Observational constraints on photoevaporation by the central star

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Collaborators

[Ne II] observations:
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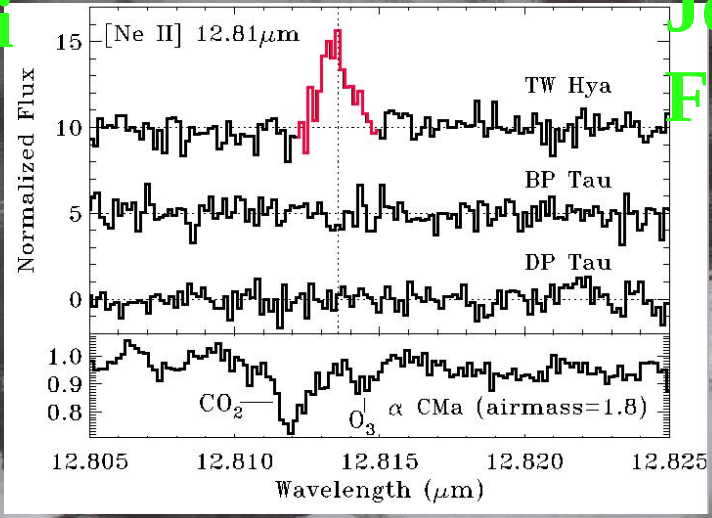
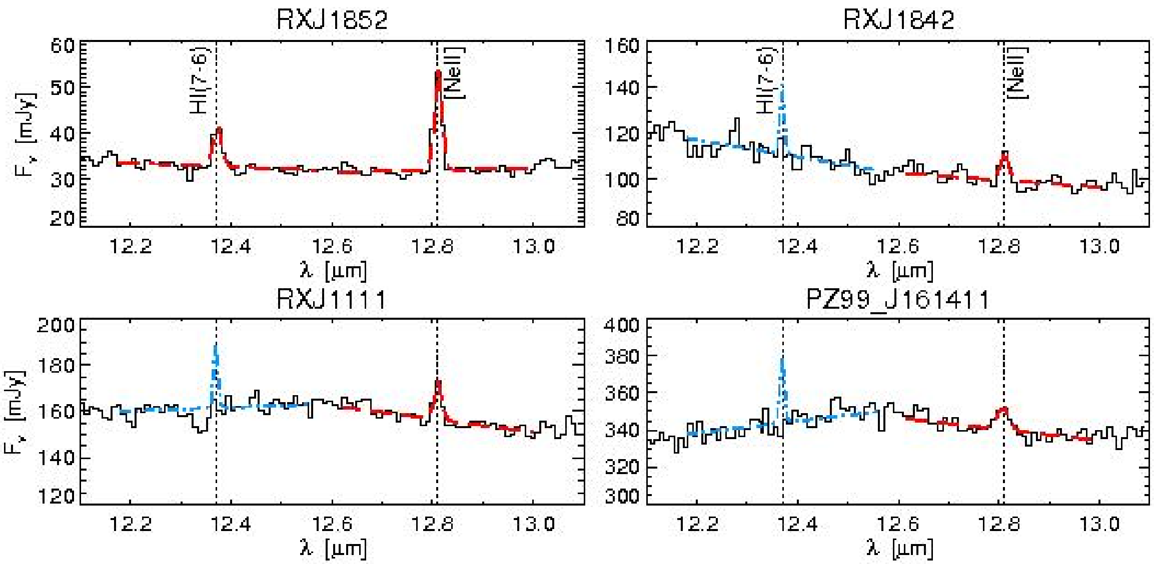
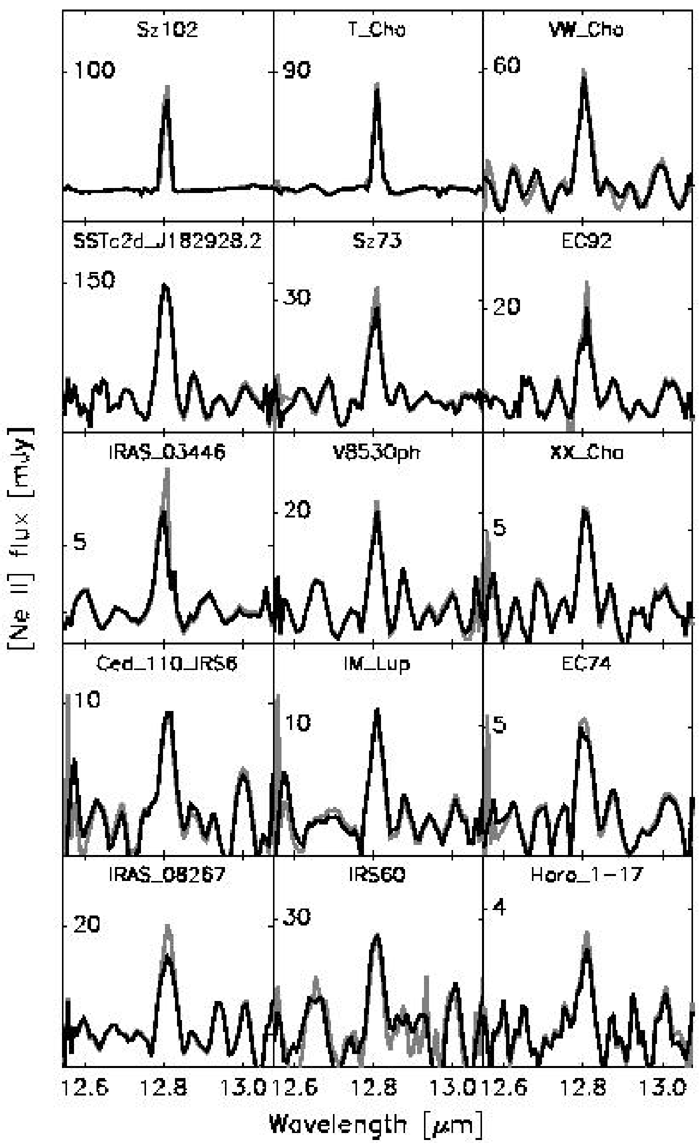


Spitzer/IRS detections of [Ne II] 12.8μm





FEPS: Pascucci et al. (2007)

Detected from 4/6 accretors:

c2d: Lahuis et al. (2007)

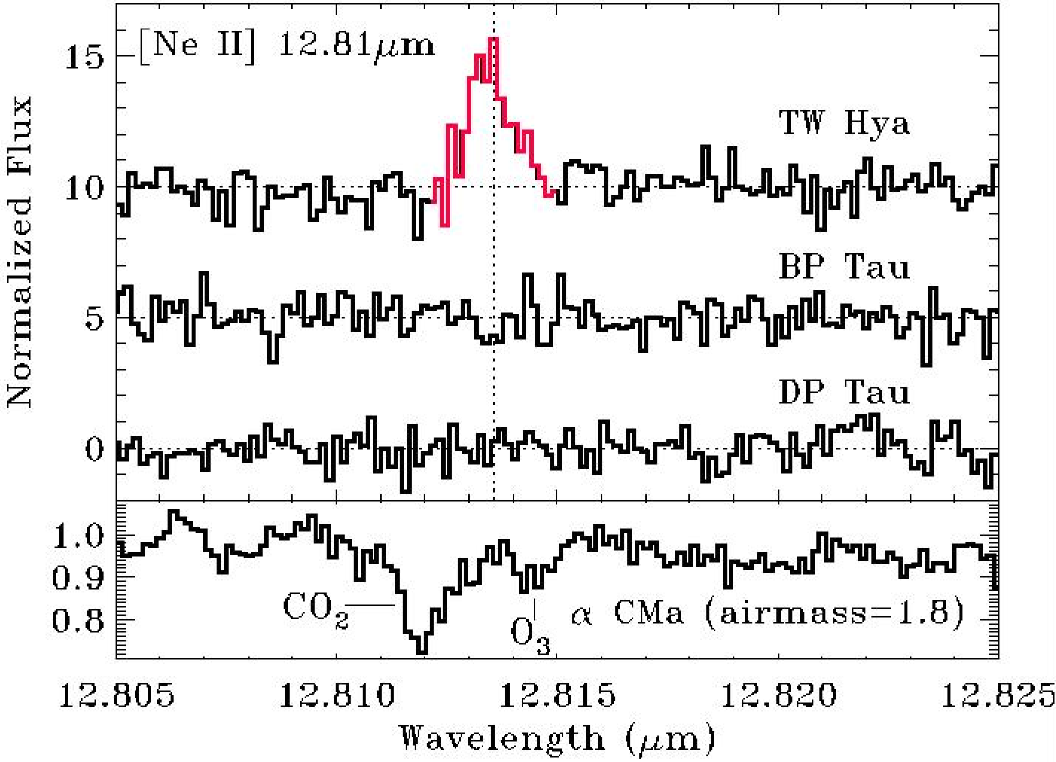
Detections from 15/76 targets

[Ne III] from one source

See also poster VI.2, Flaccomio

Gemini North/MICHELLE
[Ne II] emission from TW Hya

- R~26,000 at 12.81μm
- 40 minute exposure
- Flux: 6 x 10^{-14} erg cm^{-2} s^{-1}
  - 10^{-9} M_o if completely ionized
- FWHM = 21 +/- 4 km/s
- Line center -2 +/- 3 km/s
- Unresolved to 0.75 arcsec



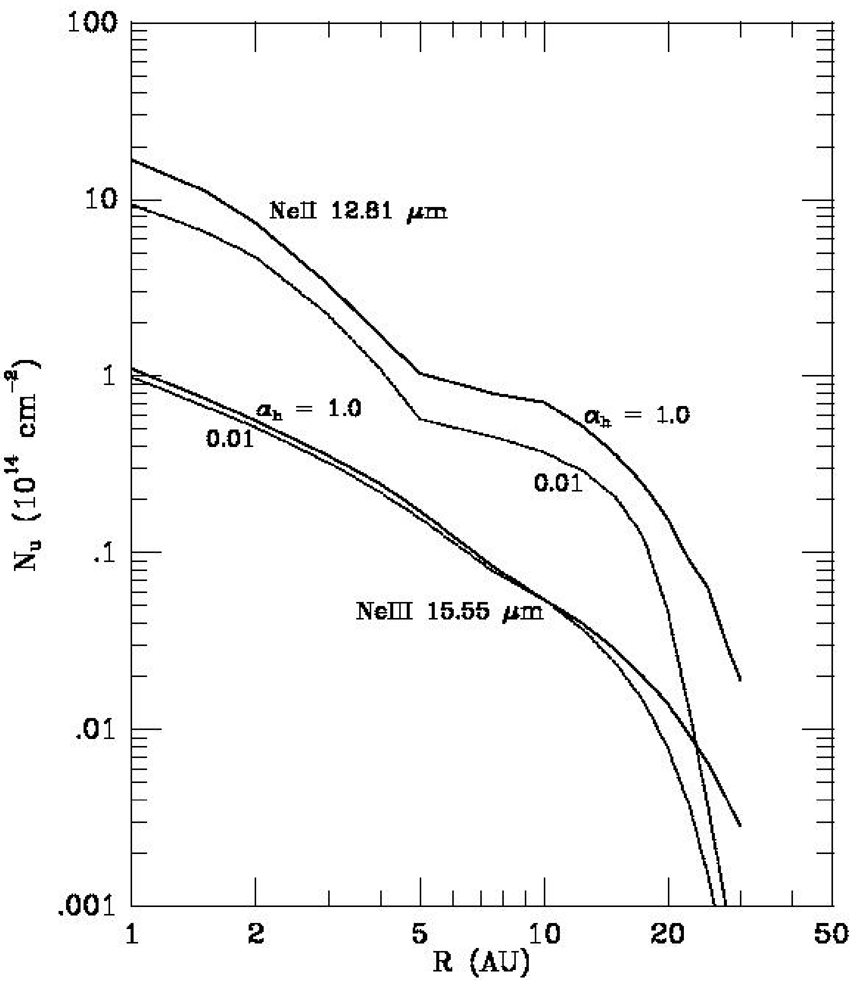
(Herczeg et al. submitted)

Likely a direct tracer of disk ionization

(at least for TW Hya-like CTTSs)

Excitation of [Ne II] emission

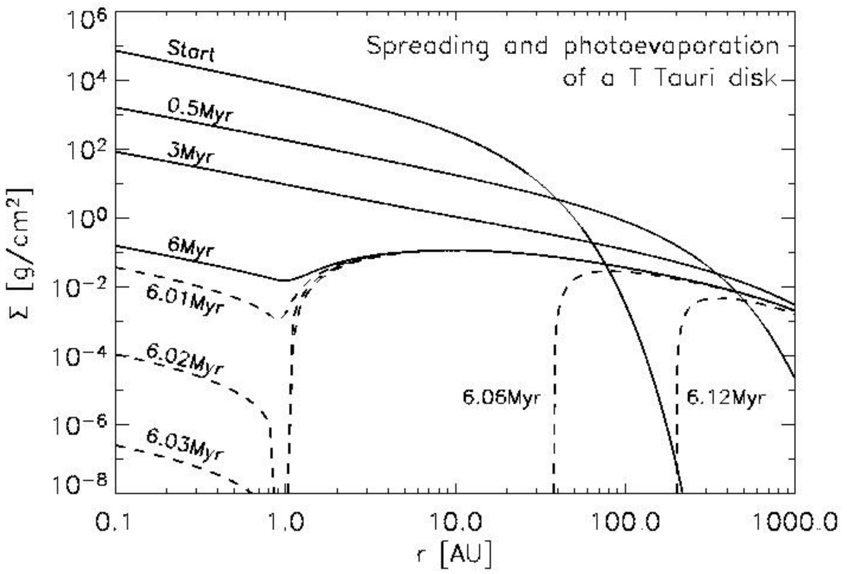
- Ionization of Ne:
  - EUV (<575 A)
  - K-shell ionization by X-rays with >0.9 keV (Glassgold et al. 2007)
    - Predicted fluxes similar to the observed fluxes
    - Predicts [Ne III]/[Ne II] flux for Sz 102
- Line broadening (21 km/s)
  - Keplerian rotation: 0.3 AU (X-ray)
  - Photoevaporative flow (EUV)
  - Turbulence in 10^4 K gas
    - Might also lead to some evaporation
    - Temperature may require EUV radiation



X-ray models of Glassgold et al. 2007

The role of photoevaporation in disk dispersal (see review by Dullemond et al. 2007)

- EUV (<912 A):
  - 1 to 10 AU
  - $M_{wind}=4x10^{-10} (\phi_{41})^{0.5} (M/M_o)^{0.5}$
    - ϕ_{41}= photons s^{-1} at <912 A
    - Hollenbach et al. (1994)
  - Alexander et al. models
    - $\phi=10^{42}$ phot s^{-1}
    - Chromospheric EUV photons
    - Accretion continuum emission does not escape accretion flow



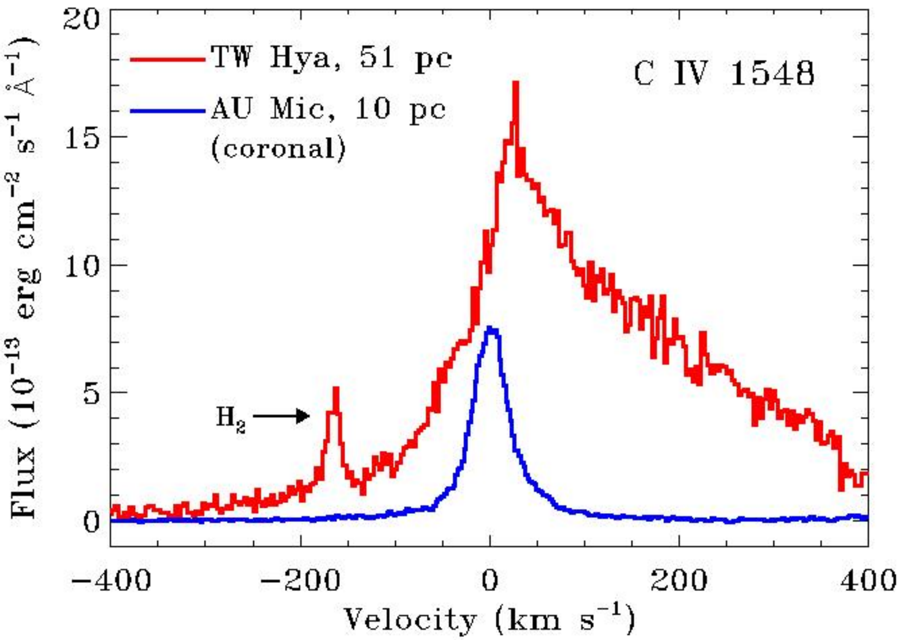
Alexander et al. 2006

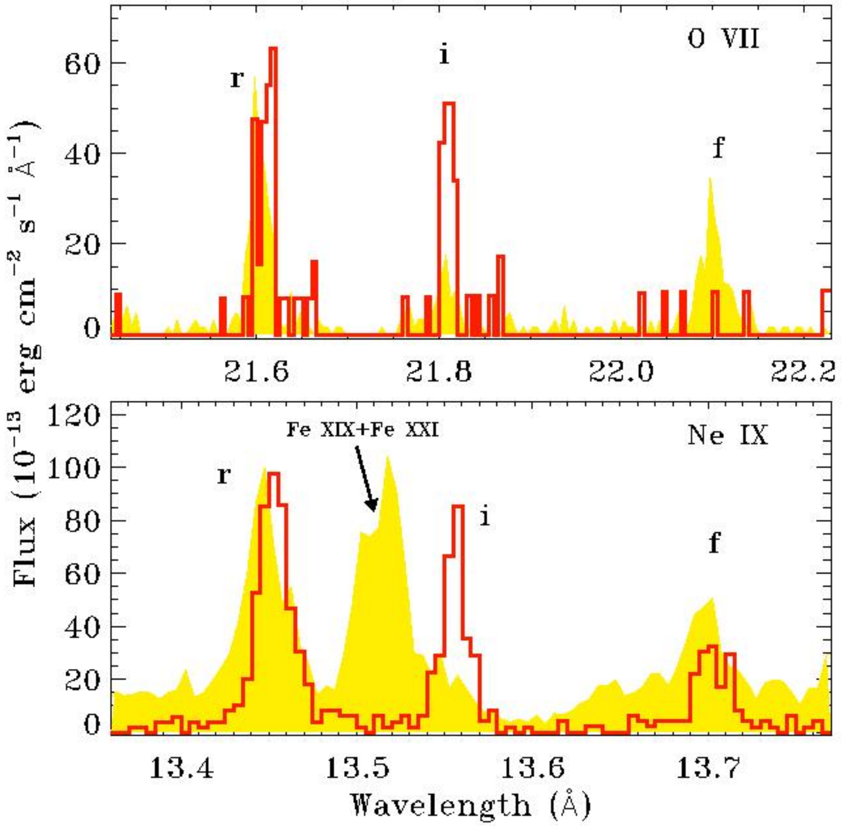
- FUV (912-2000 A):
  - Beyond 30 AU
  - Central star or IS field?

Accretion: FUV and X-rays

- FUV: Broad redshifted emission profiles in hot lines

(Johns-Krull & Herczeg 2007)

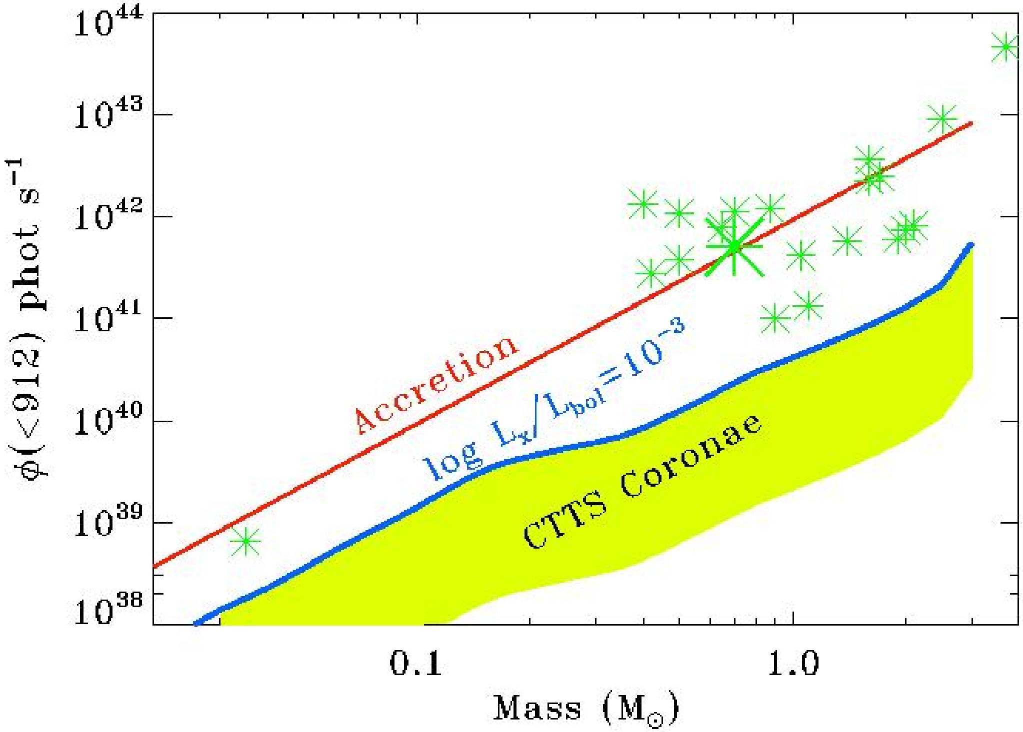


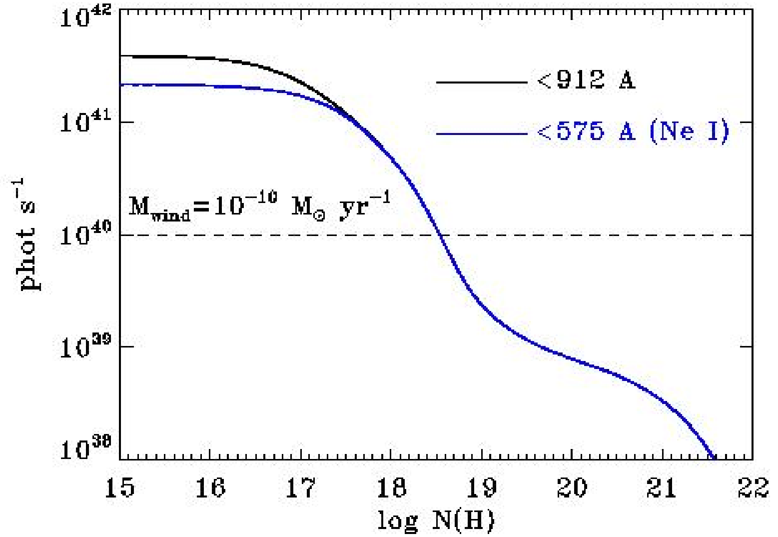


- X-rays: weak f/i ratio in He-like triplets
  - Accretion, regardless of whether the line is suppressed by high density or a strong FUV field

(Kastner et al. 2002; Stelzer et al. 2004)

EUV irradiation of disk



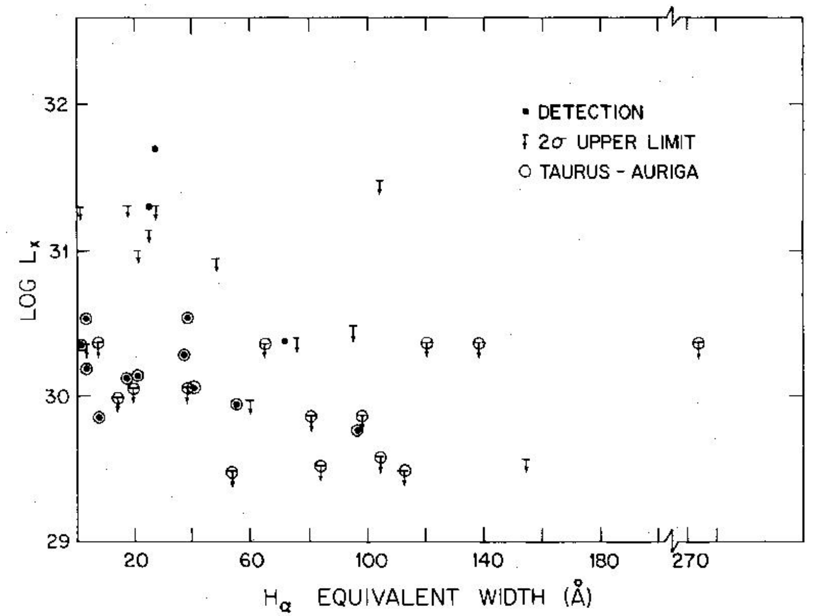


- EUV estimate from accretion following Alexander et al. (2005)
- Coronal estimate based on estimate for nearby young stars (del Zanna et al. 2002; Ribas et al. 2005)

- But do accretion and/or winds smother the EUV emission?

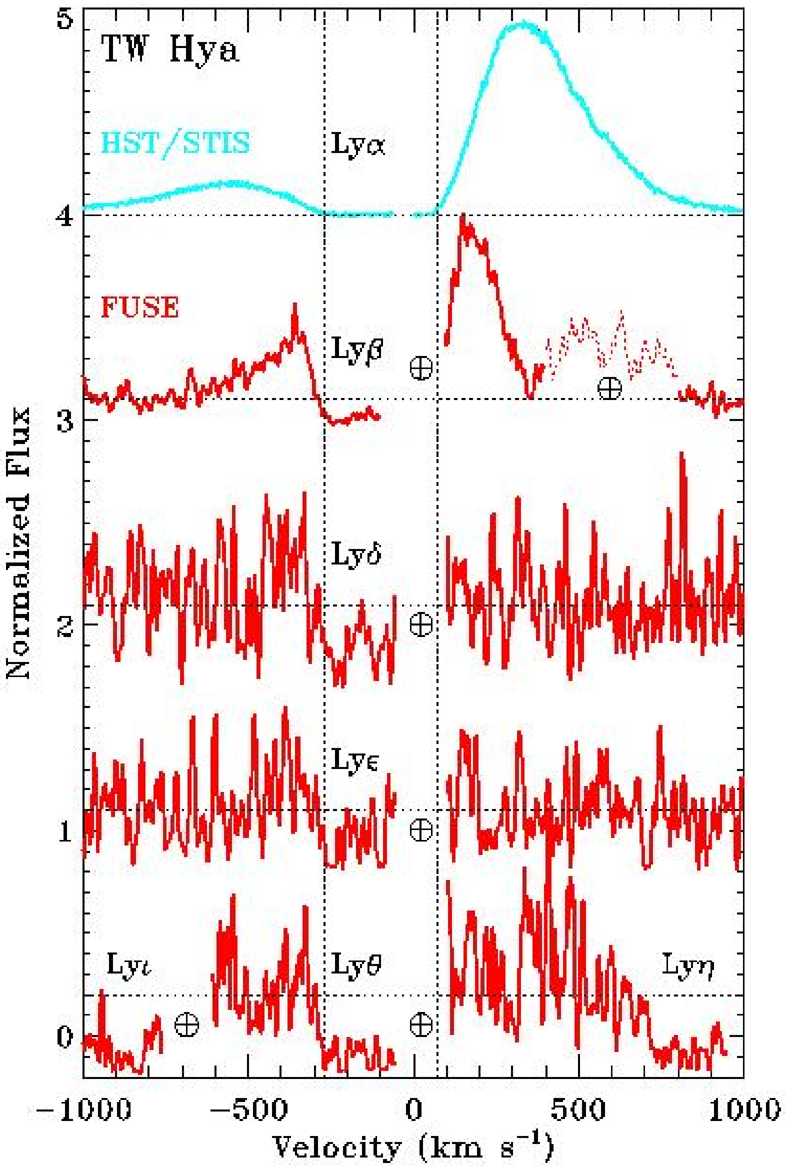
Are X-rays from CTTSs smothered?

- First proposed by Gahm (1981) and Walter & Kuhi (1981) to explain Einstein data
  - IR excess: circumstellar envelope
- Possible rotational modulation of N(H) to AA Tau
  - Schmitt & Robrade 2007 and poster by Grosso
- Accretion models by Gregory et al. (2007, also talk)
- Poster II.6, Guenther & Schmitt finds large N(H I) to X-rays relative to N(H I) from A_V



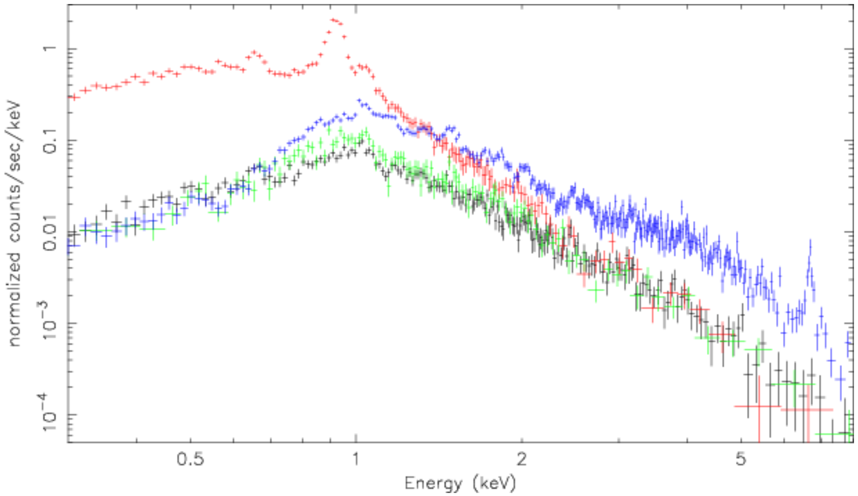
Walter & Kuhi (1981)

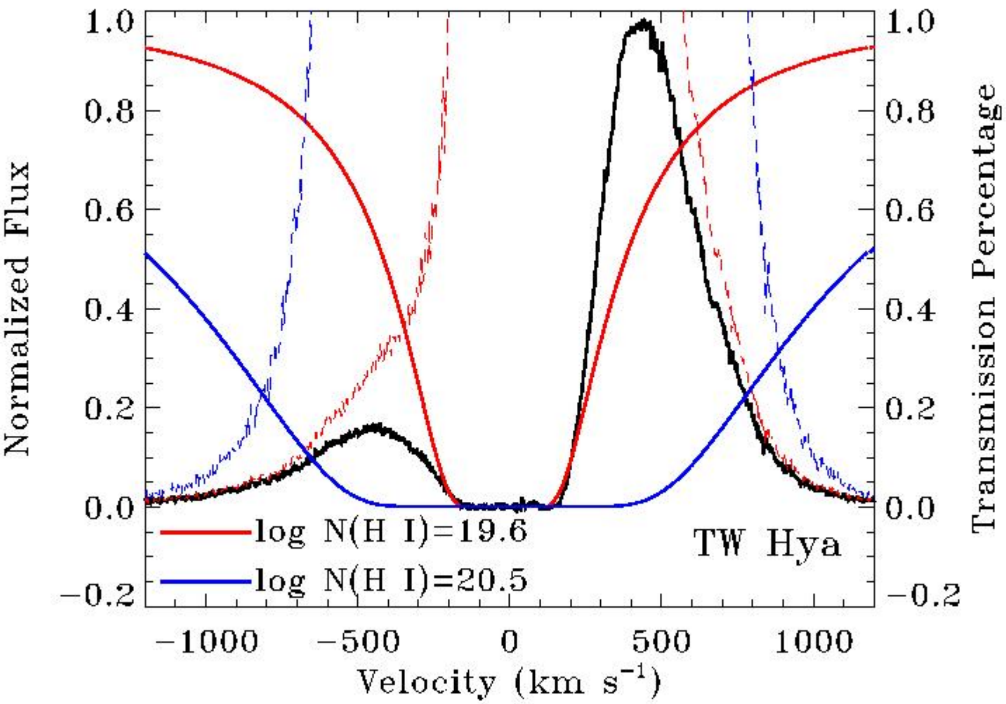
H I absorption to CTTSs



- Wind, ISM: will attenuate emission from coronae, accretion
- Accretion flow: could attenuate accretion EUV, coronal EUV, or neither
  - Geometry- and model-dependent
- Measurements:
  - X-rays: Lyman continuum absorption
  - FUV: Absorption in Lyman lines

N(H I) measurements to TW Hya





- N(H I) to X-ray emission from Robrade & Schmitt (2006, left)
  - TW Hya in red

- N(H I) to Lyα emission
  - HST/STIS E140M spectra
  - Includes wind and ISM
  - log $N(H_2)<18$ from FUSE spectrum of TW Hya (Herczeg et al. 2004)

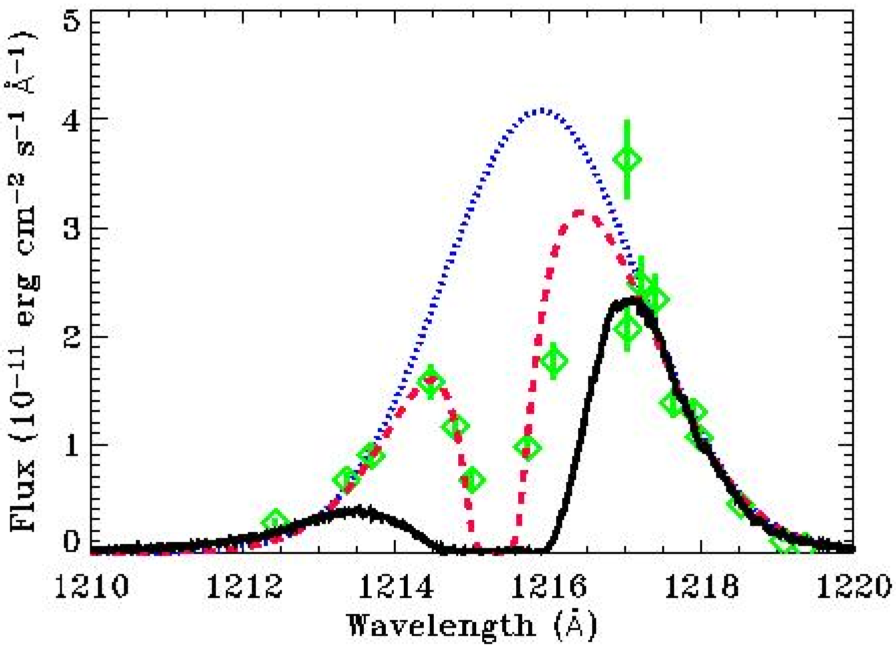
Comparing N(H I) measurements

- Uncertainties:
  - Formation of H I Ly-α emission
  - Variability in N(H I)?
    - FUV: FUSE and STIS observations at different epochs
    - X-rays: N(H I) consistent with ROSAT (Kastner et al. 1999) and Chandra/LETGS spectrum of TW Hya
  - Geometry: N(H I) may depend on viewing angle

- Two other comparisons - SU Aur, BP Tau
  - log N(H I) from FUV (Lamzin 2006) about 1 dex less than that from X-rays (Robrade & Schmitt 2006)
    - larger N(H I) than TW Hya
  - Additional uncertainties
    - No measurement of H_2 absorption
    - Based on low-resolution FUV spectrum

Absorption of coronal EUV photons

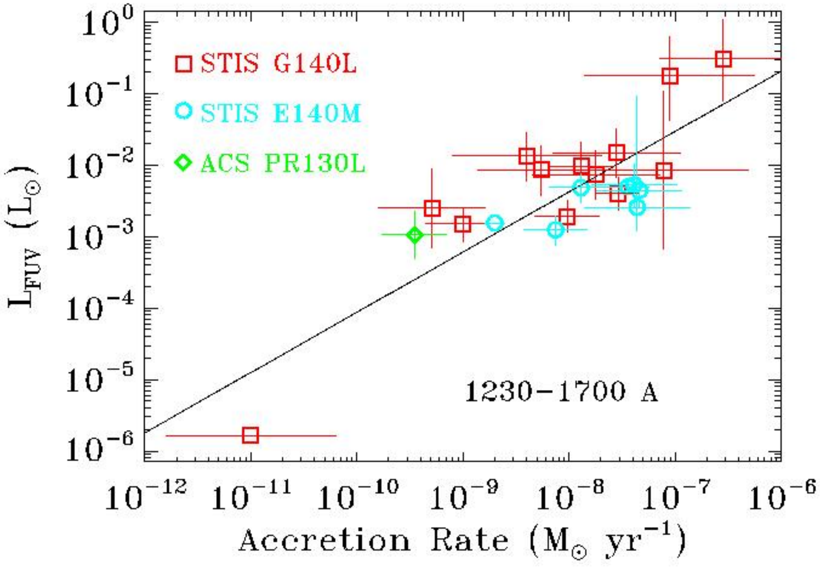
- H I Ly-α emission excites H_2 in disk around TW Hya
- Reconstructed Ly-α profile shows central blueshifted dip
  - N(H I)<18.7
  - Blueshifted by 70 km/s in rest frame of H_2
- Possible absorption by N(H I) in wind
  - More attenuation for stars with higher mass accretion rates?



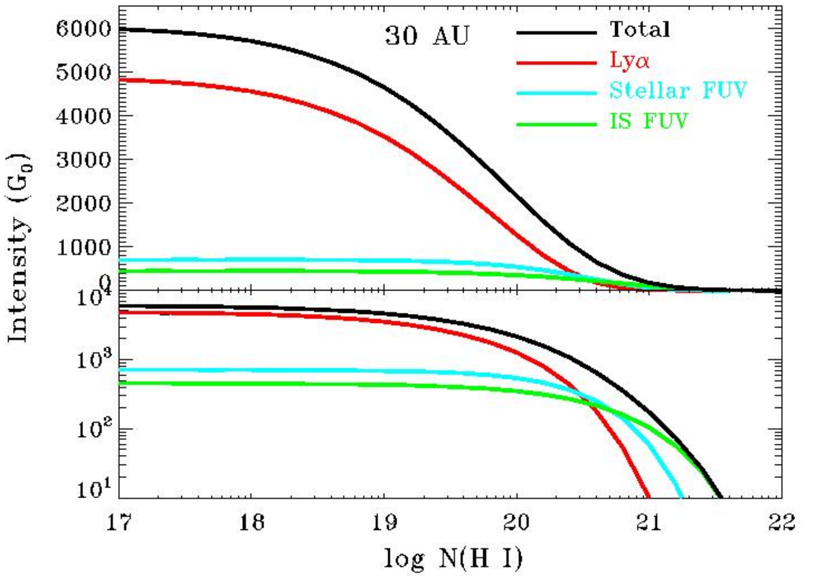
Herczeg et al. (2004)

FUV photoevaporation of disk at 30 AU

- Total FUV emission
  - 1230-1700 A emission depends on accretion rate
  - Includes many strong lines, H_2, and excess FUV continuum
  - H I Ly-α 1215.7 may be 75-90% of FUV flux for some stars (Herczeg et al. 2004)



- FUV from central star
  - Median IS field for 1 Myr old star is 900 G_0 (Adams et al. 2004)
    - Much smaller for field CTTSs
  - Weak for low-mass stars



Evaluating Photoevaporation Models

- EUV emission may not reach the disk surface
  - Soft X-ray emission smothered by accretion?
  - Reduces photoevaporation rate in Alexander et al. models
  - Supports alternate explanations (e.g., Najita et al. 2007) for transition disks

- Strong FUV emission from accretion and winds
  - May cause substantial photoevaporation at >30 AU
  - Problematic for low-mass T Tauri stars, older CTTSs?

- [Ne II], FUV H_2 emission: constrain disk irradiation
  - [Ne II]: either X-ray or EUV ionization
  - H_2: pumped by Ly-α, sensitive to intervening H I