New tricks for a mature observatory: Chandra HETG/HRC-I observations of TW Hya probe the structure of accretion

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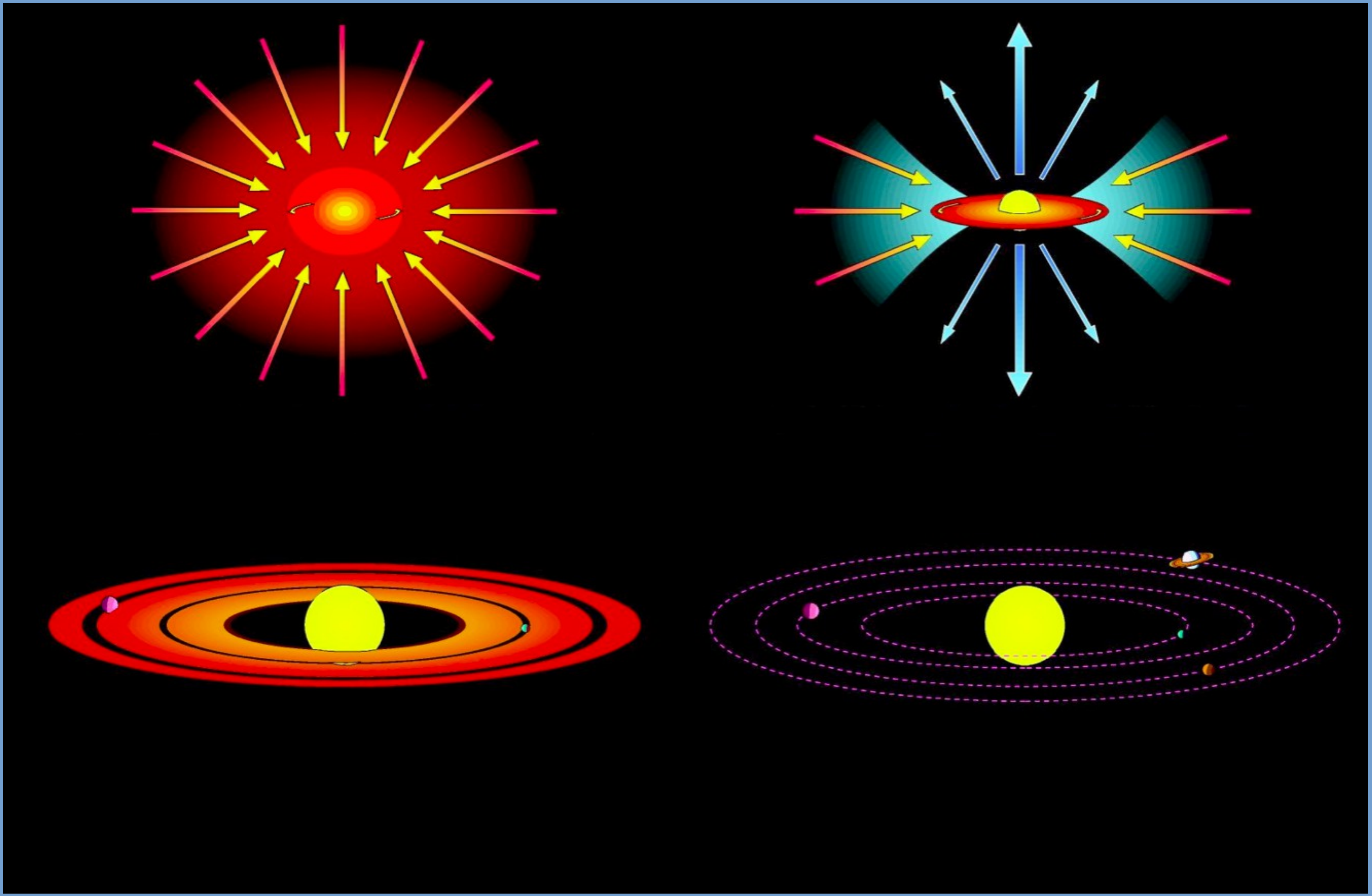
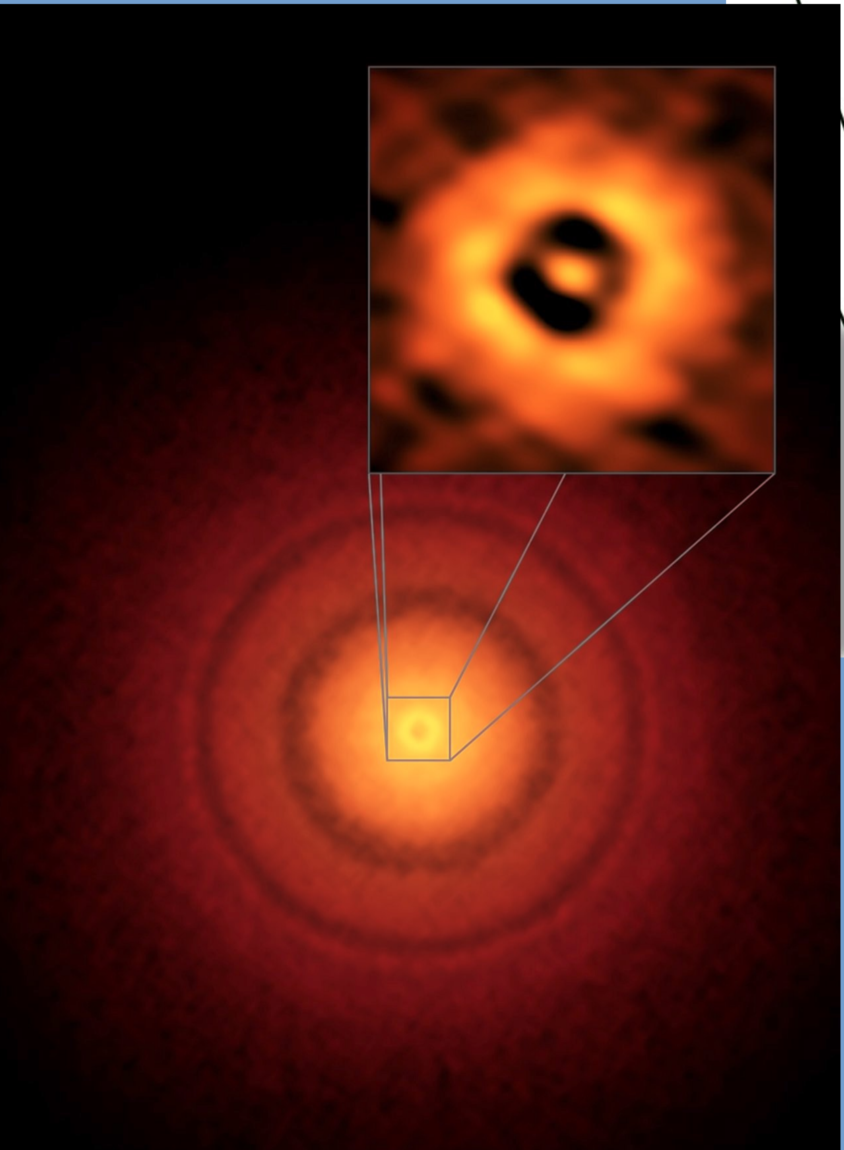
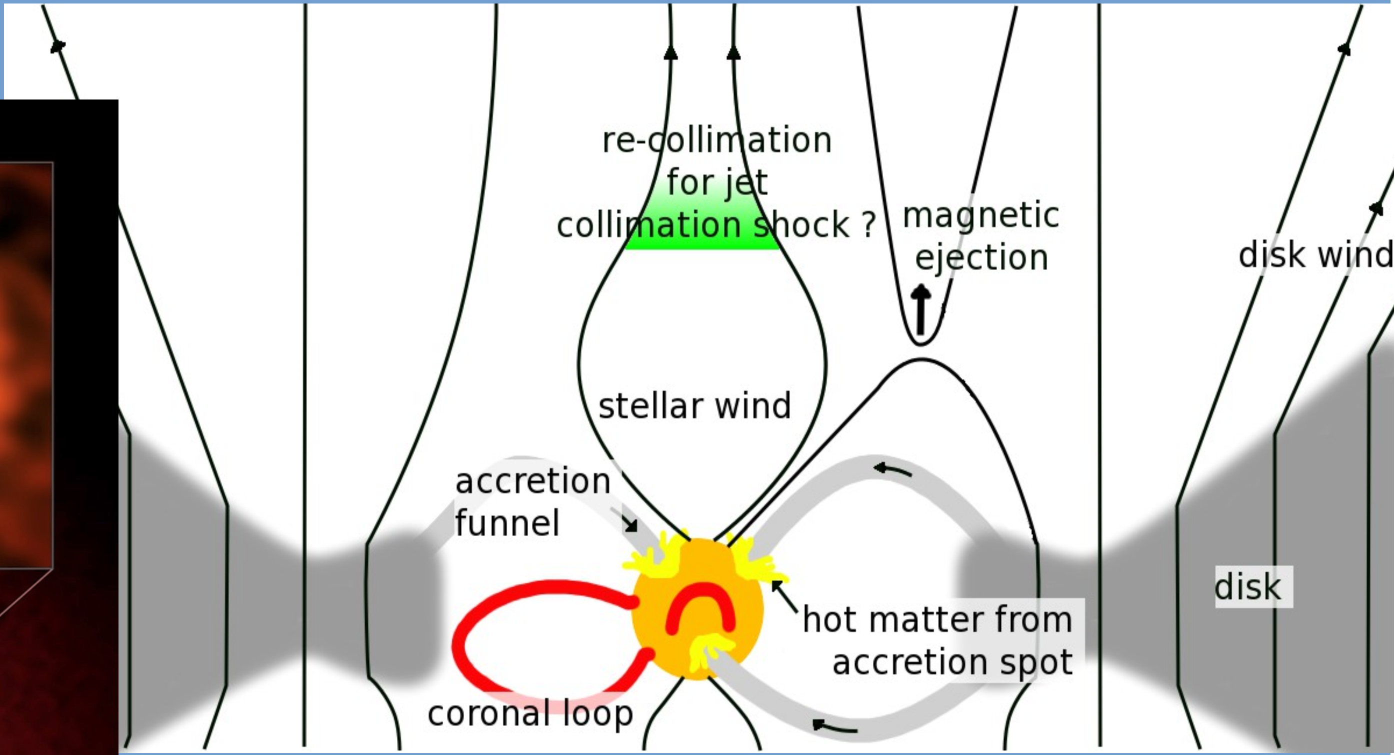
Phases of star formation



Artist: McCaughrean

Classical T Tauri stars

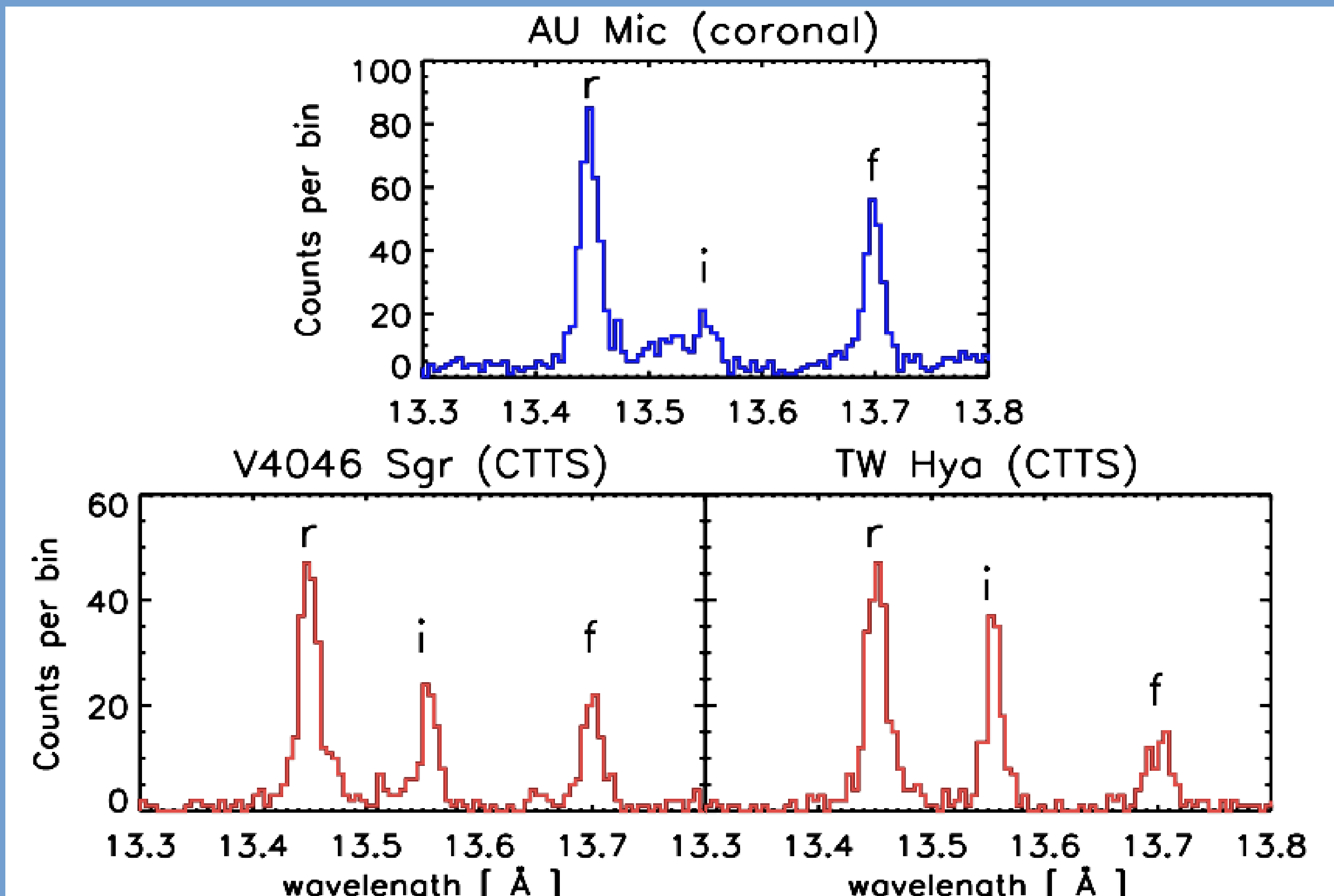




Günther (2013)

Andrews et al.
ApJL (2016)

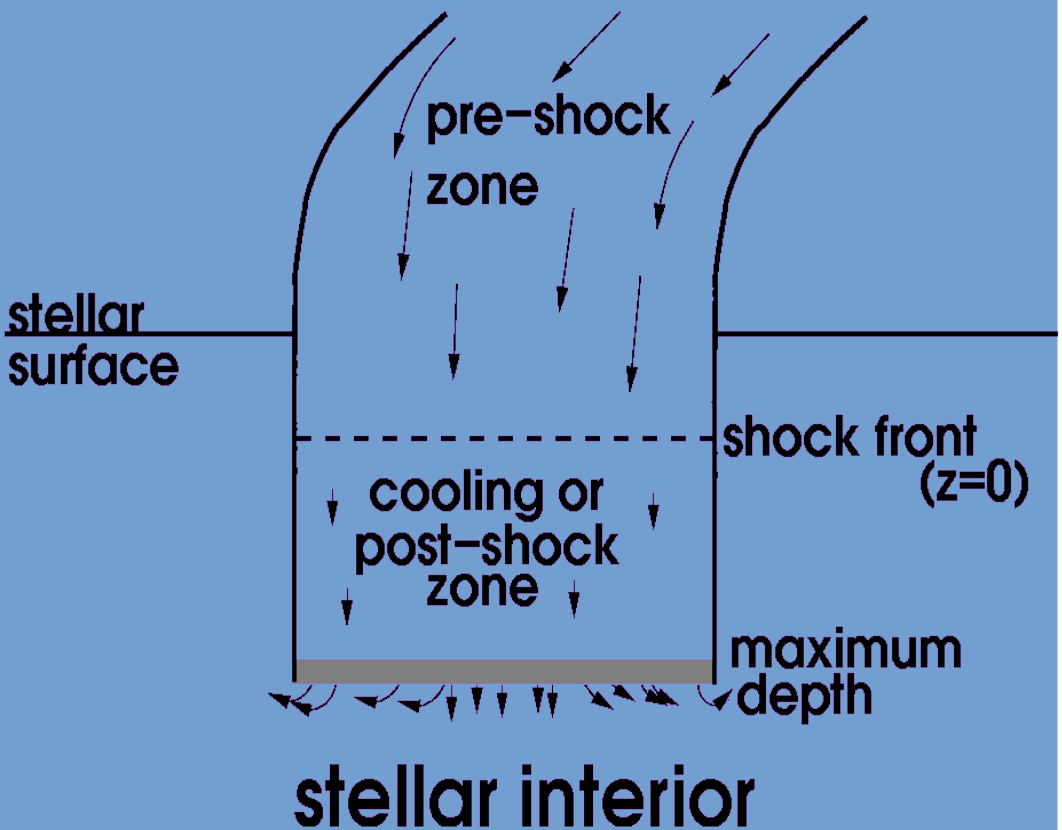
He-like triplets



Günther et al., A&A (2006)

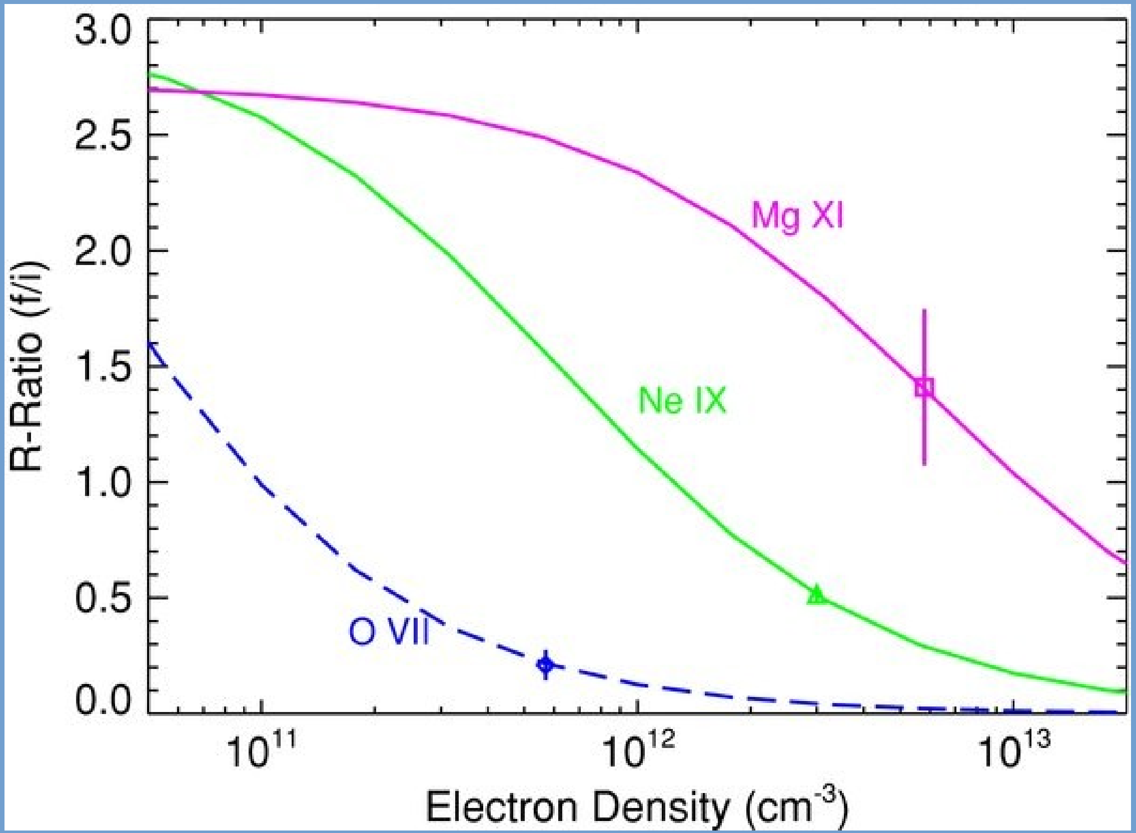
The accretion model

- 1D stationary
- optically thin
- no heat conduction
- Maxwell velocity distribution (different temperature for electrons / ions)
- magnetic field does not change dynamics
- non-equilibrium ionisation calculation

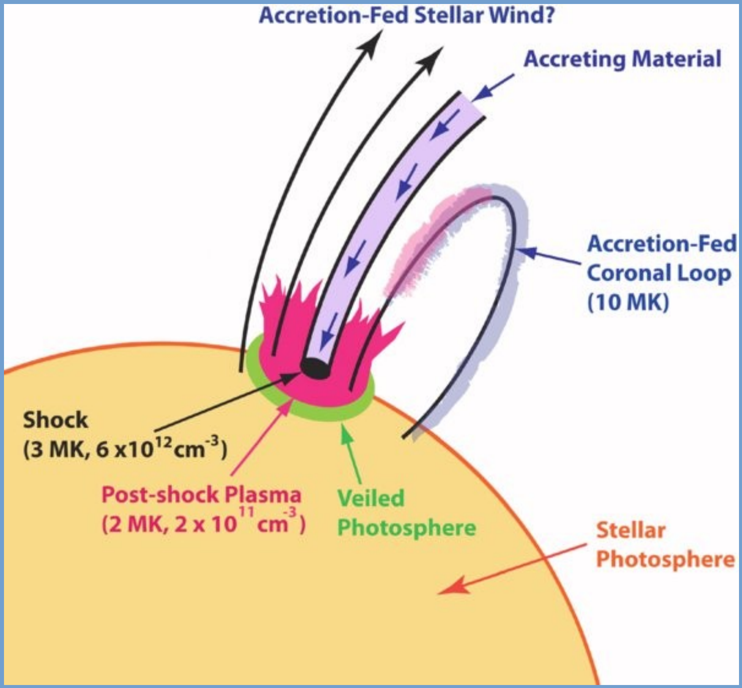


Günther et al., A&A (2008)
Günther, AN (2011)

Problems with current models: Accretion interacts with the star

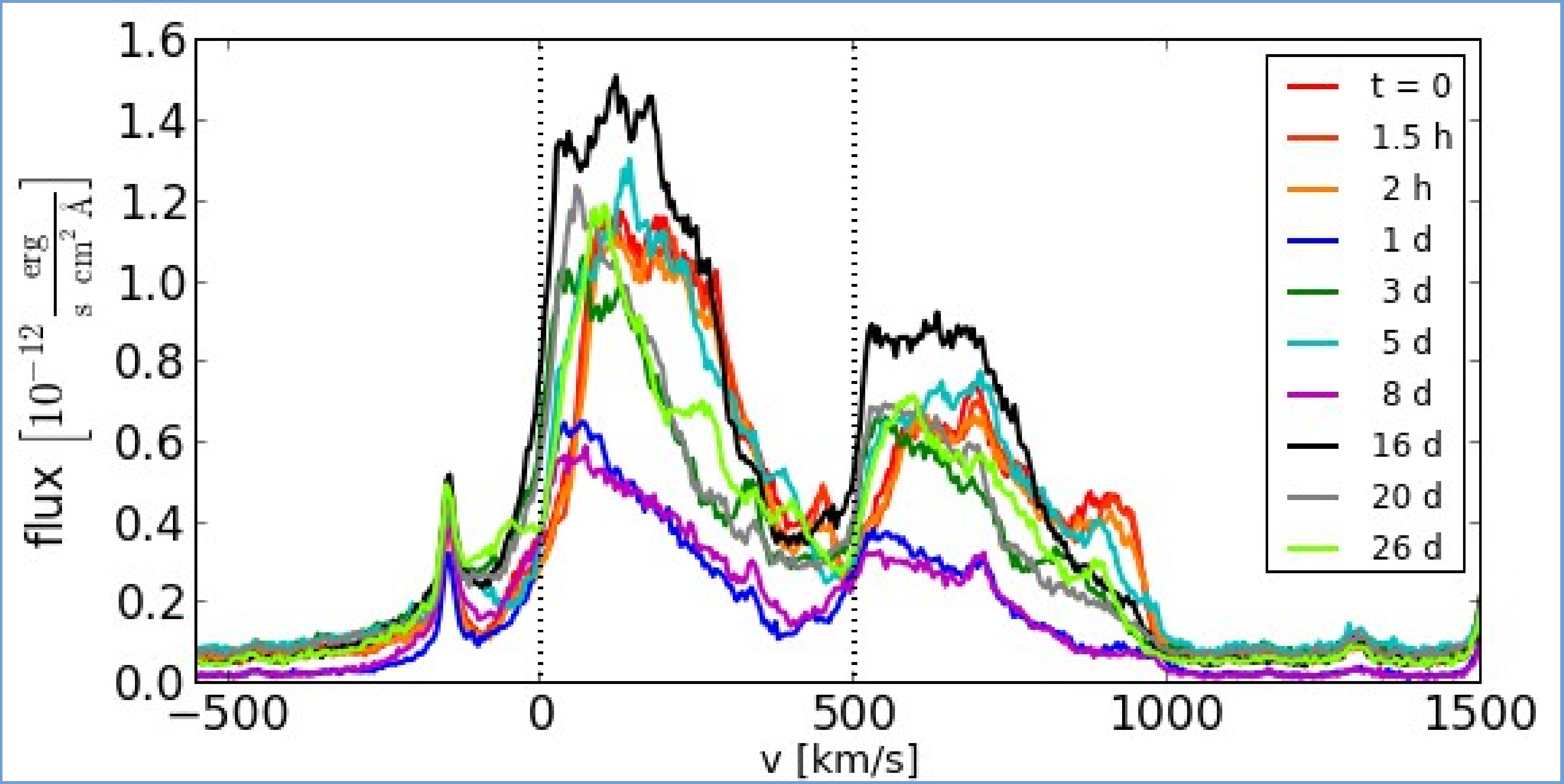


Brickhouse et al. ApJ (2010)
Brickhouse et al. ApJ (2012)



Can we resolve the line kinematically?
Can we measure time-resolved properties?

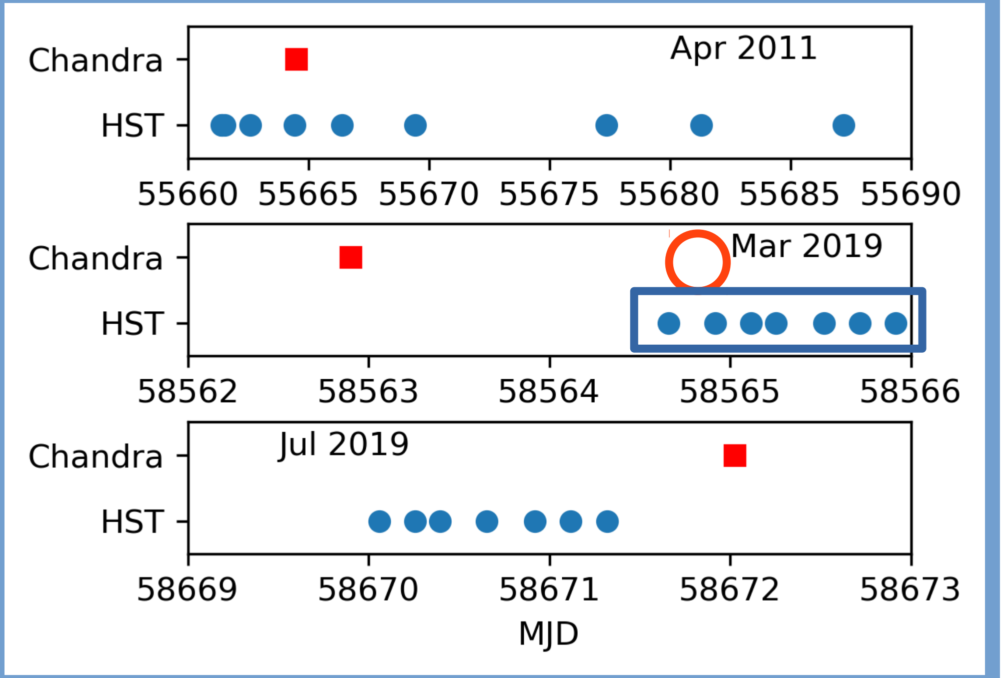
HST/COS



But, what do the X-rays do?

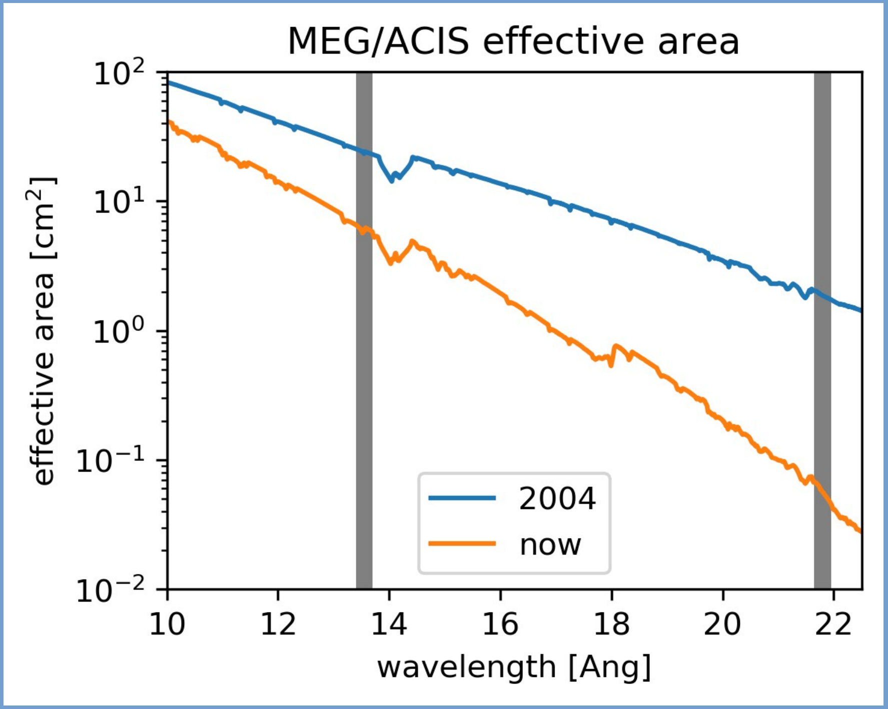
Multi-wavelength campaign of contemporaneous observations

- Chandra
- HST/COS
- Magellan/FIRE
- FLWO/TRES
- El-Trigre
- SSO
- ...



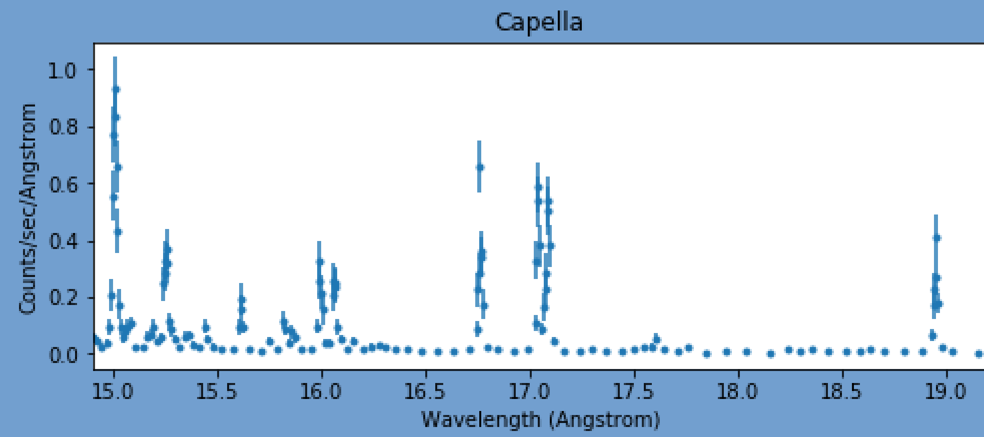
HETG/HRC-I: Why?

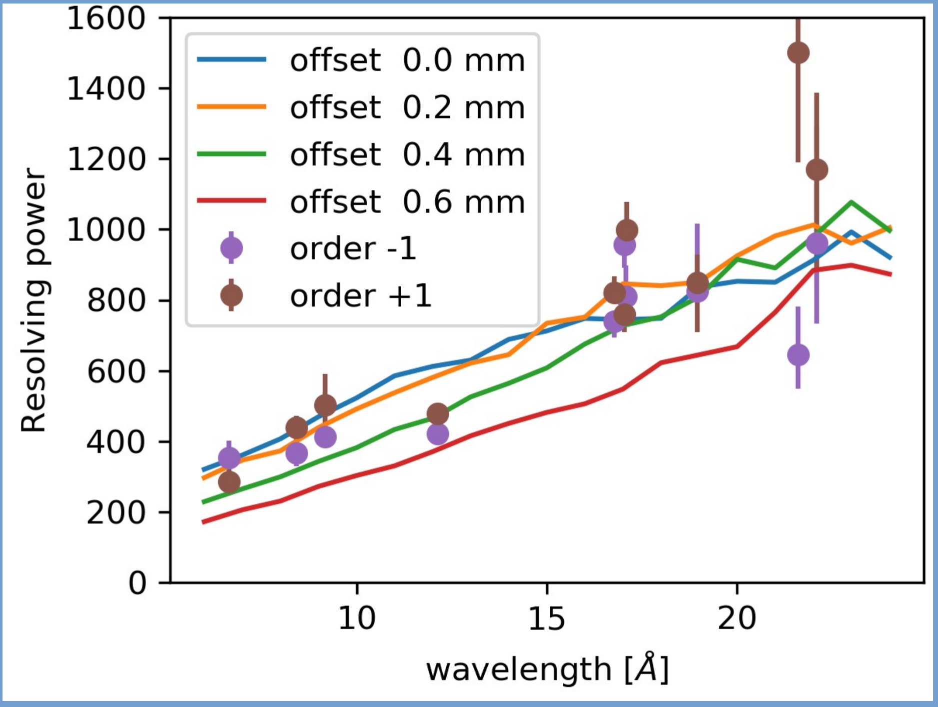
- ACIS-S contamination increases
- Energies < 1 keV hard to see
- LETG has lower resolving power
- HETG/HRC-I might be best combination for certain science targets:
  - Need for best resolution
  - Need to lines < 1 keV
  - Line dominated spectrum
- No order-sorting
  - Order confusion
  - Higher background (but less than HRC-S)
  - HRC-I is flat



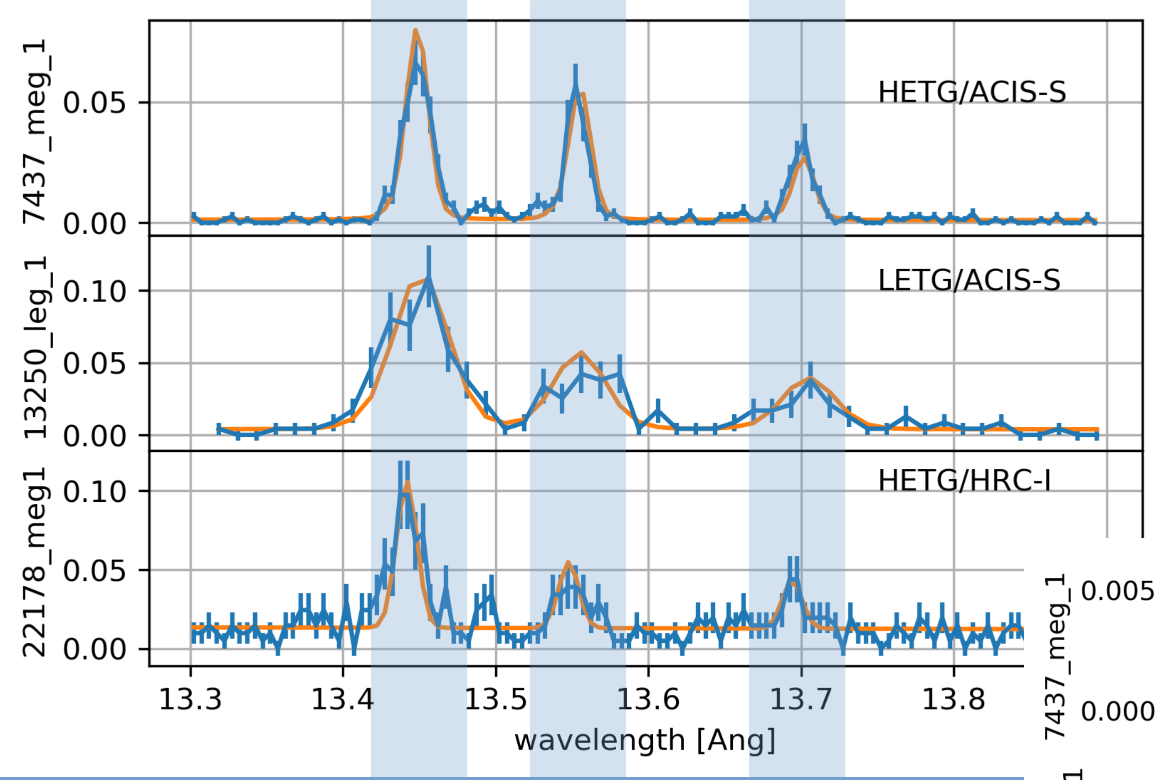
HETG/HRC-I: Status

- **NOT** a standard product in CIAO <= 4.12
- But can be reduced with CIAO tools with some monkeying
- Working on associated CALDB files, but might require custom RMFs
- *MIGHT* be fully supported in the future



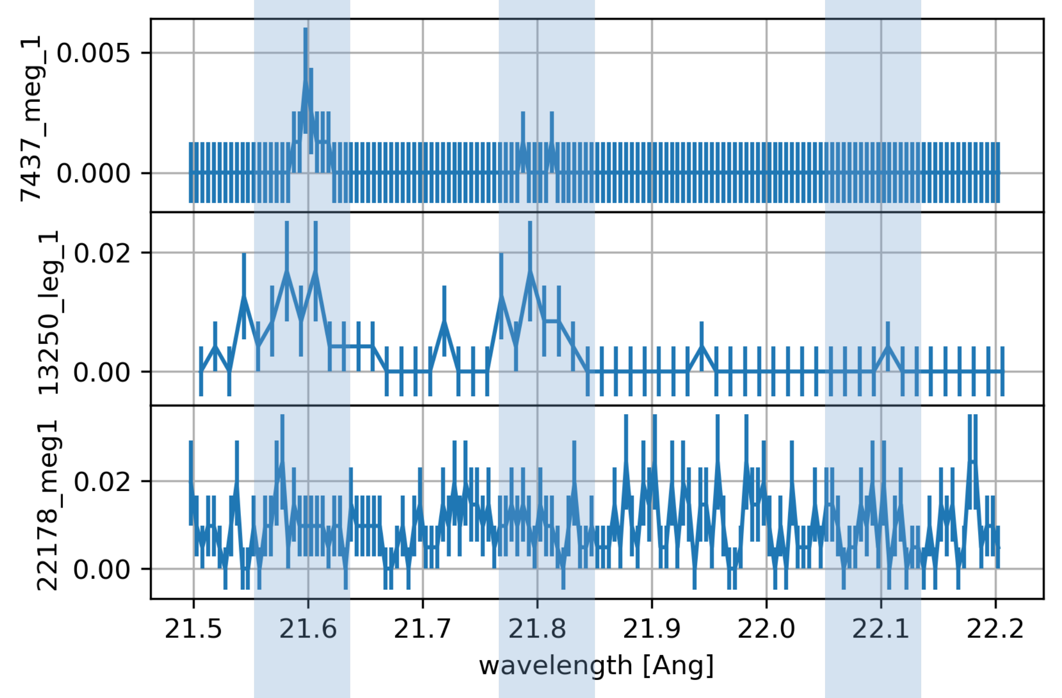


TW Hya: Triplets with Chandra

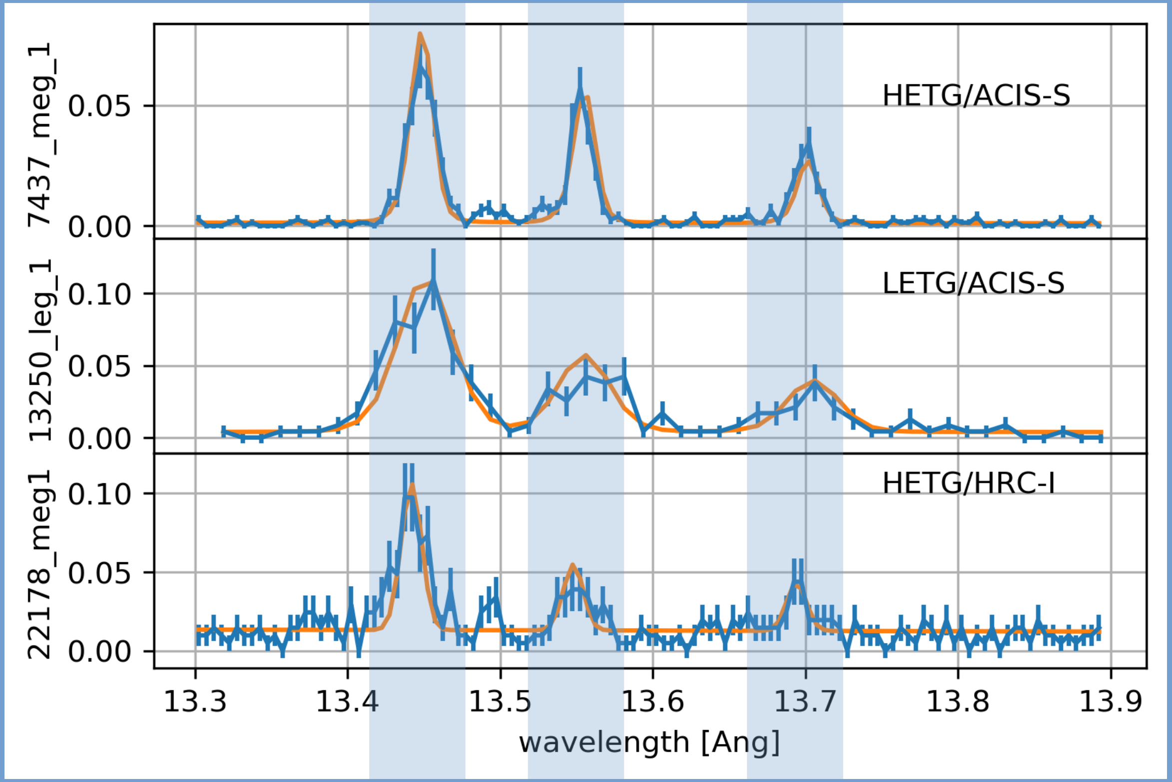


Ne IX: r i f
high density

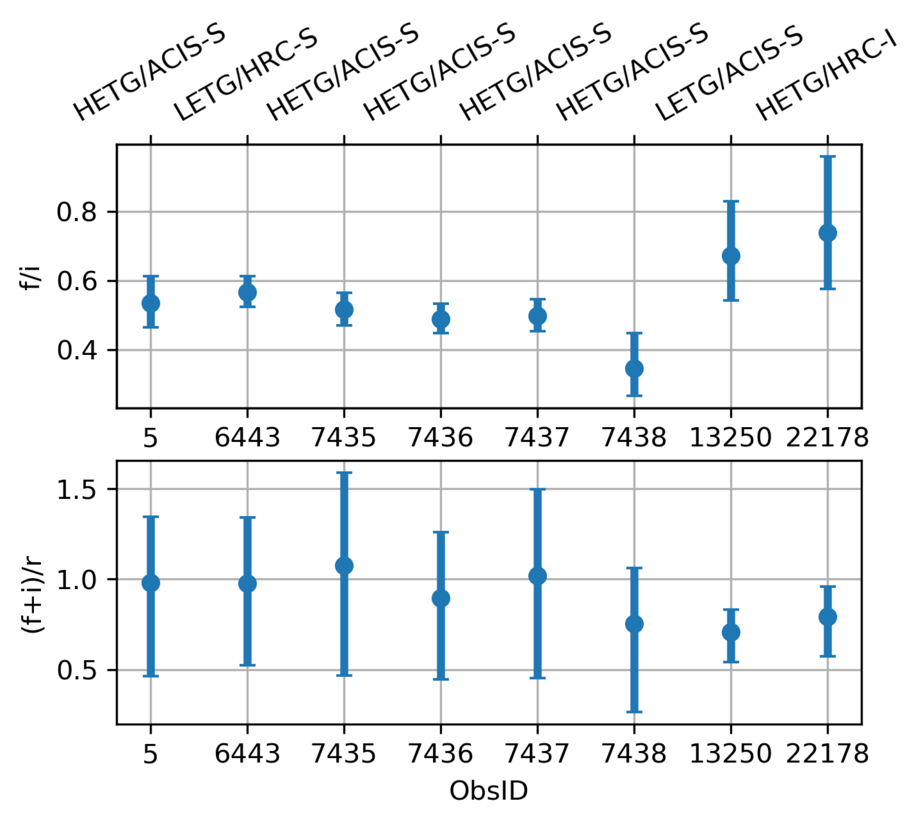
O VII high density
r i f



TW Hya: Changes in density

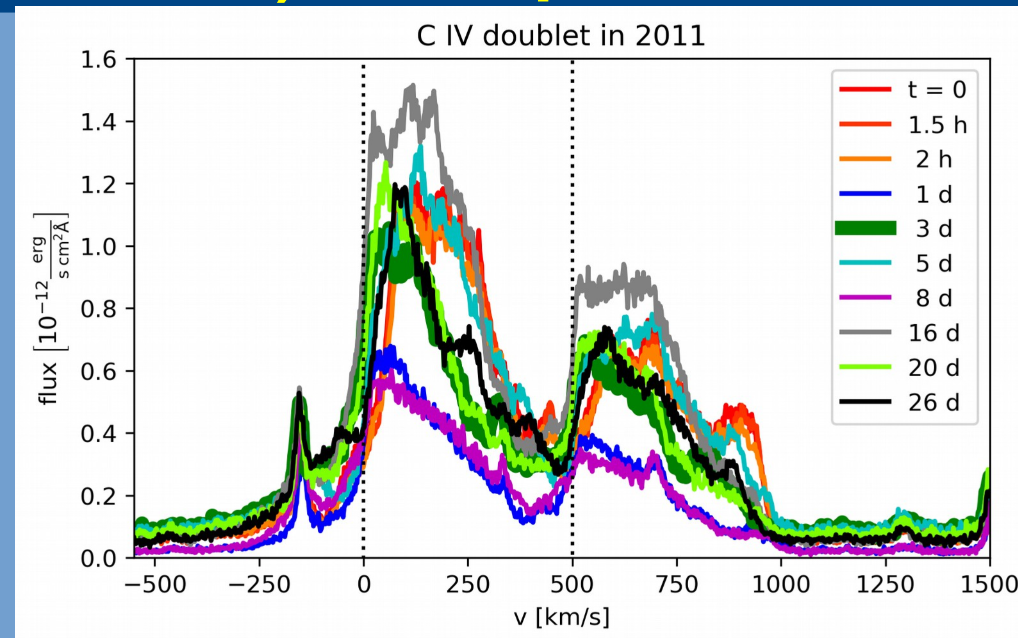


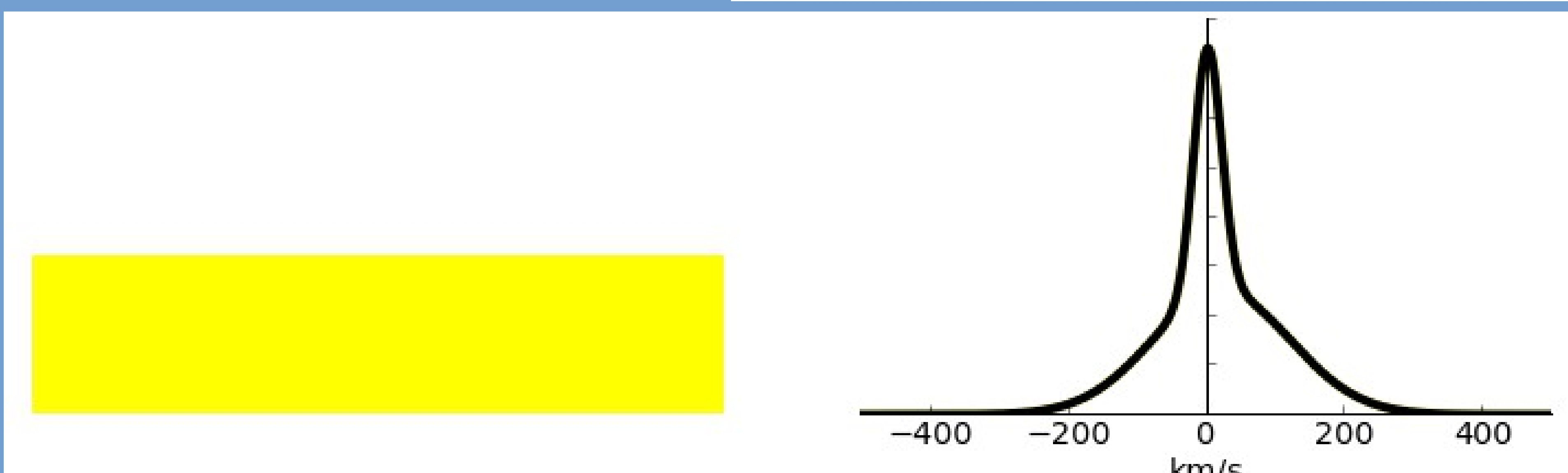
Ne IX: r i f
high density



How can we explain the C IV (and other hot ion line) shapes?

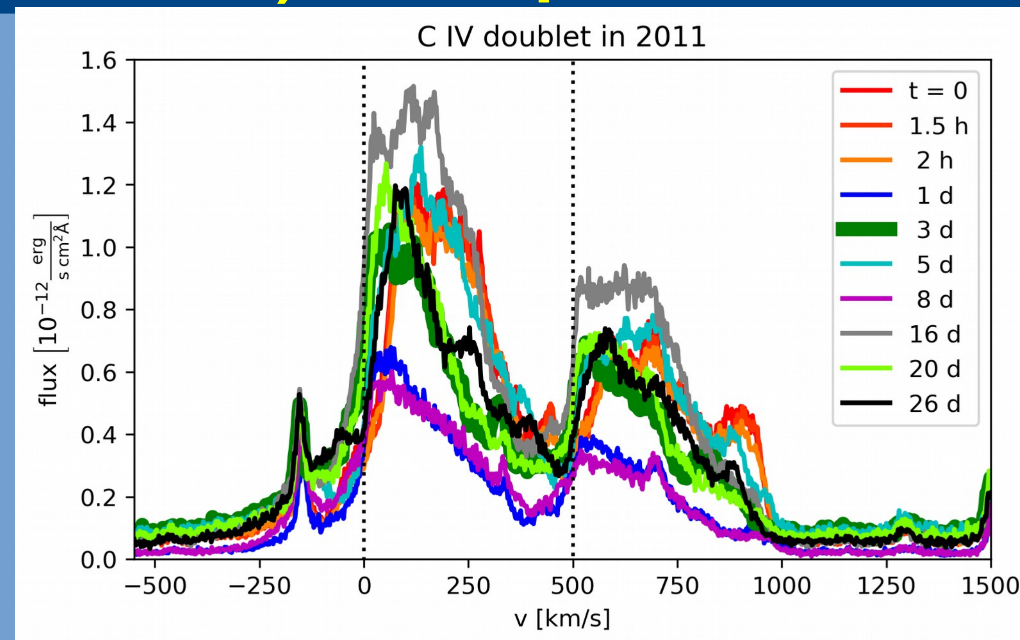
- Non-accreting TTS have two component C IV lines (Ardila et al. 2013)

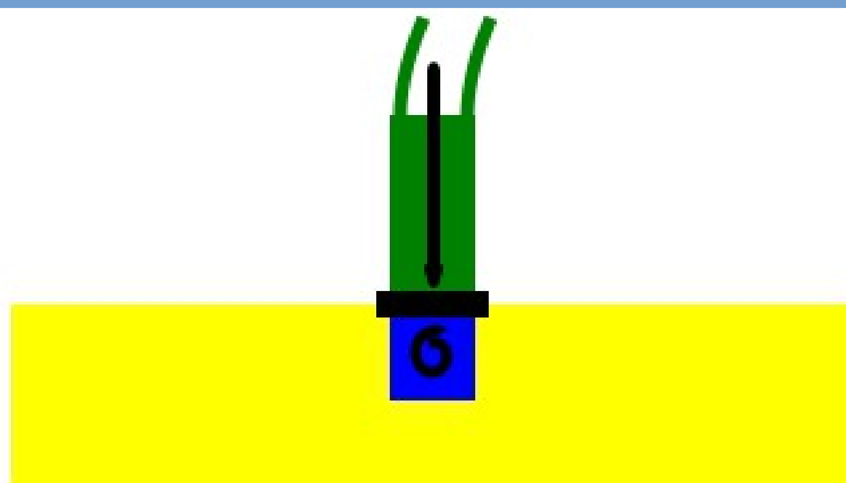


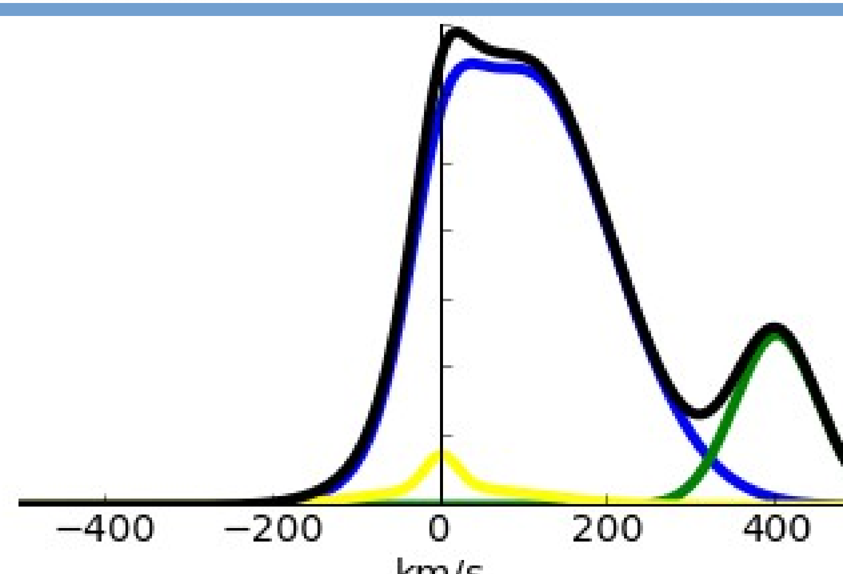


How can we explain the C IV (and other hot ion line) shapes?

- Pre-shock: freefall velocity
- Post-shock: tubulence, <¼ freefall velocity

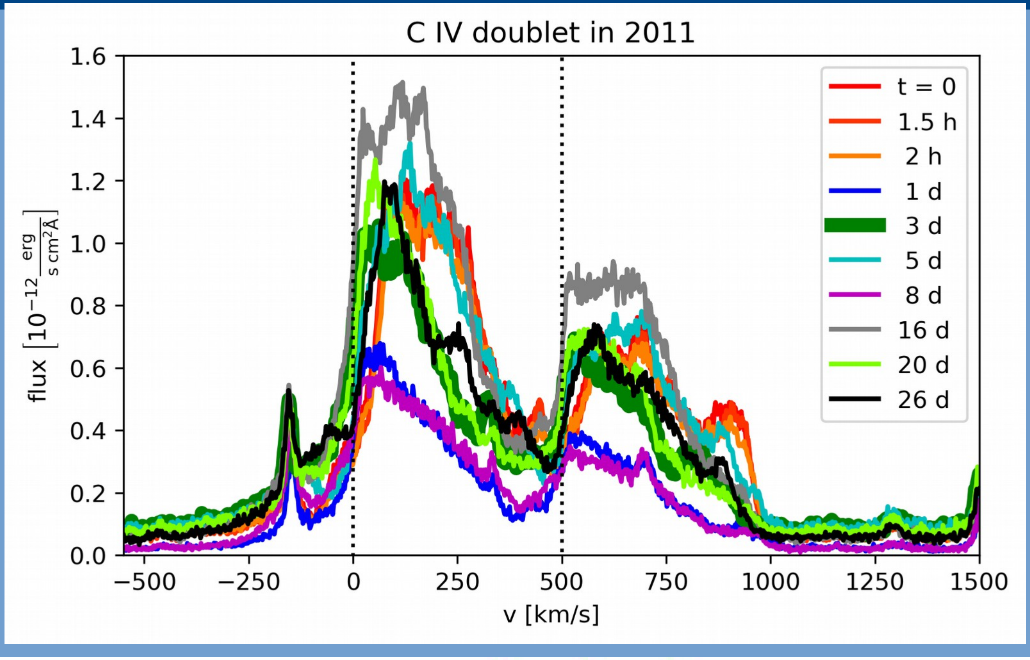


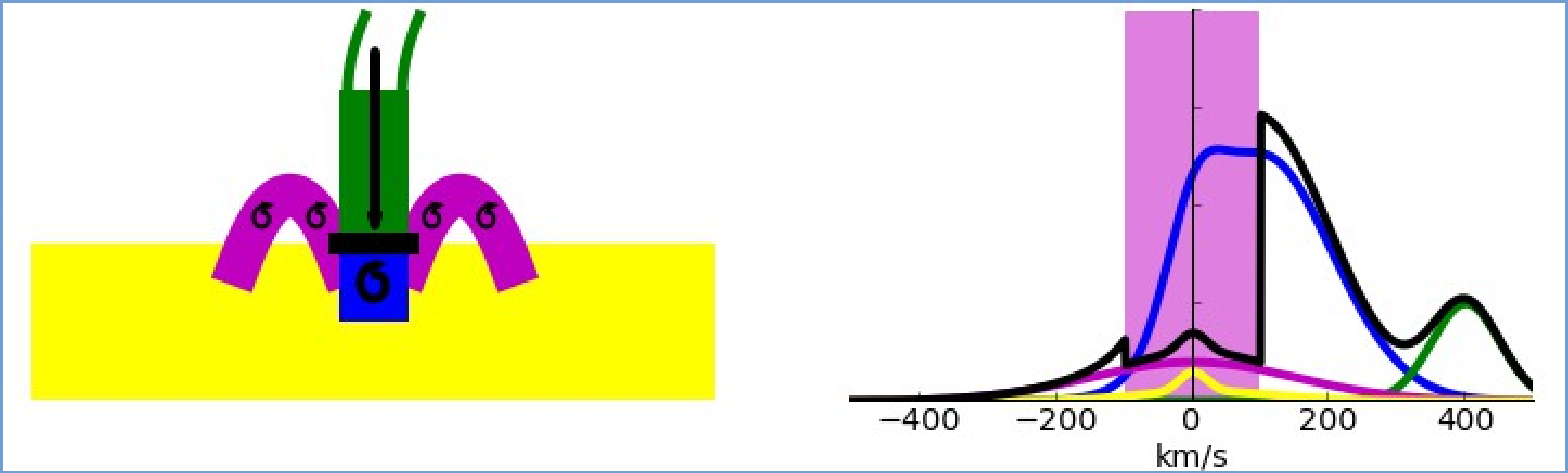




How can we explain the C IV (and other hot ion line) shapes?

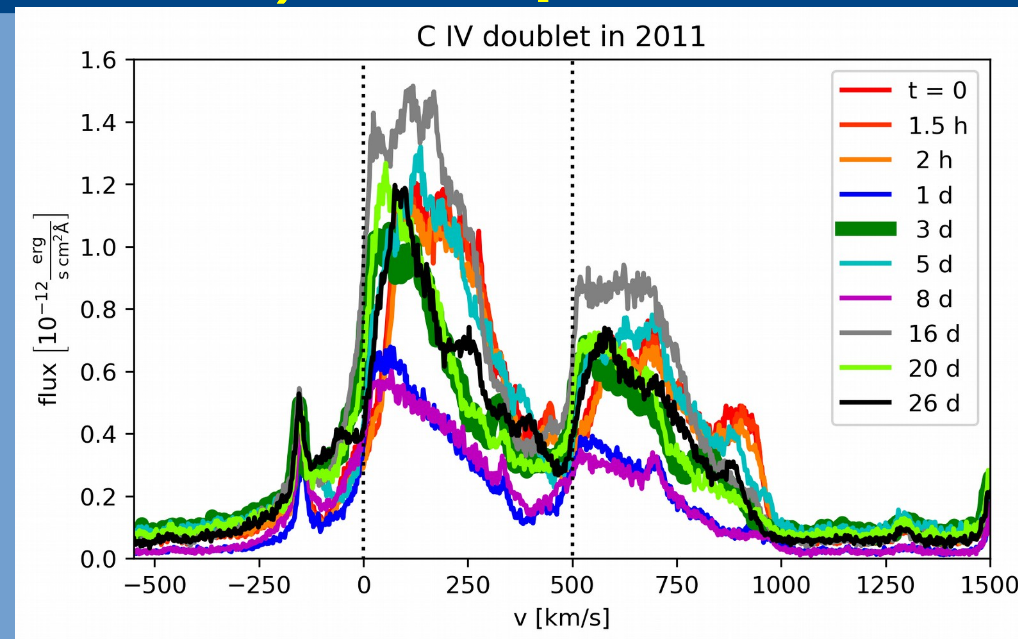
- Splatter: turbulent, variable bulk < 100 km/s absorbtion

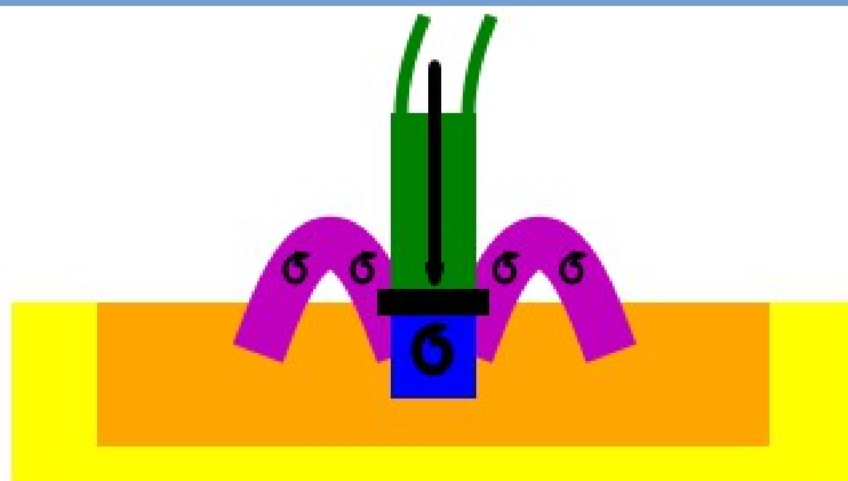


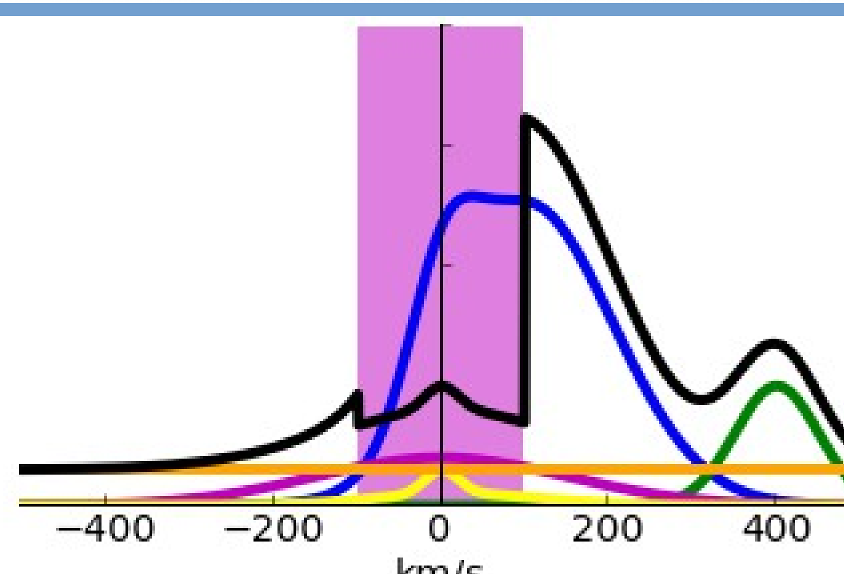


How can we explain the C IV (and other hot ion line) shapes?

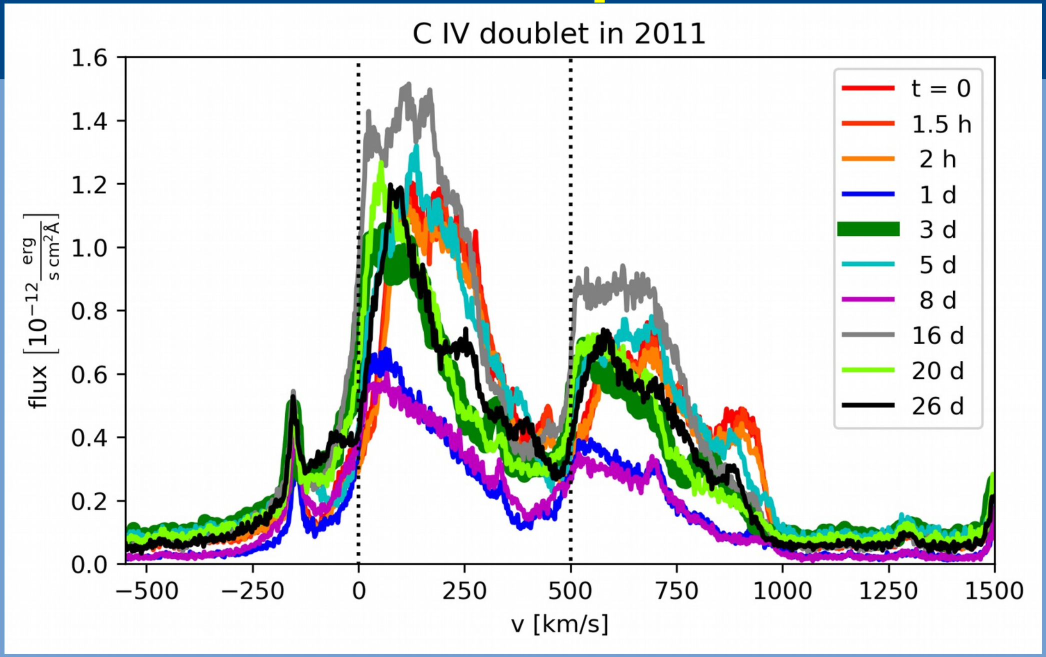
- Heated photosphere: 20,000 K varies with accretion

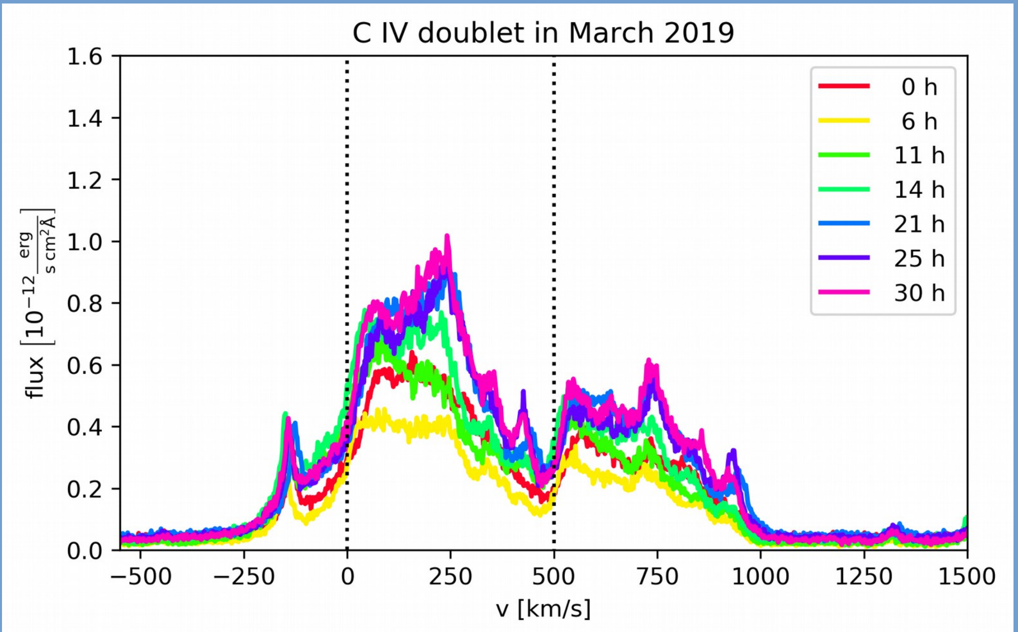


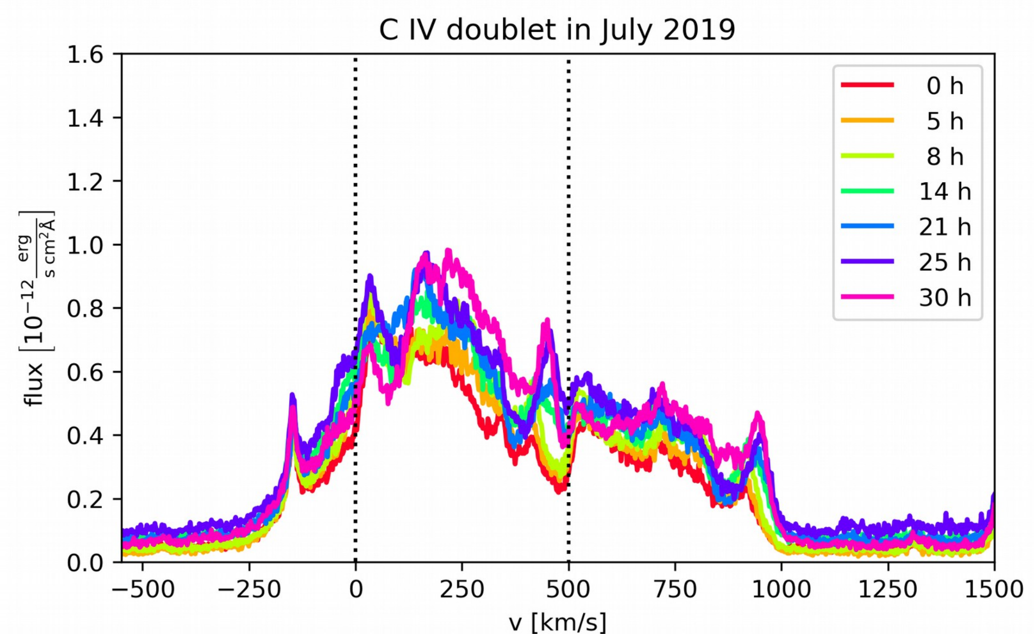




C IV line profiles







Summary

- Use HETG/HRC-I for effective area < 1 keV
- Calibration / data reduction is experimental at this point
- TW Hya has variable f/i ratio
- C IV line profiles can be explained with combination of accretion and outflow