X-Ray Spectroscopy of Young Stars

A SUMMARY OF RESULTS FROM XEST

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ESA

XMM-Newton Extended Survey of the Taurus Molecular Cloud

XEST

Proposed as a Large Program in 2003

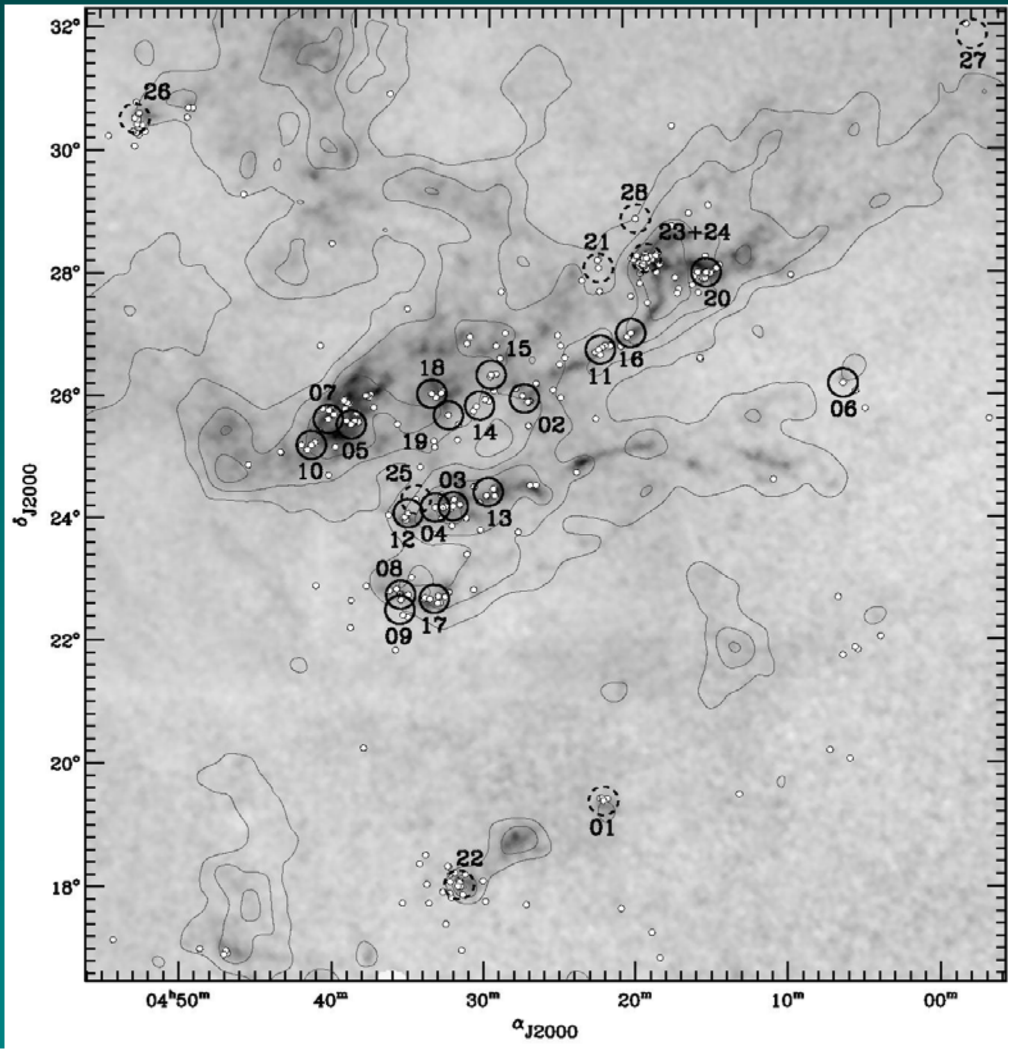
19 exposures @ 33 ks
9 archival exposures } **1.3 Ms**

5 sq. degrees

10^{28} erg s^{-1} for light absorption: should detect brown dwarfs

Why Taurus?

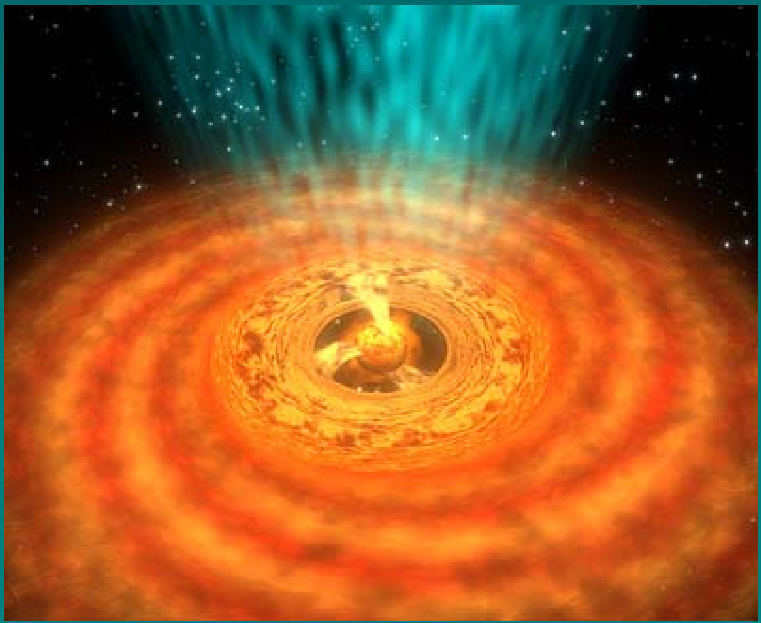
- Nearest star-forming region
- Low absorption
- "Isolated star formation"
- Low-mass stars
- Well studied sample

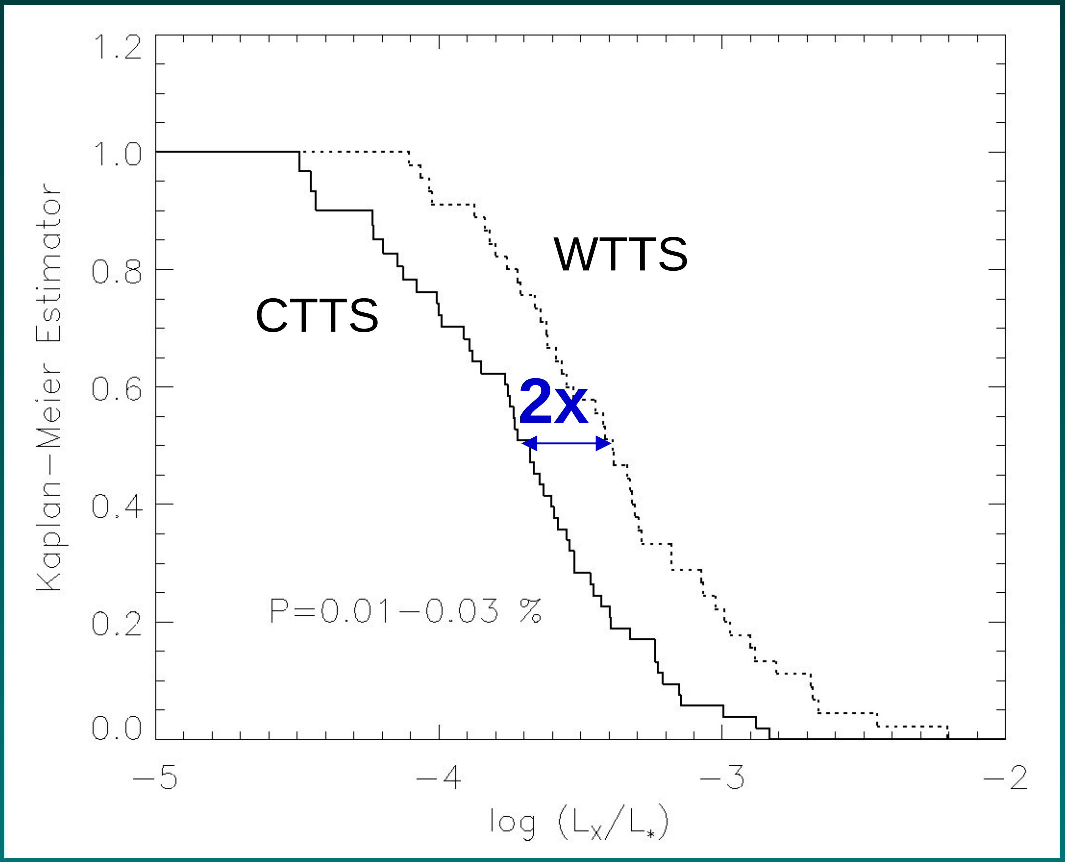


XMM-Newton Extended Survey of the Taurus Molecular Cloud

Goals:

- *- X-ray evolution from protostars to T Tauri stars: thermal structure*
- *- X-ray properties and magnetic fields on Brown Dwarfs*
- → *- X-rays and accretion disks and accretion flows*
- → *- X-rays and jets + Herbig Haro objects*
- *- X-ray flares: thermal evolution, abundances*
- → *- X-rays and environment: gas-to-dust, absorption*





(Telleschi et al. 2007)

CTTS fainter than WTTS by factor of 2

accretion-related suppression?

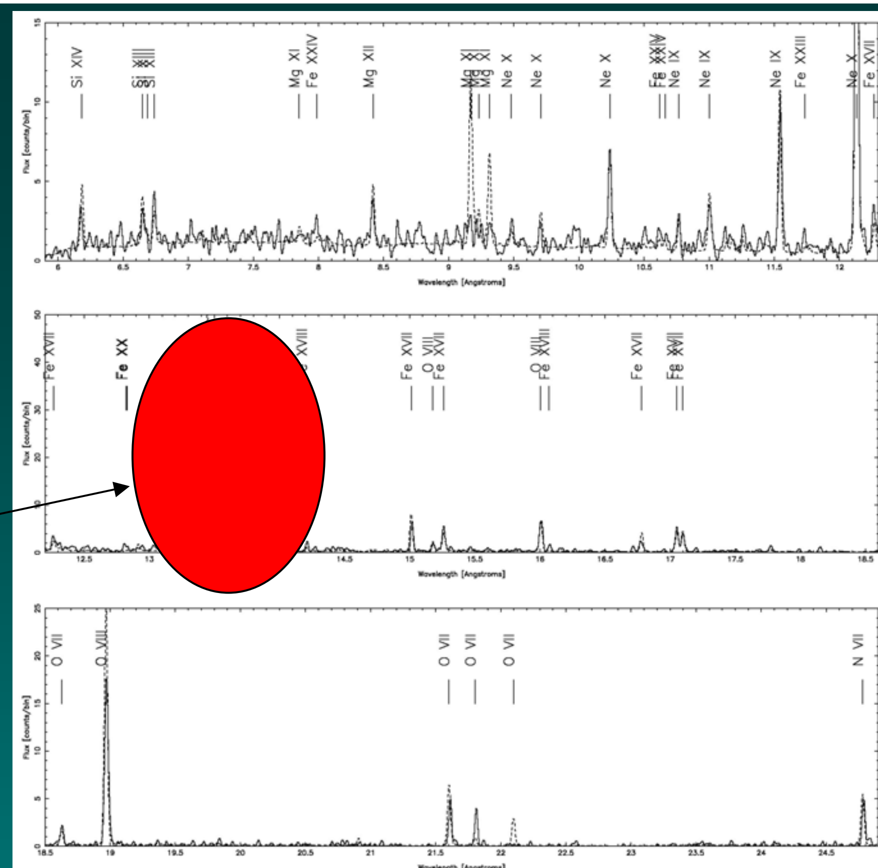
“classical” = accreting

“weak-line = non-accreting”

High-resolution X-ray spectroscopy of classical T Tauri stars

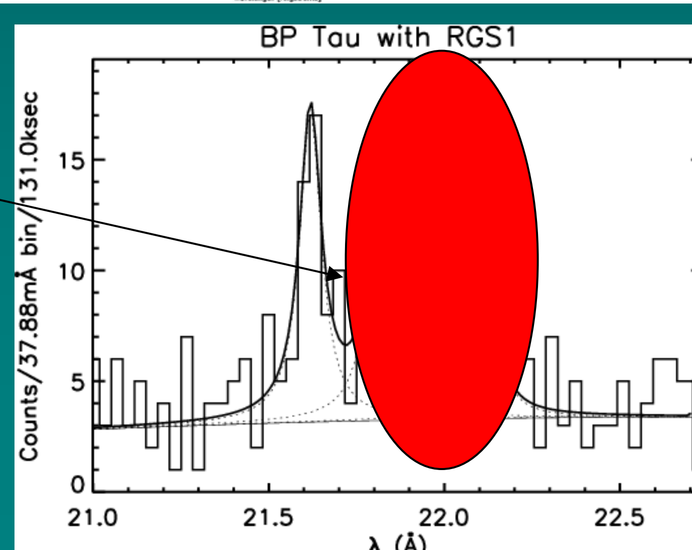
*Status 2002: **TW Hya** (Kastner et al.)*

- *very soft spectrum*
- *very high densities*
- *(10^{13} cm^{-3}, NeIX)*
- *High Ne abundance*



*Status 2005: **BP Tau** (Schmitt et al.)*

- *"normal" soft-hard spectrum*
- *intermediate densities*
  ($3x10^{11}$ cm^{-3}, OVII)



Hypothesis: Shock-induced soft X-rays

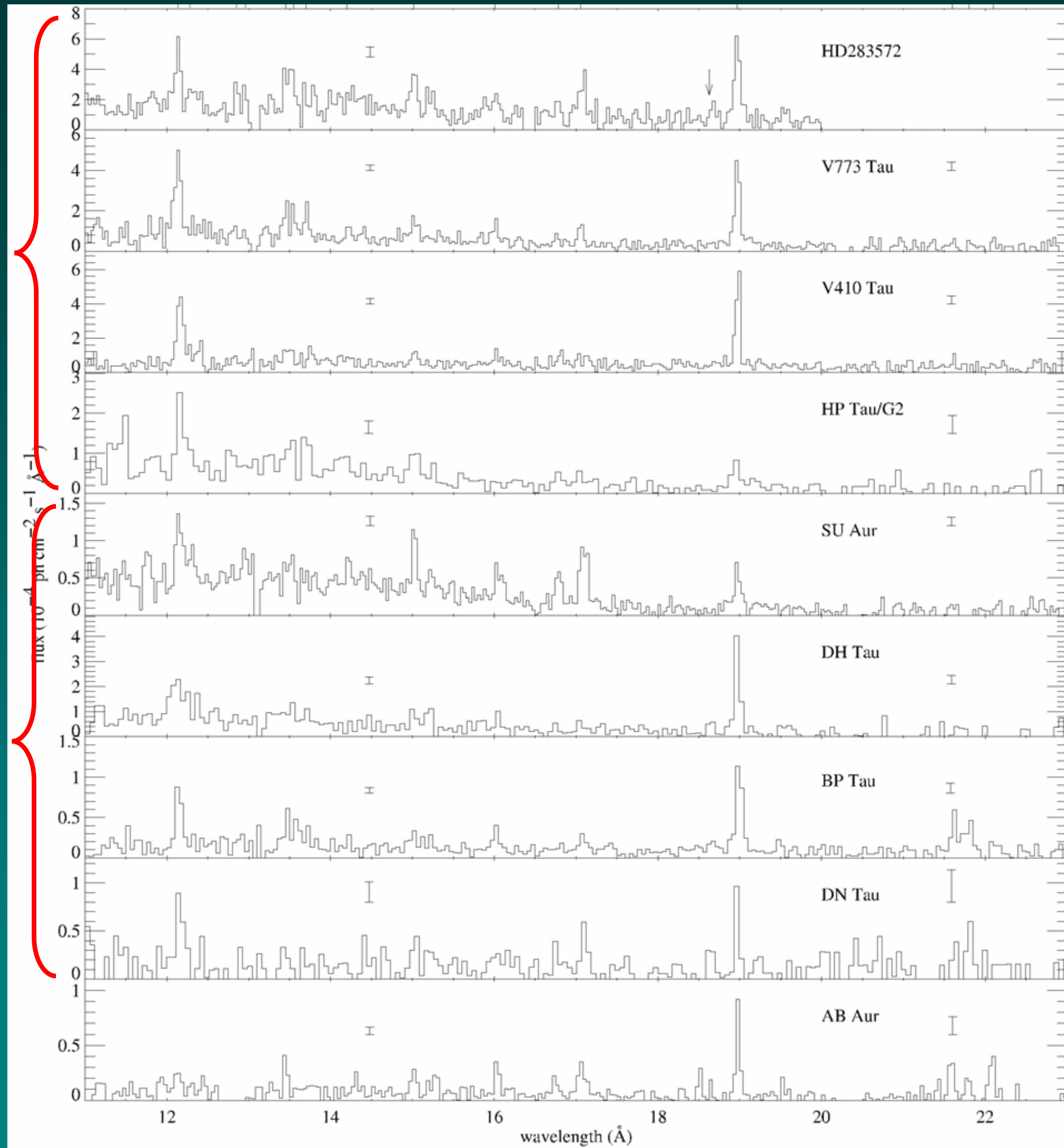
Systematics? Statistics?

XEST Sample:

WTTS

CTTS

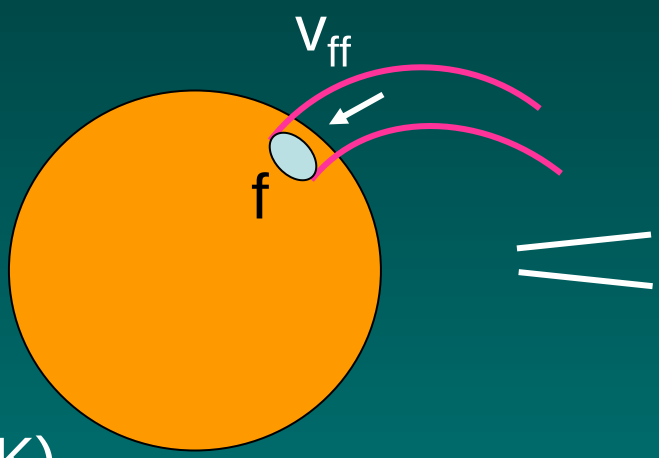
HAe



(Telleschi et al. 2007)

How does accretion interact with the „high-energy“ environment?

Shocks in accretion streams:



$T = 3\mu m_H v^2 / 16k$

$v \approx v_{ff} = (2GM/R)^{1/2}$

$\rightarrow$ T = a few MK (<< 10 MK)

$dM/dt = 4\pi R^2 f v_{ff} n_e m_p \quad \rightarrow \quad n_e \approx 10^{12}\text{-}10^{14}\ cm^{-3}$

Can test these predictions using high-res X-ray spectroscopy

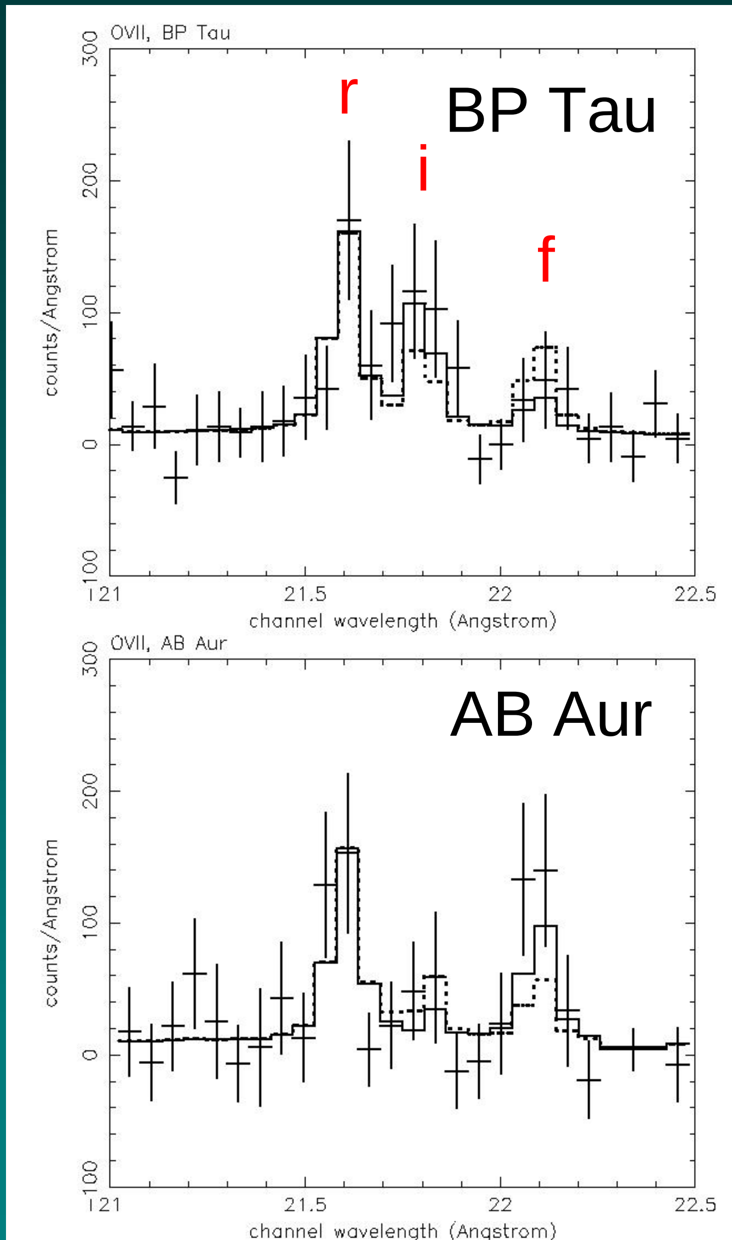
Dense, cool plasma in accretion shocks?

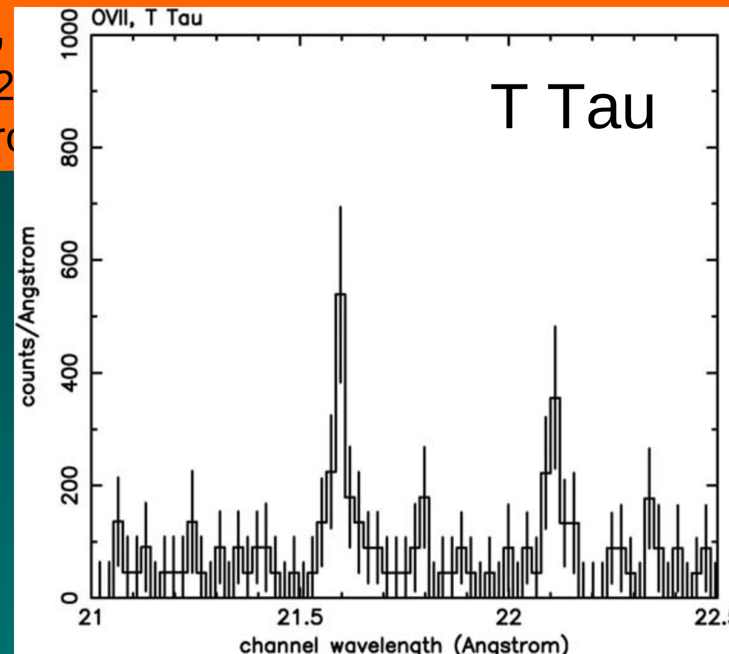
Possible for TW Hya, BP Tau, V4046 Sgr,

MP Mus, … er

& Schmitt 2…

2006, Argir…





But: Not measured in XEST targets

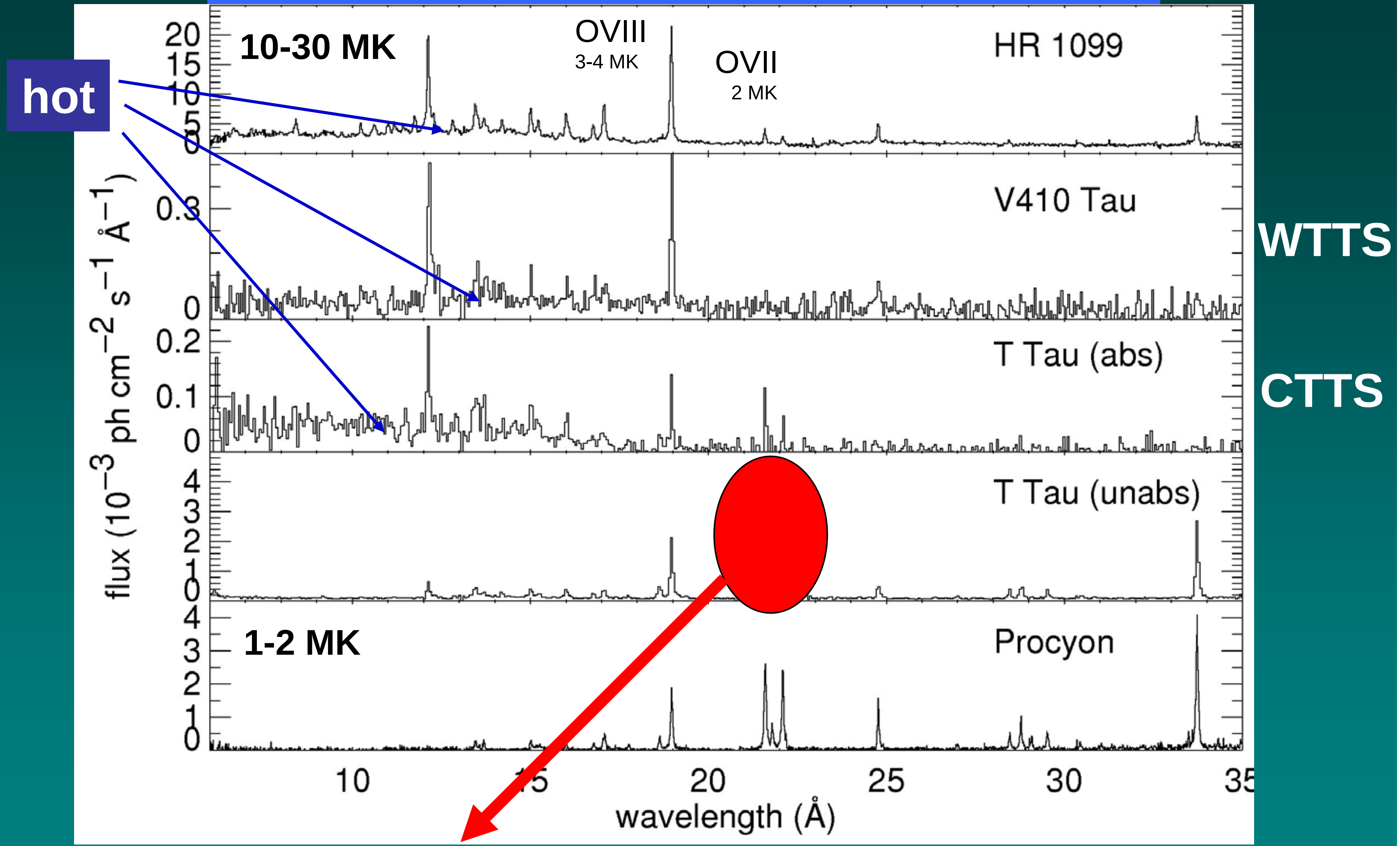
- AB Aur
- T Tau

Density < few x 10^{10} cm^{-3} << shock n_e

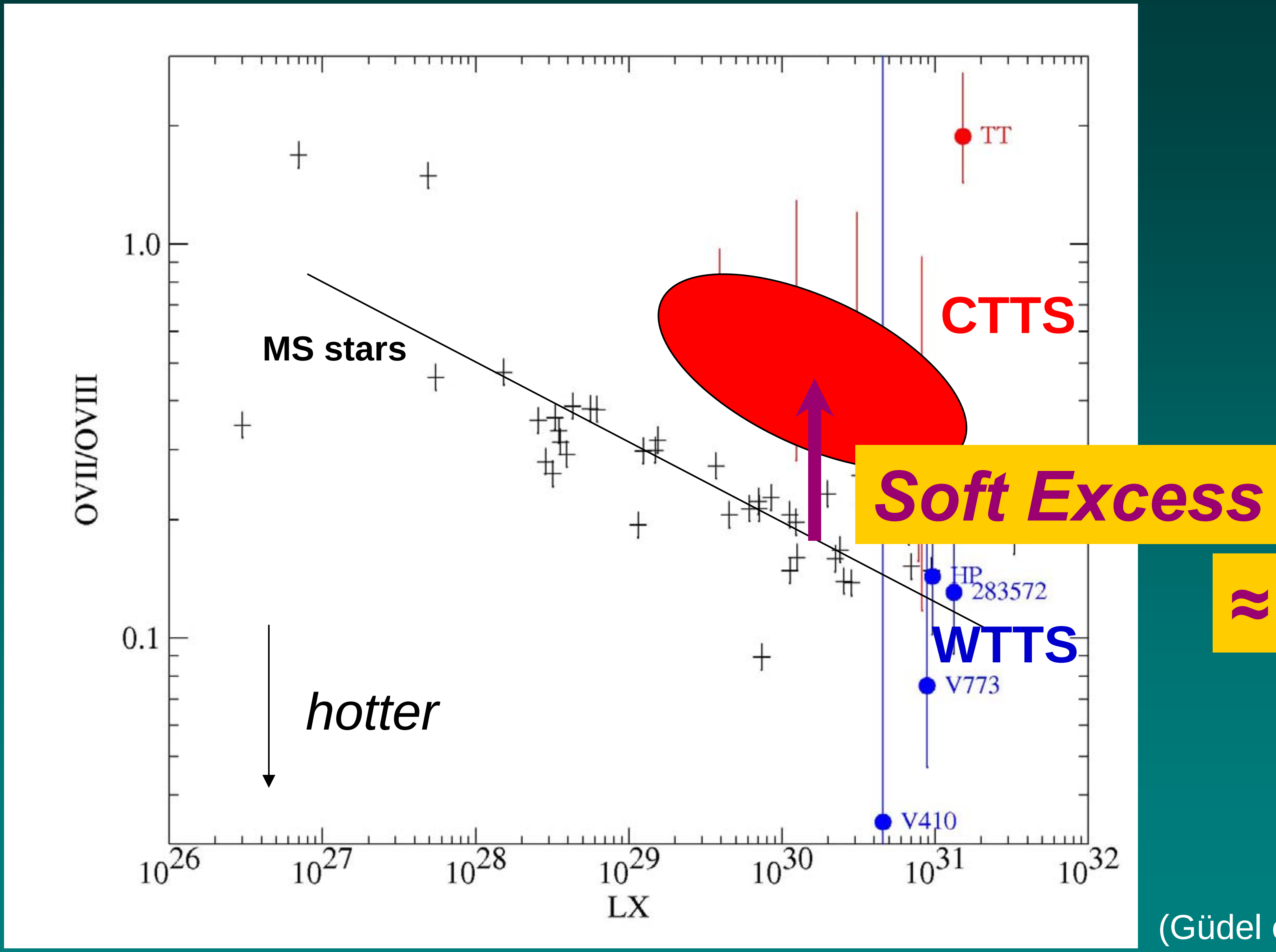
<u>So, is accretion really important?</u>

(Telleschi et al. 2007, Güdel et al. 2007)

What is the temperature of a CTTS corona?



"SOFT EXCESS" *(Telleschi et al. 2007, Güdel et al. 2007)*



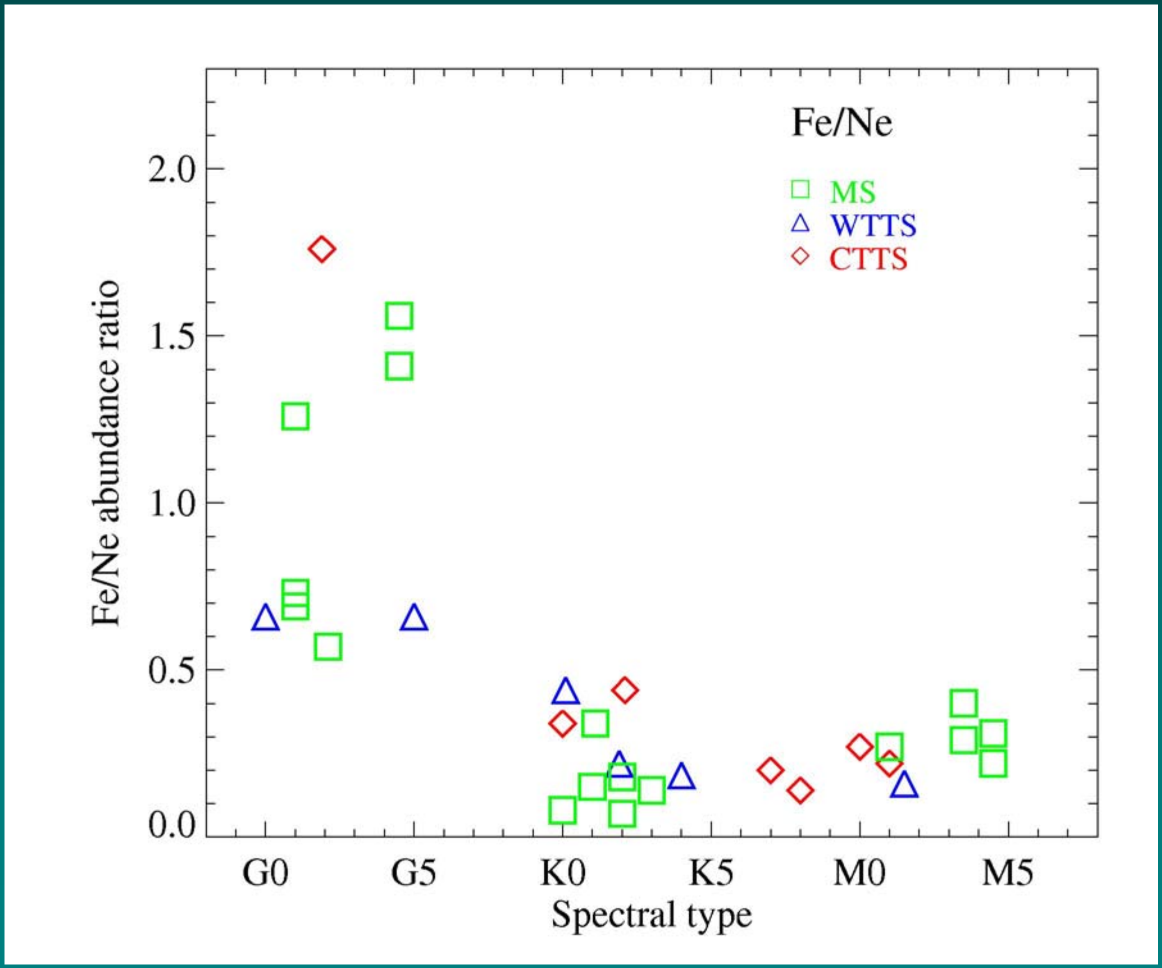
≈ 2-3x

(Güdel et al. 2007)

"Accretion adds cool material in CTTS"

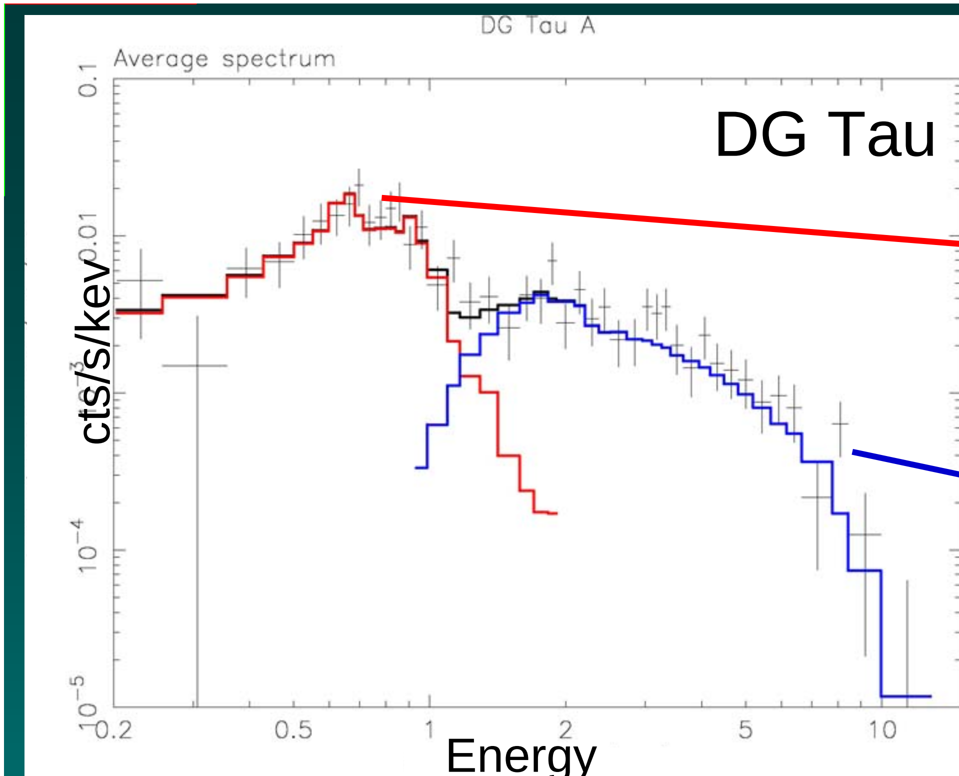
Abundances as accretion indicators?

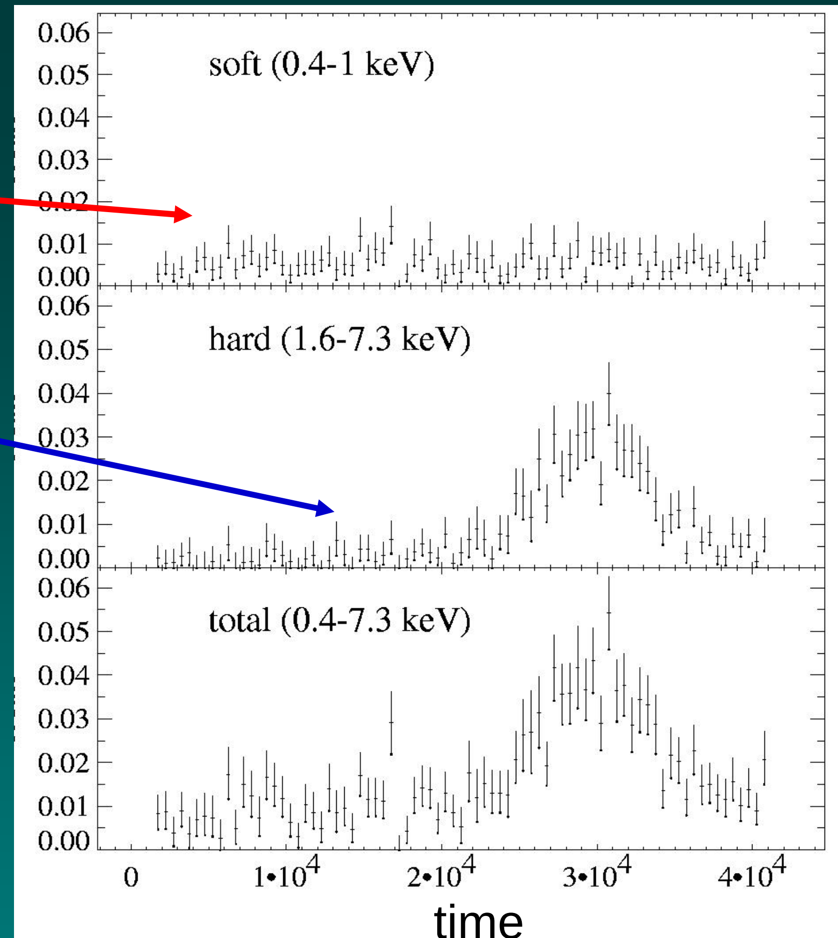
Metals like Fe may condense into grains and be retained in the disk.
$\rightarrow$ accretion streams Fe-depleted (TW Hya, Stelzer & Schmitt 2004)



… or are abundances determined by the stellar T_{eff}? (Ionisation degree)

(XEST + published values; after Telleschi et al. 07)





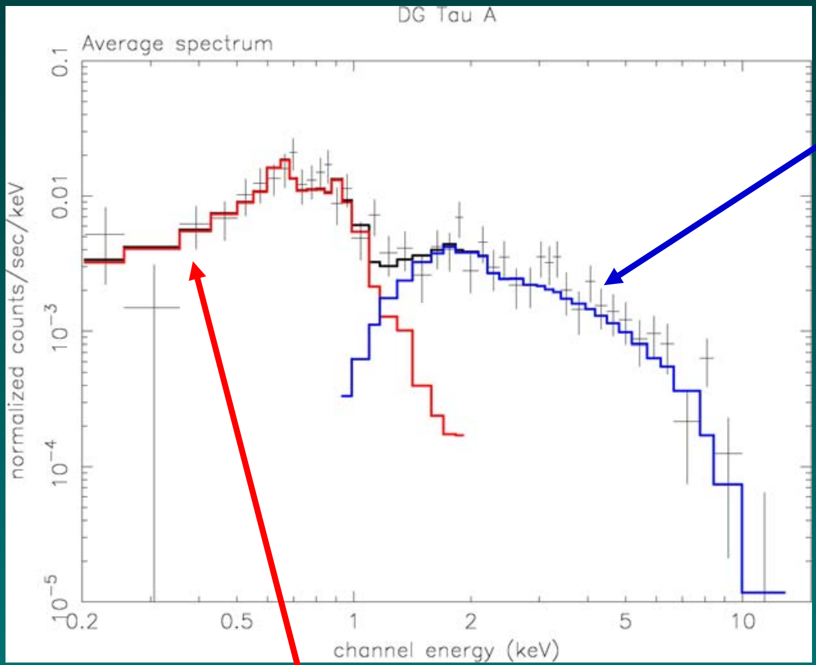
(Guedel et al. 2007)

Strongest accretors show anomalous X-ray spectra:

soft/cool component: low N_H, constant
hard/hot component: high N_H, flaring

+4 other XEST sources

What the spectrum tells us:



Hard component:

Excessively absorbed

(~10 x stellar "N_H")

→ absorption by dust-depleted accretion streams

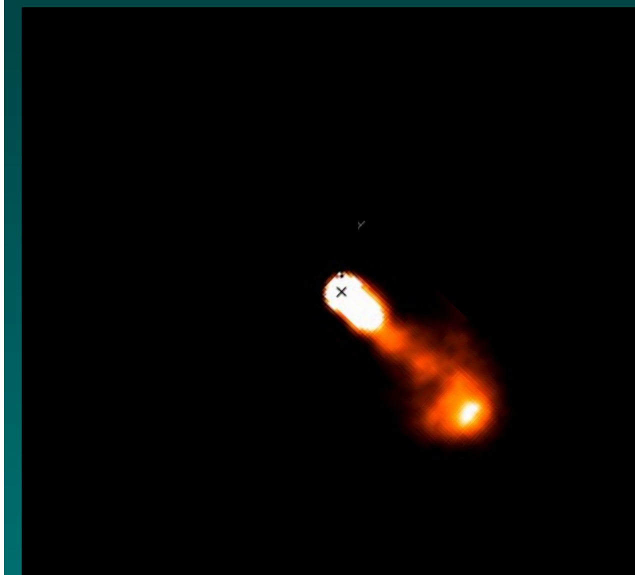
Soft component:

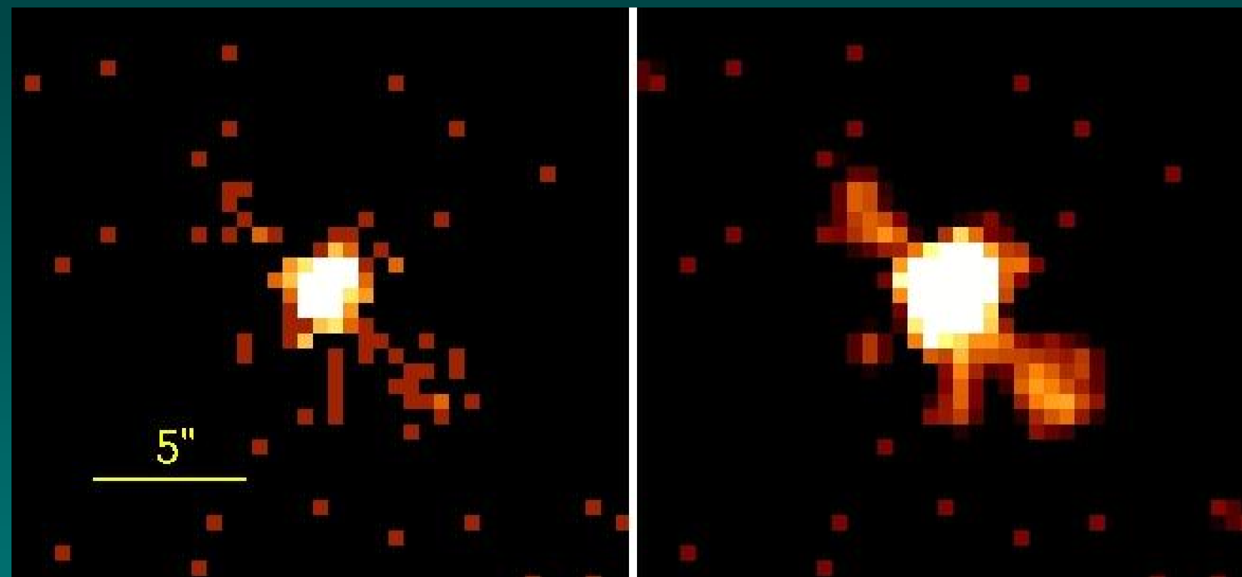
3-4 MK unusually cool

absorption < stellar "N_H"

→ X-rays from the jets

[OI] and Chandra high-resolution image of DG Tau



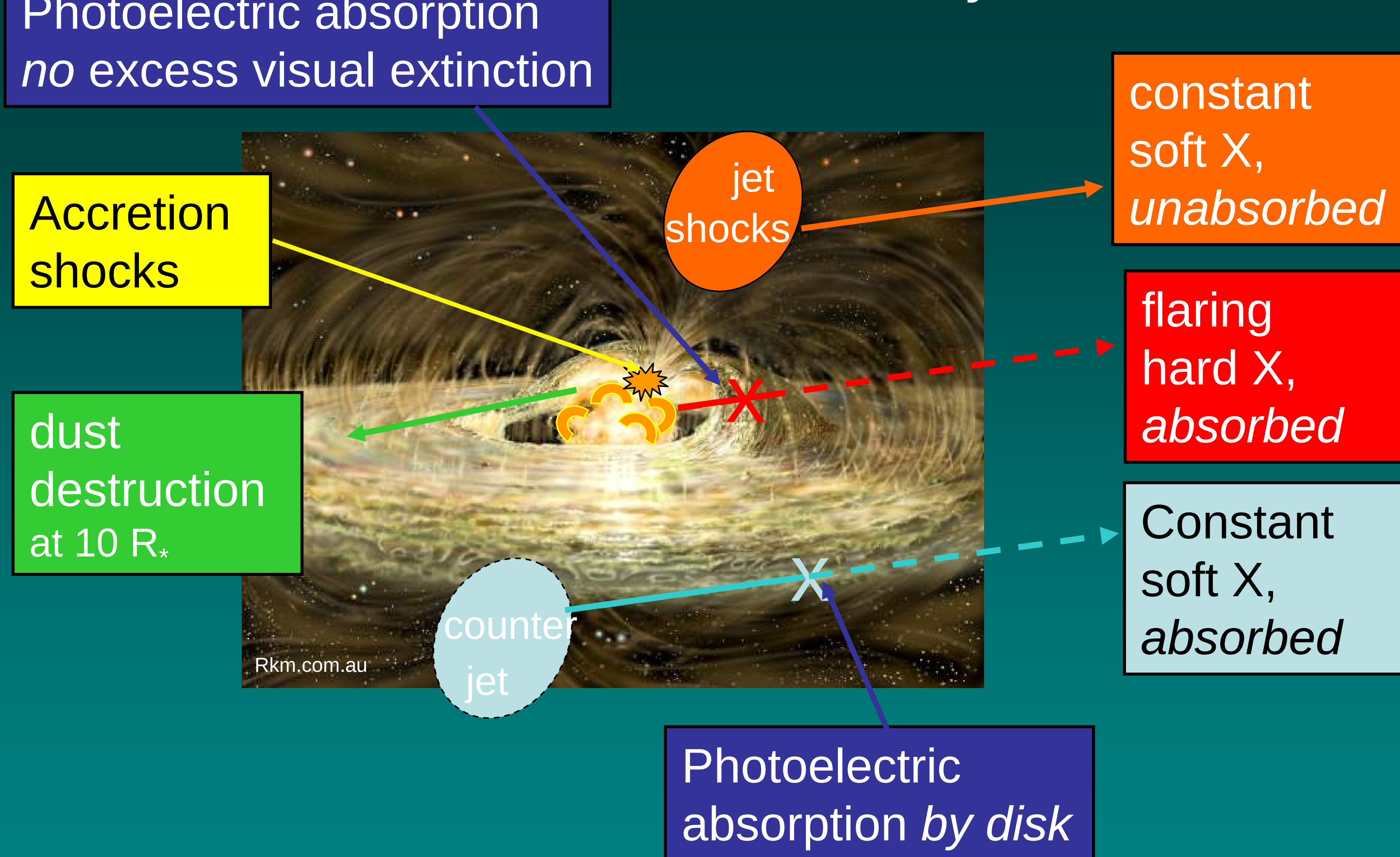


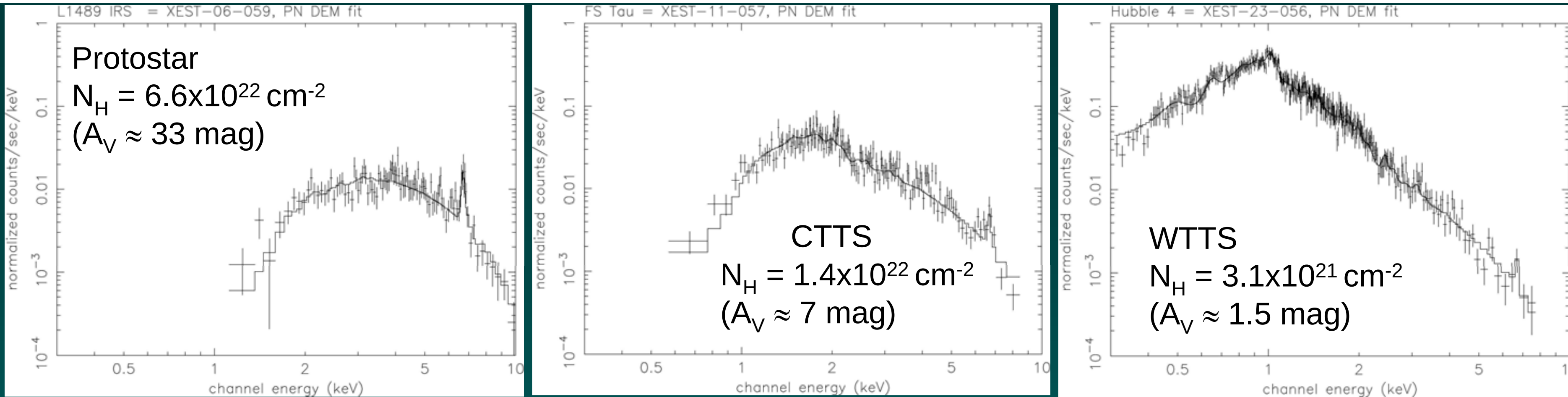
[OI] [1997] (Dougados et al. 2002)

Guedel et al. (2007); from CHANDRA

All XEST double-absorber X-ray sources drive strong jets

X-rays matter…:



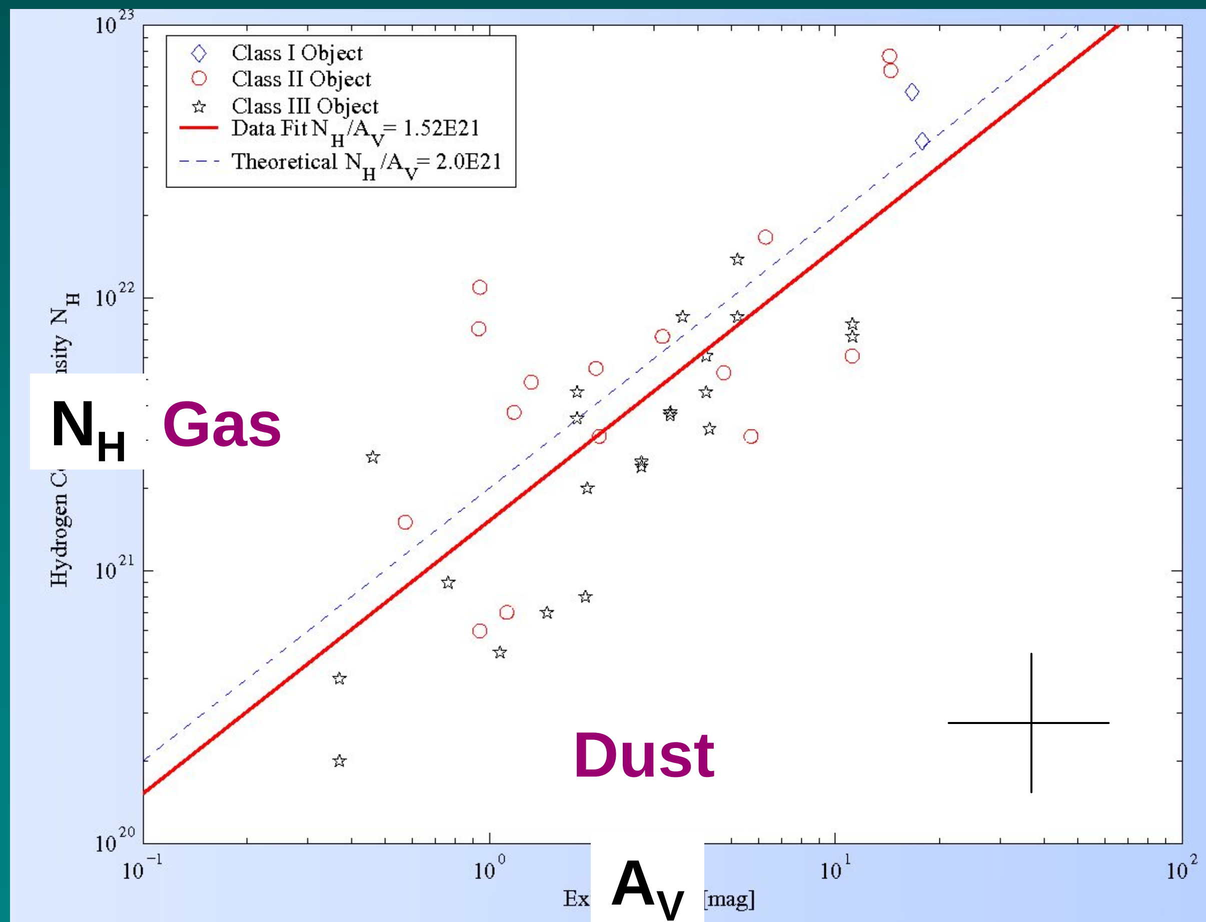


N_H: Gas column
A_V: Dust column

Gas-to-dust ratio
in stellar environment

Overall: standard
ISM; with exceptions

(Glauser et al. 2007)



Villafranca, June 6, 2007

What should/could be done next?

Top priority:

Well exposed spectra of 10 brightest CTTS + 5 WTTS:
f/I ratios $\rightarrow$ densities, soft excess, abundances: “Accretion physics”
Use of OM in U band: accretion events
(most 30-130 ks spectra so far marginal!)

15*200 ks = 3 Ms

Summary

Deepest X-ray survey of nearest star-forming region:

- detected nearly all TTS and 50% of BDs and protostars
- "complete samples"

High-resolution RGS spectroscopy:

- first coherent sample of CTTS & WTTS high-res spectra
- discovery of "Soft Excess" due to accretion
- abundance systematics for most PMS and MS stars

High-quality EPIC spectroscopy:

- Detailed spectral models with well-constrained N_H for all stars
- sample of "two-absorber X-ray spectra": X-rays from jets?

And many more…

end