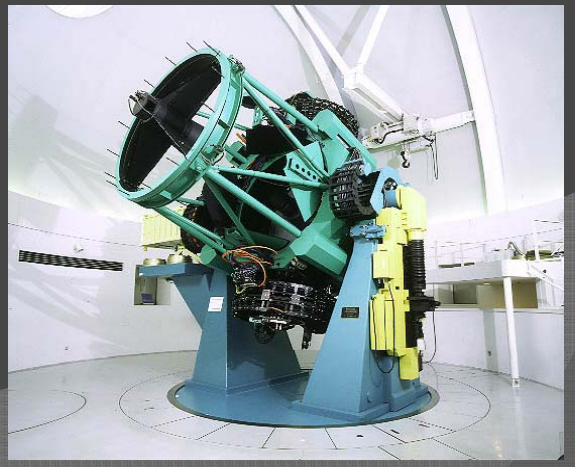
- A0535+262/V725 Tau
  - One of the most famous Be/X-ray binaries
  - O9.7IIIe + NS, V = 8.9 mag
  - orbital eccentricity: ~ 0.47, orbital period: 110.2 days
  - pulse period of NS: 103 sec
- Up to now, 6 giant outbursts have been observed:
  - in 1975, 1980, 1991, 1996, 2005, 2009
    - once every 5 or 10 years
- A0535+262 is bright enough to perform high-dispersion spectroscopy
  (the only one in northern sky at present)

Observations (1)

- Okayama Astrophysical Observatory
  - 188cm telescope/ HIDES
- Gunma Astronomical Observatory
  - 1.5m telescope/ GAOES
- R ~ 50,000, S/N ~ 100
- We were very lucky to perform monitoring during the giant outburst in Dec. 2009!!

Detailed analysis of variations can be dealt with

188cm tel. @OAO



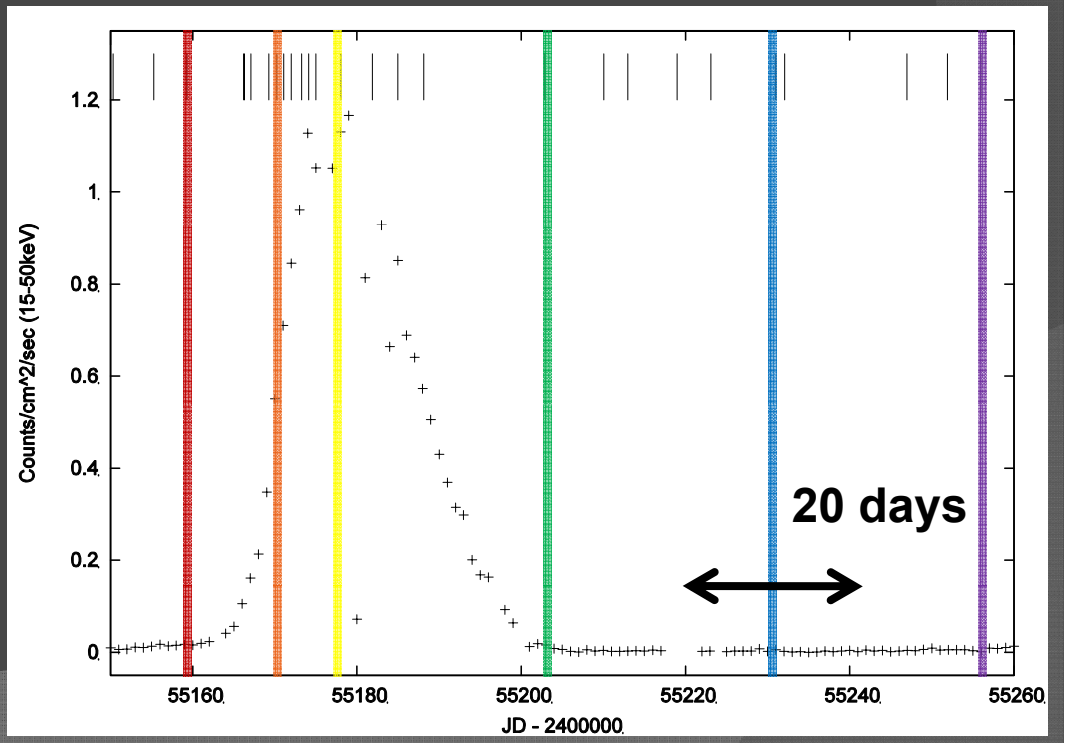
1.5m tel. @GAO

Observations (2)

- Swift/BAT light curve
  - Duration time : ~ 30 days
  - We could monitor the giant outburst from the beginning to the end.

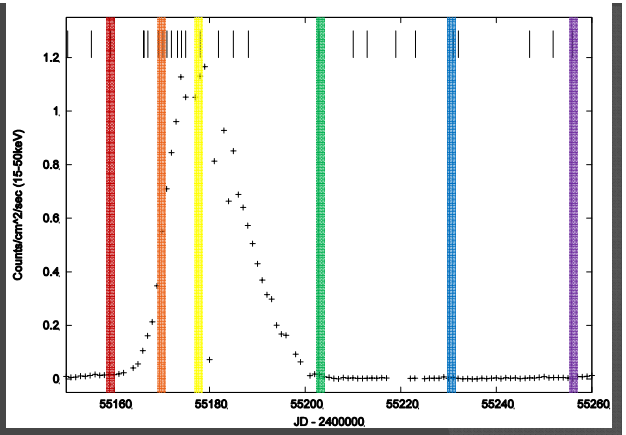
phase of outburst (orbital phase)

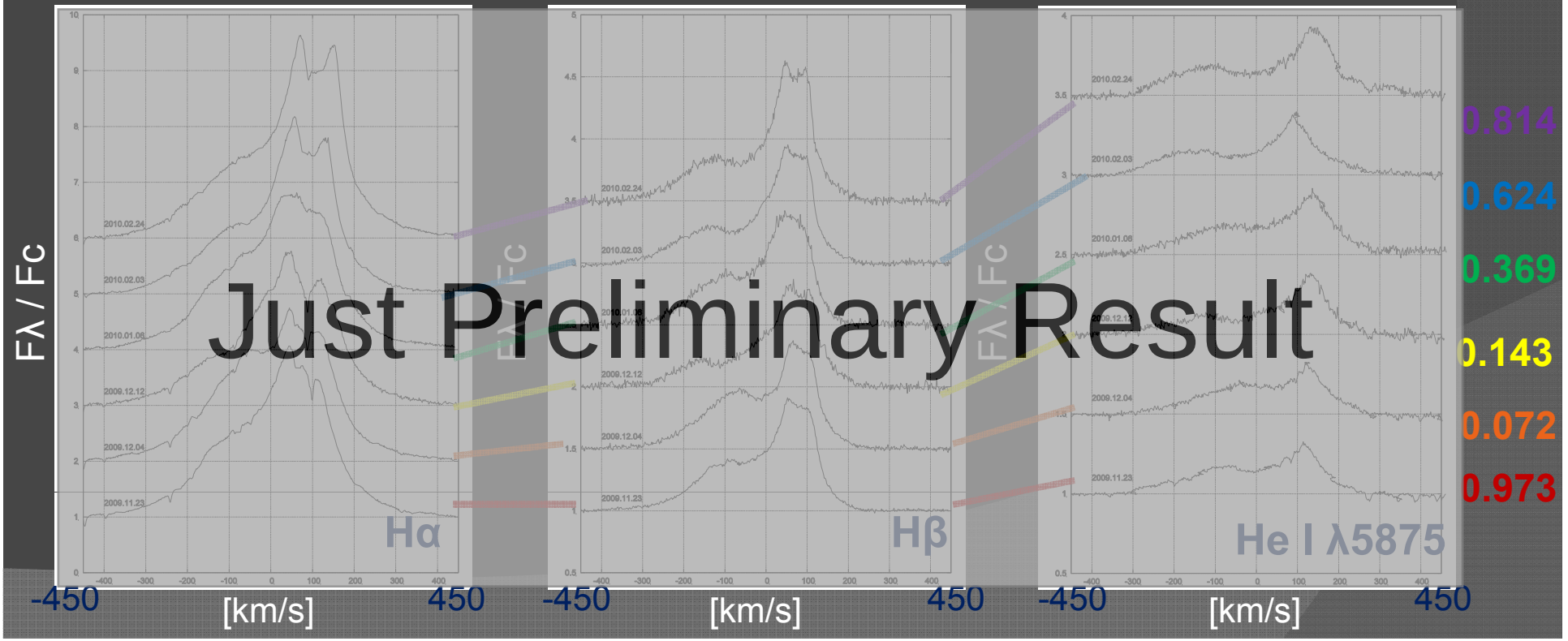
+ before the outburst (0.973)
+ the rising phase (0.072)
+ the peak (0.143)
+ end of the outburst (0.369)
+ after the outburst (1) (0.624)
+ after the outburst (2) (0.814)



Results (1)

- Representative spectra of Hα, Hβ and He Iλ5875
  - Balmer lines profiles: double-peak => double-peak and bright centre

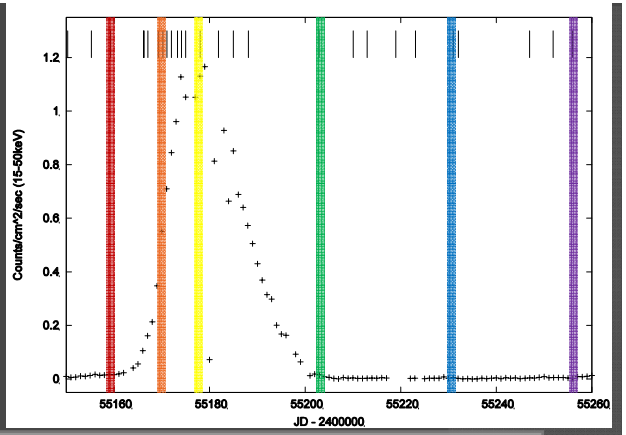


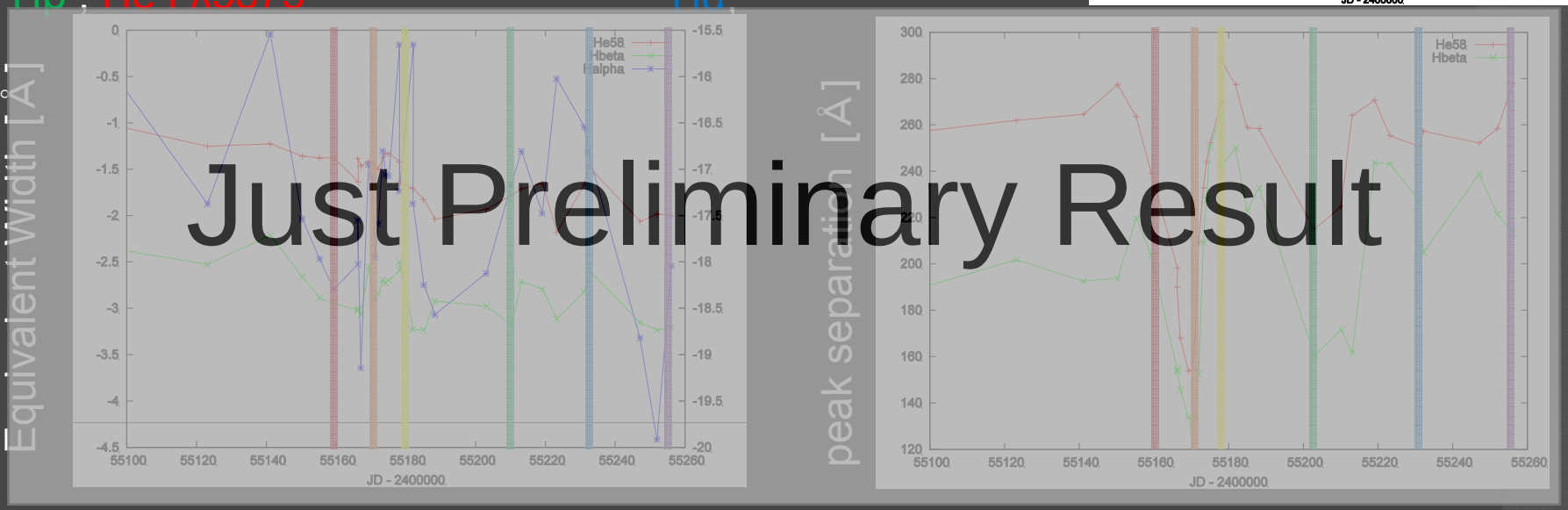


Just Preliminary Result

Results (2)

- EW, Peak Separation





Just Preliminary Result

Equivalent Width [Å] of
Hα, Hβ and He I λ5875

peak separation [Å] of
Hα, Hβ and He I λ5875

- Peak separation decreased and then recovered again during the rising phase, which means the Be disc expanded and mass escaped??

Conclusions & Future Works

- We observed the giant outburst of the Be/X-ray binary A0535+262/V725 Tau in Dec. 2009.
- The line profile dramatically changed throughout the outburst.
  - Just after the onset: the decrease of peak separation suggest that the Be disc had expanded.
  - During outburst: the line profile variability was detected.
  - After outburst (at present): the outer side of the Be disc is still enhanced!?
- More detailed analysis of these line
  - Line profile variability during the outburst, other lines and so on
- Reduction and Analysis Spectropolarymetric observations by HowPOL/ KANATA in Hiroshima Univ.
- The next periastron is coming, 20 Mar. 2010!