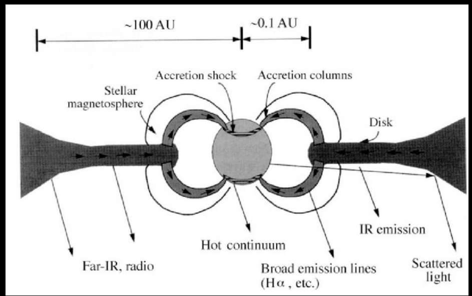
Surveying excess U-band emission onto young stars and brown dwarfs



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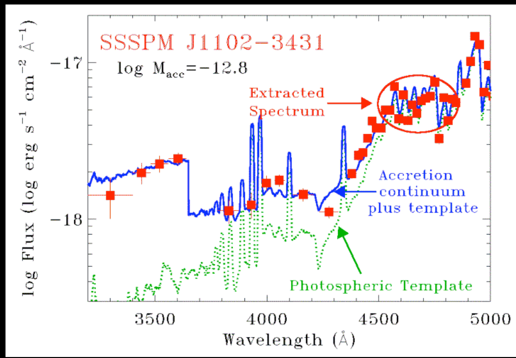
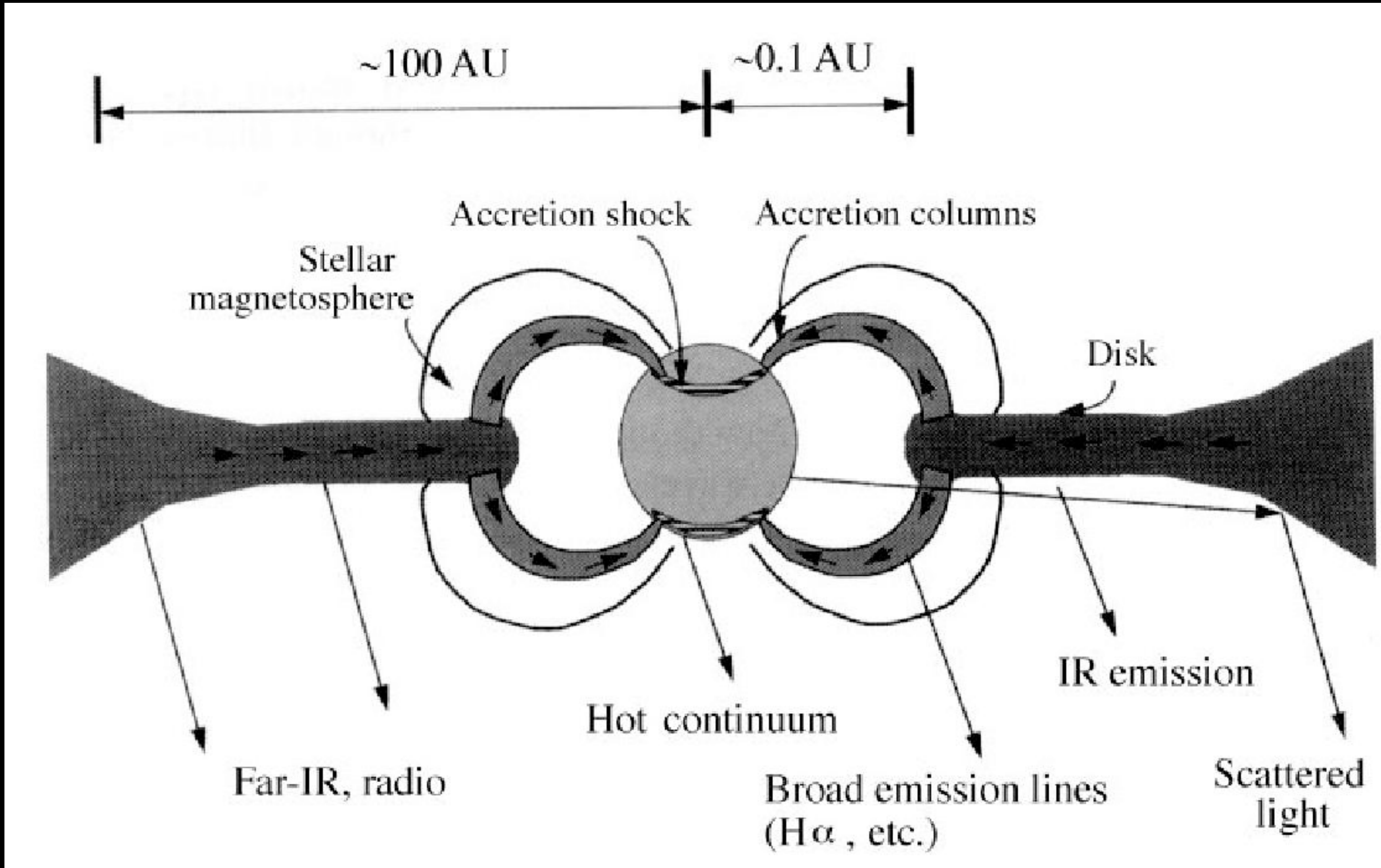
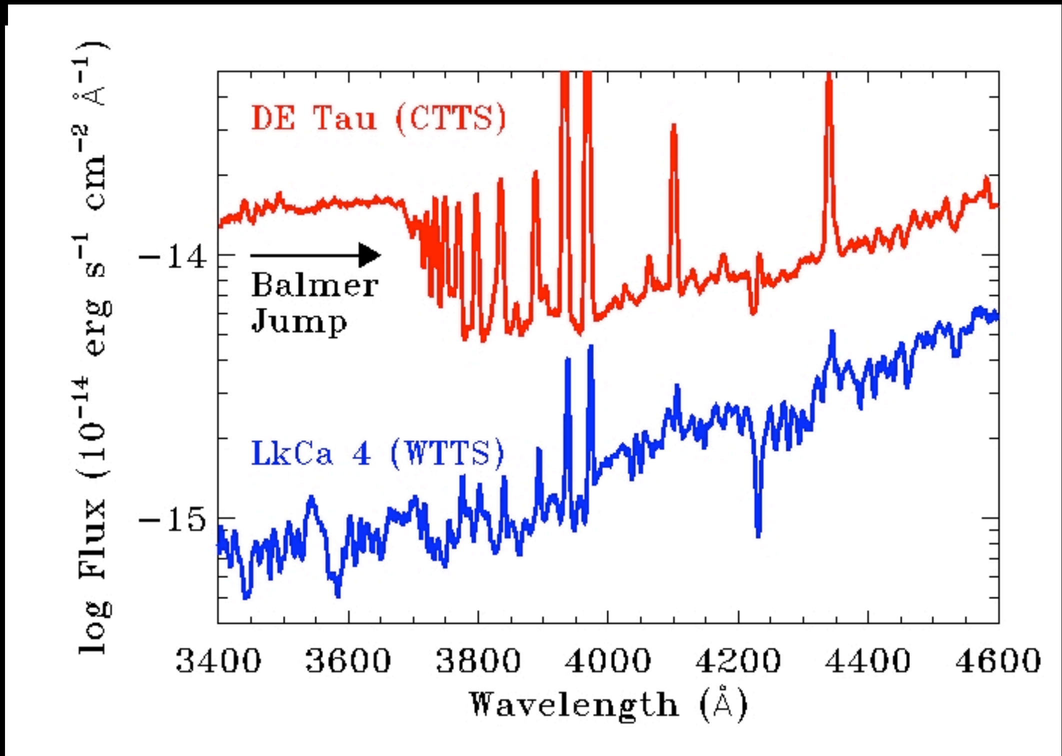


Magnetospheric accretion



Hartmann 1998

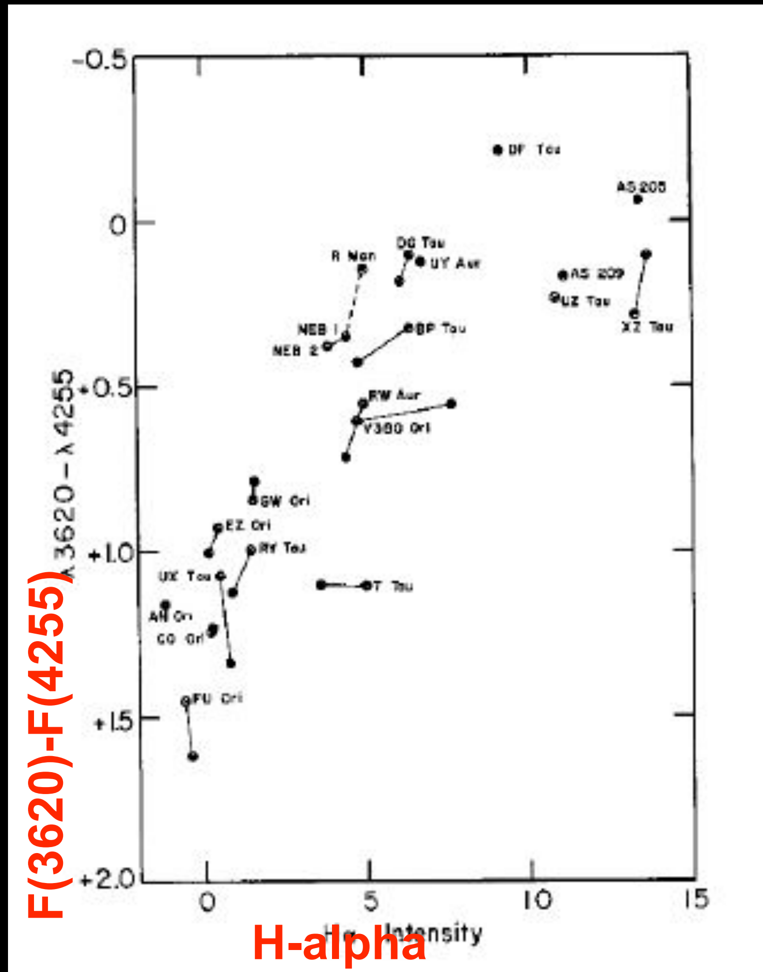
Classification of young stars



- CTTS classification:
  - IR excess
  - U-band excess
  - Balmer line emission
  - Other lines frequently detected
- Naked (Weak-lined) T Tauri star
  - Weak lines

Methods to measure accretion

- UV (U-band) excess
  - Spectroscopic or photometric (poster by Rigliaco et al.)
  - Most direct and accurate method, when possible
- Optical veiling
  - Direct but less sensitive
- Correlations between line emission and accretion luminosity
  - Posters by Fang et al. and Antoniucci et al.
  - LMC/SMC: de Marchi et al. (2009)
- Hα 10% width
  - Poster by Fedele et al. (presence of accretion)

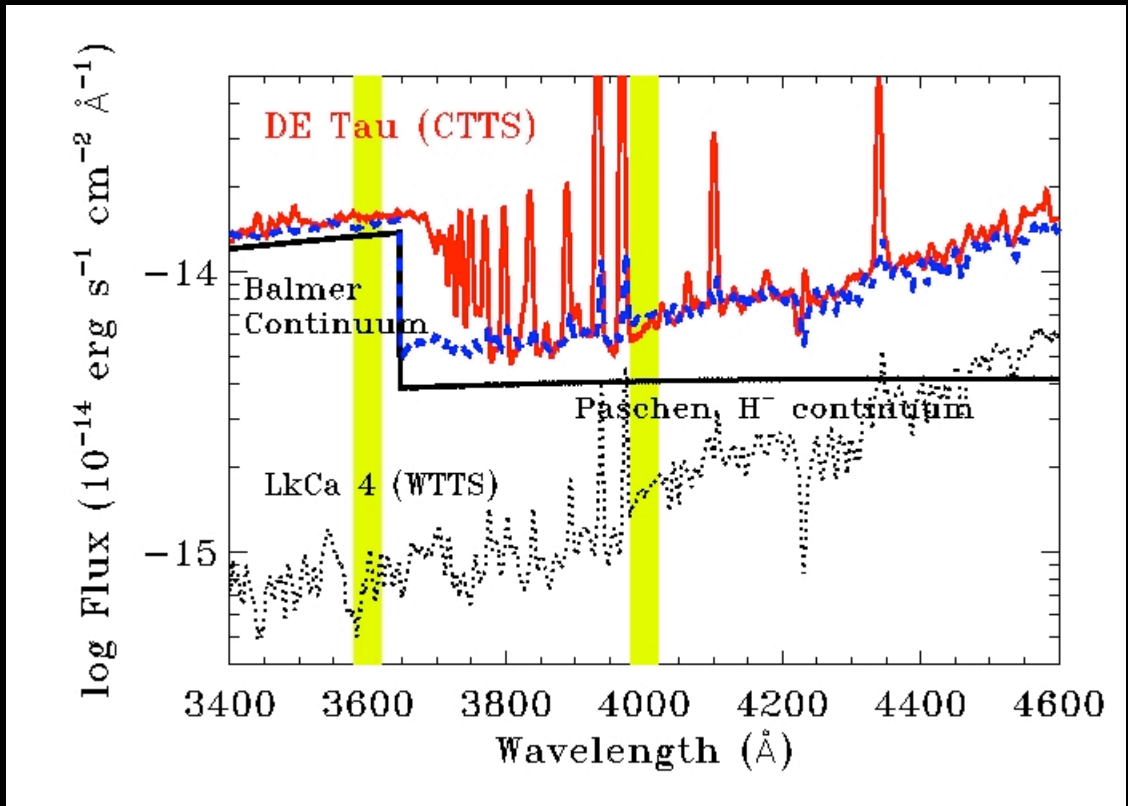


Kuhi 1966

UV Excess Measures of Accretion

$$\dot{M} = (1 - \frac{R_*}{R_{in}})^{-1} \frac{L_{acc} R_*}{G M_*} \sim 1.25 \frac{L_{acc} R_*}{G M_*}$$

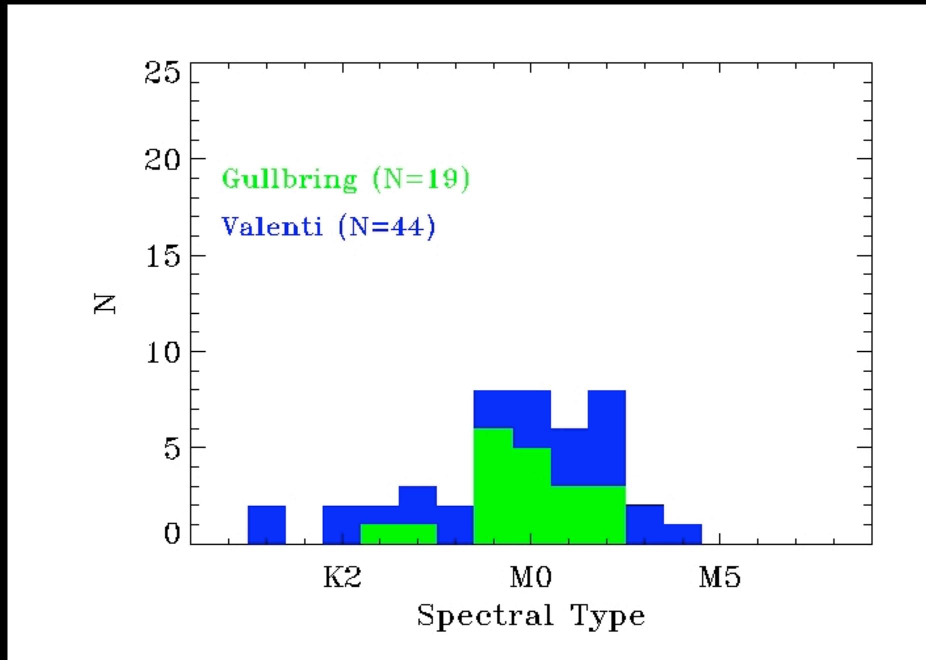
- Balmer Jump:
  - Flux ratio of 3600 A to 4000 A.
- At 4000:
  - Contributions from photosphere, Paschen continuum, H- continuum
- Balmer continuum at 3646 A
  - Jump at 3700 A due to line blending



Previous U-band measures of accretion

- U-band Spectroscopy:
  - Valenti et al. (1993)
  - Gullbring et al. (1998, 2000)

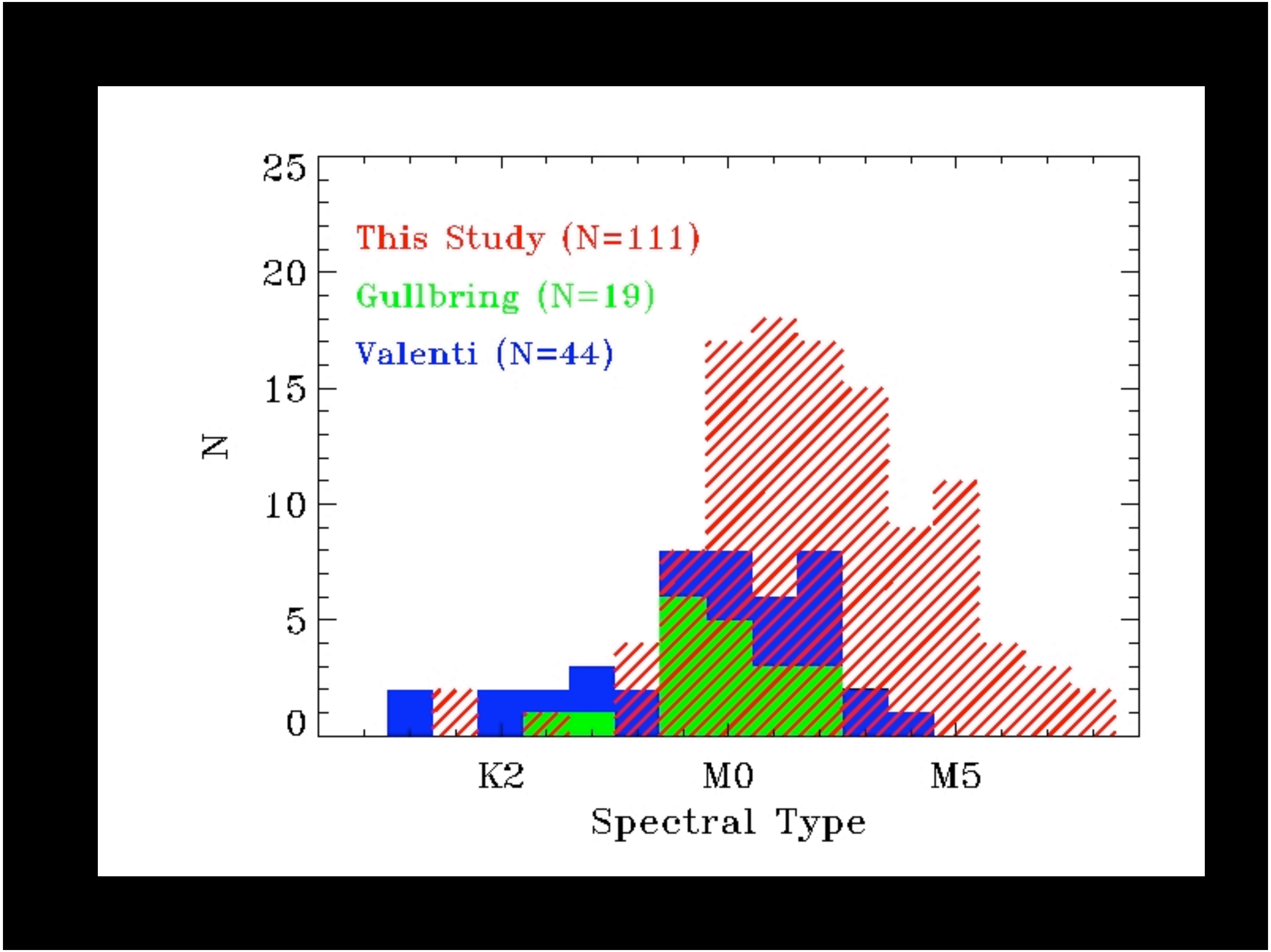
- U-band photometry:
  - Based on rates from spectroscopy
  - Hartmann et al. (1998)
  - White & Ghez (2001)
  - Rigliaco et al. (poster)

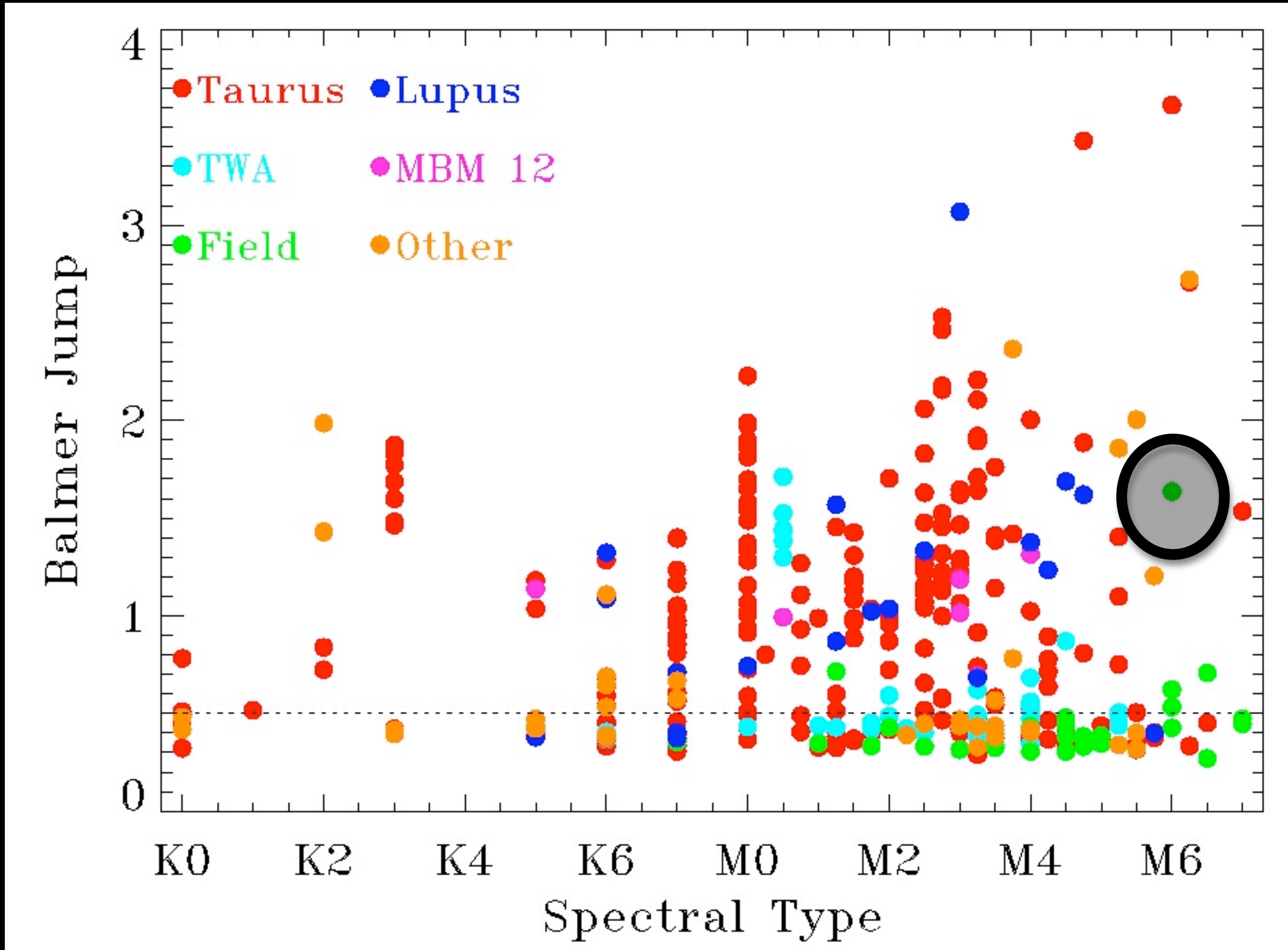


Palomar/Keck Spectra

(BDs in Herczeg & Hillenbrand 2008, Herczeg et al. 2009 low-mass stars in prep)

- Low-resolution optical spectra (3200-8700 A)
  - DBSP on Palomar, LRIS on Keck
- About 300 T Tauri stars, 40 field dwarfs
  - Good coverage of known Taurus members from K5-M4.5
  - MBM12, TWA, some Lupus
  - Repeated observations of 40 stars
  - Covers both WTTS and CTTS
- 900s sensitivity: U=26 (Keck), 22 mag (Palomar)

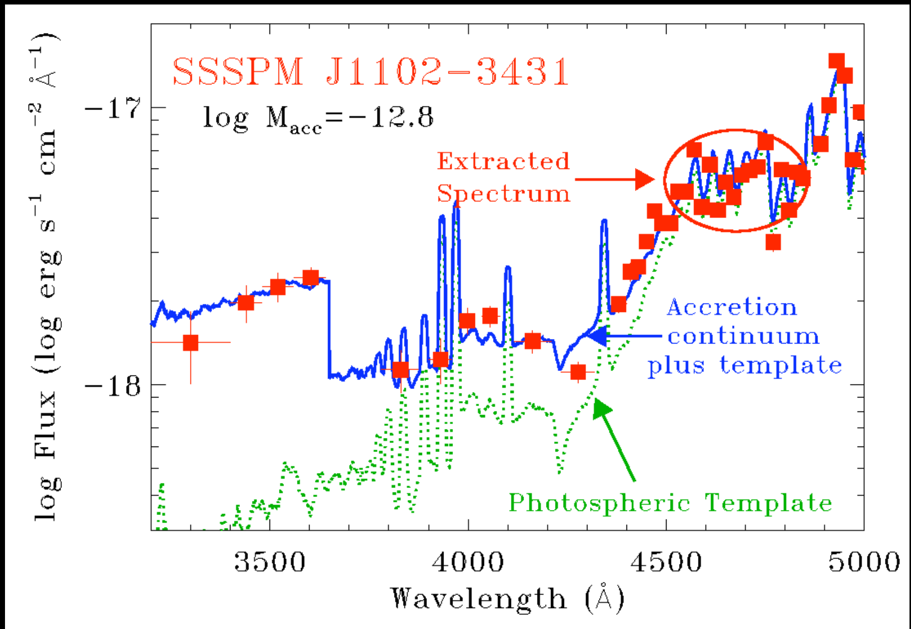

This Study (N=111)
Gullbring (N=19)
Valenti (N=44)
25
20
15
10
5
0
N
K2
M0
M5
Spectral Type



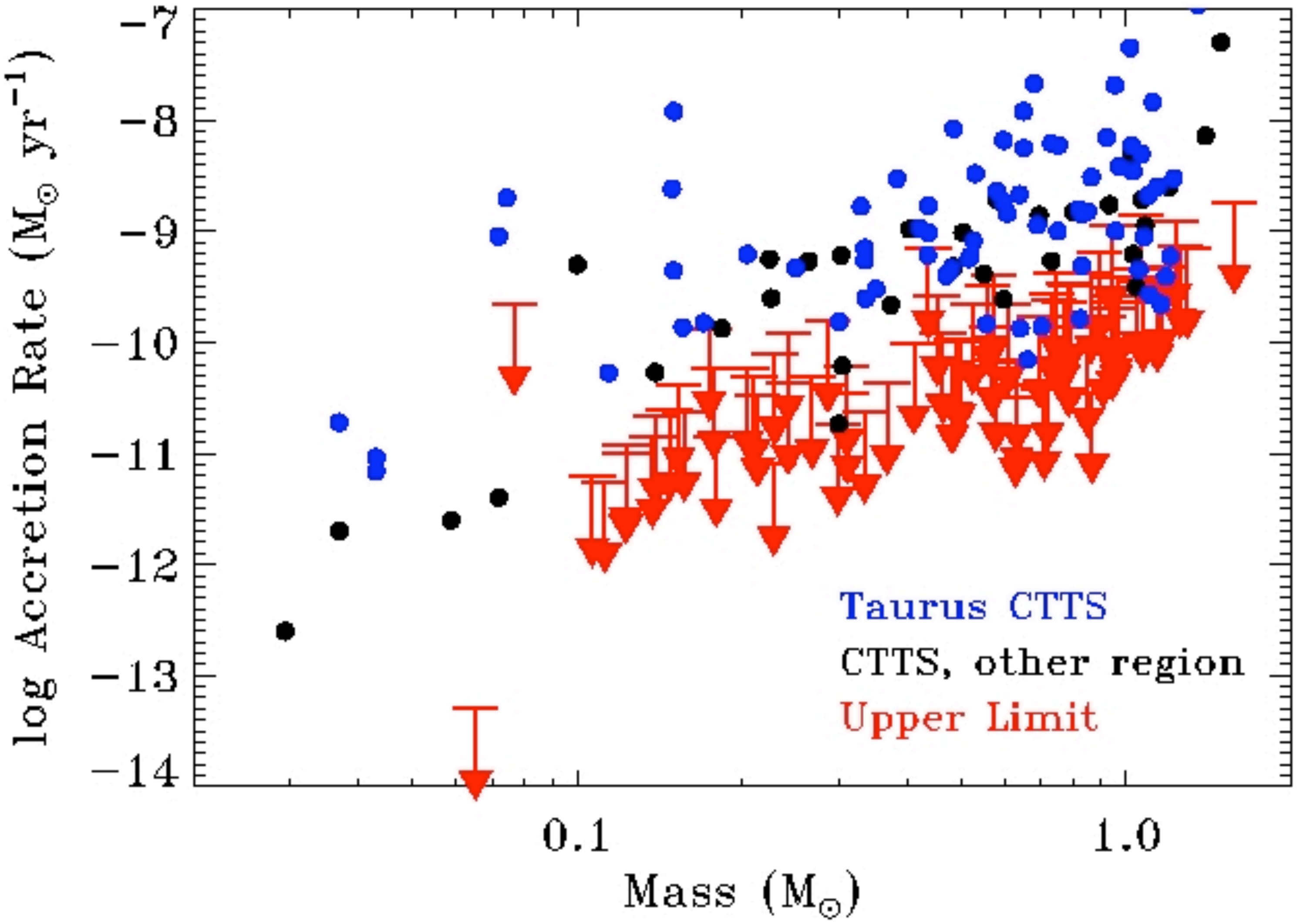
Taurus
Lupus
TWA
MBM 12
Field
Other
Balmer Jump
0
1
2
3
4
K0
K2
K4
K6
M0
M2
M4
M6
Spectral Type

Accretion onto Brown Dwarfs

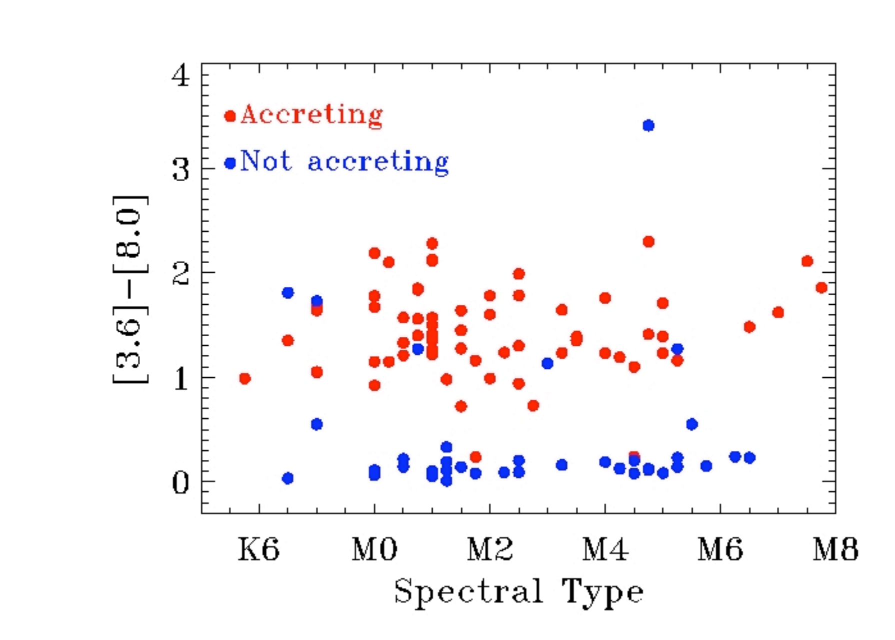
(Herczeg & Hillenbrand 2008; Herczeg et al. 2009)

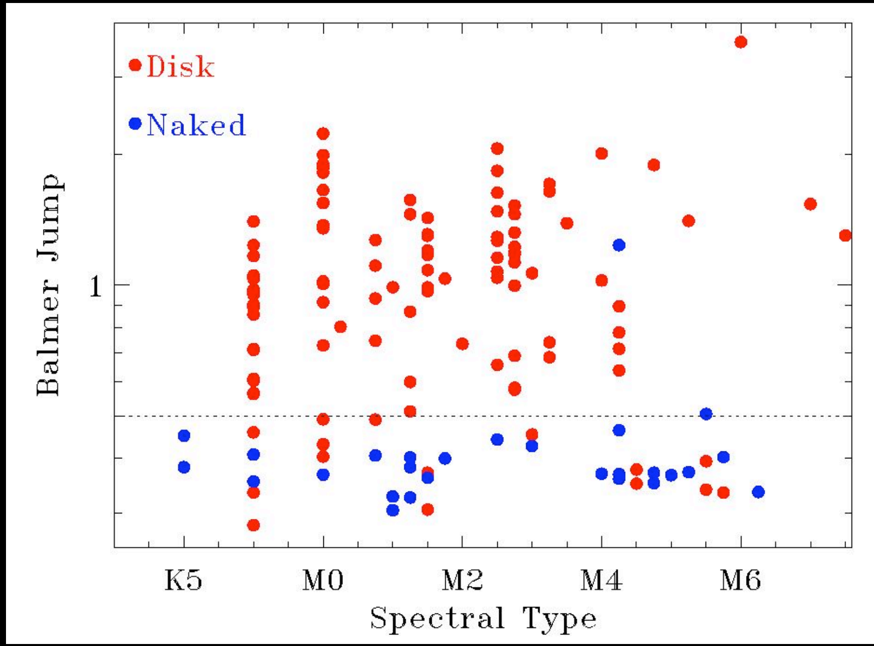


- Confirms low accretion rates from other diagnostics
  - Some significant discrepancies
- Accretion rates as low as 1.6 x 10^{-13} M_{sun}/yr
- See poster by Reiners for accretion onto an older BD

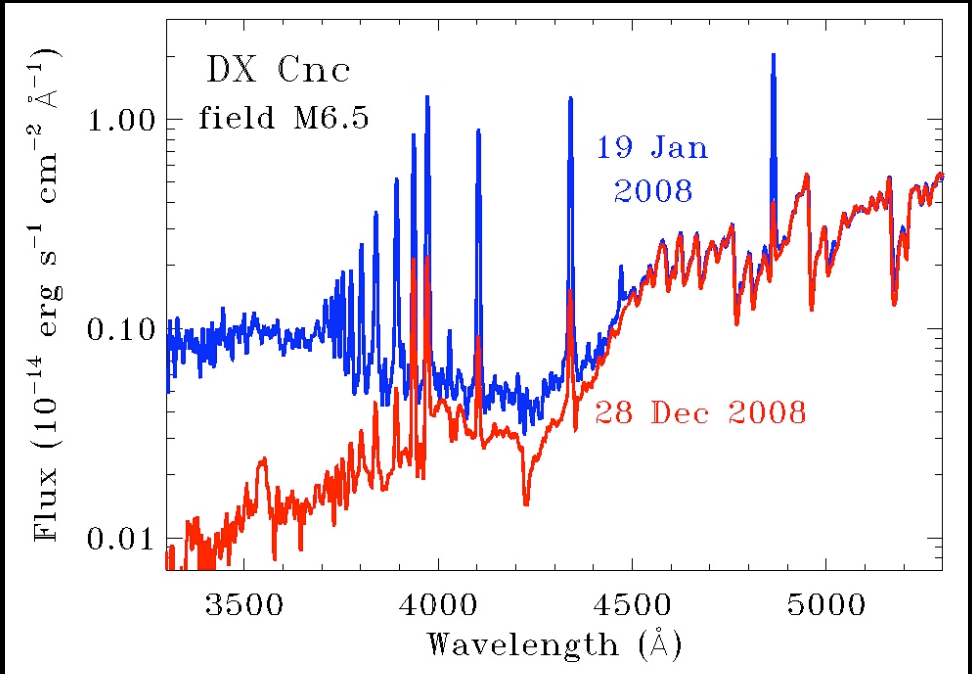

log Accretion Rate ($M_\odot$ yr^{-1})
Mass ($M_\odot$)
-7
-8
-9
-10
-11
-12
-13
-14
0.1
1.0
Taurus CTTS
CTTS, other region
Upper Limit

Accretion and disks





Chromospheric Flaring

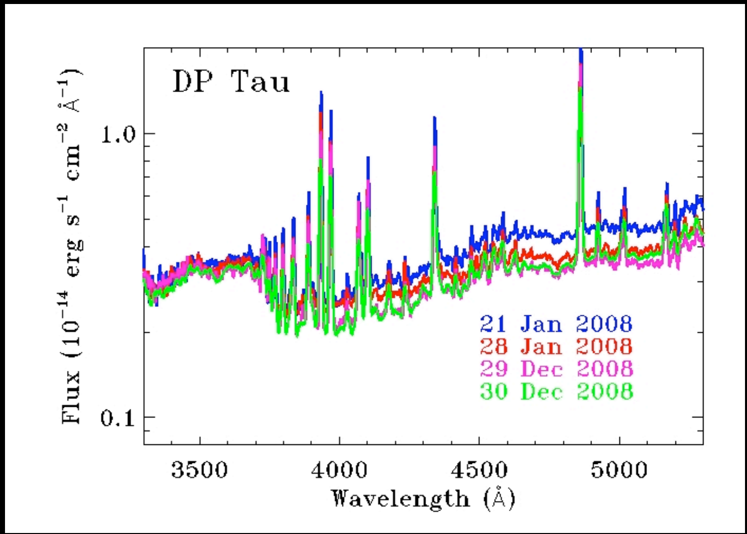


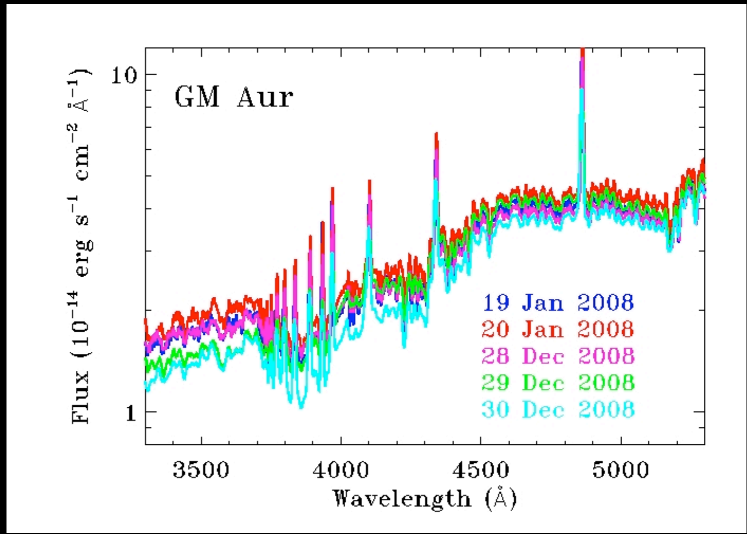
- DX Cnc/GJ 1111
- Balmer continuum emission detected from flare star
    - First such detection from a stellar chromosphere?
- The Balmer continuum/jump not a clean diagnostic
    - Our ability to detect accretion onto diskless stars is limited

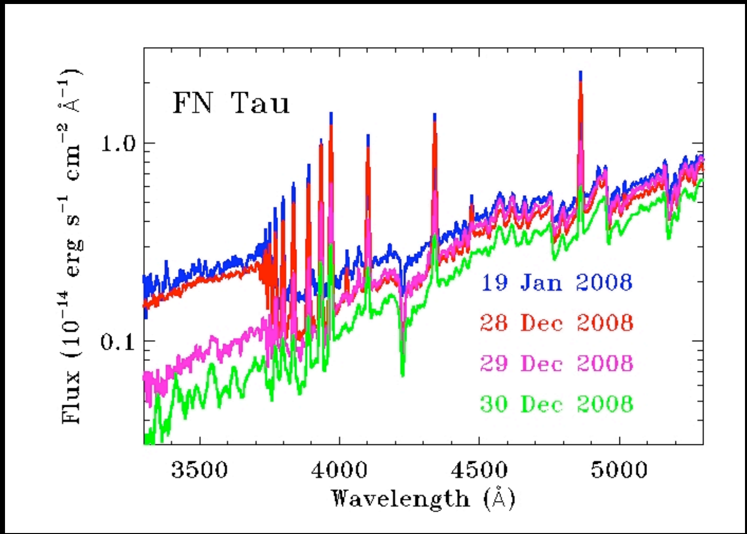
Disk but no detectable accretion?

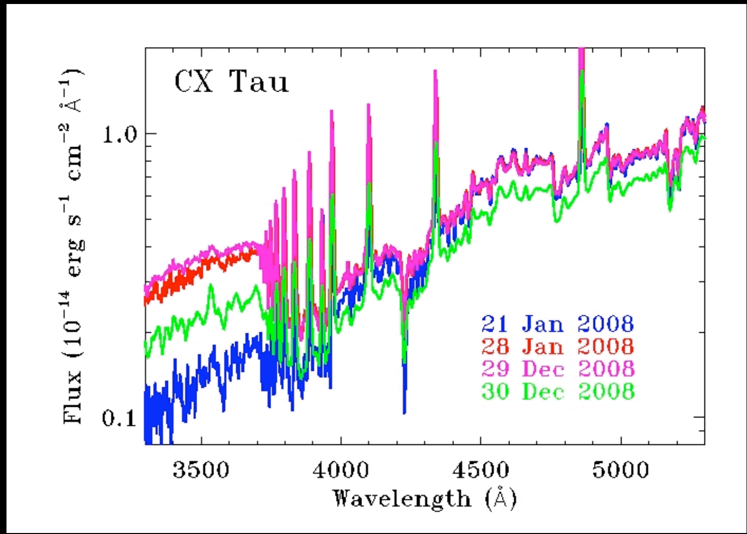
- Cleared inner hole
  - CoKu Tau/4
- CTTS/WTTS binary
  - CZ Tau: bright disk around secondary (McCabe et al. 2006)
- Variability
  - FN Tau sometimes shows no accretion
  - Little accretion on IM Lup

Variable accretion

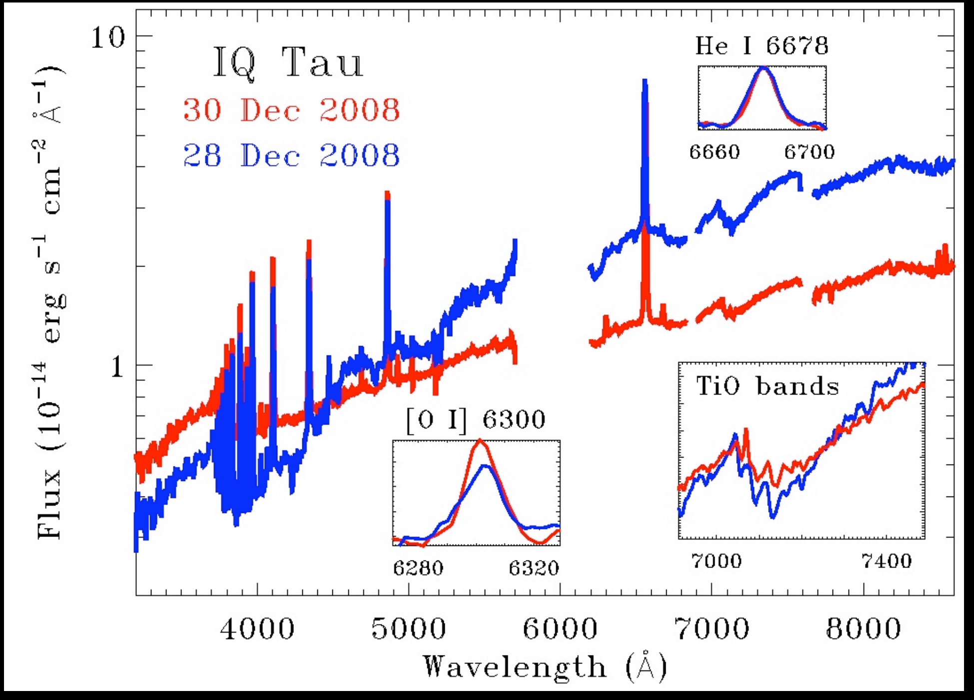








AA Tau-like variability of IQ Tau?



- Observations separated by 2 nights
- Obscured photosphere (extinction?)
- Increased accretion rate
- No change to He I, [O I] line fluxes

Uncertainties in accretion rates

$$\dot{M} = \left(1 - \frac{R_*}{R_{in}}\right)^{-1} \frac{L_{acc} R_*}{G M_*} \sim 1.25 \frac{L_{acc} R_*}{G M_*}$$

- Systematic uncertainties:
  - Bolometric correction in accretion luminosity
  - PMS tracks
  - Factor of 2 for radiative transfer (Hartigan et al. 1995)
  - Inner truncation radius (or random?)
  - Exclusion of emission lines (especially for BDs)

- Random uncertainties:
  - Extinction, Distance (Lacc, R)

- Methodological uncertainties for other, indirect measures of accretion
  - Scatter in emission line-accretion luminosity relationship (0.2-0.8 dex)
  - Uncertainties in origin of line emission

Conclusions

- The UV excess is a useful and direct probe of accretion for young low-mass stars
  – No clear separation between accreting and naked TTSs
  – Some closeted accretors may not show emission when we look
  – Chromospheric flaring can produce excess Balmer continuum emission

- Time domain is essential for understanding accretion
  – Single-band photometry (COROT, Favata et al.)
  – Low-resolution (here, but limited)
  – High resolution (AA Tau, Bouvier; Nguyen et al. (2009) in Jayawardhana's talk)