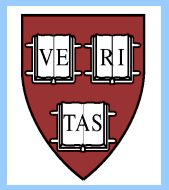
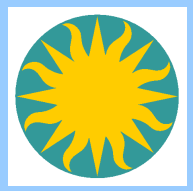
Accretion, winds & jets:

High-energy emission from young stellar objects



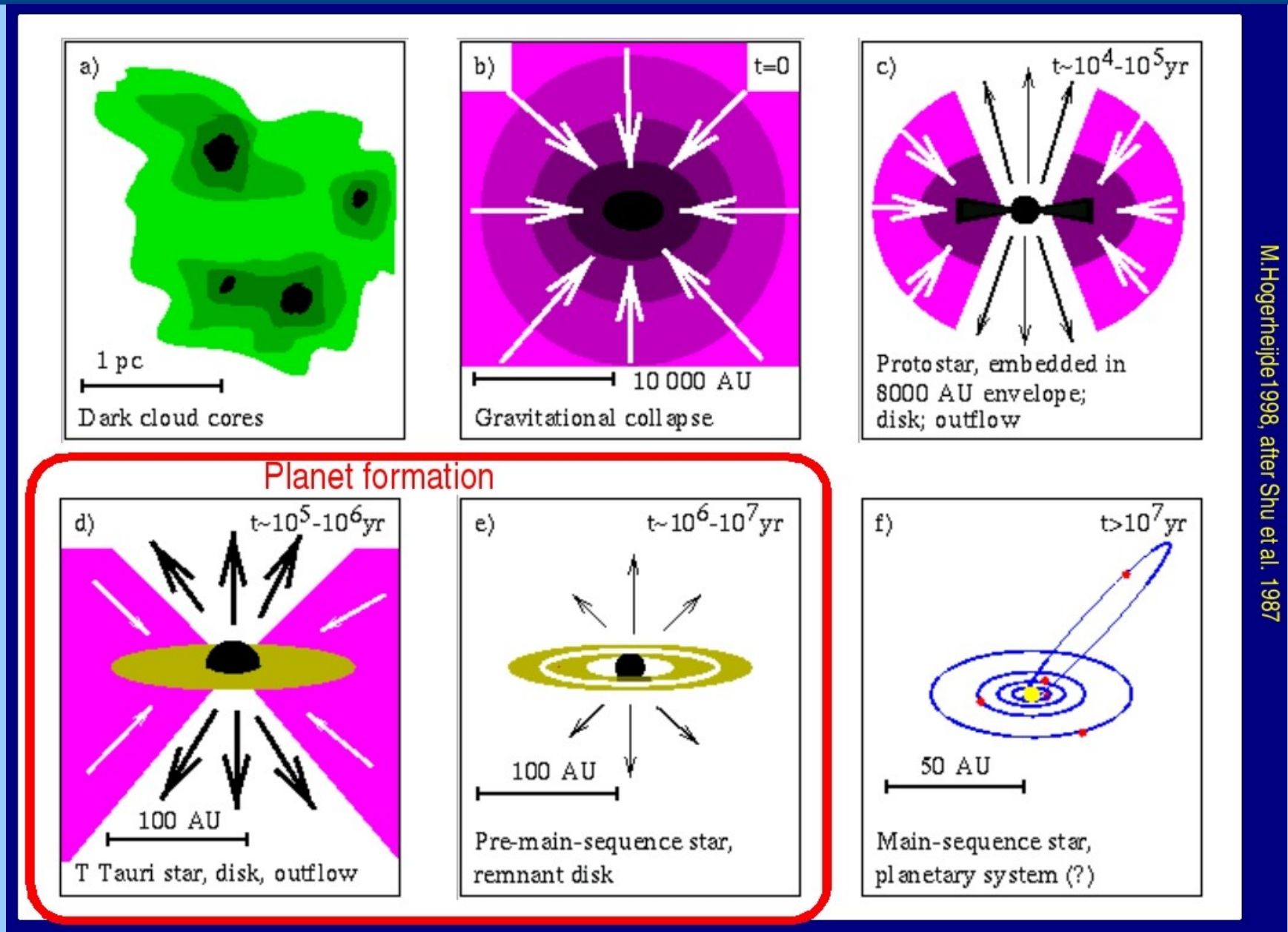
Hans Moritz Günther
CfA



Outline

- Introduction
- Classical T Tauri stars (CTTS)
  - Observational pecularities
  - Accretion
  - Jets & winds
- Herbig Ae/Be stars (HAeBe)
- Conclusion

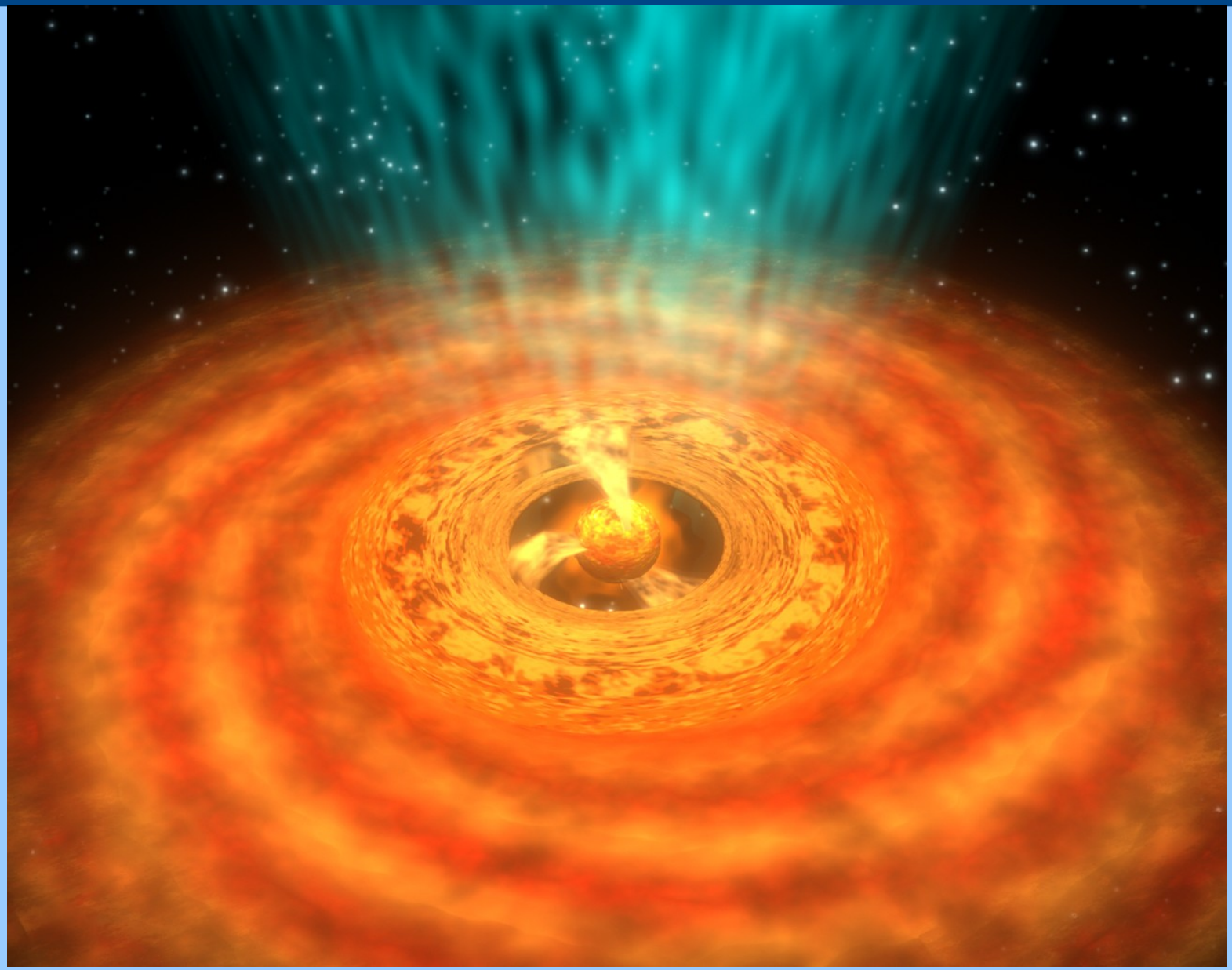
Phases of star formation



Young stars

Classical T Tauri Stars (CTTS)	Herbig Ae/Be Stars (HAeBe)
• Spectral type M-F • Age < 30 Myr • IR excess • Hα EW > 10 Å • Cool stars • X-rays from active corona	• Spectral type A-B • Age < a few Myr • IR excess • No convective envelope • Often unresolved companions

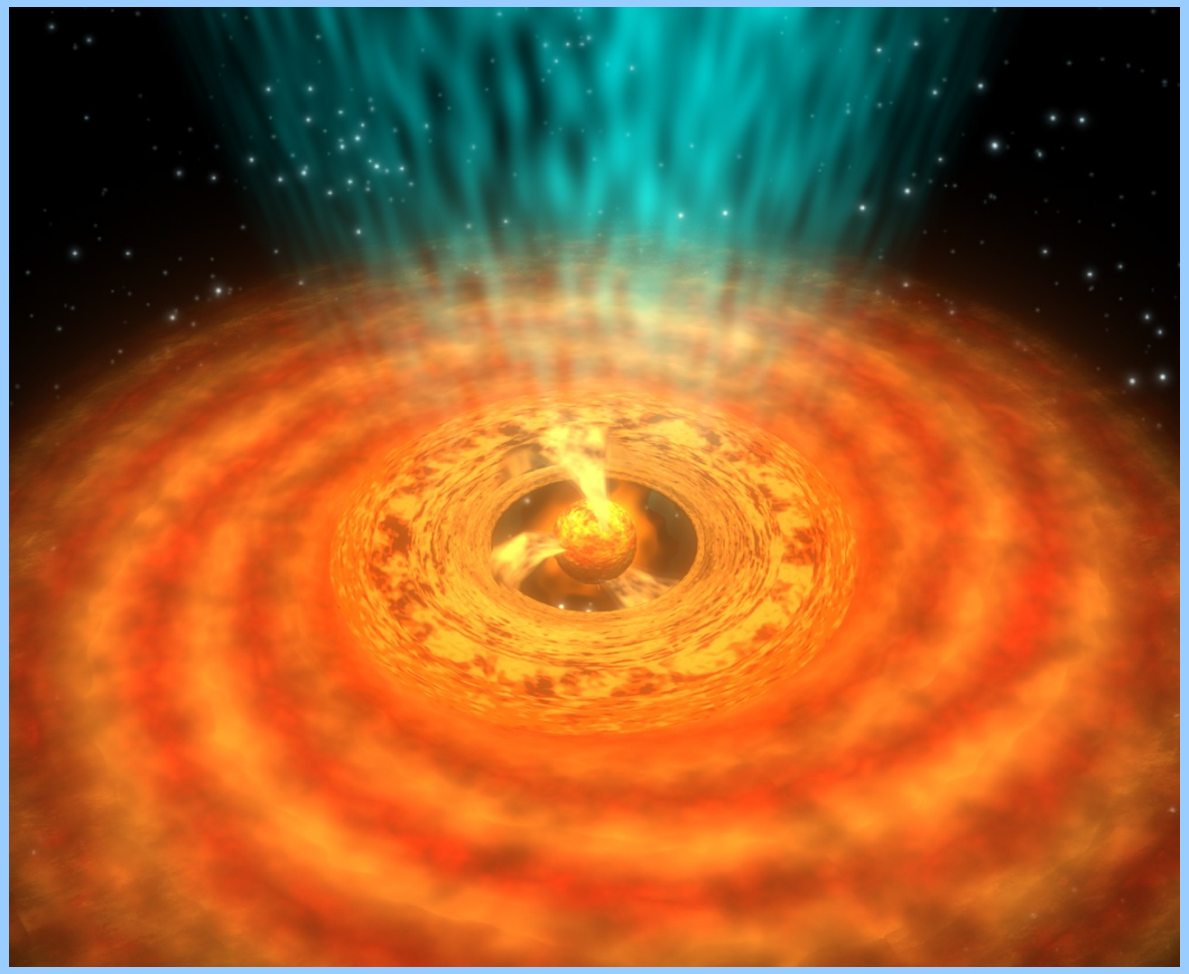
Classical T Tauri Stars



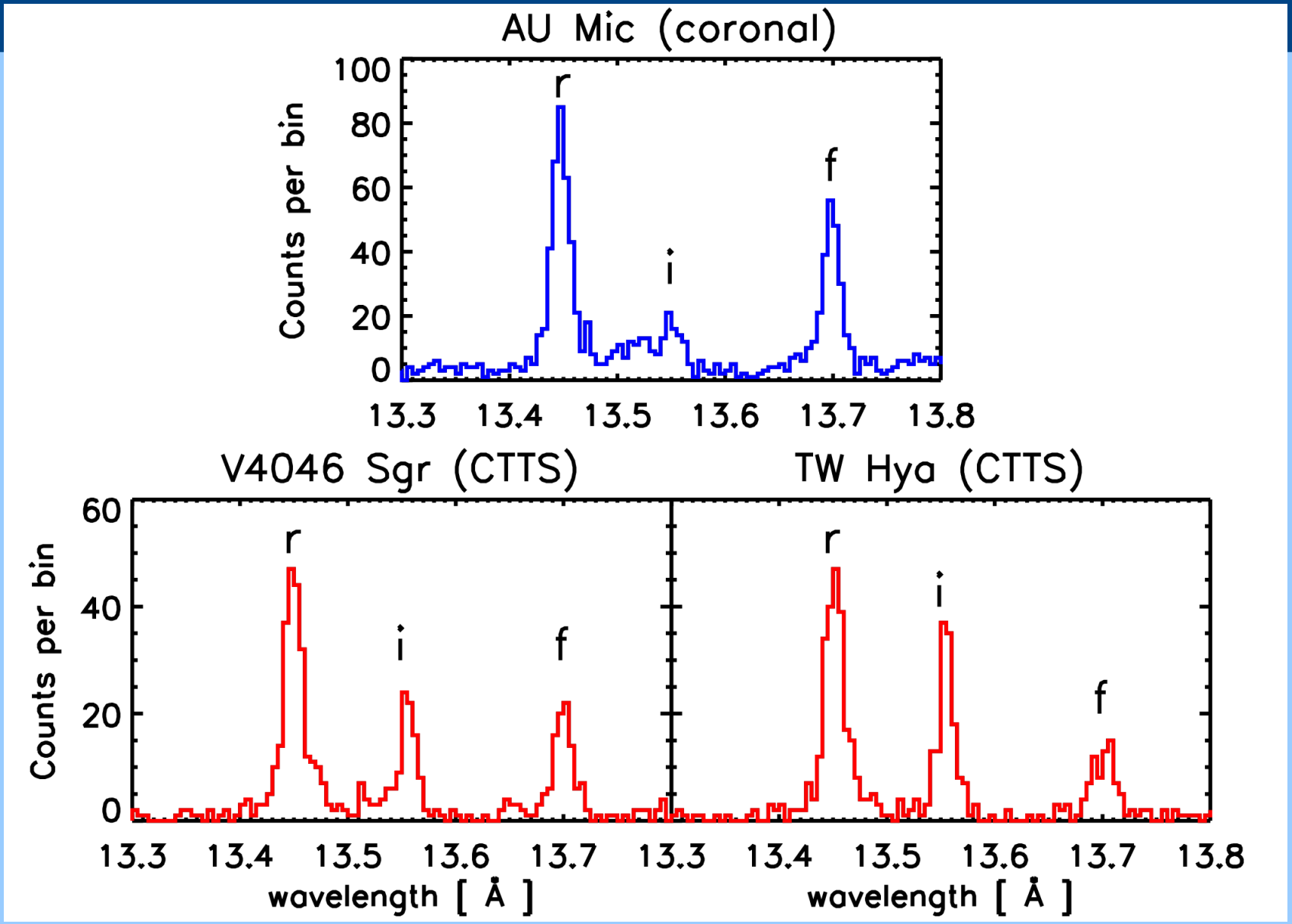
ESA

Classical T Tauri Stars

Observations in X-rays

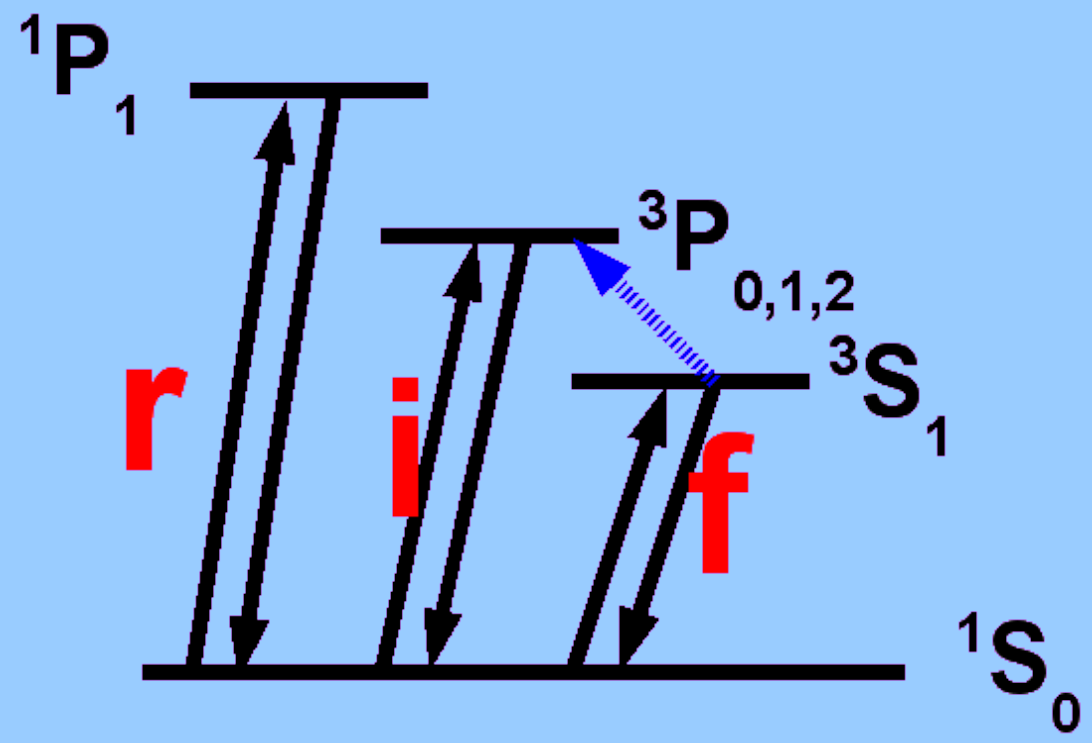


He-like triplets



Günther et al., A&A (2006)

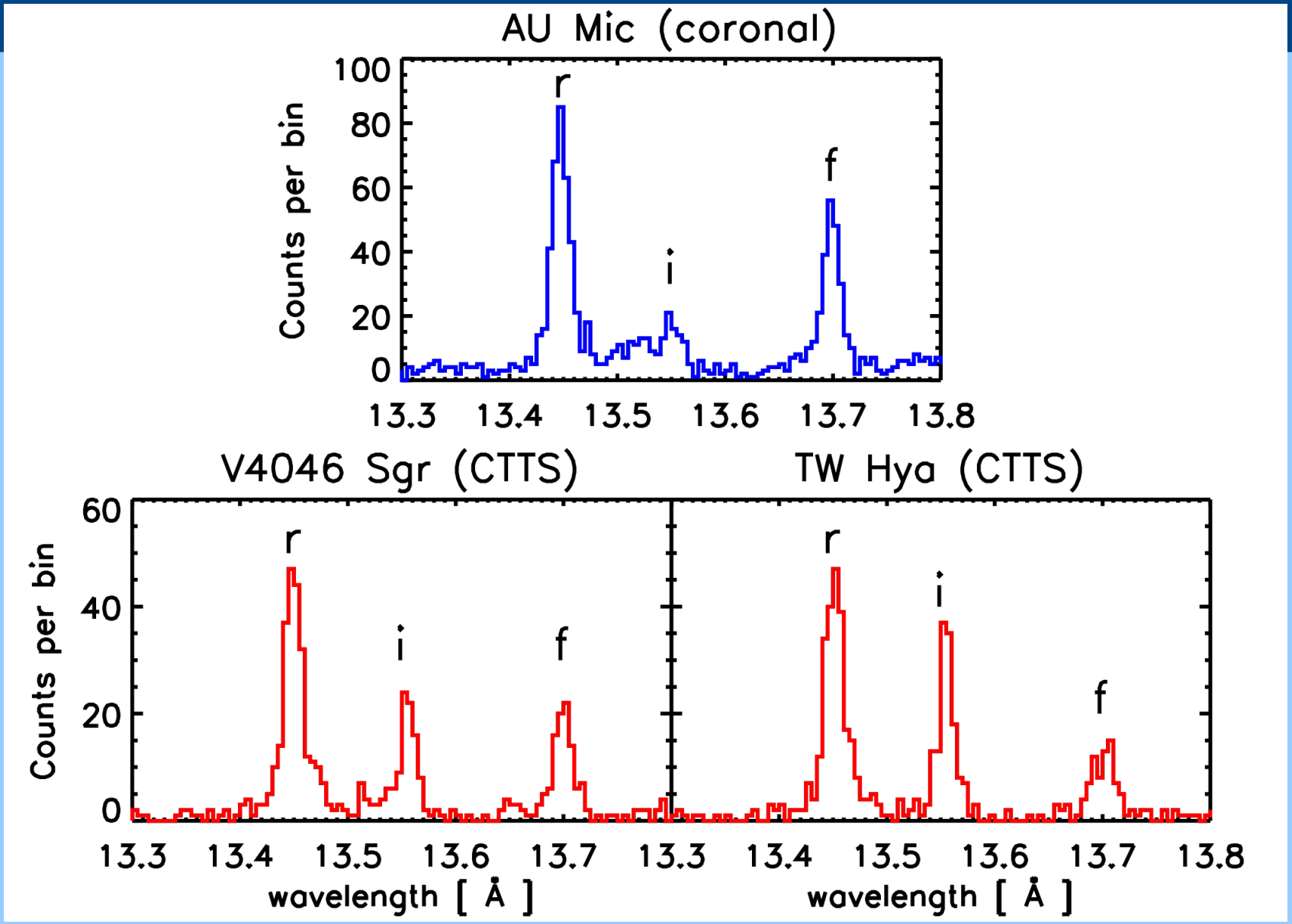
He-like triplets: Theory



f/i large:

- low density
- weak UV-field

He-like triplets



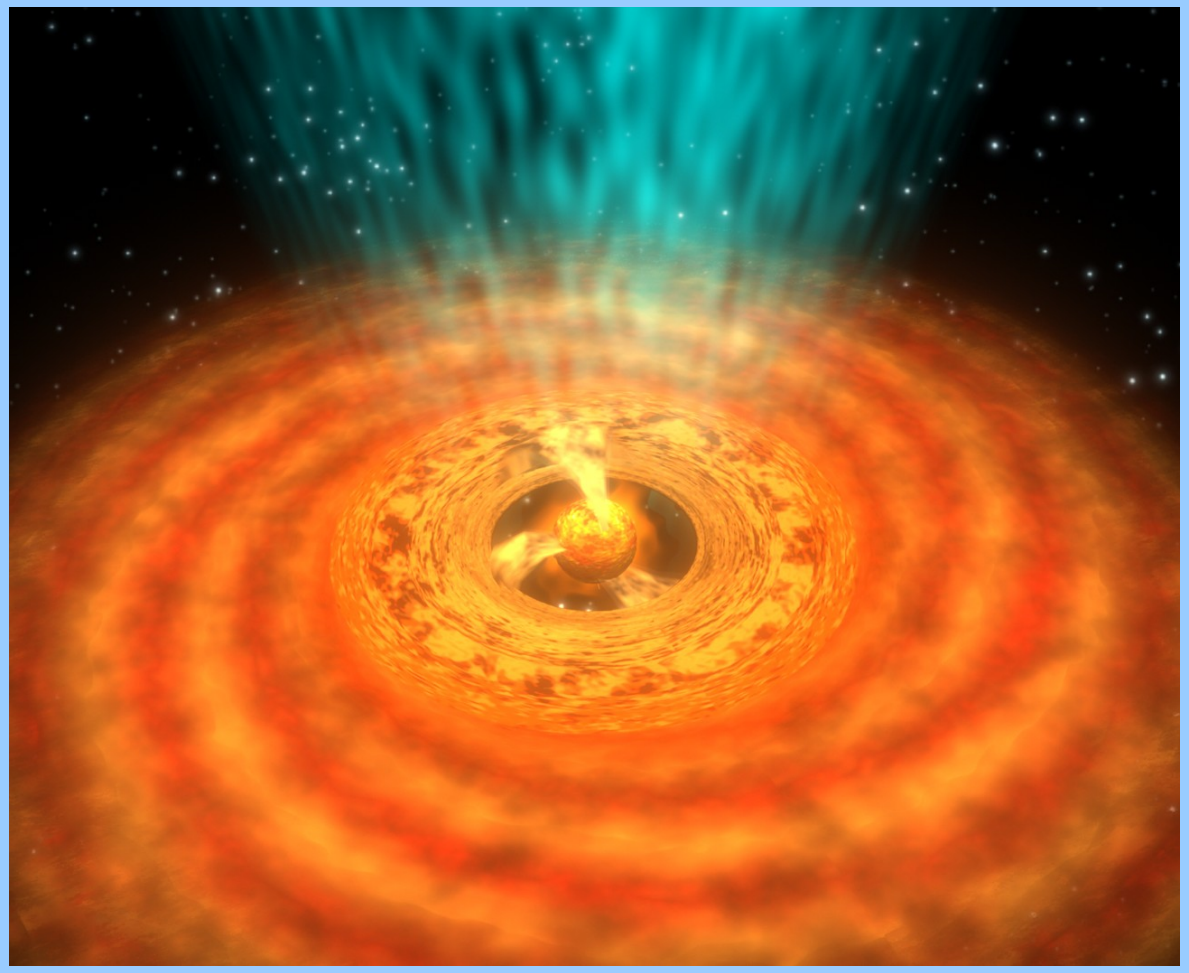
Günther et al., A&A (2006)

CTTS: Observations

- CTTS show excess emission at 1-2 MK.
- CTTS show low f/i ratios.

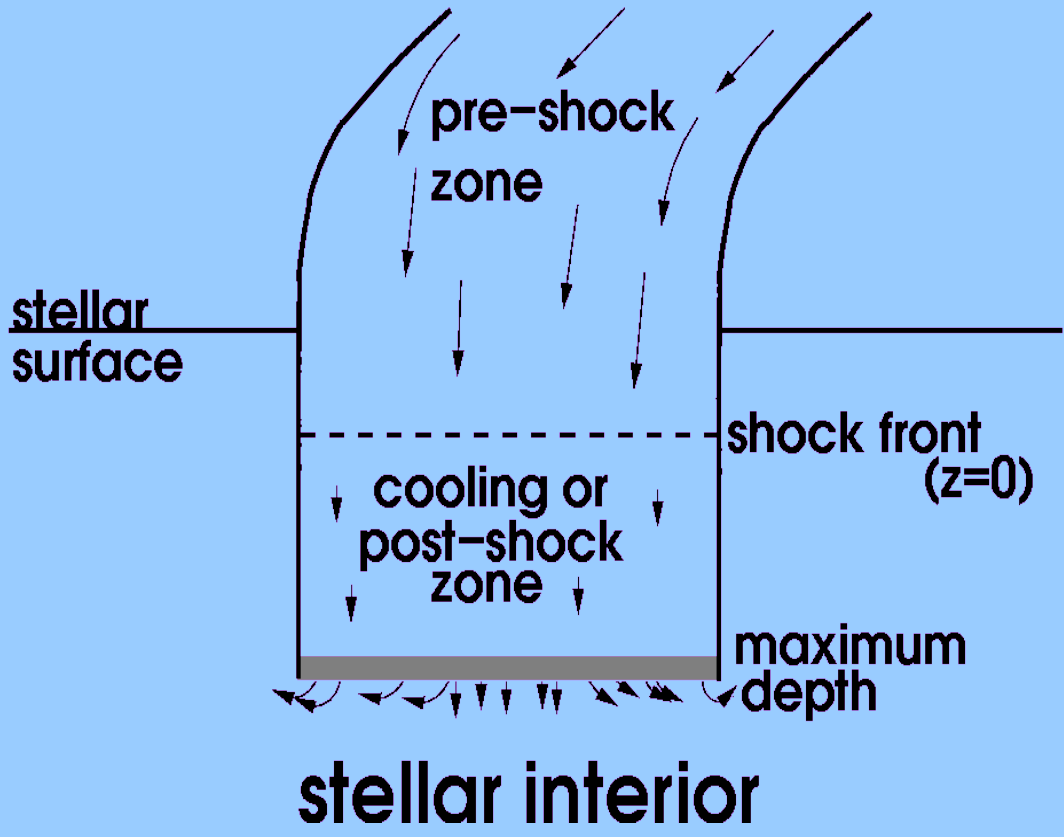
Classical T Tauri stars

Accretion



The accretion model

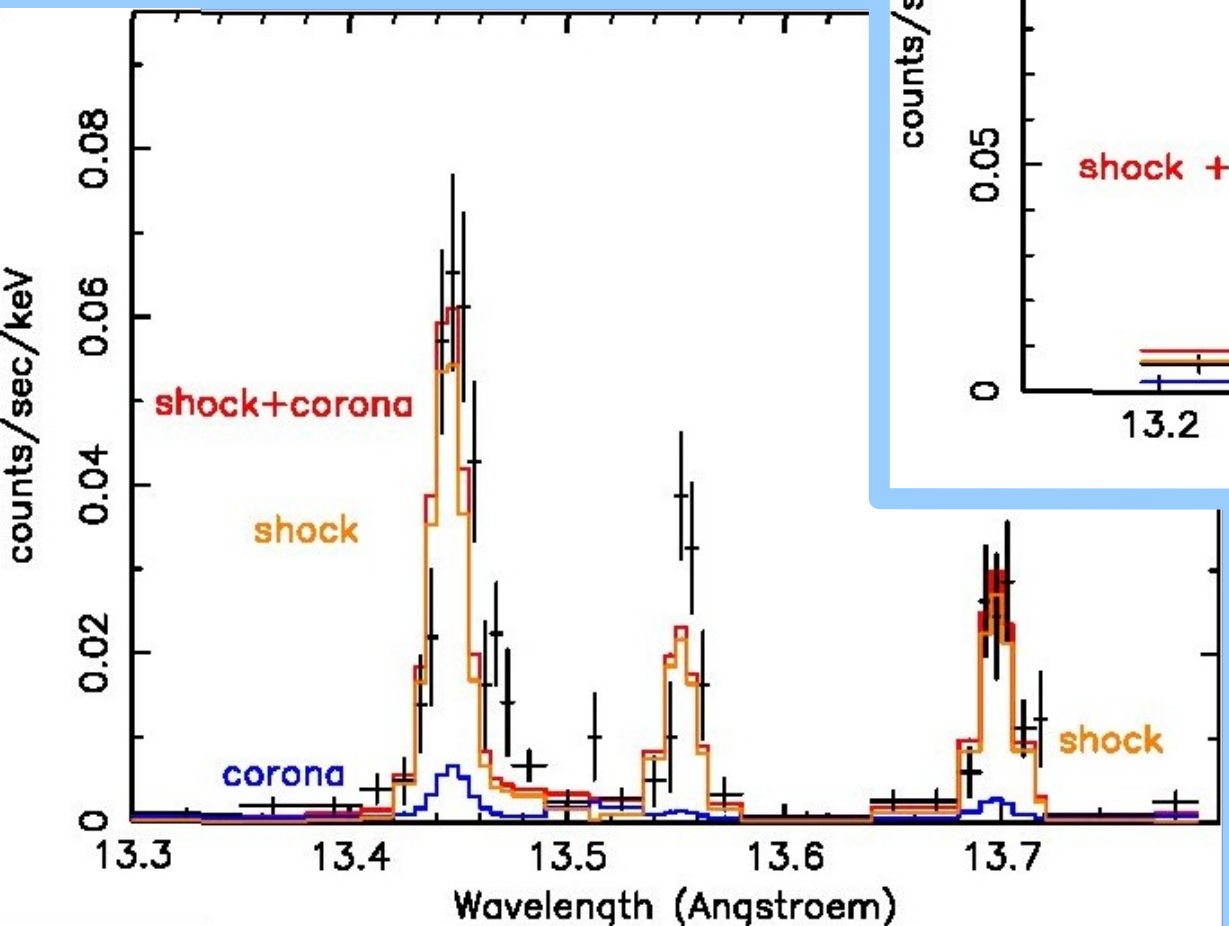
- 1D stationary
- optically thin
- no heat conduction
- Maxwell velocity distribution (different temperature for electrons / ions)
- magnetic field does not change dynamics
- non-equilibrium ionisation calculation

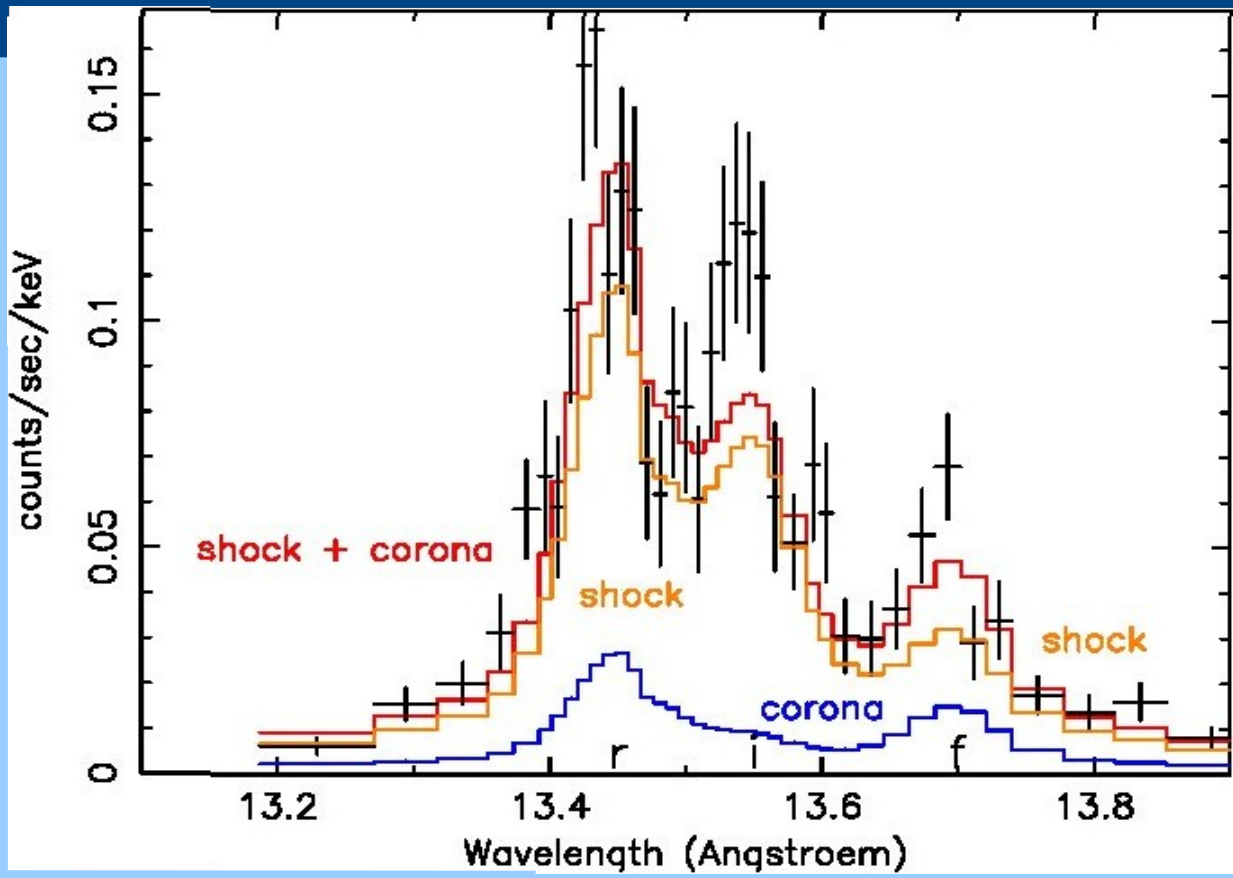


Günther et al., A&A (2008)

Fits to He-like triplets

XMM-Newton: TW Hya
Günther et al., A&A (2007)





Chandra: V4046 Sgr
Günther et al., MmSAI (2007)

Best-fit results

parameter	TW Hya	V4046 Sgr
infall velocity	525 km/s	540 km/s
preshock density	10^{12} /cm^3	2 10^{11} /cm^3
shock/corona (0.3-2.5 keV)	2/1	1/1
filling factor	0.20%	0.10%
mass accretion rate	2 10^{-10} M_{sun}/year	3 10^{-11} M_{sun}/year
best fit reduced χ^2	1.57	1.2

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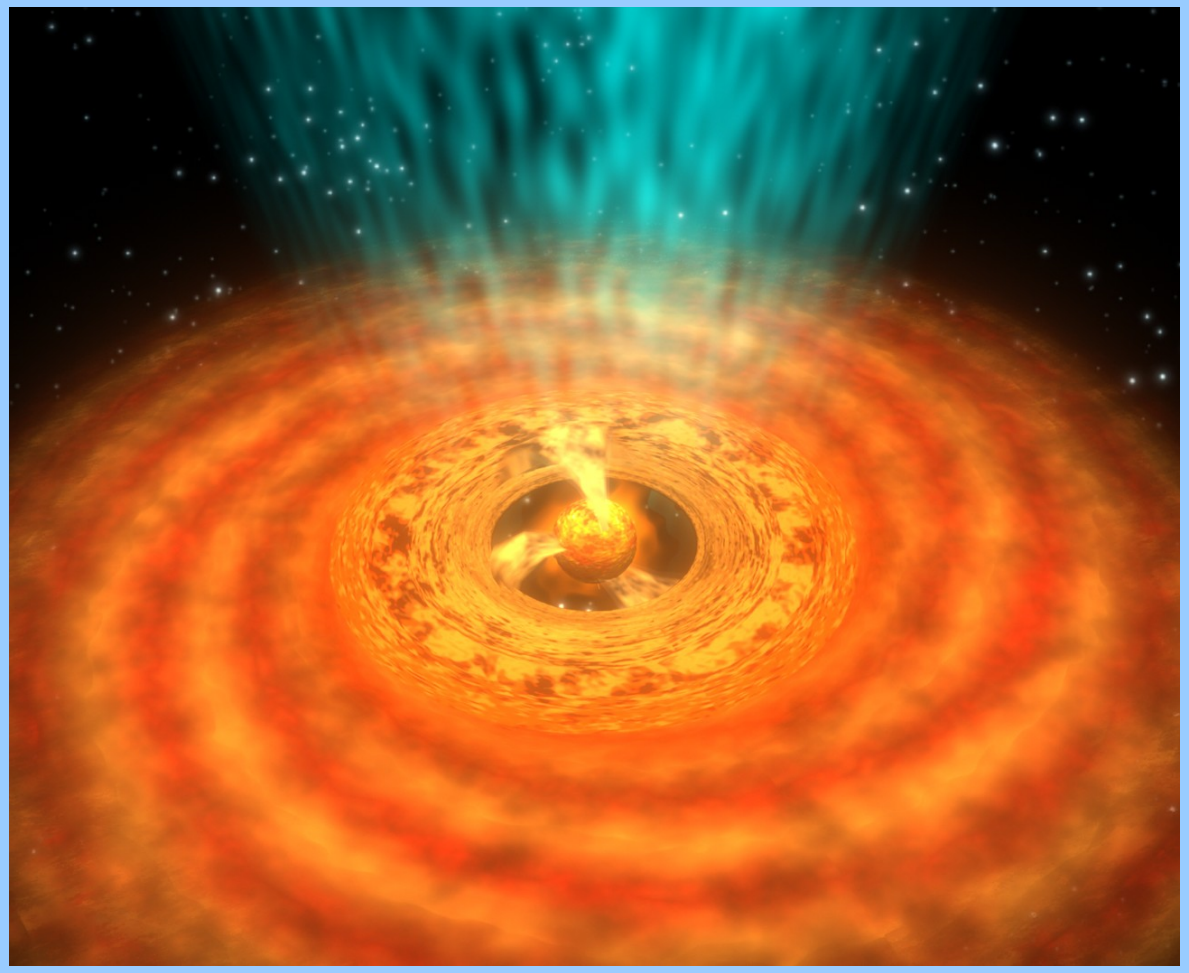
CTTS: Accretion

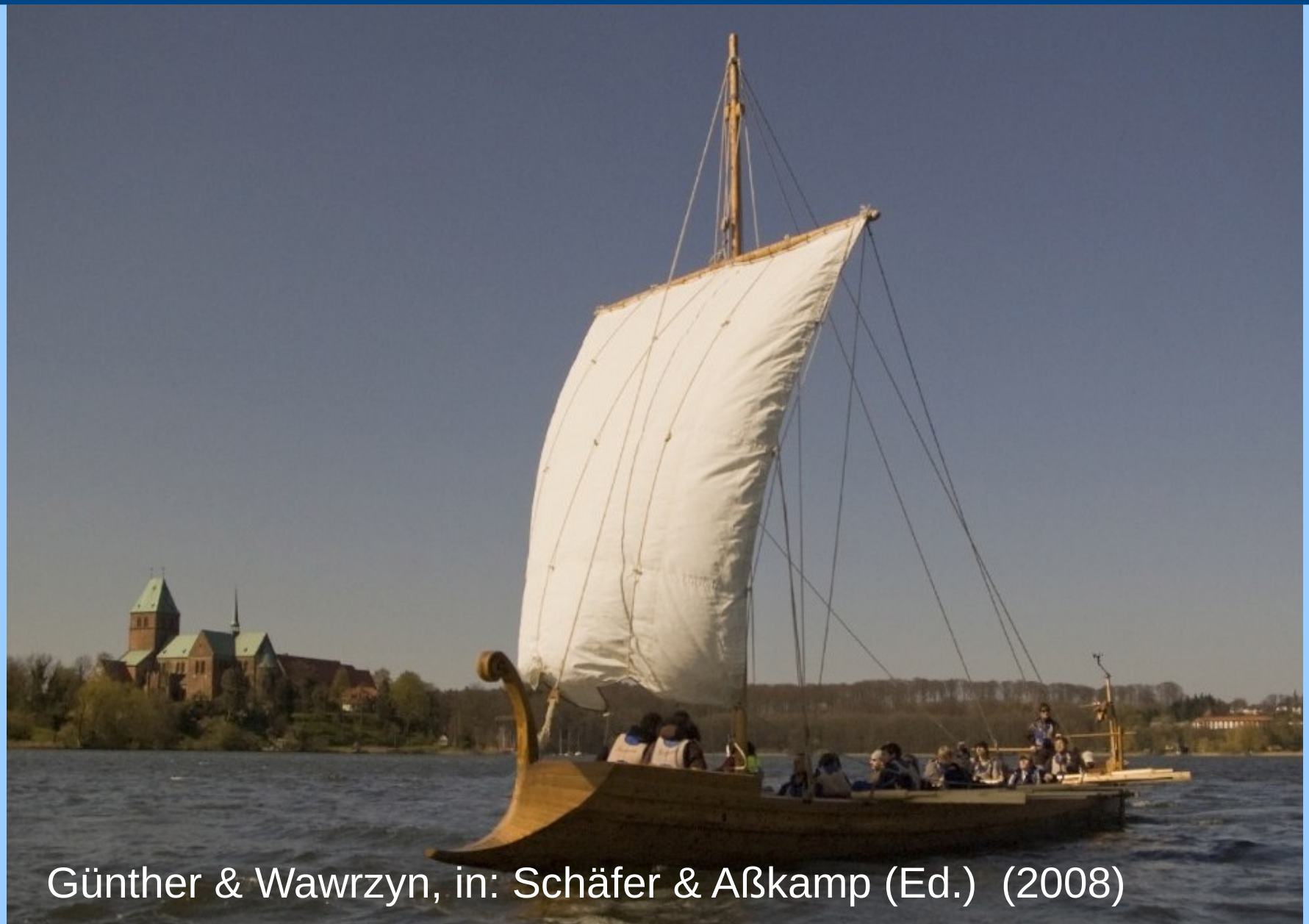
- An accretion spot contributes to the X-ray luminosity.
- It is responsible for the soft emission.
- The emitting region has a high density, leading to a low f/i-ratio.

Classical T Tauri stars

Jets & Winds

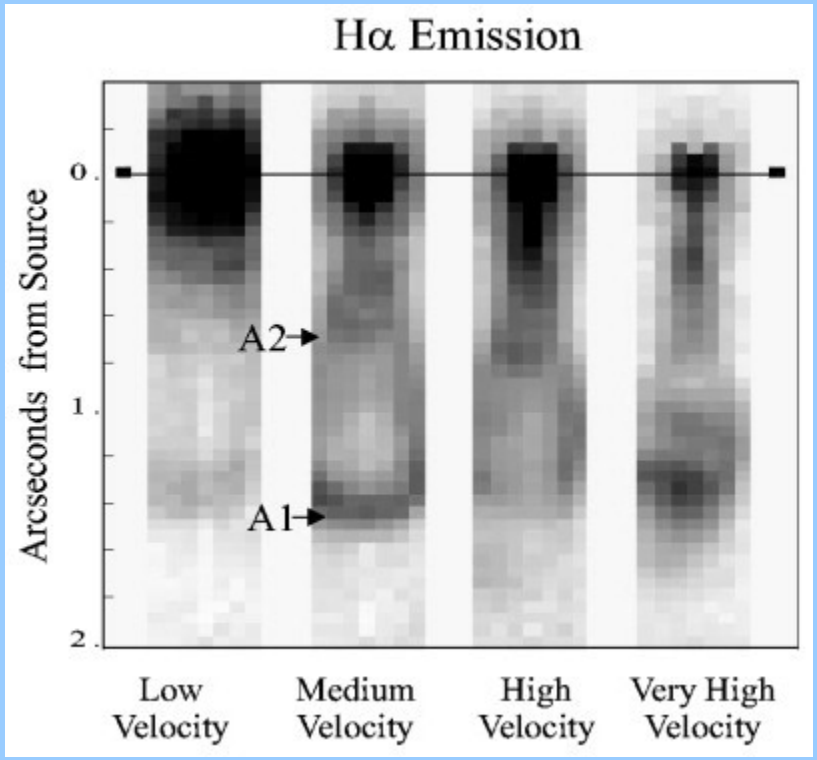


Winds

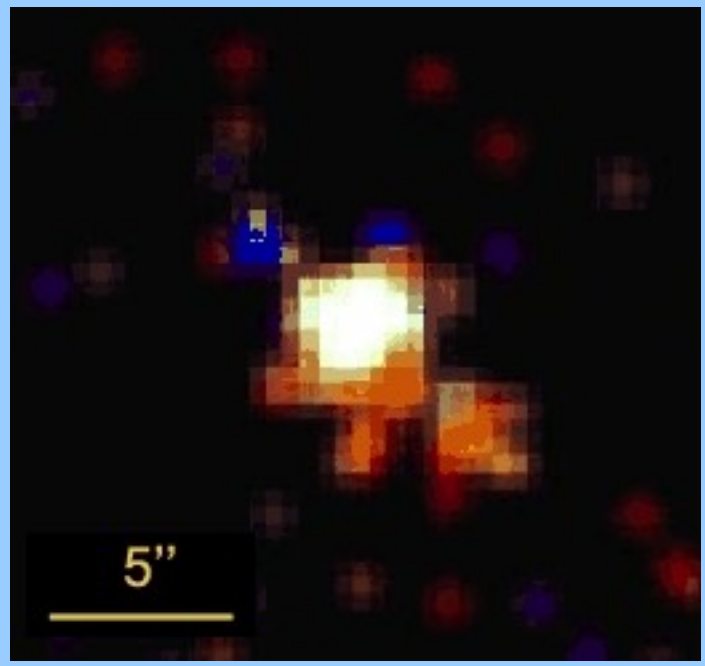


Günther & Wawrzyn, in: Schäfer & Aßkamp (Ed.) (2008)

Collimated outflows

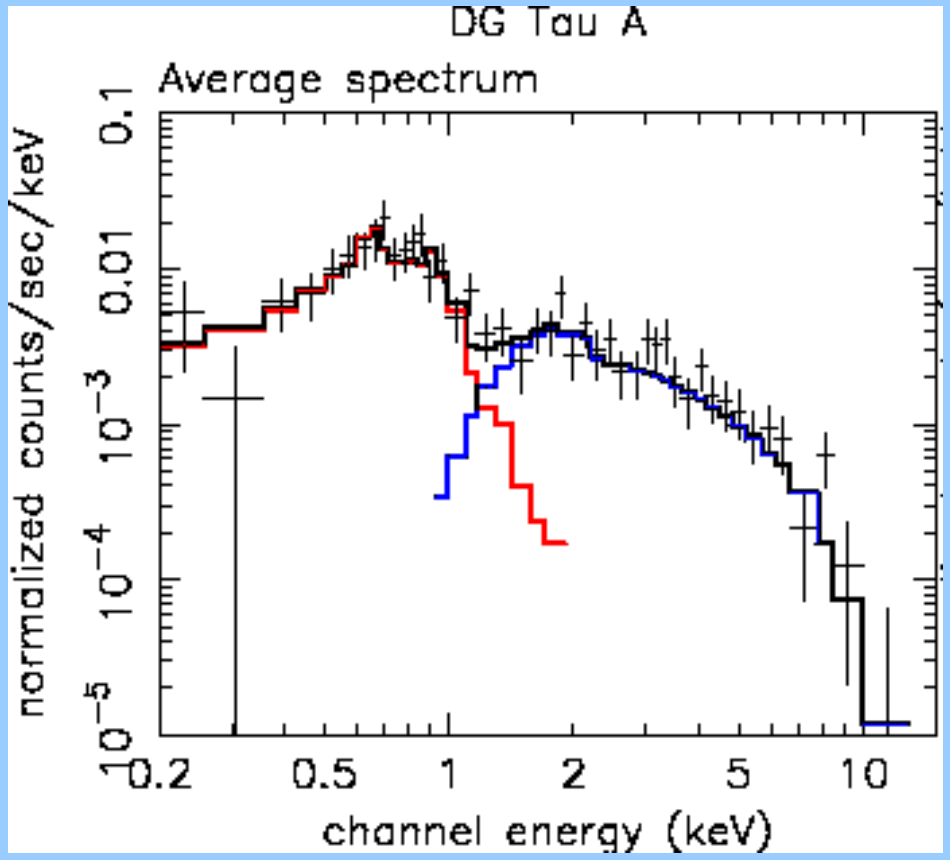


HST/STIS:
Bacciotti et al., ApJ (2000)

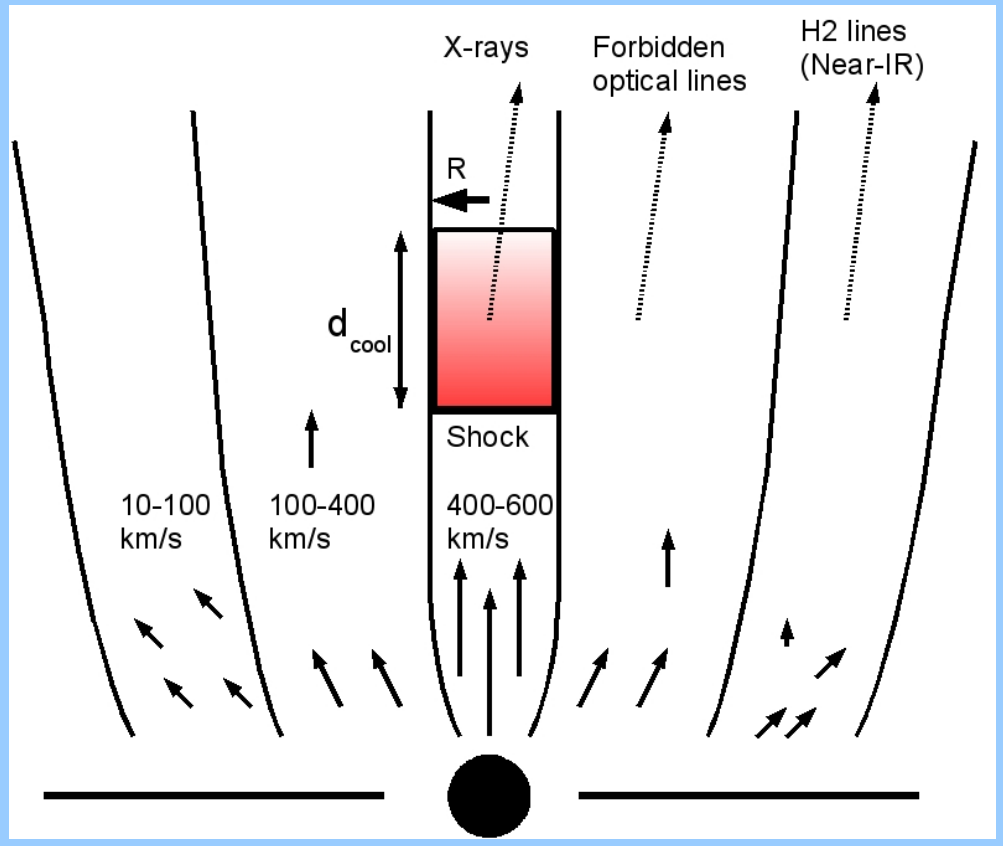


Chandra:
Güdel et al., A&A (2008)

X-rays from jets

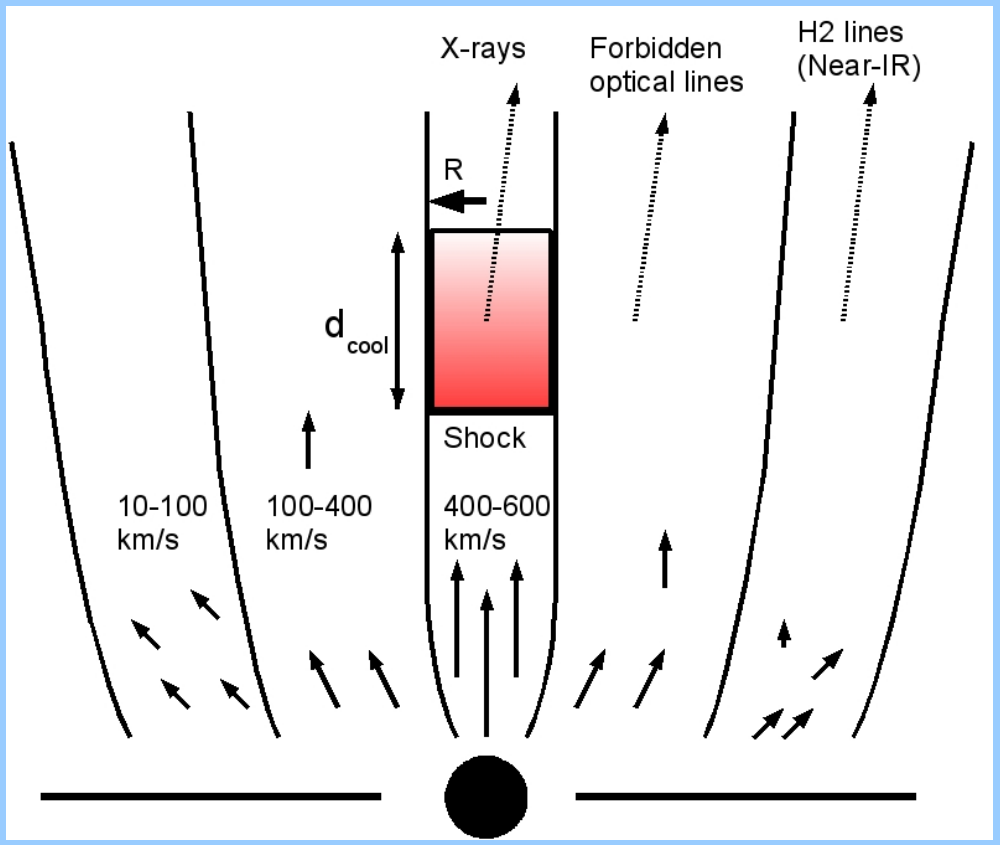


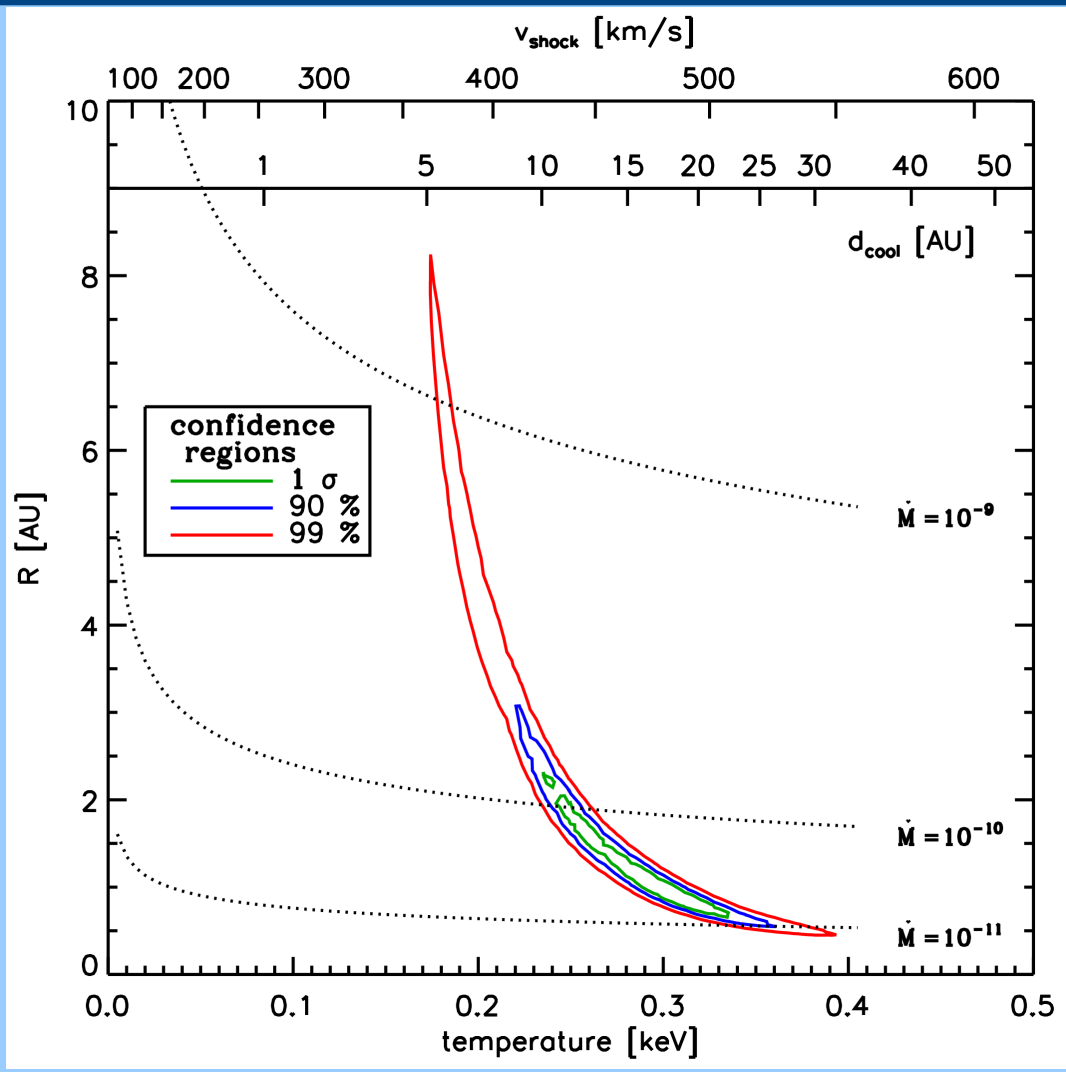
Güdel et al., ApJ (2007)



Model:
Günther, Matt & Li, A&A (2009)

X-ray generation in the jet





Günther, Matt & Li, A&A (2009)

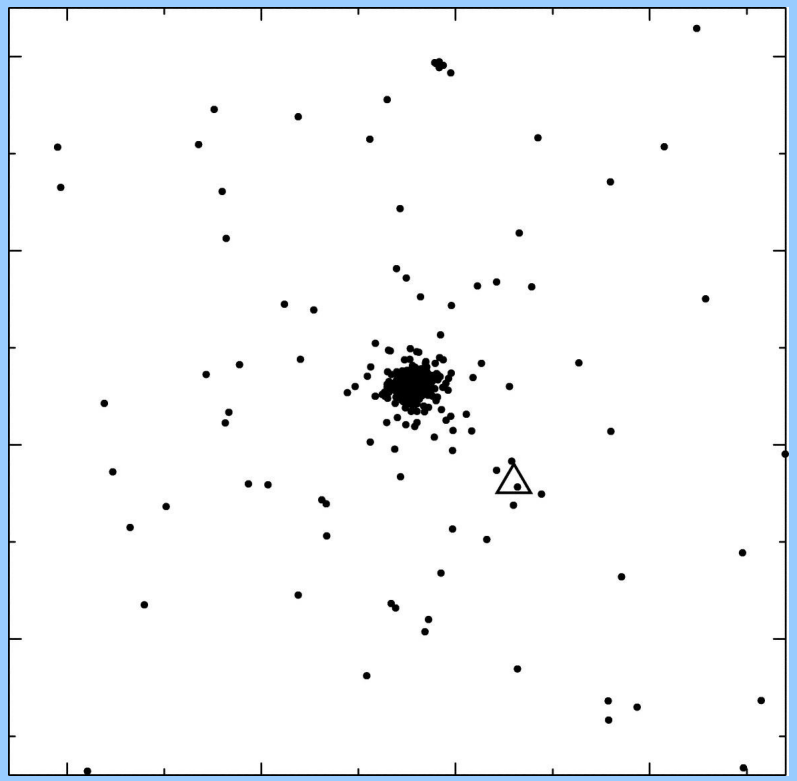
CTTS: Jets

- Jets can emit X-rays.
- They are heated by internal shocks.
- Several shock scenarios can explain the observed emission.

HAeBe stars

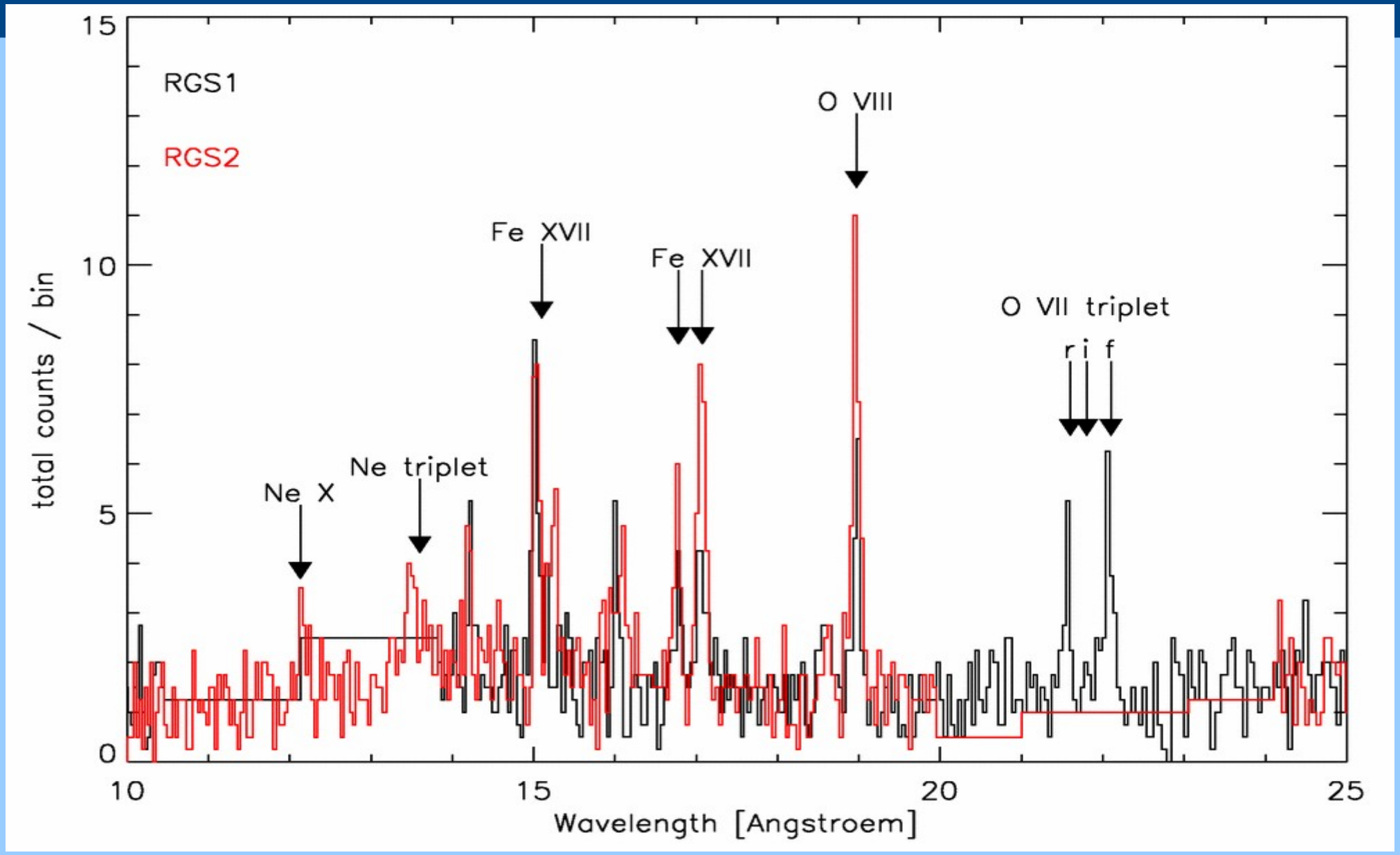
HST/STIS: Grady at al., ApJ (2000)

Chandra (20 ks)



Swartz et al., ApJ (2005)

HD 163296: XMM-Spectrum



Günther & Schmitt, A&A (2009)

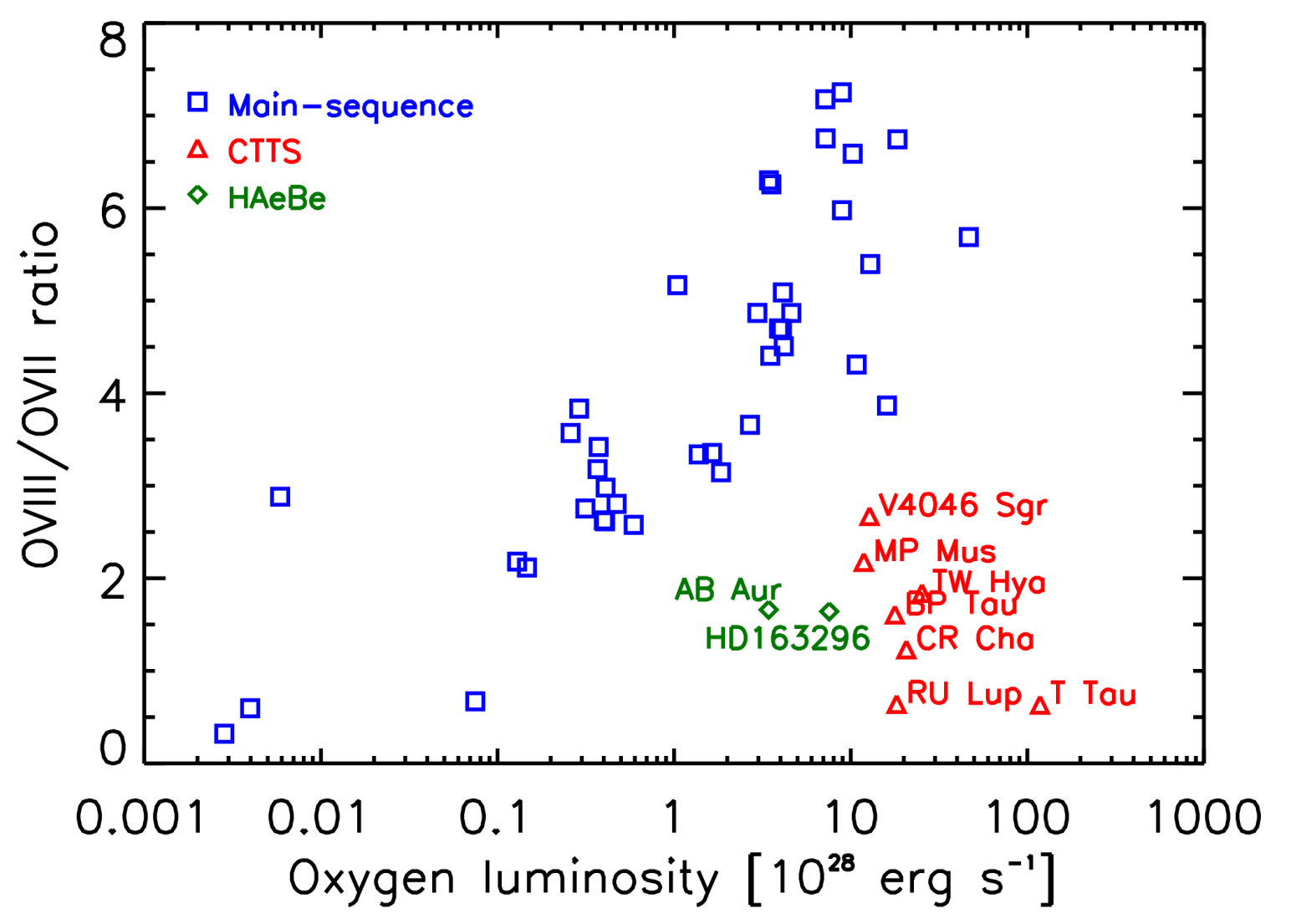
HAeBes: HD 163296

- Its X-ray emission is soft.
- It possibly originates in a jet similar to CTTS.

Conclusion

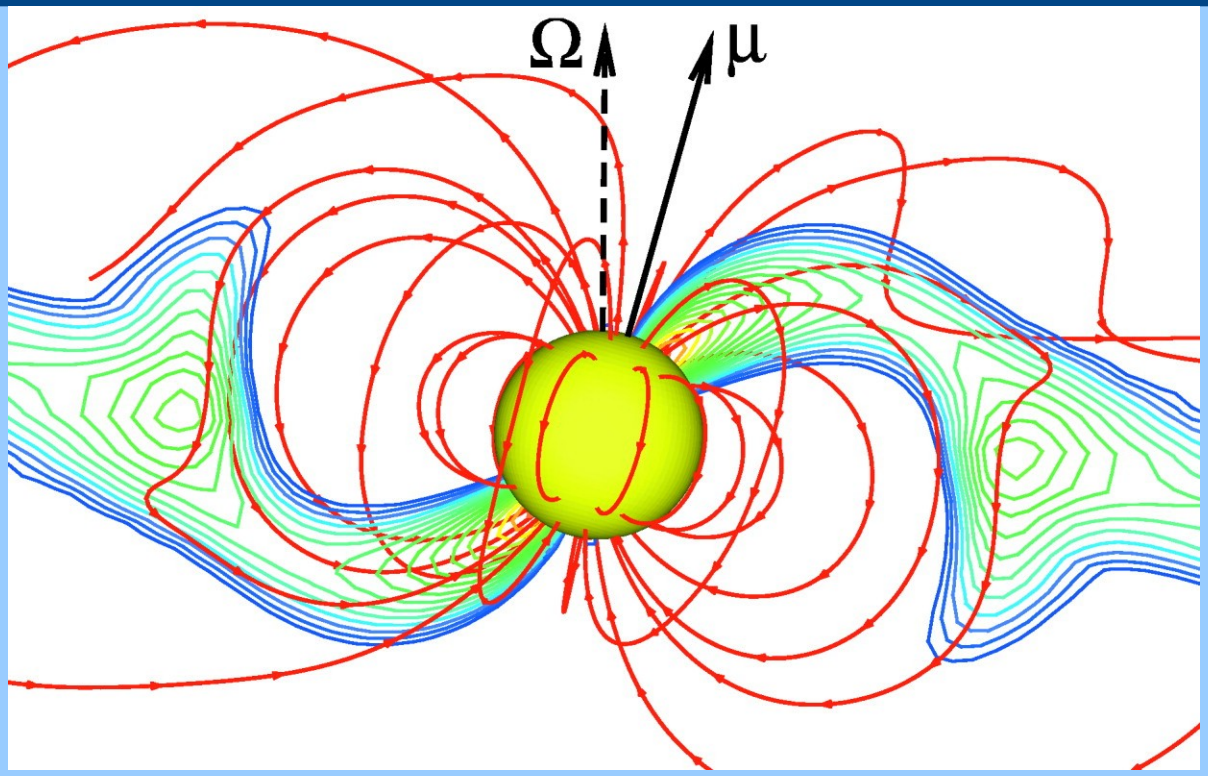
- Origin of X-ray emission in CTTS
  - Corona
  - Applied model to observations:
    X-ray and UV emission from accretion spot
  - Model: Inner jet heating by shocks
- Origin of X-ray emission in HAeBes
  - Discovered hot component: Corona
  - Discovered soft component offset from stellar surface: Jet

Soft X-ray excess

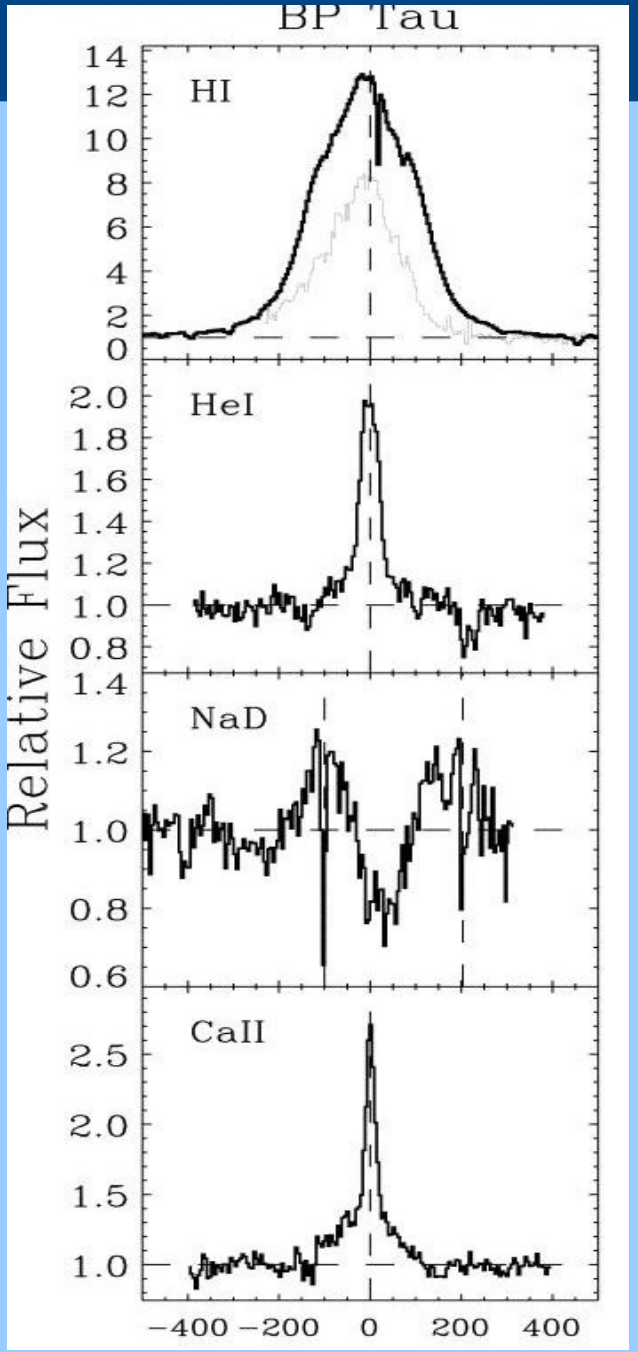


Robrade & Schmitt, A&A (2007), Günther & Schmitt, A&A (2008)

Accretion flow

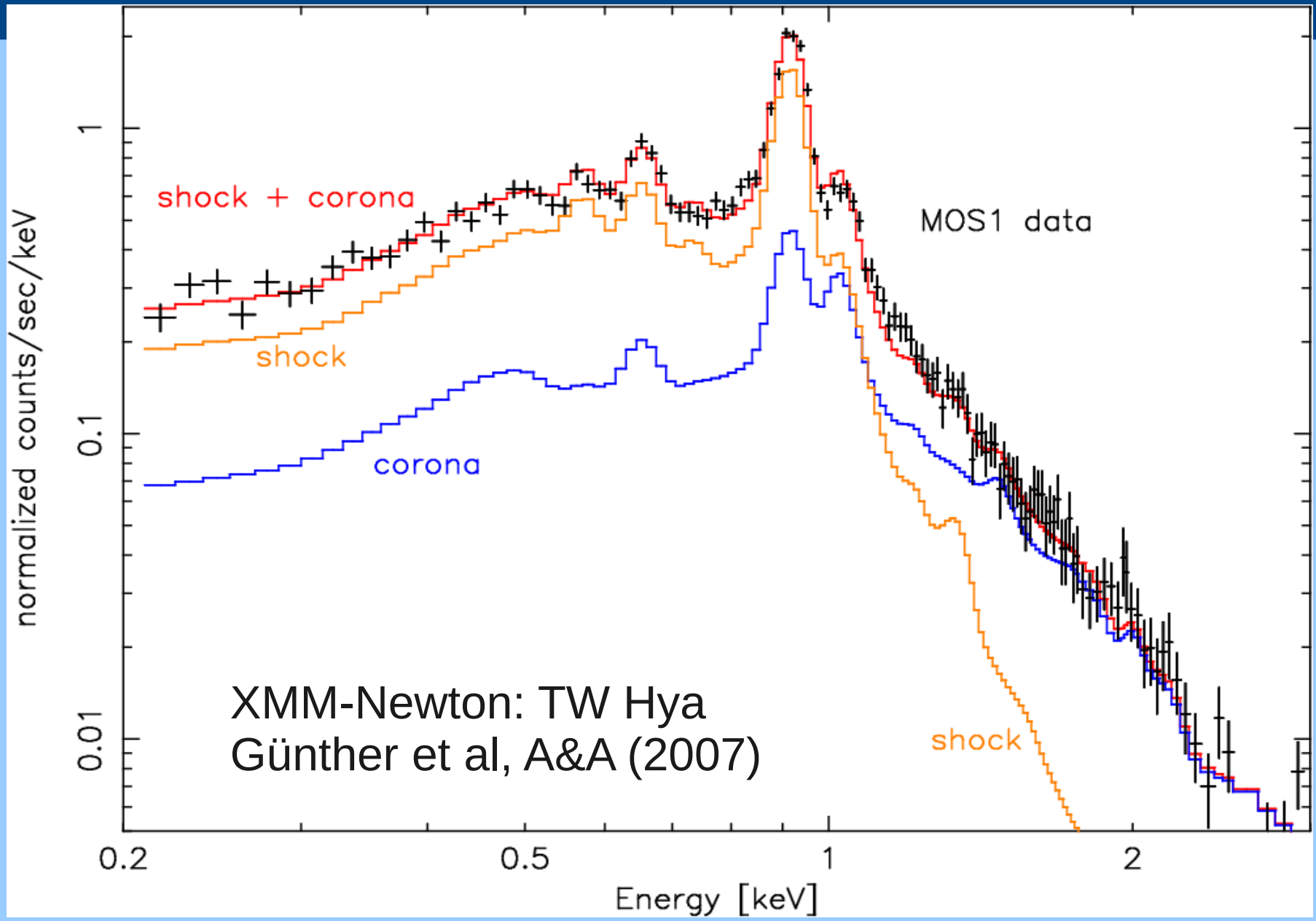


Romanova et al., ApJ (2004)

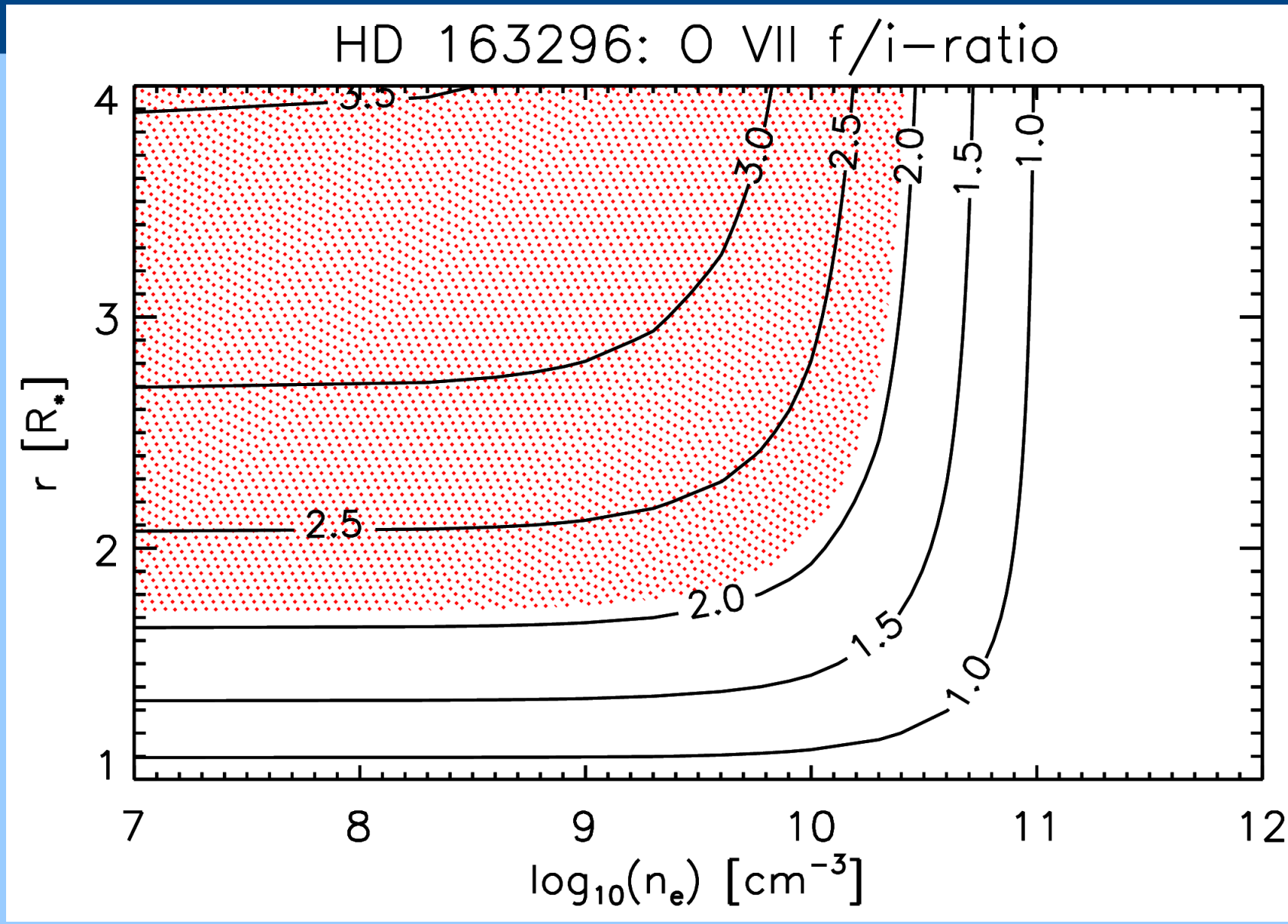


Ardila et al., ApJ (2002)

Fits to broad band spectra



HD 163296: OVII f/i ratio



Günther & Schmitt, A&A (2009)