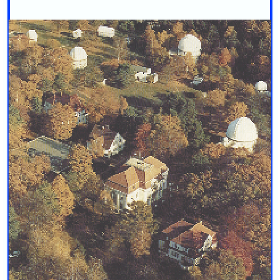
IAUS 243

Hamburger Sternwarte



Evidence for excesses in CTTS

Outflows and accretion in X-rays and FUV

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Soft X-ray excess

An excess in O VII emission is found in all CTTS observed so far with high resolution gratings (TW Hya (Kastner et al. 2002; Stelzer & Schmitt 2004), BP Tau (Schmitt et al. 2005), V4046 Sgr (Günther et al. 2006), T Tau (Güdel et al. 2006), MP Mus (Argiroffi et al. 2007) and RU Lup (Robrade & Schmitt submitted to A&A)).

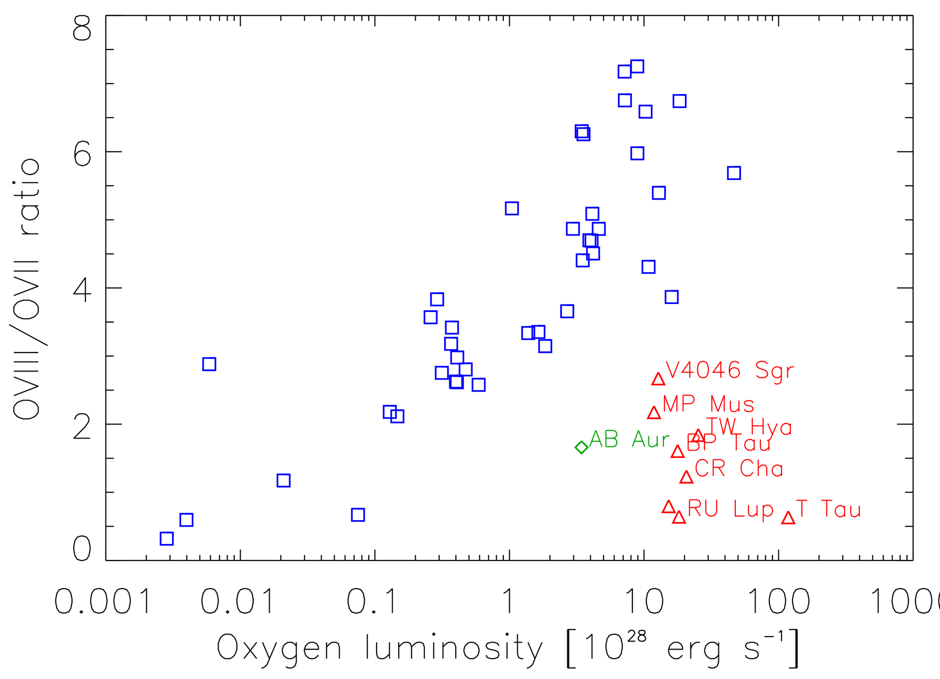

Figure 1: Ratio of the emitted O VIII(Ly$_\alpha$)/O VII(r) line flux vs. total luminosity in those lines for MS stars (squares), CTTS (triangles) and the Herbig Ae star AB Aur (diamond).

With *FUSE* we address the question, whether this excess is also visible in O VI:

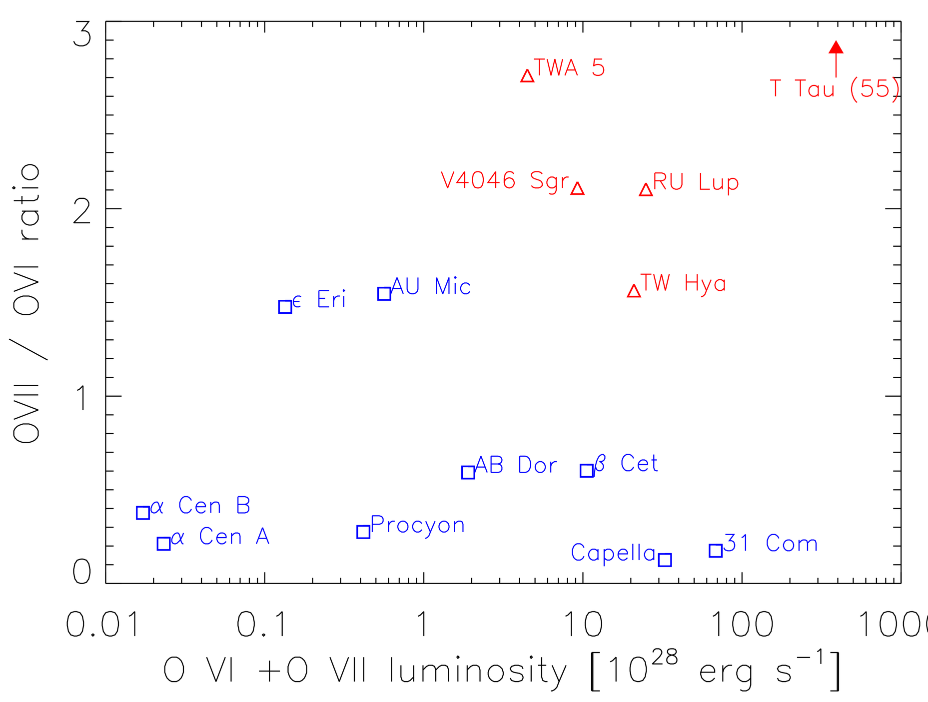

Figure 2: Ratio of dereddened fluxes in the O VII triplet at 22 Å to the O VI 1032 Å line vs. total luminosity in those lines for CTTS (triangles) and MS stars (squares). The ratio for T Tau is 55, it position above the plot is indicated with an arrow.

O VII and only O VII is significantly enhanced in CTTS compared to MS stars, corresponding to a temperature range of 1-2 MK.

This can be naturally explained by magnetospheric infall with free-fall velocity onto an hot accretion spot. In Günther et al. (2007) we show that this scenario also explains the ratios in the density sensitive triplets of O VII and Ne IX quantitatively.

Anomalous FUV line shifts

Some CTTS have been observed in the FUV with *FUSE*. From the available CTTS spectra we extracted the C III lines at 977 Å and the O VI doublet at 1032 Å and 1038 Å.

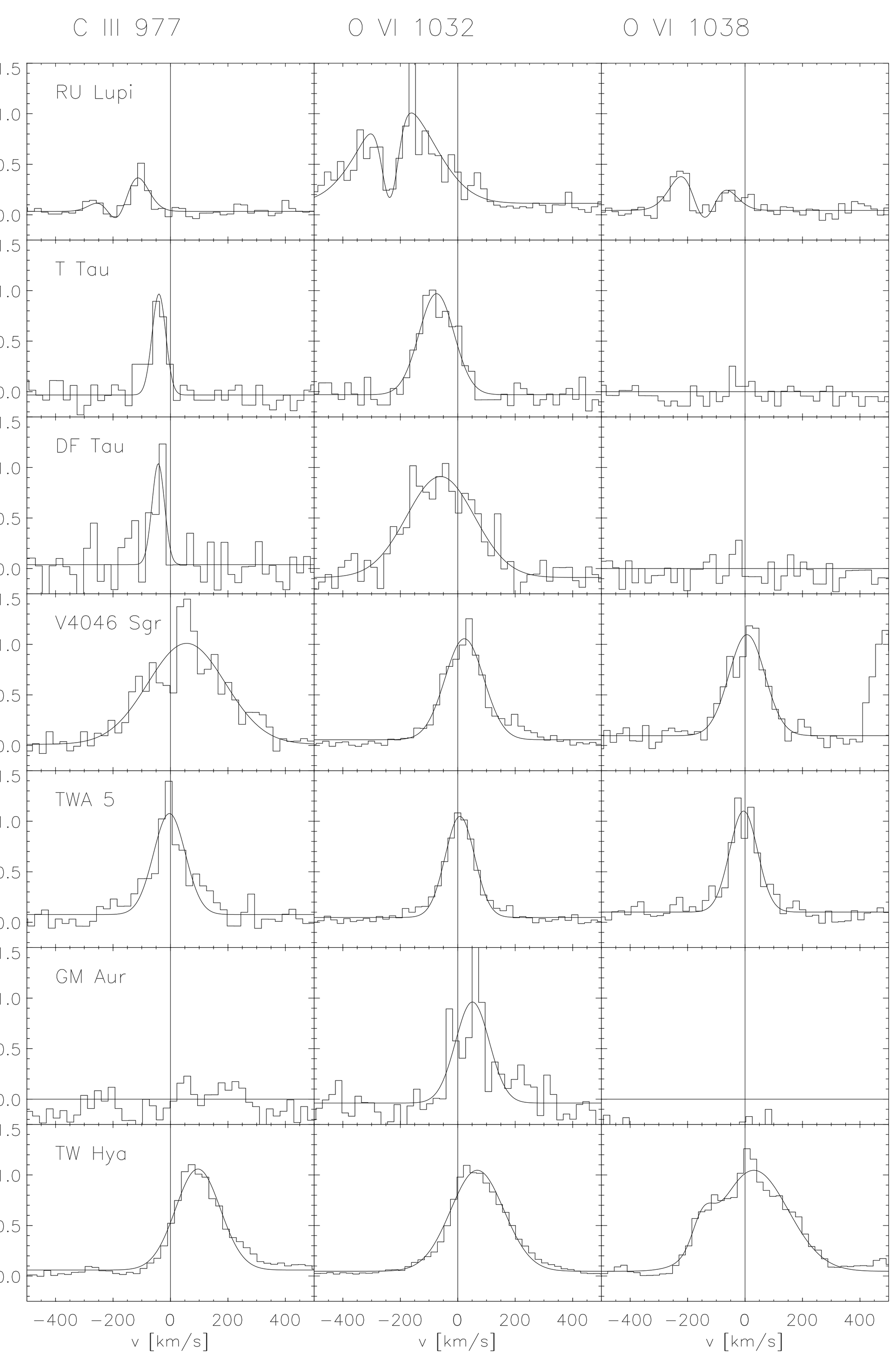

Figure 3: FUV emission lines observed with *FUSE* in CTTS and best fit Gaussian profiles ordered by the shift in the O VI 1032 Å line. For RU Lup an additional absorption component is used.

Lines are superrotationally broadened!
Blue-shifted lines:

- in RU Lup, T Tau and DF Tau
- up to -200 km s^{-1} in RU Lup
- emission measure $\approx 10^{51}$ cm^{-3}
- origin in outflow (wind, jet)?

Red-shifted lines:

- in V4046 Sgr, GM Aur and TW Hya
- up to 100 km s^{-1} in TW Hya
- emission measure $\approx 10^{51}$ cm^{-3}
- origin unclear, likely NOT in accretion funnels, since O VII is only formed close to star at free-fall velocity, so the lines should be double peaked: free-fall (500 km s^{-1}) and post-shock (125 km s^{-1})

Excess absorption

Young stars are often located close to or in molecular clouds. When they reach the CTTS phase their envelope already vanished and the remaining circumstellar material is concentrated in a disk. X-ray observations allow to determine the total X-ray absorbing column density N_H. Relating the thus derived hydrogen column to an optical extinction with the usual formula $N_H = A_V \cdot 2 \times 10^{21}$ cm^{-2} we find an X-ray absorption excess for some CTTS.

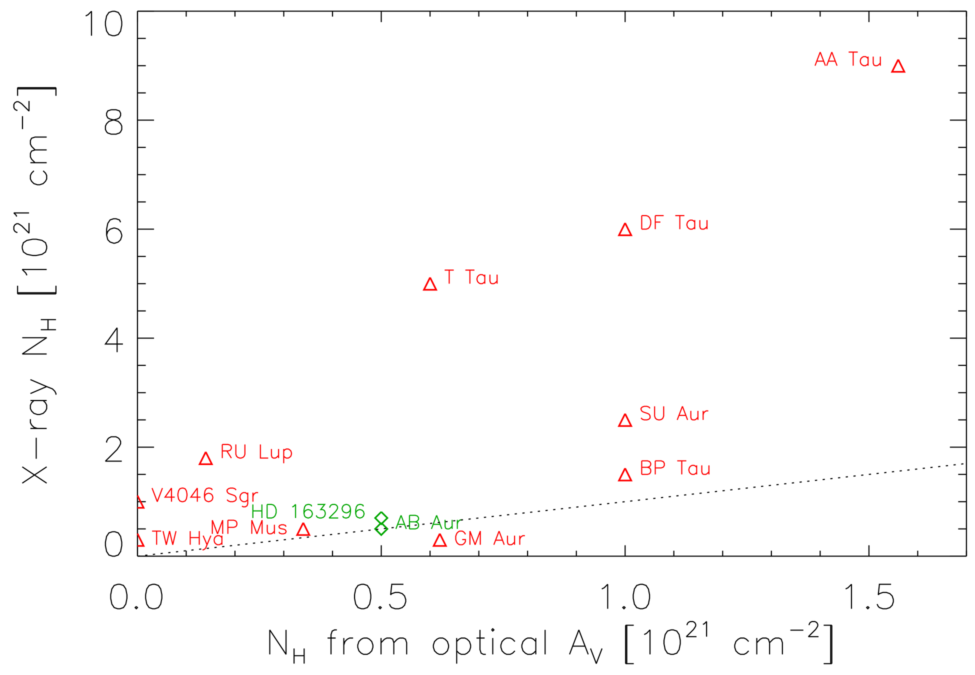

Figure 4: Absorbing column densities from X-ray and optical measurements for CTTS (triangles) and Herbig AeBes (diamonds). The line indicates compliance with the conversion formula.

The optical reddening is caused by dust, whereas the main contributor to the X-ray absorption is gas. Depending on the inclination angle the emerging light may pass through the disk, accretion funnels, winds or jets. In objects with known inclination we can use this to study in- and outflows.

Dust depleted absorber in some CTTS

- AA Tau: Seen at $i \approx 75°$ $\Rightarrow$ disk?
- RU Lup: Seen nearly pole-on: Known outflows (Herczeg et al. 2005)
- CTTS with blue-shifted lines all have $N_H > A_V \cdot 2 \times 10^{21}$ cm^{-2}
  Consistent with outflows too hot to form dust as predicted in some models (von Rekowski & Brandenburg 2006)
- Not only $N_H > A_V \cdot 2 \times 10^{21}$ cm^{-2}, but also large absolute absorption.
- MP Mus: Apparently no excess absorption $\Rightarrow$ Different behaviour within CTTS class? Age dependence?

Summary

- All CTTS show a strong O VII excess → plasma at 1-2 MK, interpreted as hot accretion spot
- Some CTTS show excess absorption of dust-depleted gas, possibly due to a warm / hot environment (outflows?)
- CTTS with blue-shifted FUV lines show excess absorption, again possibly winds / jets / outflows?