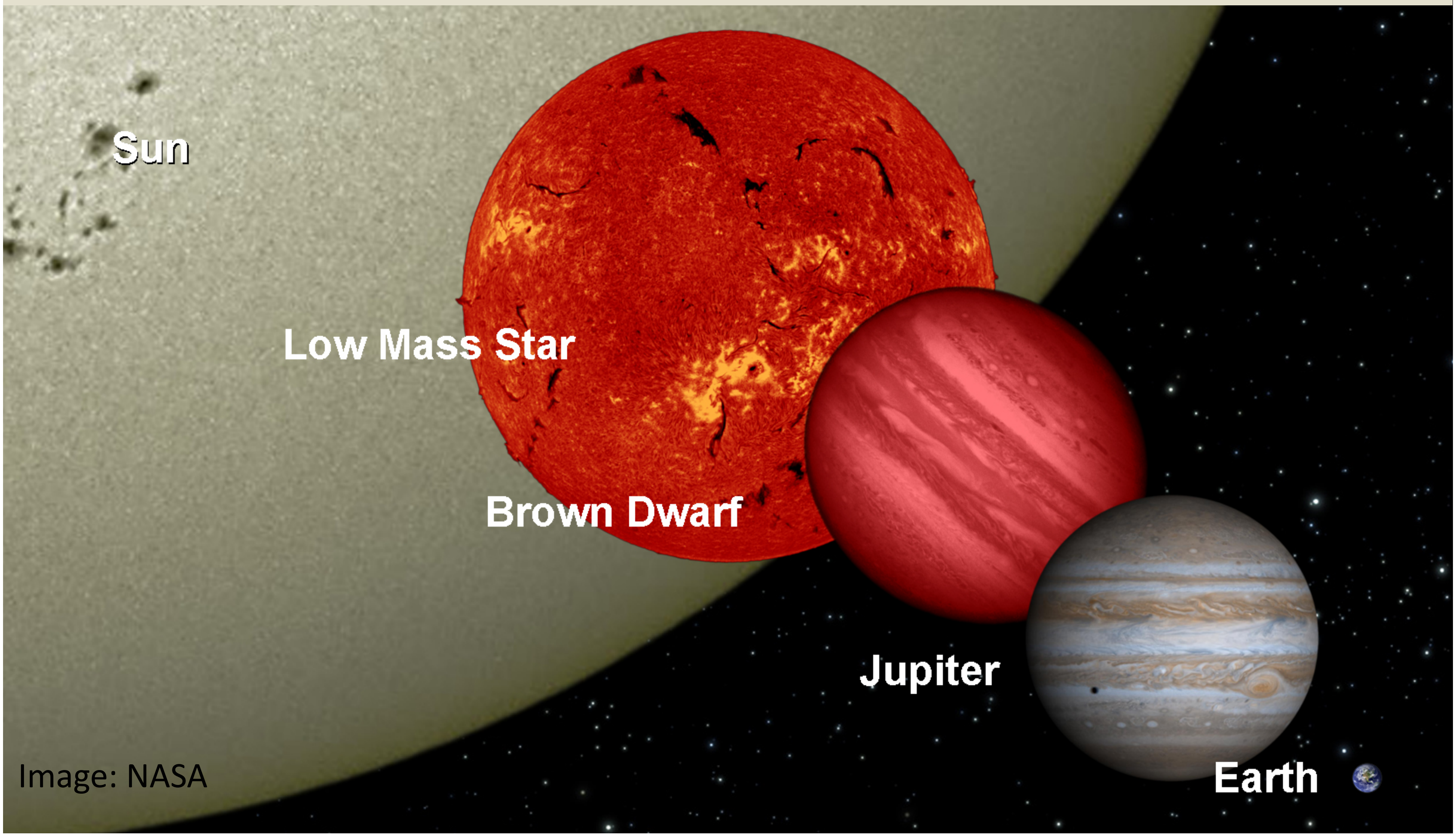
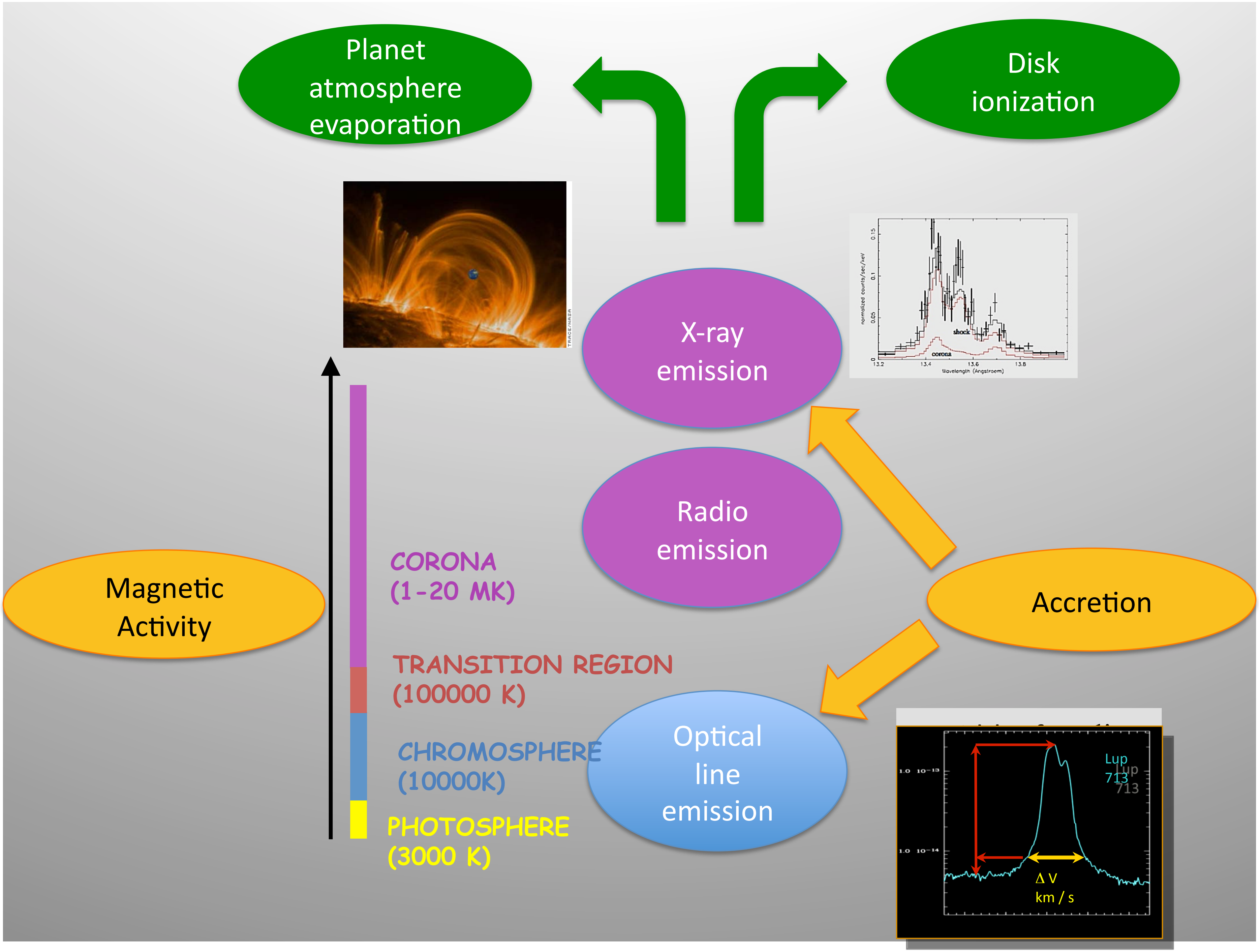
Magnetic activity and accretion in low-mass stars and brown dwarfs

Beate Stelzer (INAF – OAPa)




Planet atmosphere evaporation
Disk ionization
X-ray emission
shock
corona
Radio emission
Magnetic Activity
CORONA
(1-20 MK)
TRANSITION REGION
(100000 K)
CHROMOSPHERE
(10000K)
PHOTOSPHERE
(3000 K)
Accretion
Optical line emission
Lup 713
Δ V
km / s

Magnetic activity at the bottom of the stellar sequence and beyond

Ultracool dwarfs (UCDs)
= objects with SpT equal or later M7

Substellar objects
= Brown Dwarfs
= objects unable to burn hydrogen

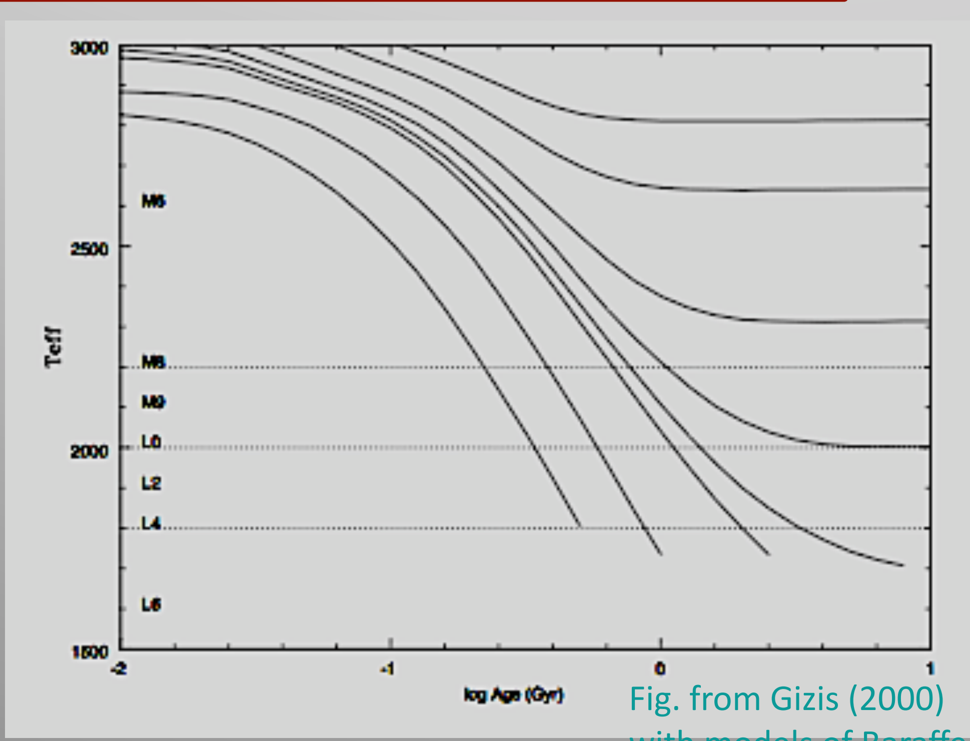


Fig. from Gizis (2000) with models of Baraffe et al. (1998)

Stars

Brown dwarfs

Late M and early-L SpT can be star or a brown dwarf depending on age

Young "ultracool" dwarfs are brown dwarfs

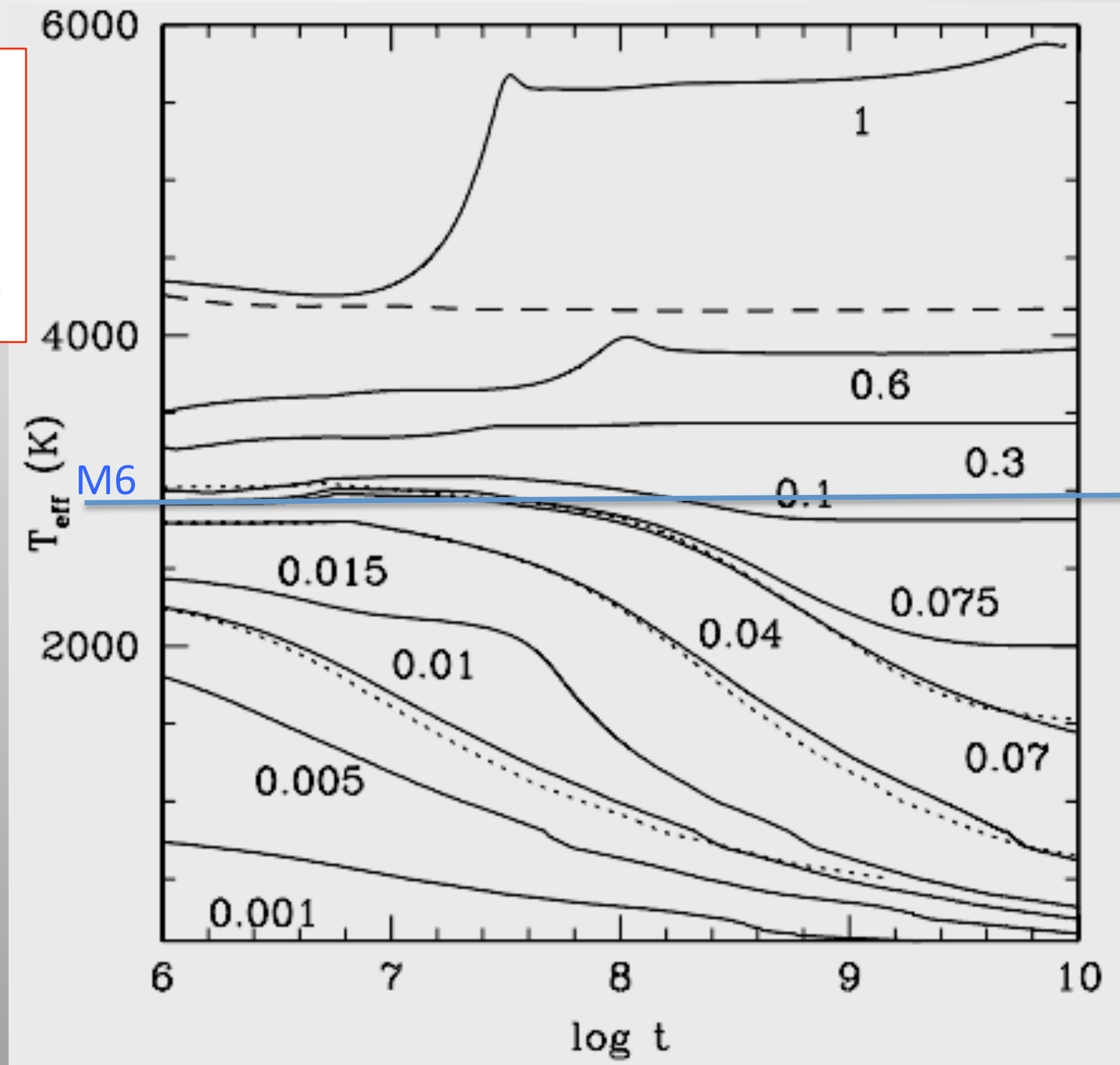
Any object at ~1 Myr
with SpT > M6
is substellar

→ "Brown Dwarf Candidate"

YOUNG AGE:
Low-mass pre-MS stars
and brown dwarfs
are fully convective

OLD AGE:
Low-mass stars become
Fully convective at ~ M3

→ Same dynamo in all ?



Chabrier & Baraffe (2000)

Can VLM stars and brown dwarf atmospheres be heated ?

Suppose: magnetic stress is generated in photosphere (τ ~ 1)
and transported to chromosphere + corona

Question: How much magnetic energy can be generated in photosphere of VLM stars / BDs ?

What is the magnetic Reynolds number ?

Length scale

Convective velocity

Magnetic Reynolds-number $R_m = \frac{\nabla \times (v \times B)}{\eta \nabla^2 B} = \frac{lv}{\eta}$

diffusivity

$$\eta = \frac{c}{4\pi\lambda} \qquad \lambda \longrightarrow \infty \quad R_m \longrightarrow \infty \qquad \lambda \longrightarrow 0 \quad R_m \longrightarrow 0$$

Possibly in UCD atmospheres the conductivity λ is very low

→No currents $j \sim \lambda E$

→ $\nabla \times B = \frac{4\pi}{c} j = 0$

→ $B = \nabla \Phi$ (potential field = state of minimum energy → there is no free energy)

Dynamo number $N_D = N_\alpha \cdot N_\Omega = \frac{\alpha L}{\beta} \cdot \frac{\nabla \Omega L^2}{\beta}$ $\qquad N_D \sim \frac{1}{R_0^2}$ $\qquad R_0 = \frac{P_{rot}}{\tau_{conv}}$

…ratio between induction and diffusion terms

Activity/accretion and age in the VLM regime

Young brown dwarfs (~ 1 Myr) are

- warm

  significant ionization in atmosphere that enables coupling matter-field

- bright

  If magnetic activity saturates,

  i.e. $\log\left(\frac{L_x}{L_{bol}}\right) = const.$

  bright activity signatures easy to detect

- far (>140pc)

  faint signal

- ongoing accretion

  need to disentangle accretion vs activity signatures

Old ultracool dwarfs (Gyr) are

- cool

  little ionization in atmosphere, coupling matter-field questionable

- faint

  If magnetic activity saturates,

  i.e. $\log\left(\frac{L_x}{L_{bol}}\right) = const.$

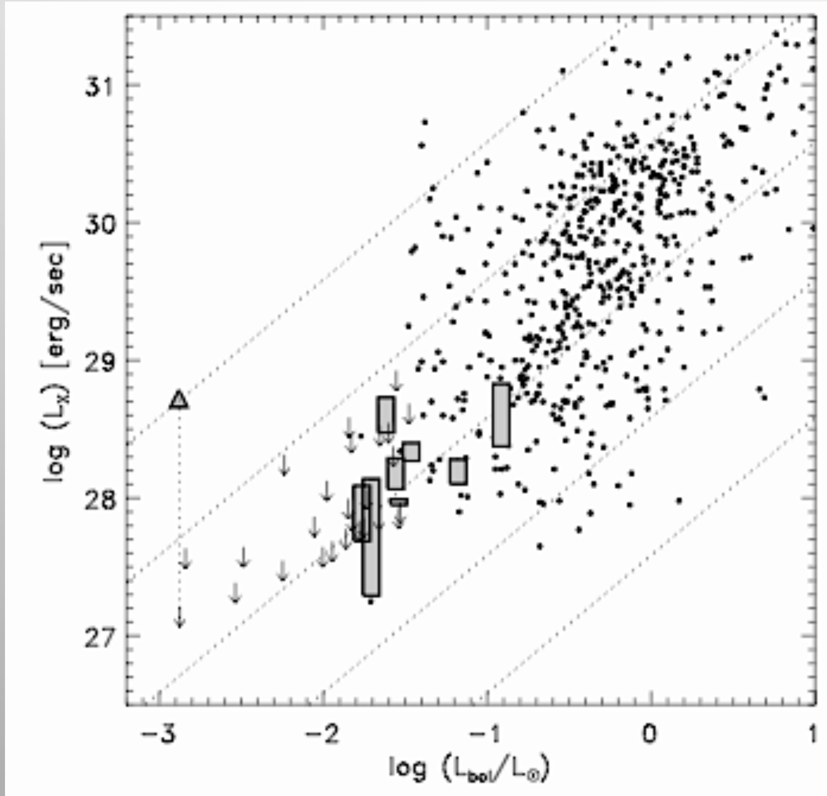
  faint activity signatures difficult to detect

- nearby (many in 10…20 pc)

  good signal

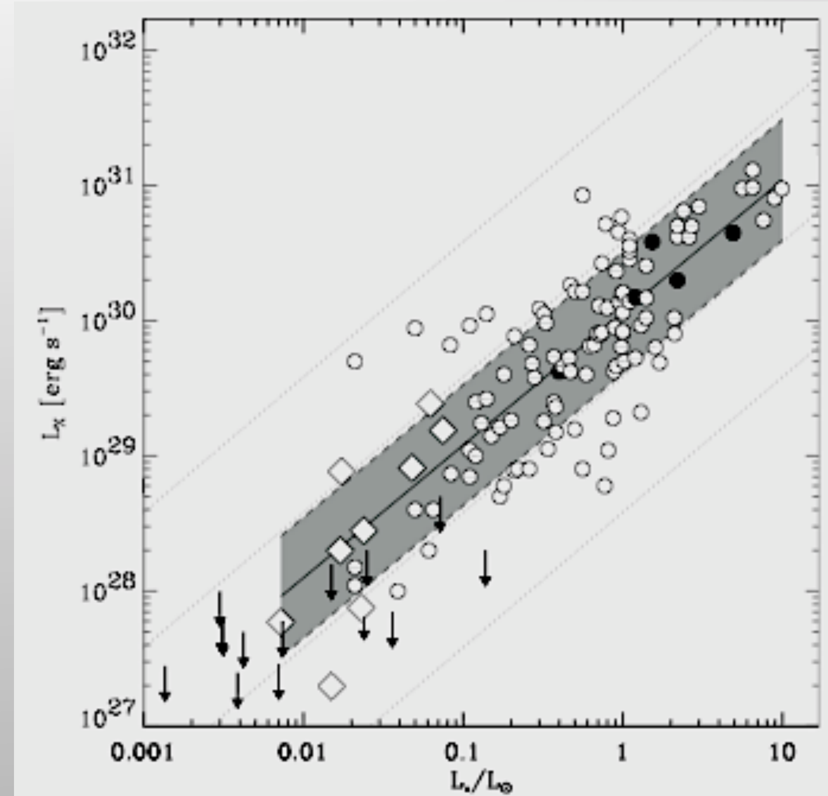
X-ray vs. bolometric luminosity for young BDs

COUP (Chandra Orion Ultradeep project)



Preibisch et al. (2005)

XEST (XMM Extended Survey in Taurus)



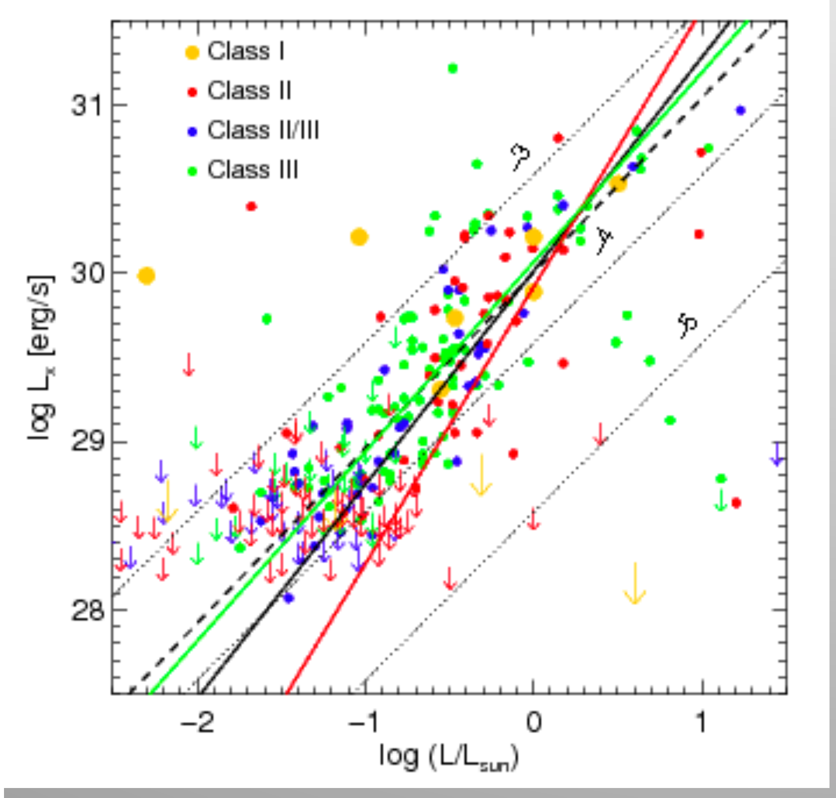
Grosso et al. (2007)

In Orion L_x / L_{bol} of BDs identical to higher-mass stars, in Taurus lower ?

X-ray vs. bolometric luminosity for young BDs

Open cluster IC 348:
Age = 2-3 Myr
Dist = 320 pc
> 300 opt/IR members

4 Chandra pointings in IC348
Partially overlapping (t_{max} ~ 180ksec)



PROPERTIES	*Infalling Protostar*	*Evolved Protostar*	*Classical T Tauri Star*	*Weak-lined T Tauri Star*	*Main Sequence Star*
SKETCH					
AGE (YEARS)	10^4	10^5	$10^6 - 10^7$	$10^6 - 10^7$	$> 10^7$
mm/INFRARED CLASS	Class 0	Class I	Class II	Class III	(Class III)
DISK	Yes	Thick	Thick	Thin or Non-existent	Possible Planetary System
X-RAY	?	Yes	Strong	Strong	Weak
THERMAL RADIO	Yes	Yes	Yes	No	No
NON-THERMAL RADIO	No	Yes	No ?	Yes	Yes

Stelzer et al. (2011), A&A in press

In IC348: L_x / L_{bol} steeper than in ONC

In IC348: L_x / L_{bol} steeper for Class II than for Class III

X-ray vs. bolometric luminosity for young BDs

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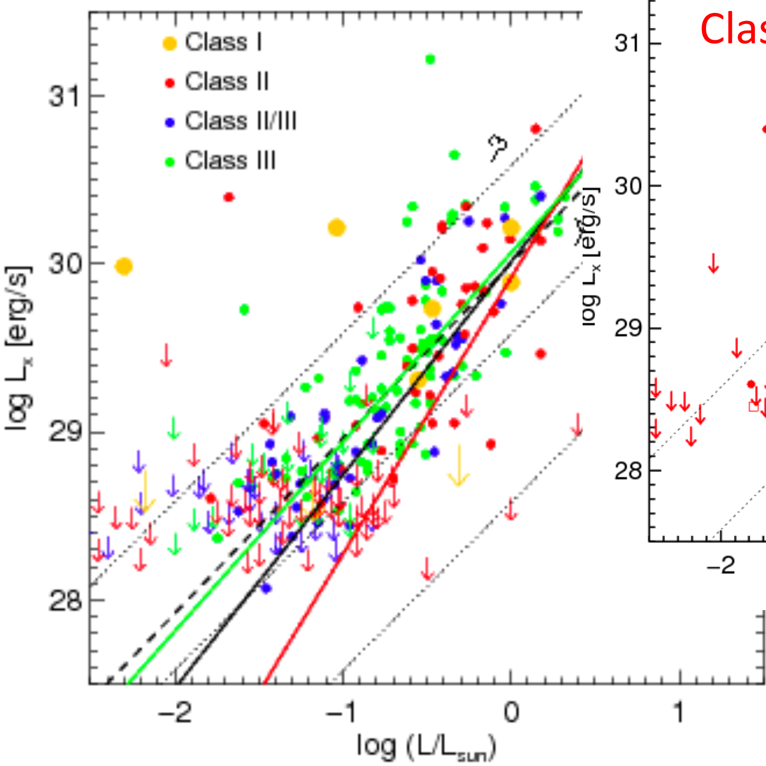
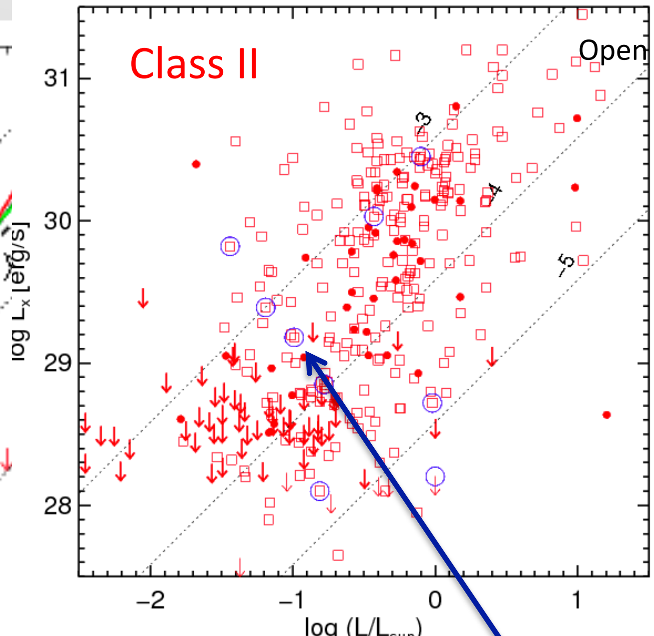
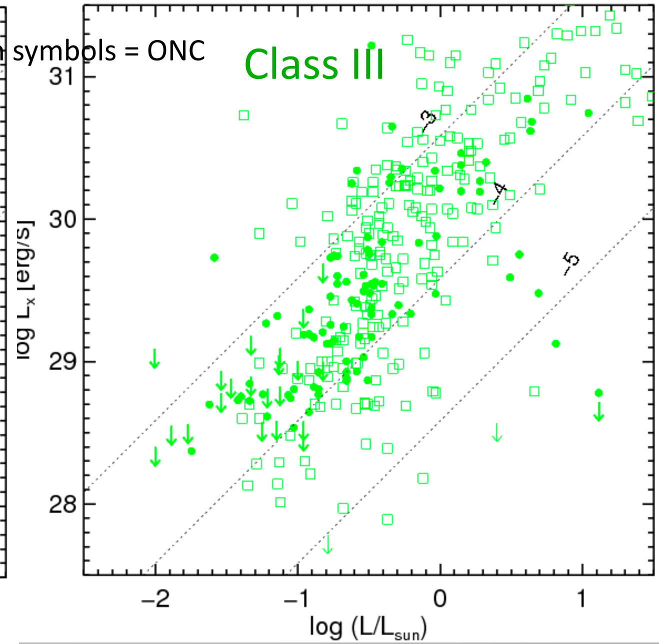




Open symbols = ONC



Stars with warped disk
(Morales-Calderon et al. 2011)

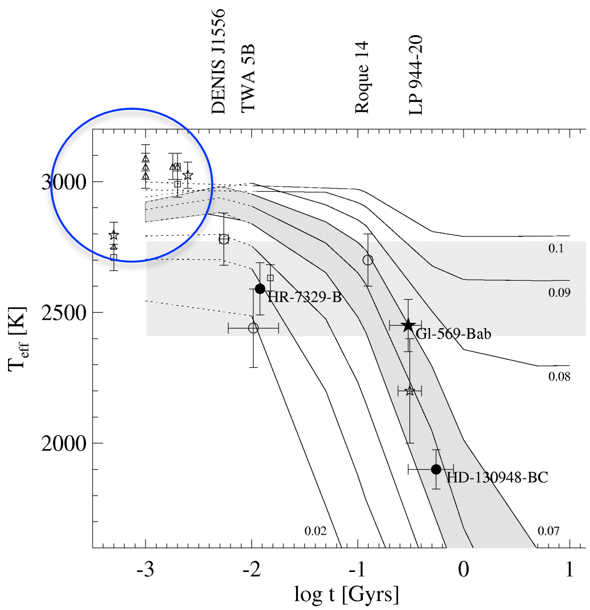
Stelzer et al. (2011), A&A in press

In IC348: L_x/L_{bol} steeper than in ONC

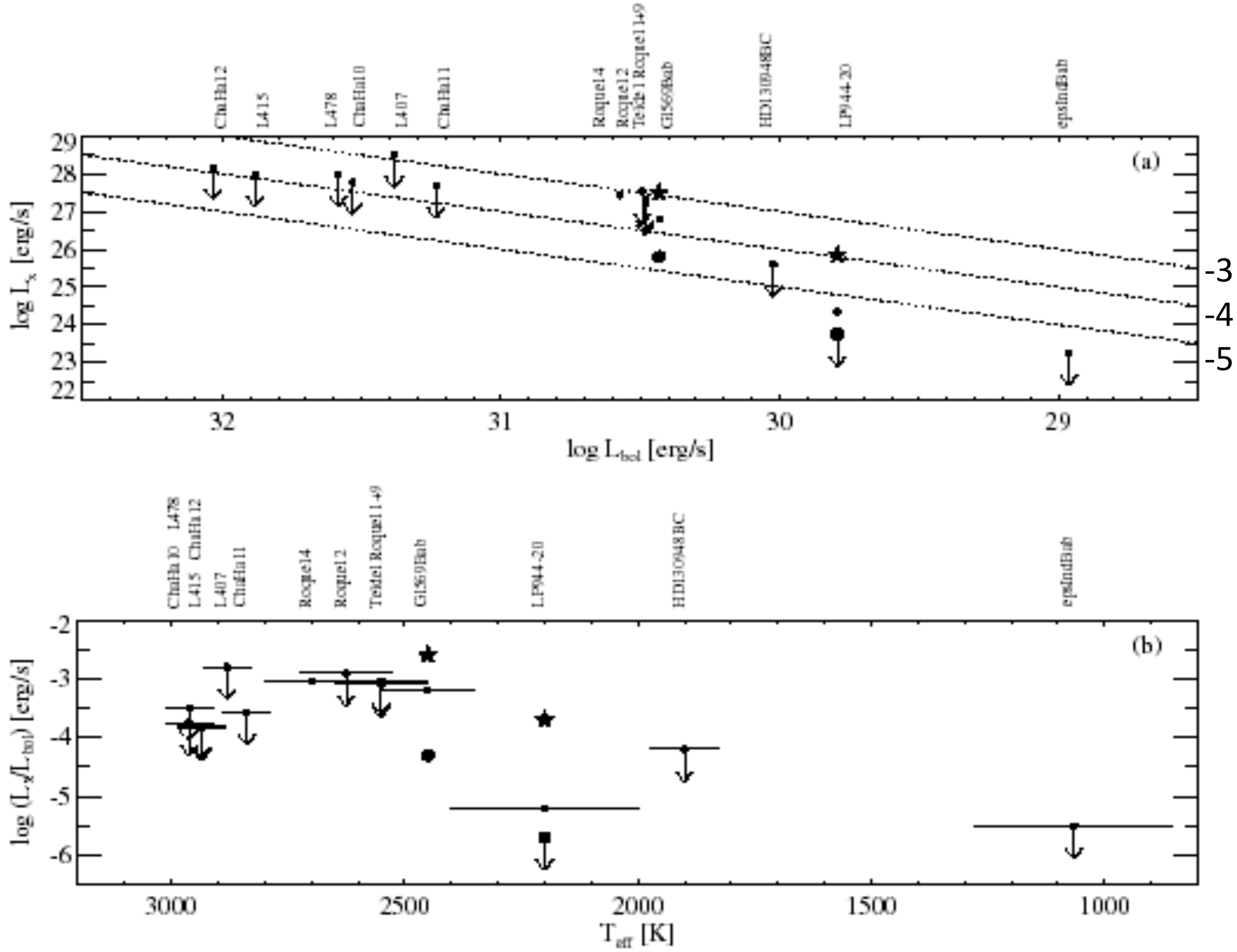
L_x/L_{bol} dependence on YSO state may be universal.

In IC348: L_x/L_{bol} steeper for Class II than for Class III

X-ray vs. bolometric luminosity for evolved BDs



BDs with 0.05-0.07 M_{sun}

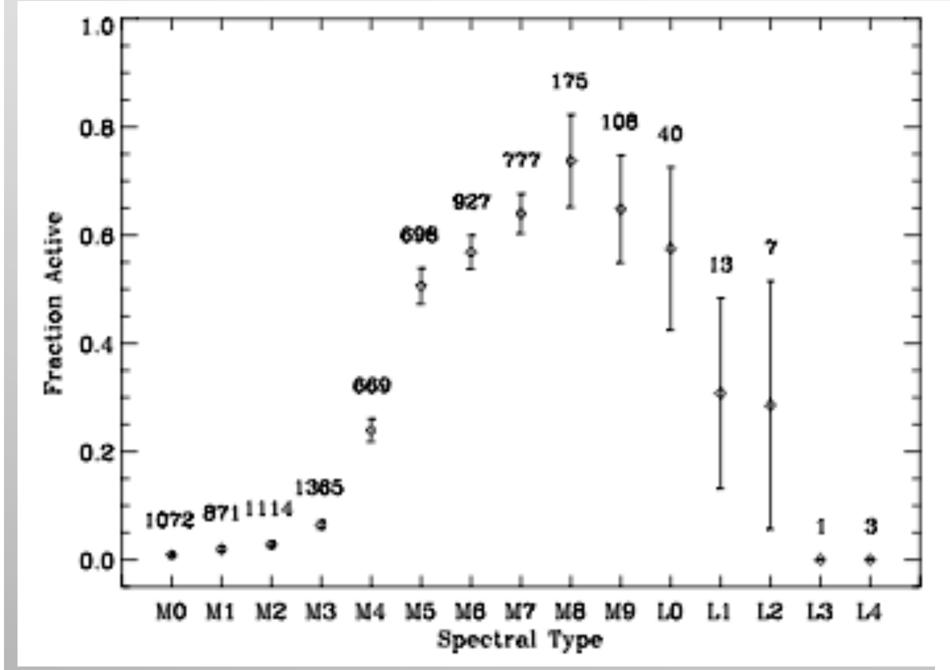


Only upper limits shown for young BDs in star forming regions because all detected young BDs are above model isochrones and stellar parameters unconstrained

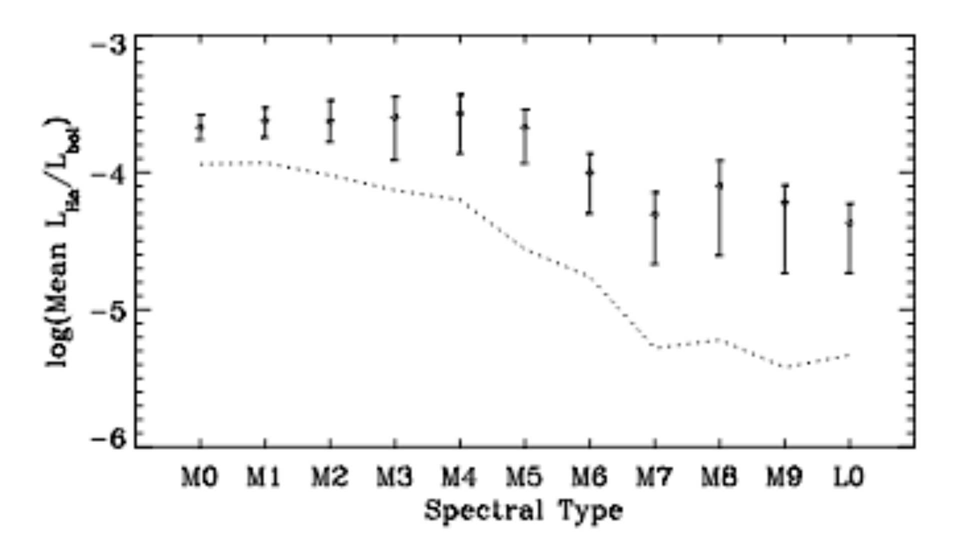
- L_x /L_{bol} decreases for faintest BDs
- decrease due to low T_{eff} ?

Stelzer et al., (2006a)

Hα vs. bolometric luminosity for evolved UCDs



Sloan Digital Sky Survey (SDSS) yields large number of M/L stars:
1910 Hα active stars,
5930 Hα inactive stars

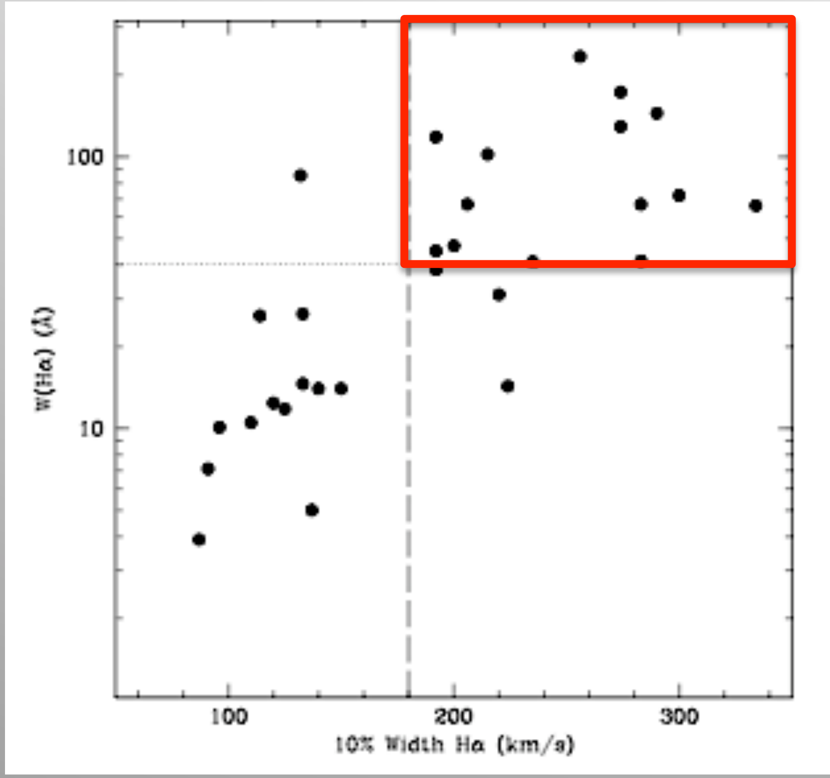


West et al., (2004)

- maximum fraction of active stars:
  ~ M7…M8
- at peak
  ~ 73 % active in SDS
- $L_{h\alpha}/L_{bol}$ decreases around M5..M7

Hα emission from young brown dwarfs: Accretion vs. chromosphere

Hα spectroscopy for 39 VLM stars and BDs
In Taurus and Cha I (Muzerolle et al. 2005):



→ 17 accreting VLM objects
11 of which are BDs

Empirical boundary between accretion and chromospheric activity for SpT later M6 based on Hα emission
(White & Basri 2003)

- $v_{H\alpha;10\%} > 270 km/s$
- $W_{H\alpha} > 40\mathring{A}$

But: many young brown dwarfs have $v_{10\%} < 270$ km/s although $W_{h\alpha} > 40$ AA

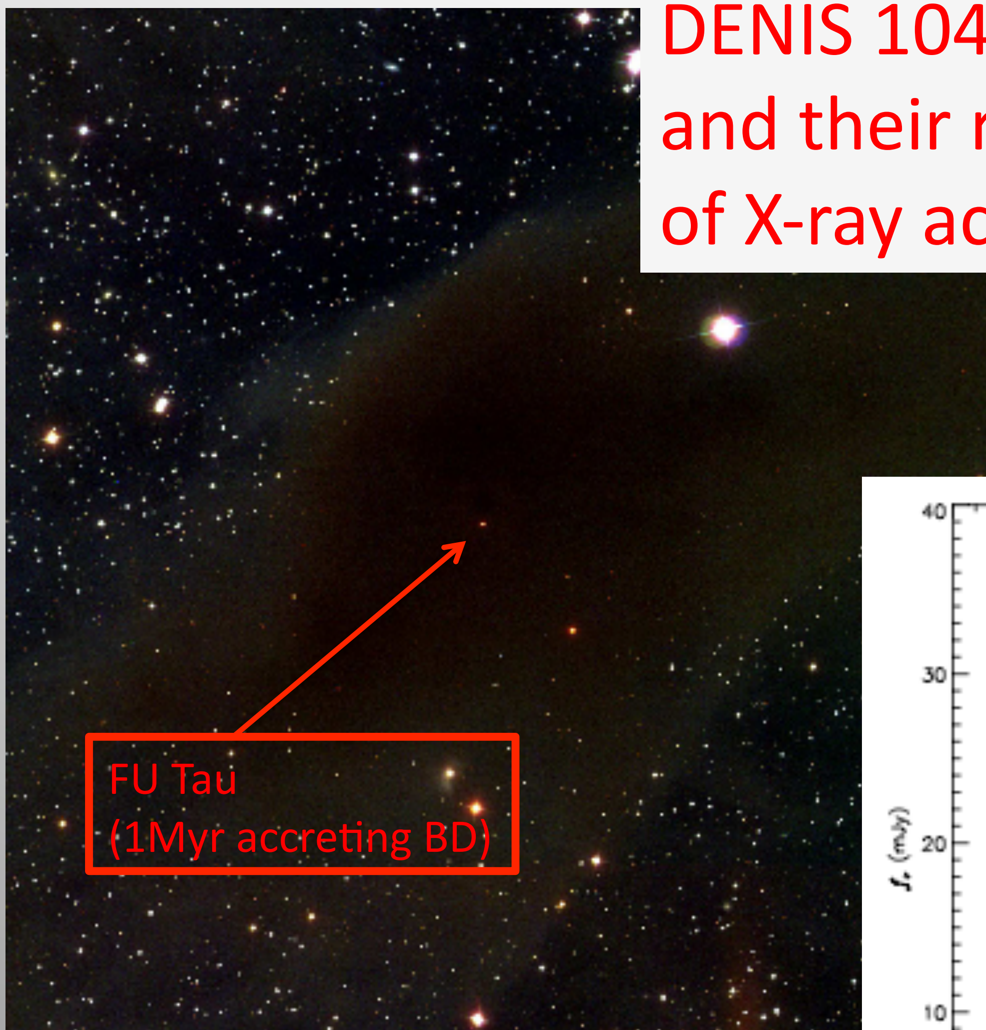
due to lower infall velocities for lower mass

$$v_{ff} = \sqrt{\frac{2GM_\star}{R_\star}}$$

→ line width criterium must be lowered to $v_{H\alpha;10\%} > 180...200 km/s$

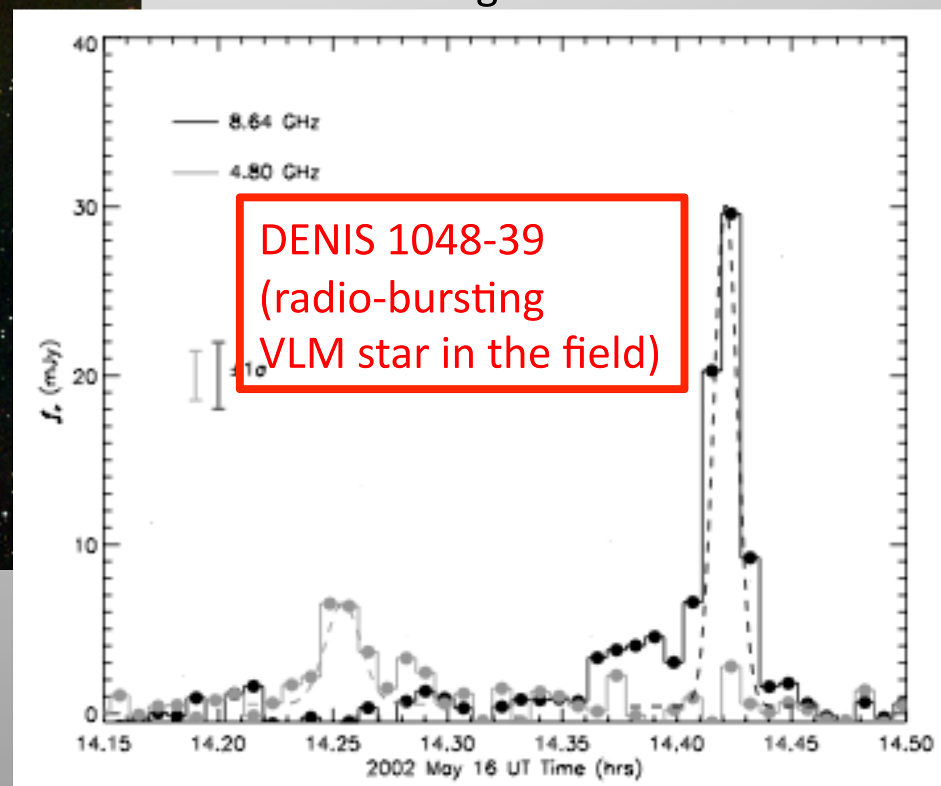
DENIS 1048-39 and FU Tau A, and their role within the class of X-ray active very low-mass objects

SDSS 0.5 x 0.5 sq.deg



Luhman et al. (2009)

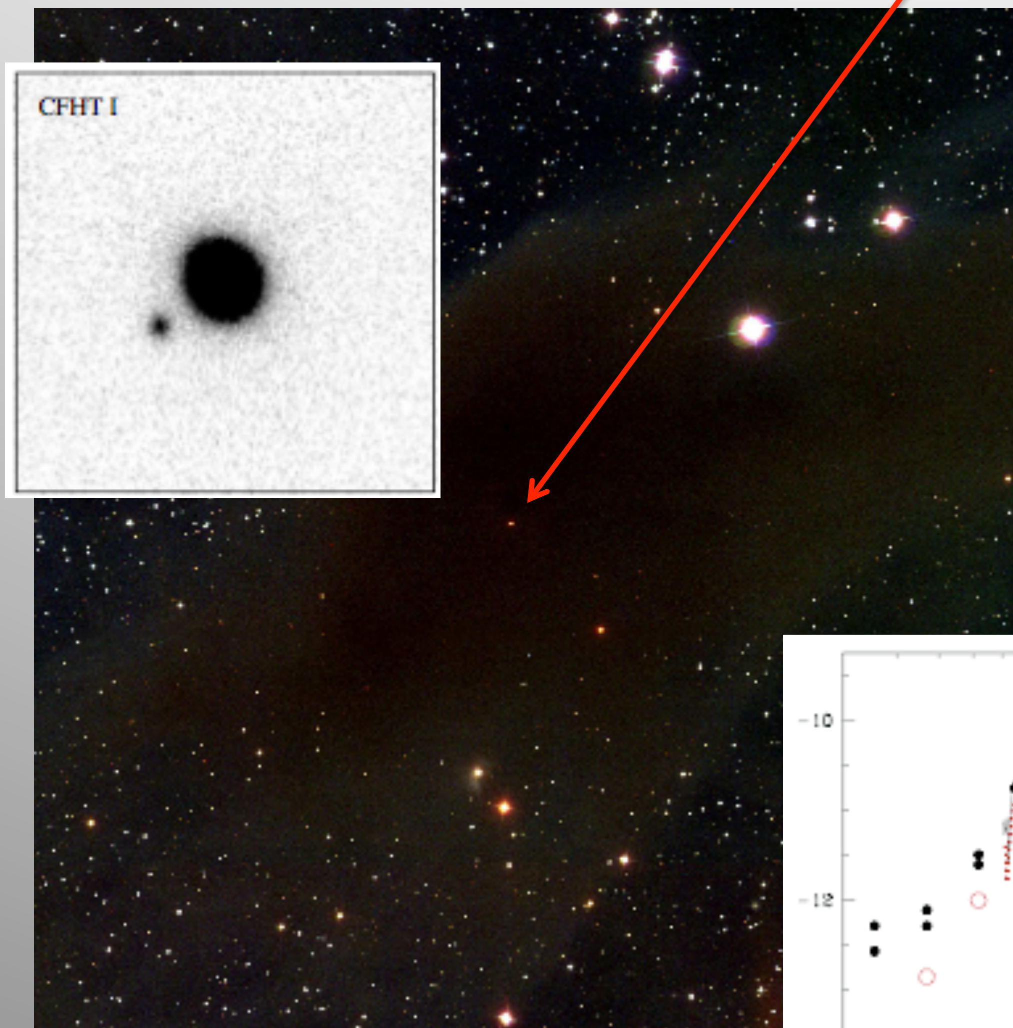
Radio lightcurve



Burgasser et al. (2005)

The enigmatic benchmark Brown Dwarf FU Tau

SDSS 0.5 x 0.5 sq.deg



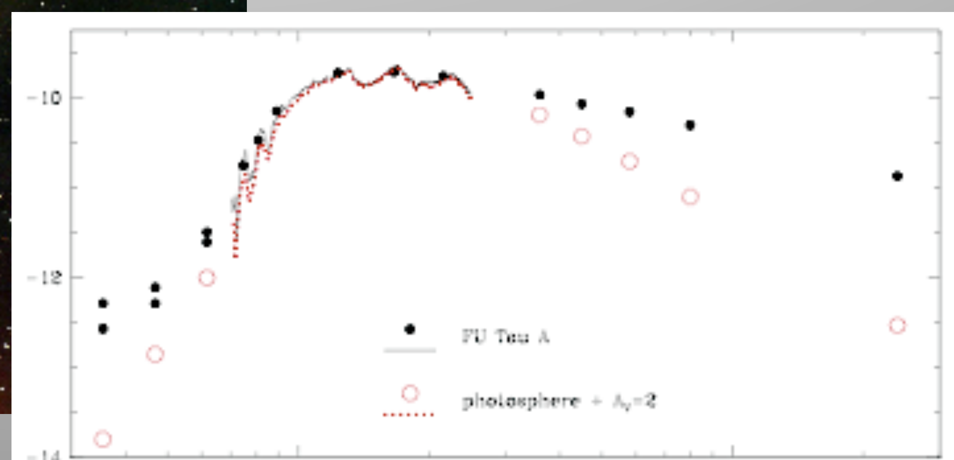
Luhman et al. (2009)

Isolated
wide brown dwarf binary (200AU);

most BD formation mechanisms involve nearby higher-mass stars (ejection, disk fragmentation, disk photo-evaporation)

M7.25 + M9.25 (A + B)

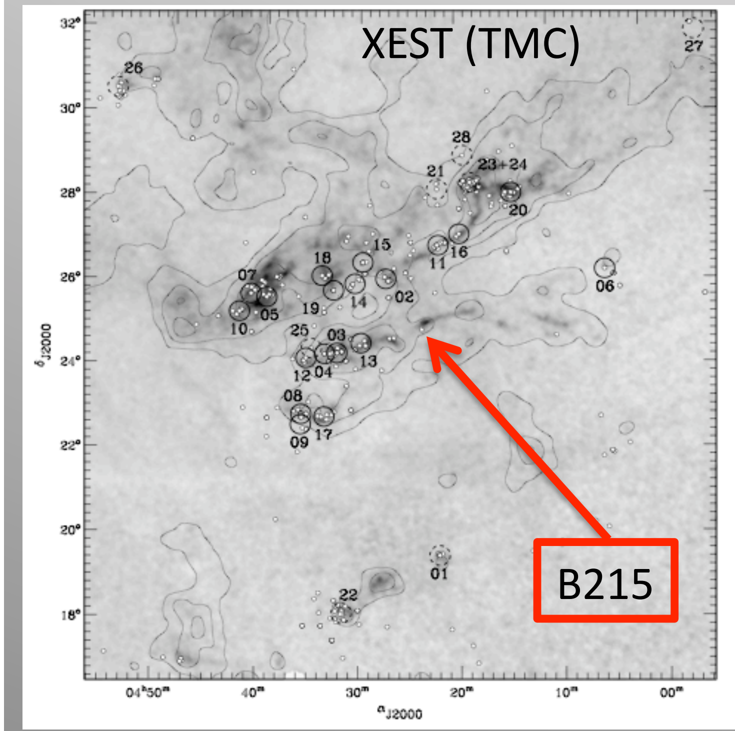
Blu and IR excess → disks

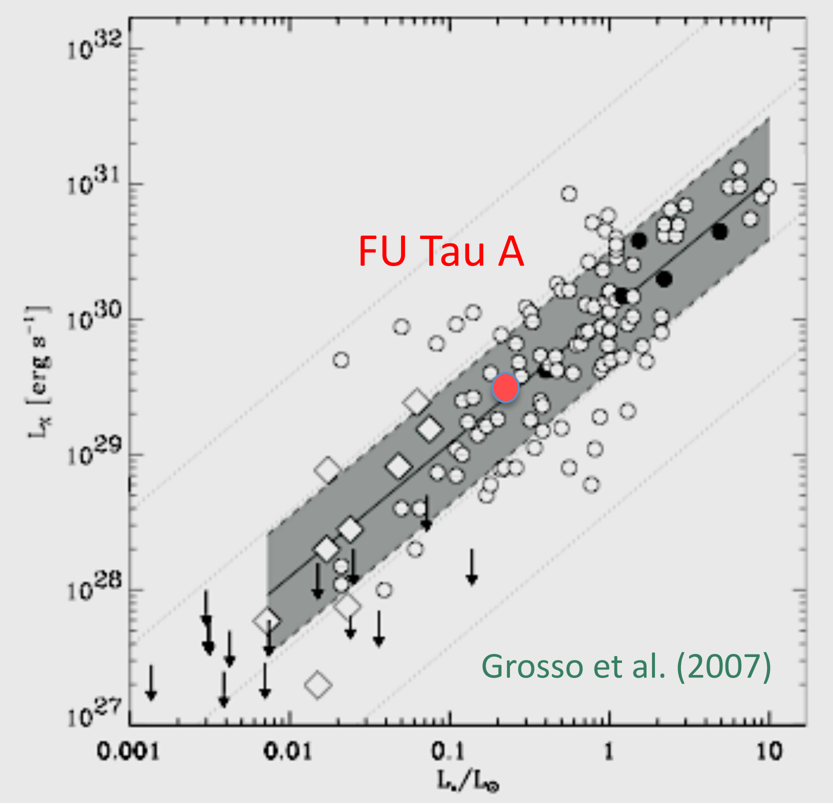


New observational material for FU Tau A

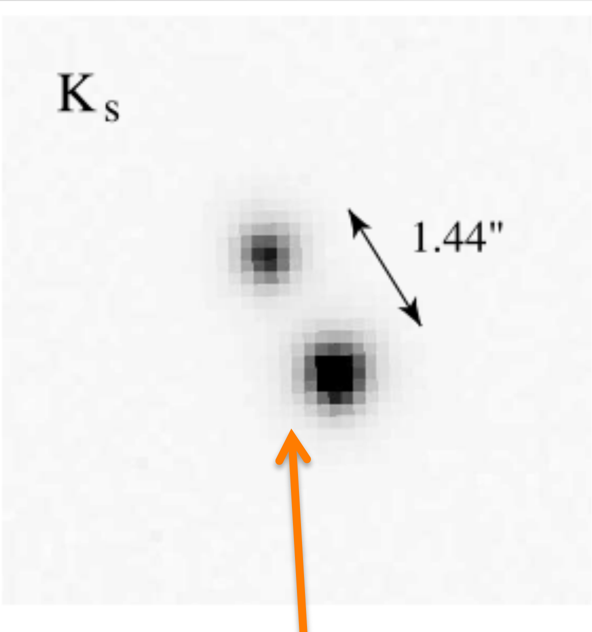
55 ksec Chandra/ACIS	from Oct 2009	Stelzer et al. 2011
~ 10d photometric monitoring on CAHA	from Dec 2010	Scholz et al., subm.
X-Shooter spectrum	from Jan 2011	analysis underway

FU Tau in the context of XEST

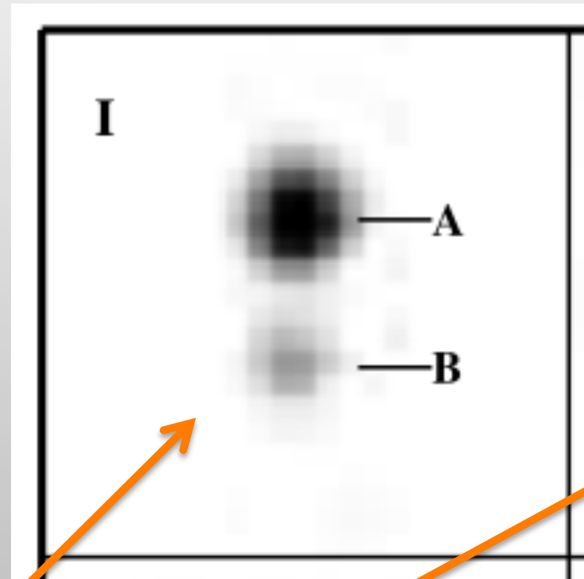




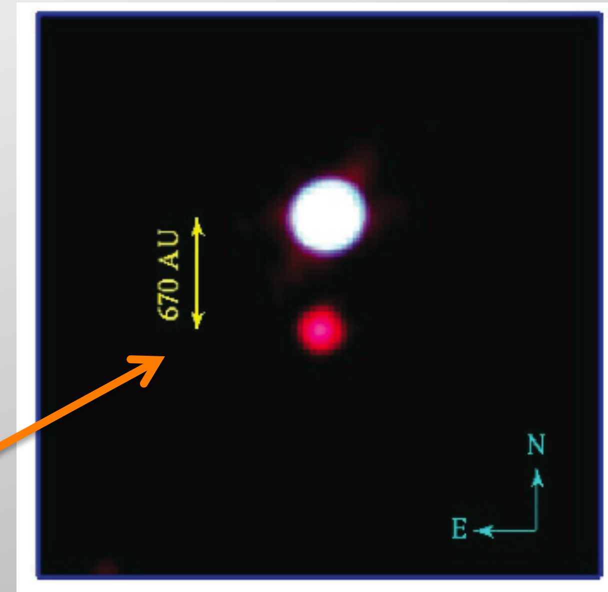
Known wide BD binaries



Luhman et al. 2004



Luhman et al. 2007;
Close et al. 2007;
Jayawardhana et al. 2006



Bejar et al. 2008

Name	dist [pc]	Age [Myr]	Sep [″]	A_V [mag] A	A_V [mag] B	SpT A	SpT B	M [$M_\odot$] A	M [$M_\odot$] B	Priority Chandra
Oph 1622-2405	145	~ 10	1.94	0.5	0.5	M7.25	M8.25	~ 0.055	~ 0.019	July10,2011
USco CTIO 108	145	~ 5	4.6	< 2	< 2	M7	M9.5	~ 0.057	~ 0.013	-2-
2M 1101-7732	160	~ 1	1.4	1.6	0	M7.25	M8.25	~ 0.05	~ 0.025	*observed*
FU Tau	140	< 1	5.7	2	< 1	M7.25	M9.25	~ 0.05	~ 0.015	*observed*

The enigmatic benchmark Brown Dwarf FU Tau

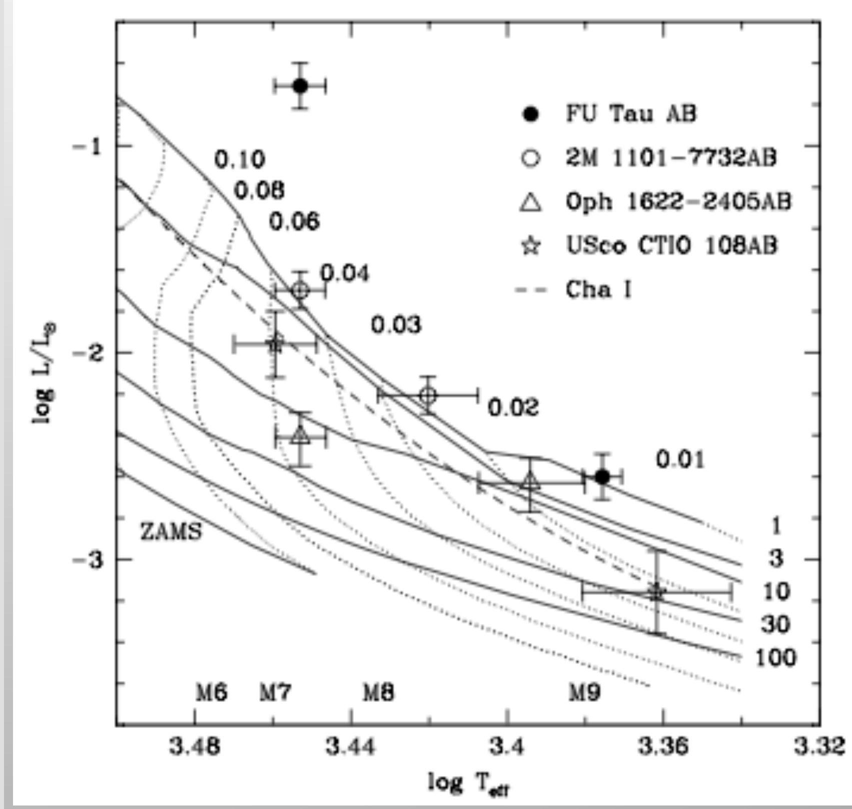
FUTau A is „peculiar“:
far above the evolutionary models
in the HR diagram
and not coeval with FUTau B

→ Extreme youth ?

→ Strong accretion (excess luminosity) ?

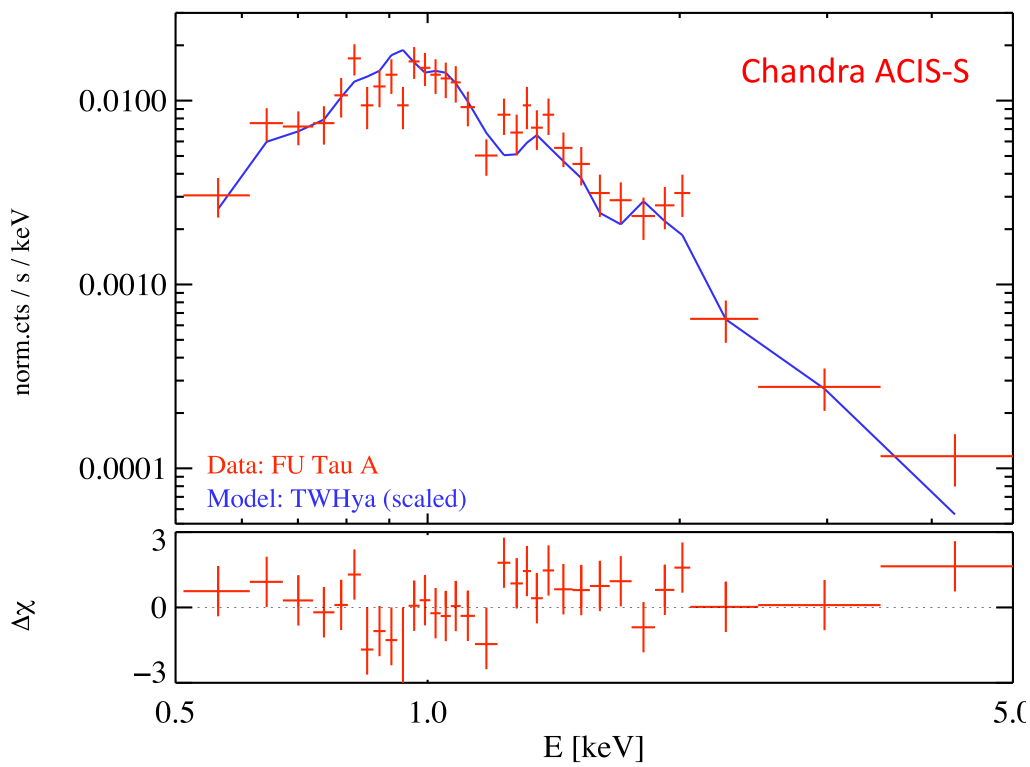
→ What is its mass ?
(„wrong“ T_{eff} due to reduced convection
or star spots;
Chabrier et al. 2007; MacDonald & Mullan 2009)

→ Foreground object ?



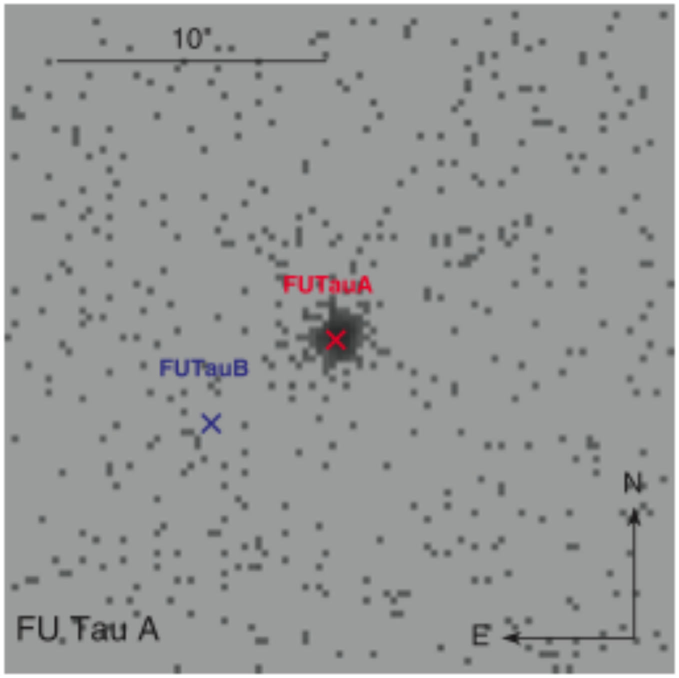
Luhman et al. (2009)

X-ray observation of FU Tau A

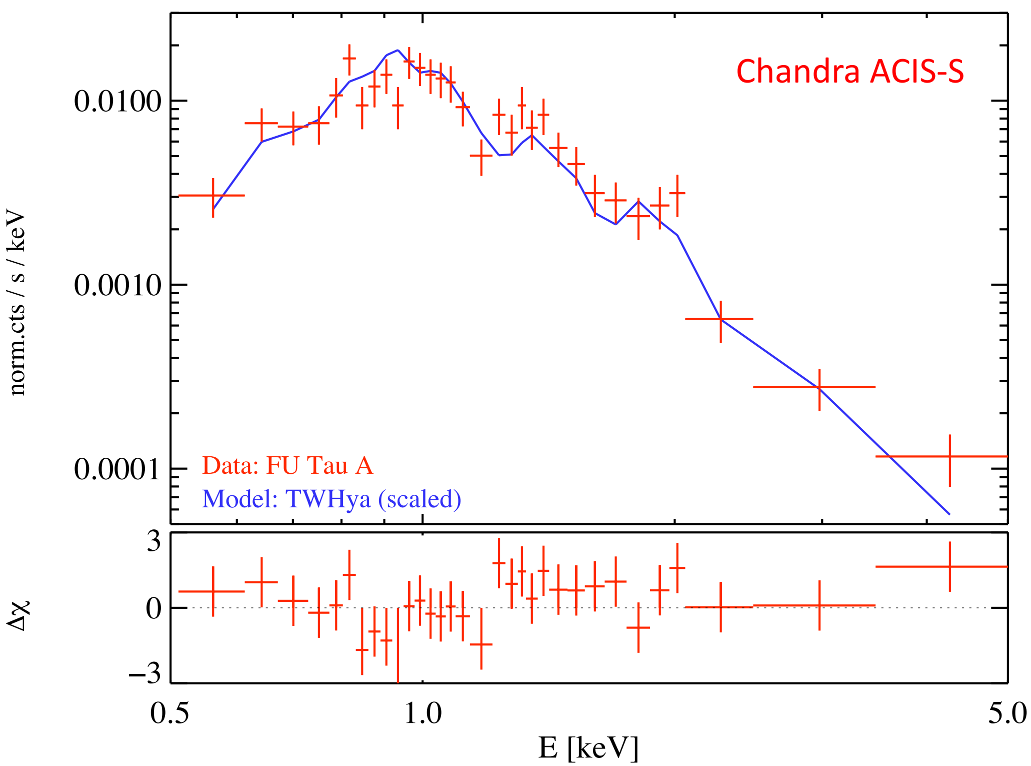


Stelzer et al. 2010

Highest quality X-ray data for a BD so far:
~ 600 cts for FUTauA



X-ray observation of FU Tau A
Emission from accretion shocks?



Stelzer et al. 2010

Highest quality X-ray data for a BD so far:
~ 600 cts for FUTauA

→Untypically low temperature (0.24 keV); as in the prototype accreting TTS TW Hya !

Brickhouse et al. 2010

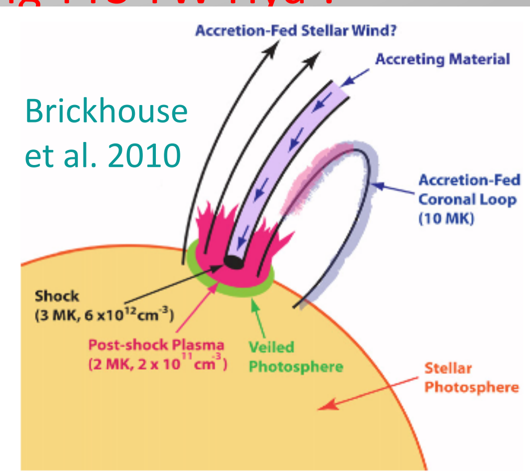
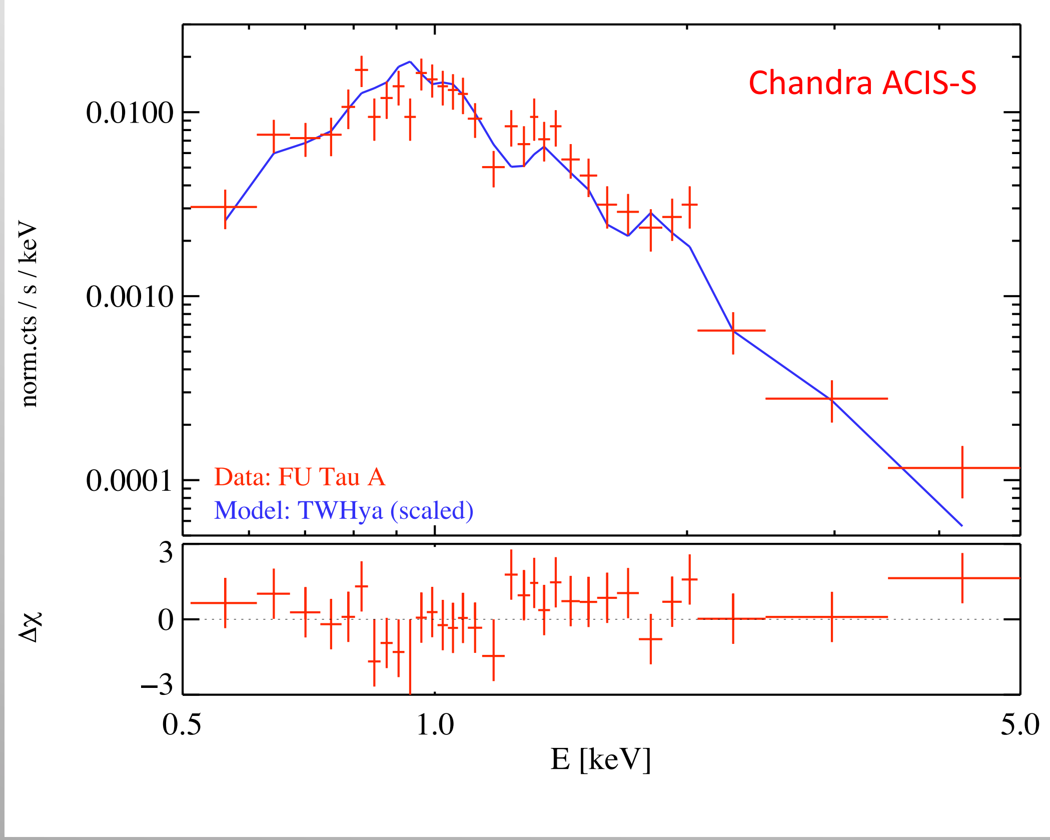


Table 2. X-ray spectral parameters of the absorbed 2-T APEC model for FU Tau A compare

Object	Instrument	χ^2_{red} (d.o.f.)	log N_H (cm^{-2})	kT_1 (keV)	kT_2 (keV)	l		
FU Tau A	*Chandra*/ACIS	0.9 (27)	$21.8^{21.9}_{21.5}$	$0.24^{0.34}_{0.19}$	$.12^{1.28}_{0.99}$	$52.9^{53.5}_{52.1}$	$52.3^{52.4}_{52.2}$	29.5
TW Hya[b]	*XMM–Newton*/EPIC-pn	2.3 (216)	20.8	0.23	1.22	53.0	52.2	29.8

X-ray observation of FU Tau A
Emission from accretion shocks?



Stelzer et al. 2010

Highest quality X-ray data for a BD so far:
~ 600 cts for FUTauA

→Untypically low temperature (0.24 keV); as in the prototype accreting TTS TW Hya !

X-rays from accretion diagnosed by

1) Soft spectrum

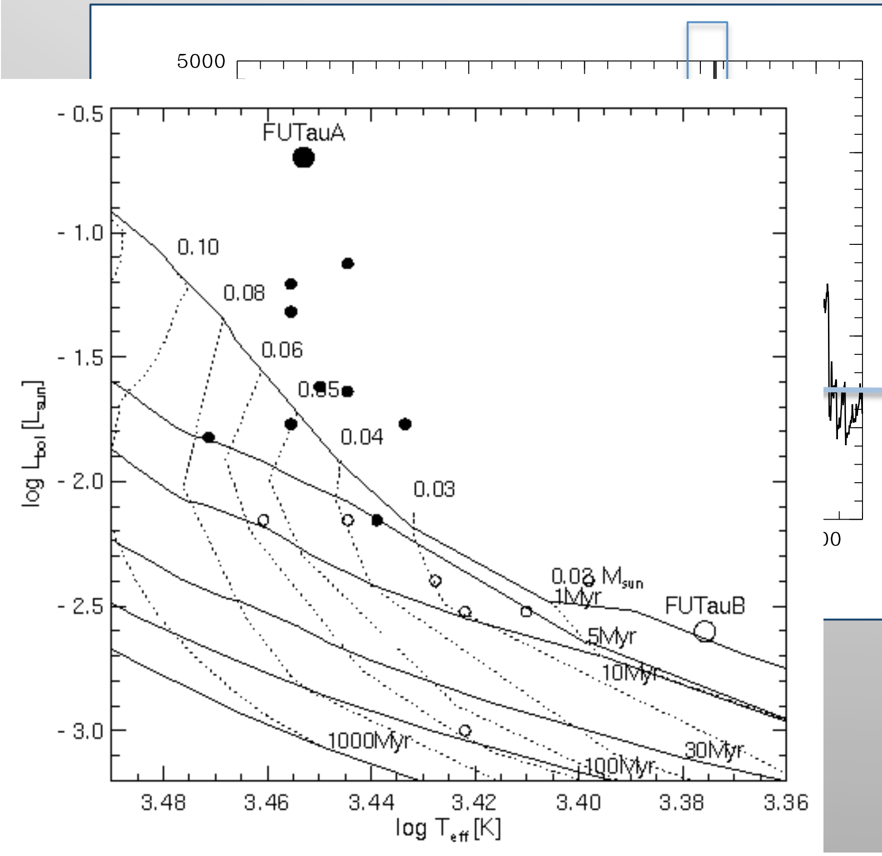
$$T_{\mathrm{psh}} = \frac{3}{16}\frac{\mu m_{\mathrm{p}}}{k_{\mathrm{B}}} v_0^2$$

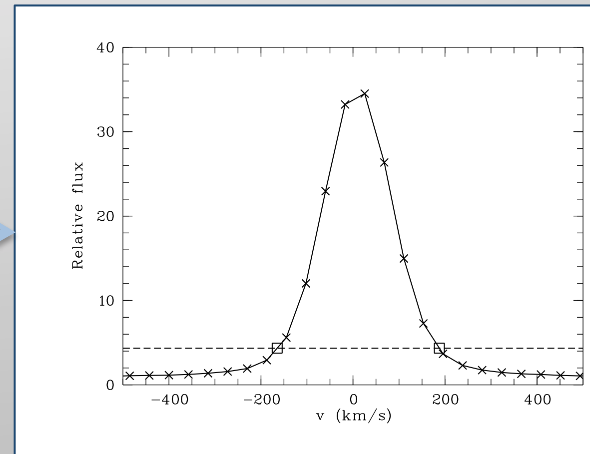
2) High density

What velocities are measured?

X-rays from accretion shock in FU Tau A ?

The velocity problem





Stelzer et al. (2010)

$$T_{\rm psh} = \frac{3}{16}\frac{\mu m_{\rm p}}{k_{\rm B}} v_0^2$$

$v_{H\alpha}$ ~ 175 km/s → T_{psh} ~ 0.03 keV << T_{obs}

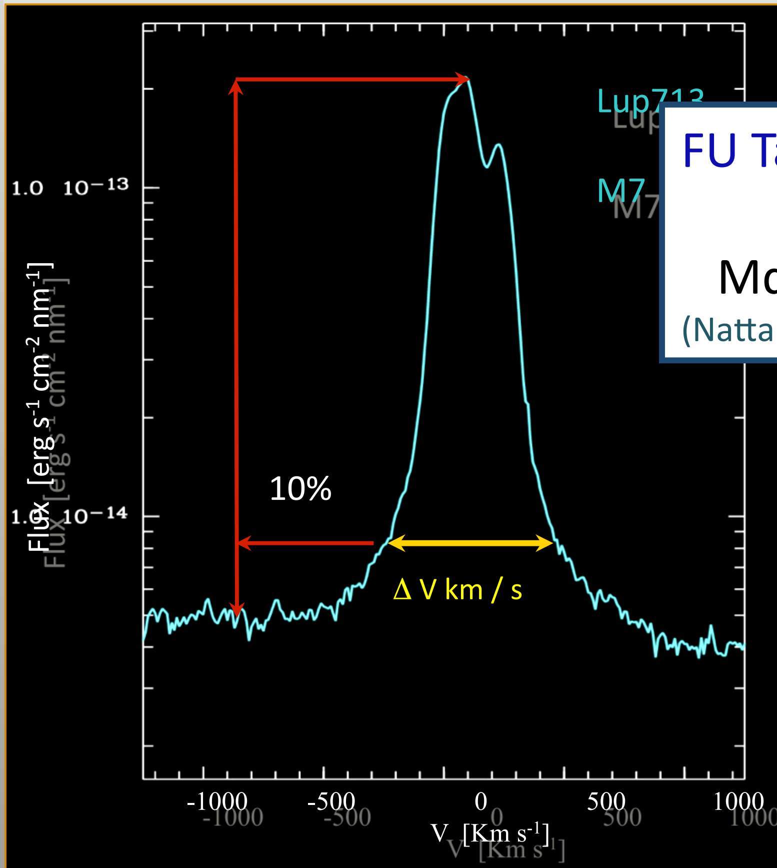
for M = 0.05 M_{sun}

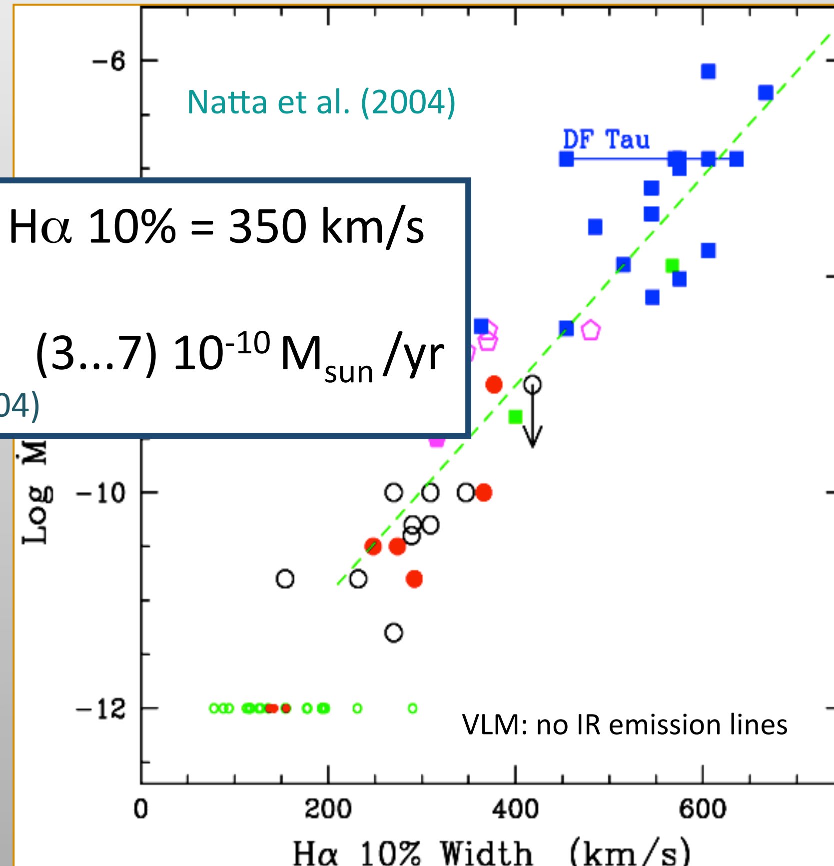
v_{ff} = SQRT(2GM/R) ~ 100 km/s < $v_{H\alpha}$

Diagnostics of mass accretion

10% width of Hα emission

width of Hα line @ 10% of peak





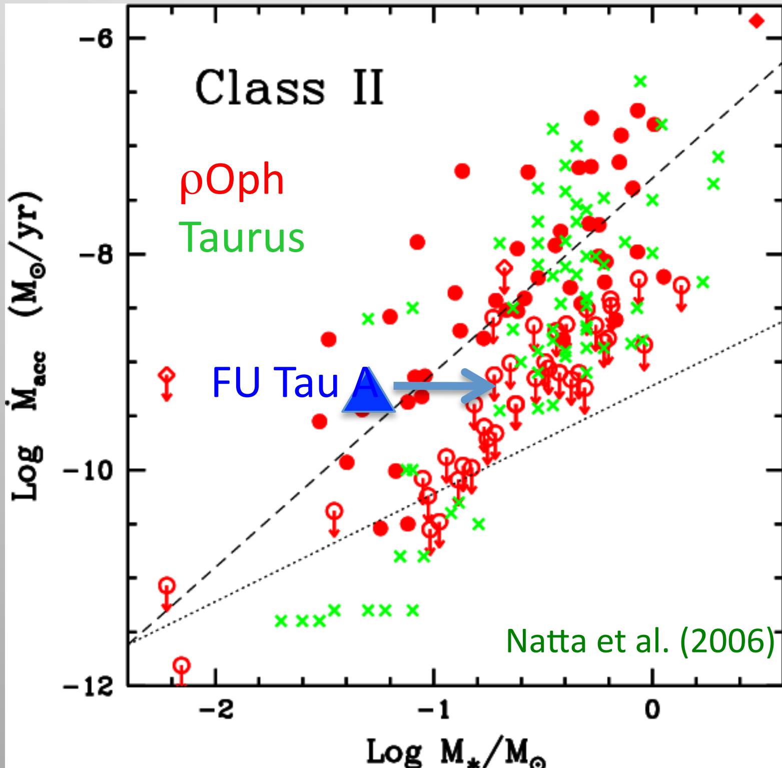
FU Tau A: Hα 10% = 350 km/s

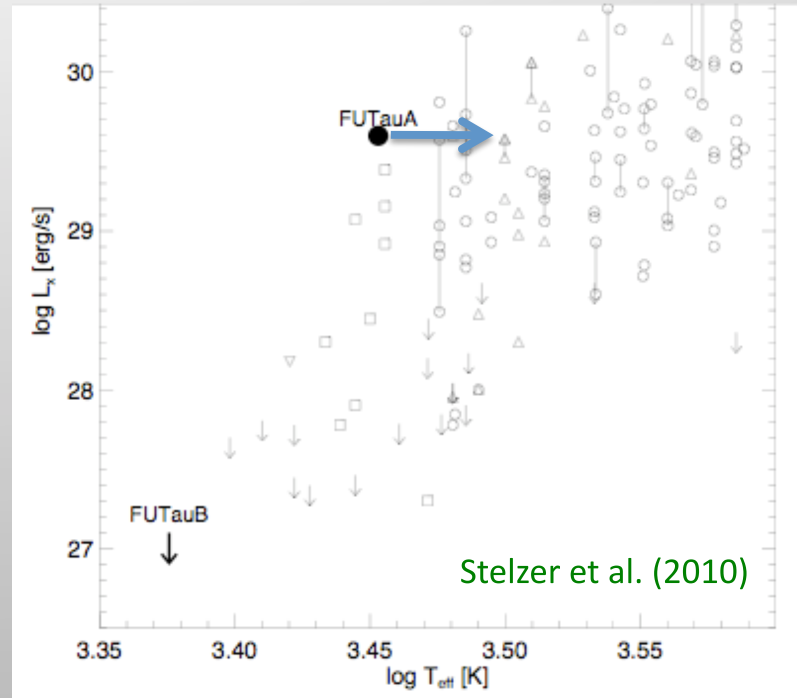
Mdot = (3…7) 10^{-10} M_{sun}/yr

(Natta et al. 2004)

$$\log M_{acc} = -12.9\ (\pm 0.3) - 9.7(\pm 0.7) \times 10^{-3}\ W(H\alpha\ 10\%)$$

Evolutionary state of FU Tau A ?





FU Tau A has high accretion rate for Taurus

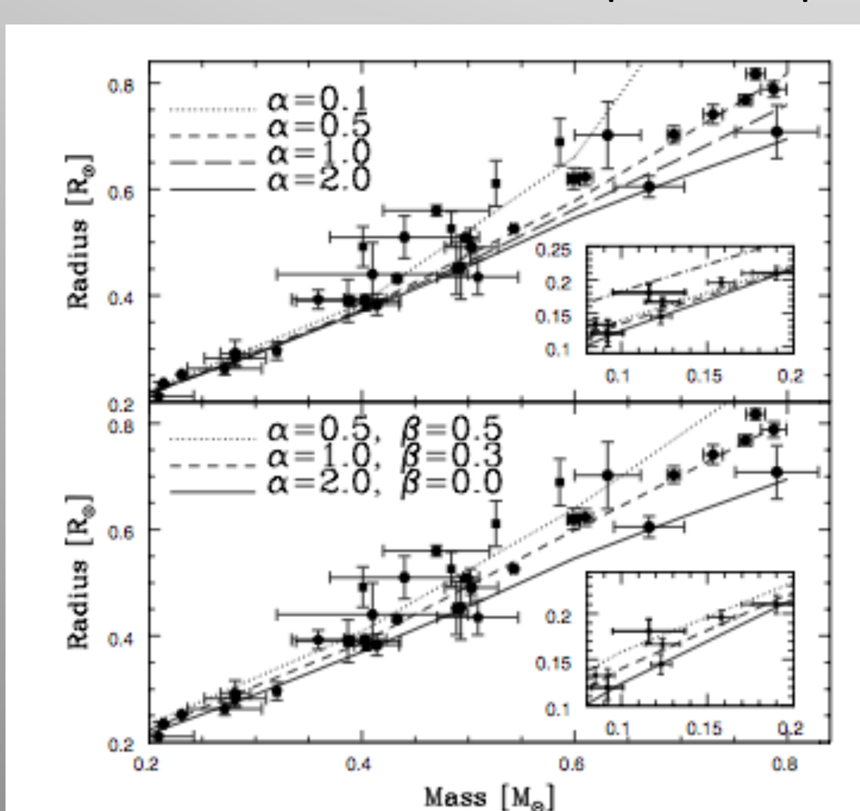
FU Tau A has low X-ray temperature and high X-ray luminosity

→ Is FU Tau A extremely young?

Or more massive?

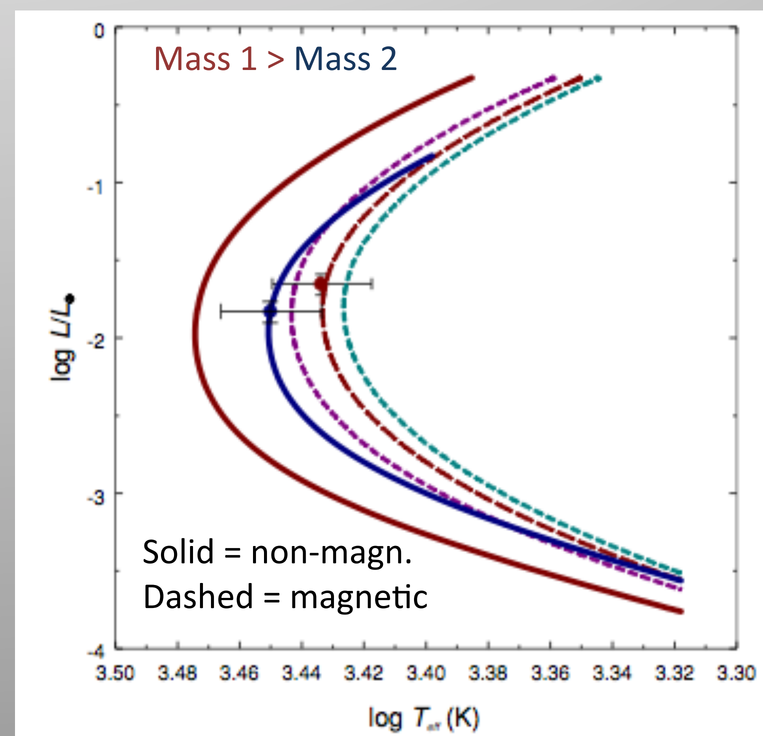
Stellar parameters of FU Tau A ?

Rotation/magn.field + spot coverage reduces convective flux (Chabrier et al. 2007)
→enhanced radiation transport
→steeper temp.gradient
→cooler T_{eff}
→decrease of interior temp. and expansion



Magn.field influences criterion for convective stability
(MacDonald & Mullan 2009)
→evol.track shifts to the right

BD eclipsing binary 2M0532-05:
More massive component is cooler
(Stassun et al. 2007)



Stellar parameters of FU Tau A ?

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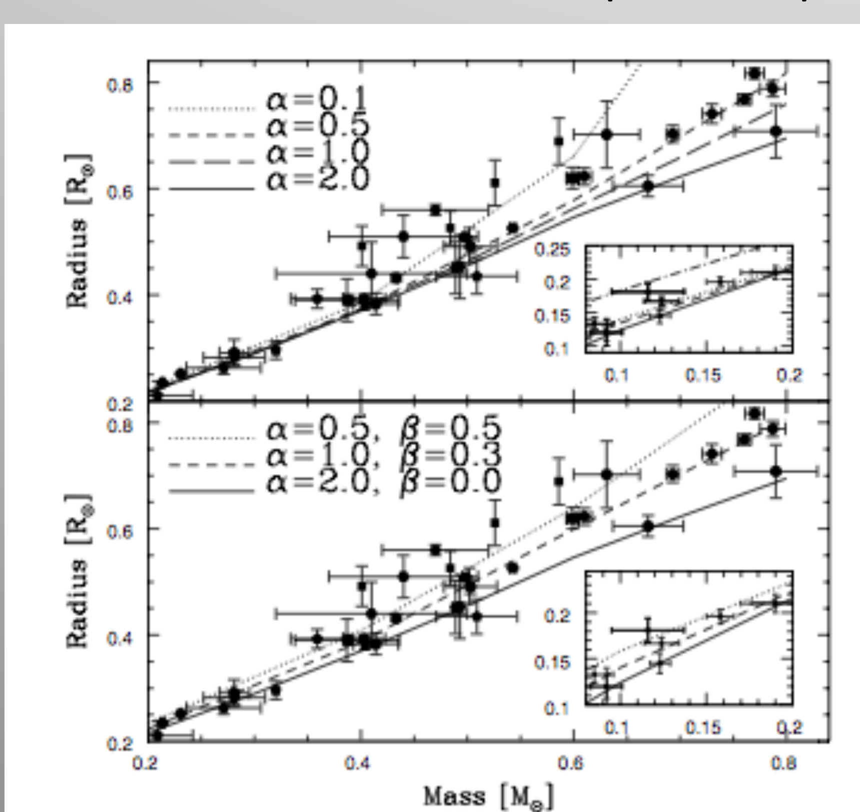
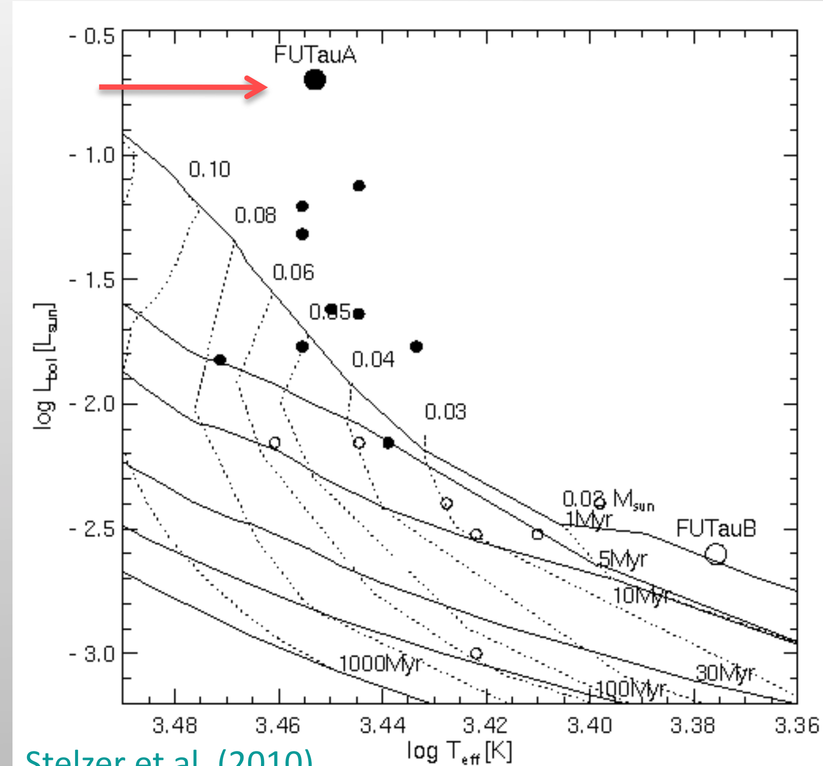




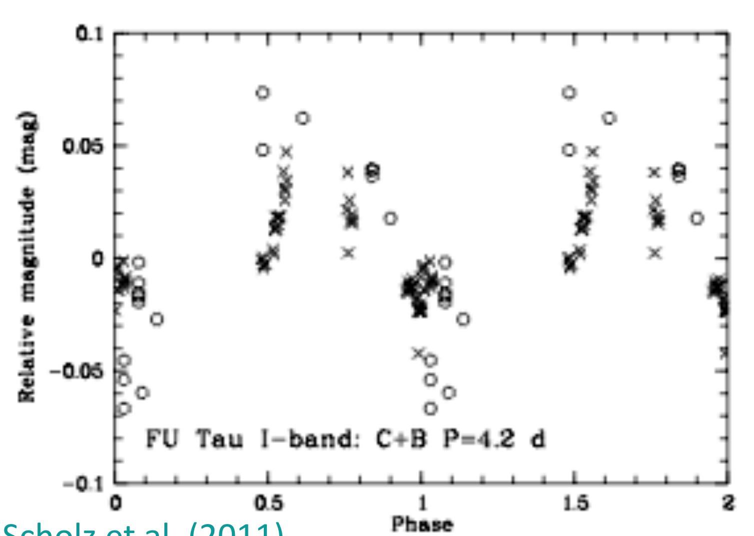
Stelzer et al. (2010)

→ Is FU Tau A a star ($M>0.075M_{sun}$)?

$v_{H\alpha}$ ~ 175 km/s → T_{psh} ~ 0.03 keV << T_{obs}

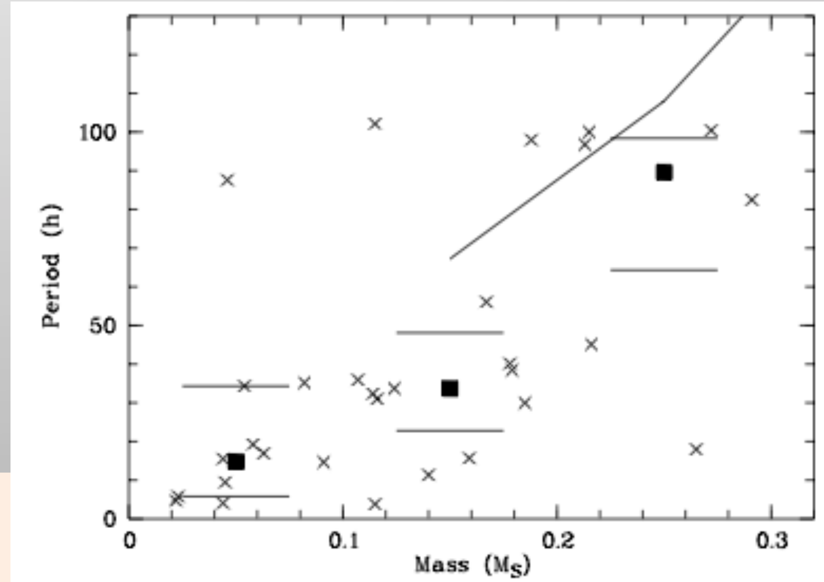
for M = 0.2 M_{sun}
v_{ff} = SQRT(2GM/R) ~ 200 km/s ~ $v_{H\alpha}$

Rotation period of FU Tau A
CAFOS + BUSCA monitoring



Scholz et al. (2011)

Calar Alto runs Nov/Dec 2010:
5n CAFOS R+I band (dedicated)
+ 5n BUSCA I band (few data points)



Scholz & Eisloeffel (2005):
Photometric monitoring in εOri cluster (2-10 Myr);
period correlated with mass;
BDs are rapid rotators

Results:

- period ~ 4 d with amplitude ~ 0.1mag
  (variations larger at I-band w.r.t. R-band; cool spots)

- long-term amplitude ~ 0.2…1 mag (from 2002….2010)

FU Tau A is slow rotator → higher mass?

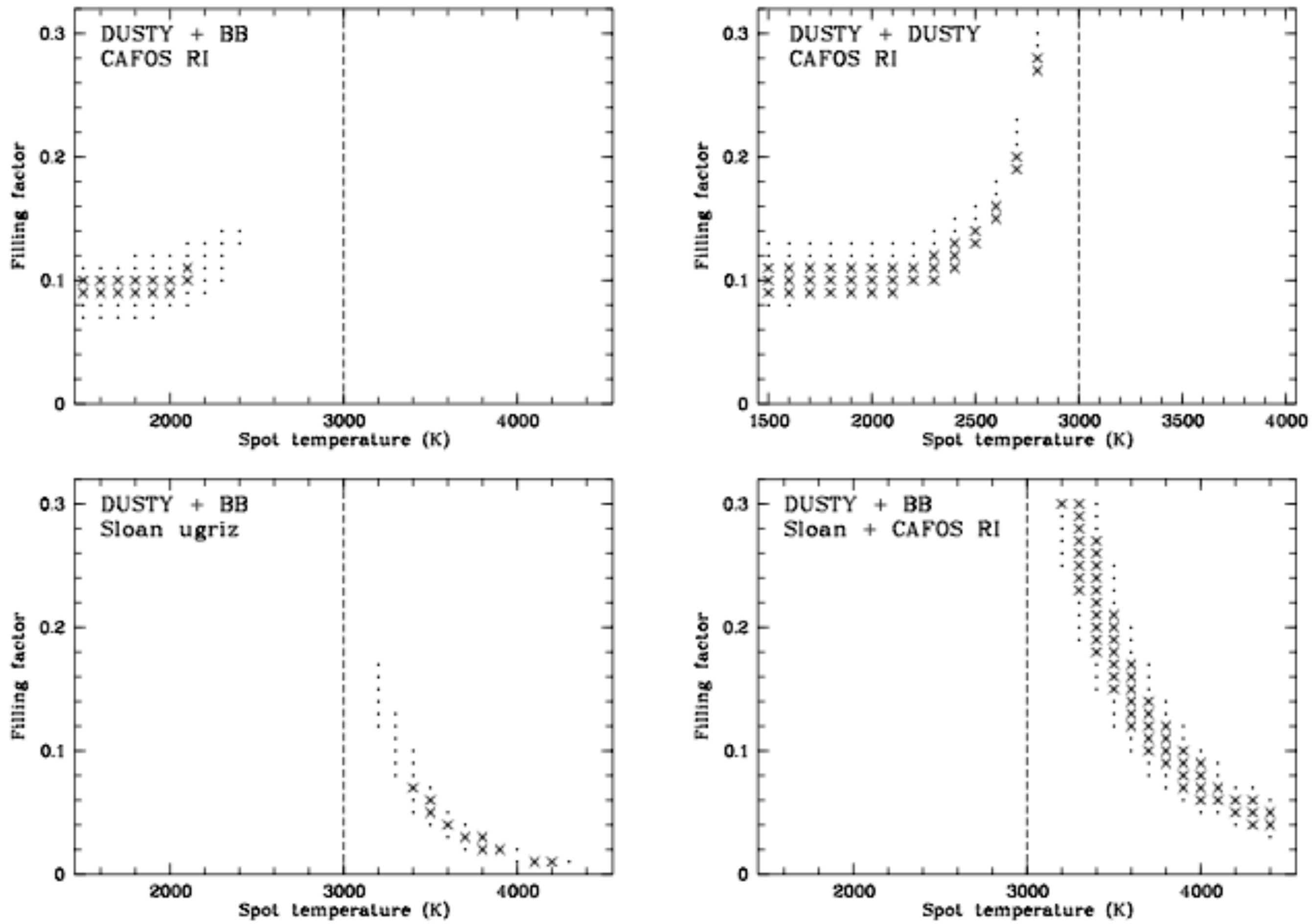
Rotation period of FU Tau A
CAFOS + BUSCA monitoring

Spot modeling:

DUSTY photosphere (3000K) + 1 spot with filling factor f (DUSTY or BB)

$$1/N \sum_{i=1}^{N} (\Delta X - m_X)^2$$

Scholz et al. (2011)

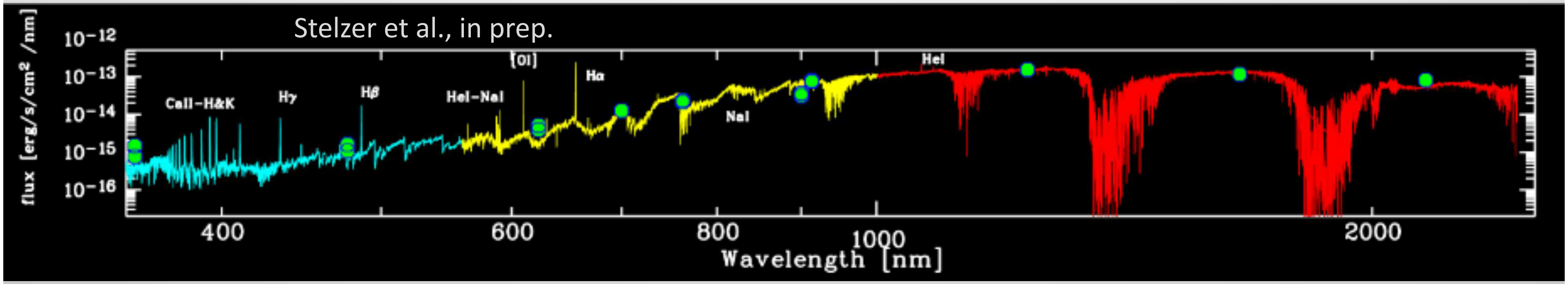


Results:

A) CAFOS:
cool spots; f ~ 0.1
activity dominates
short-term variation

B) SDSS:
hot spots; f < 0.1
accretion dominates
long-term variation

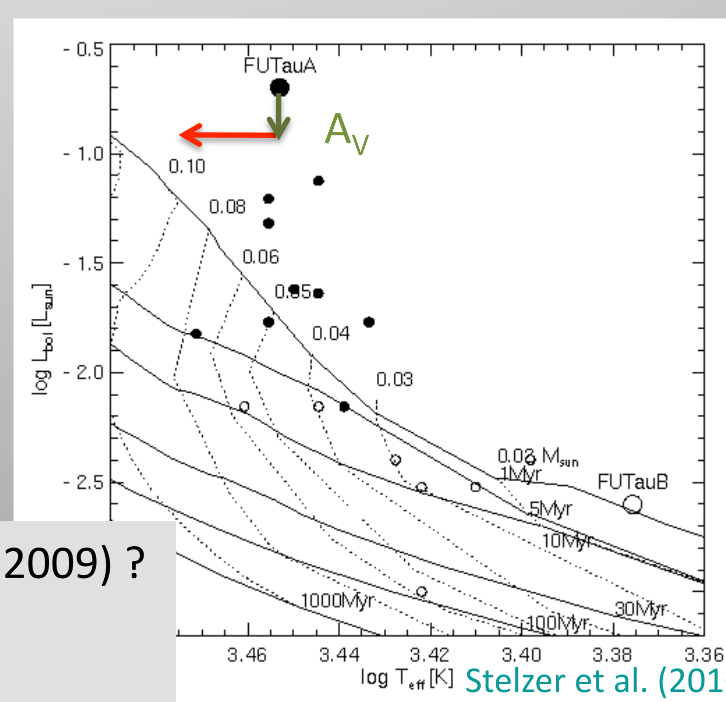
The X-Shooter spectrum of FU Tau A



X-Shooter Setup for FU Tau A:

UVB/VIS/NIR arm

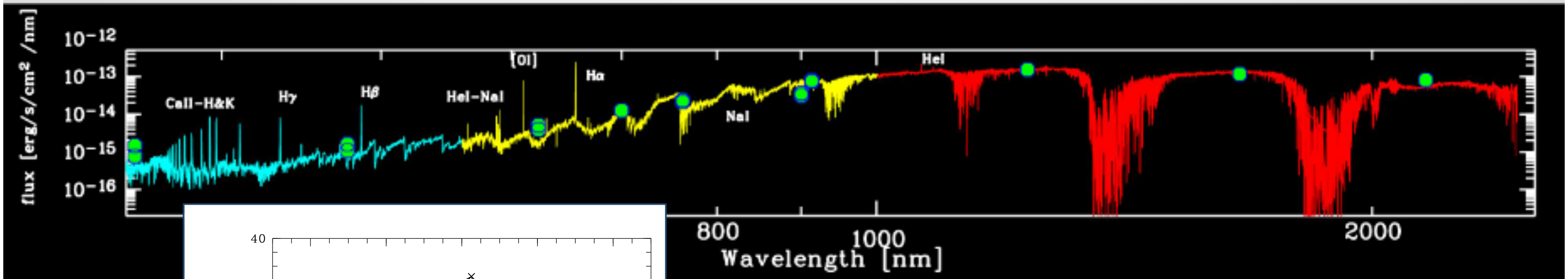
1.0”/0.9”/0.9”
(R ~ 5100/8800/5600)

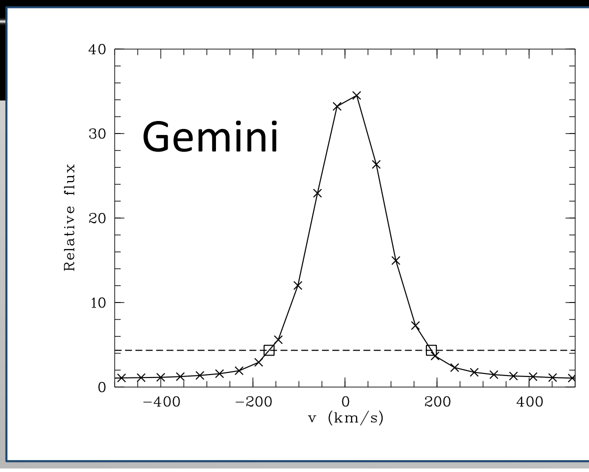


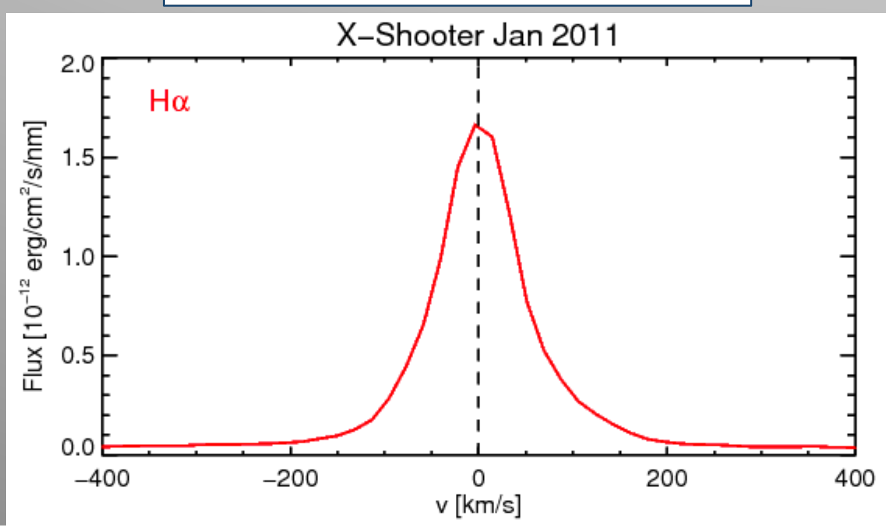
Stelzer et al. (2010)

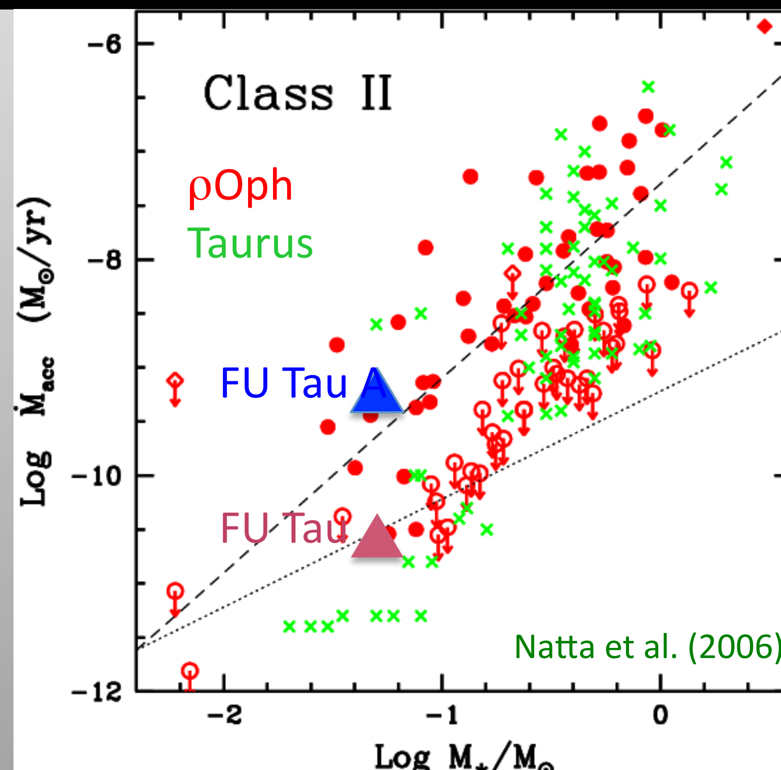
- extinction lower than A_V = 2 mag (from Luhman et al. 2009) ?
- SpT ~ M6 ?
- M > 0.08 M_{sun} ?

The X-Shooter spectrum of FU Tau A







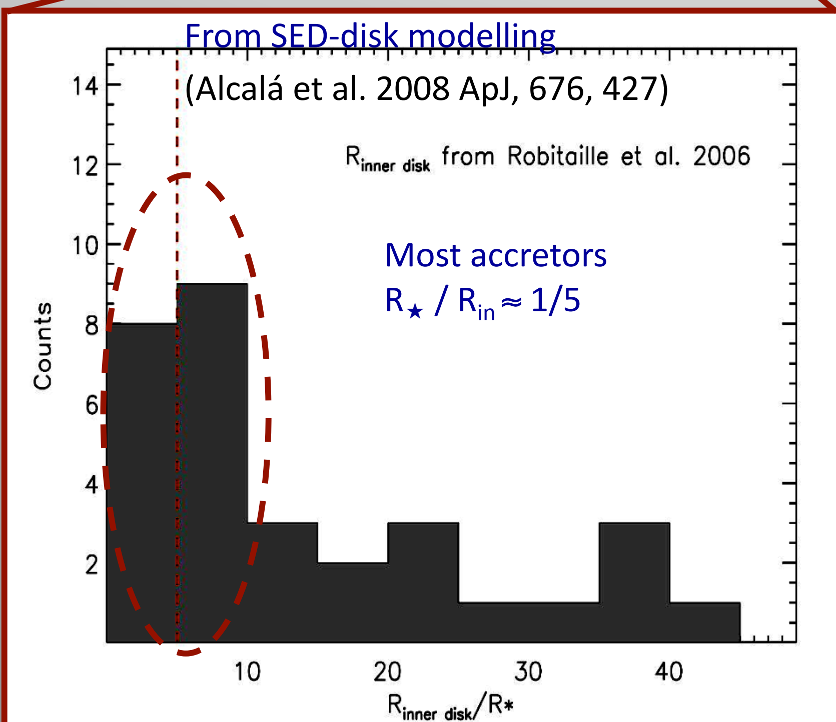


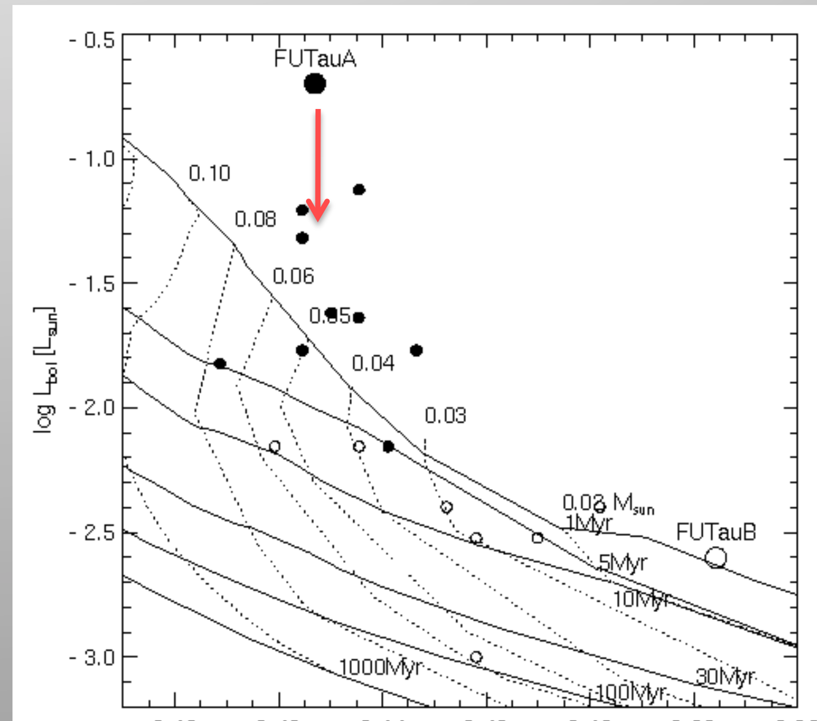
Mass accretion rate and accretion luminosity

$$L_{line} = 4\pi d^2 F_{line} = 4\pi d^2 \int_{\lambda_1}^{\lambda_2} f_\lambda \cdot d\lambda \qquad L_{acc} = a + b\, L_{line}$$

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

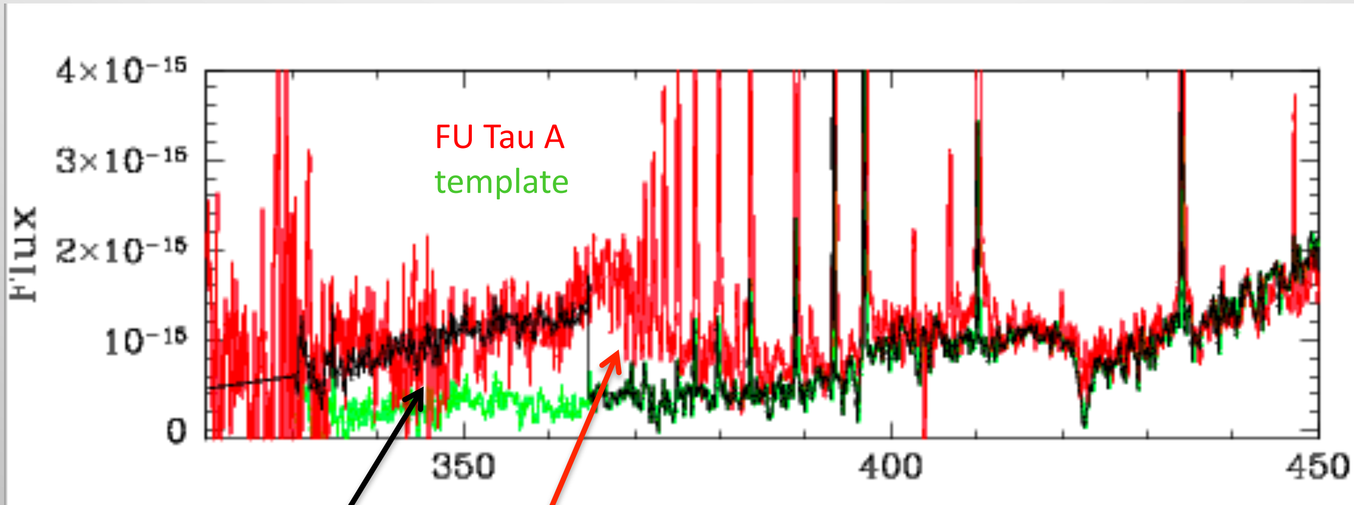
tion?





Stelzer et al. (2010)

Balmer jump modeling



Pseudo-continuum from Balmer lines

From Balmer Jump modelling for several accretors with slab model for accretion shock:

- $T_{gas} \approx 10^4$ K
- $n_e \approx [10^{13} : 10^{14}]$ cm^{-3}
- $l \approx 10^7$ cm
- $L_{acc} \approx [10^{-6} : 10^{-1}]$ $L_\odot$

Accretion luminosity from slab model:
L_{acc} → Accretion rate ~ 10^{-10} M_{sun}/yr

(similar to values from emission lines)

FU Tau A ....

Conclusions for FU Tau A

....is a strong and soft X-ray source (similar to TW Hya)

....has both cool and hot surface spots

- → spot coverage may affect convection and stellar parameters
- → accretion spots

....has variable accretion

<u>Most likely explanations:</u>

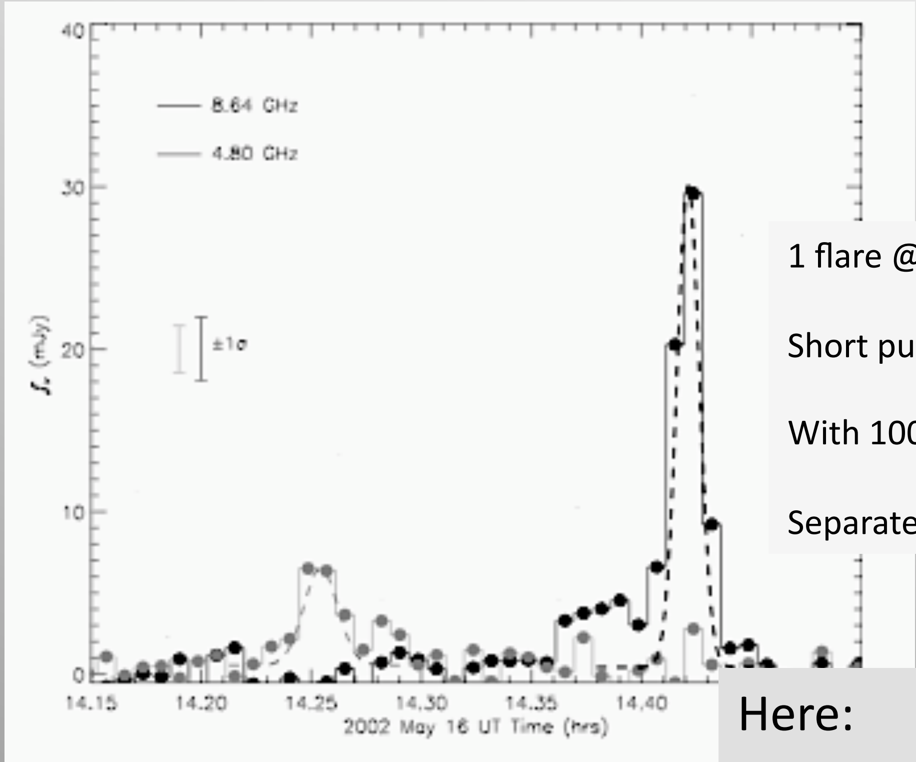
A) FU Tau A has higher mass than inferred from evolutionary models

> tainty. In addition, the unknown evolutionary stage and accretion history means that we cannot trust the isochrones for mass estimates. Thus, barring a more complete understanding of magnetic activity and its effect on the observable properties as well as protostellar evolution it does not seem feasible to derive a mass function for very young very low mass stars and brown dwarfs.

B) FU Tau A is at closer distance

DENIS 1048-3956:
A nearby radio-bursting M9 dwarf
The nearest UCD

SpT M9
D = 4 pc
Vsini ~ 18..30 km/s
log ($L_{h\alpha}$ /L_{bol}) = -4.0 (during flare)
log L_x < 26.3 erg/s (from ROSAT)



Burgasser et al. (2005)

1 flare @ 4.8GHz; 1 flare @ 4.8 GHz

Short pulses (4-5 min)

With 100% circular Polarization

Separated by ~ 10 min

Here:

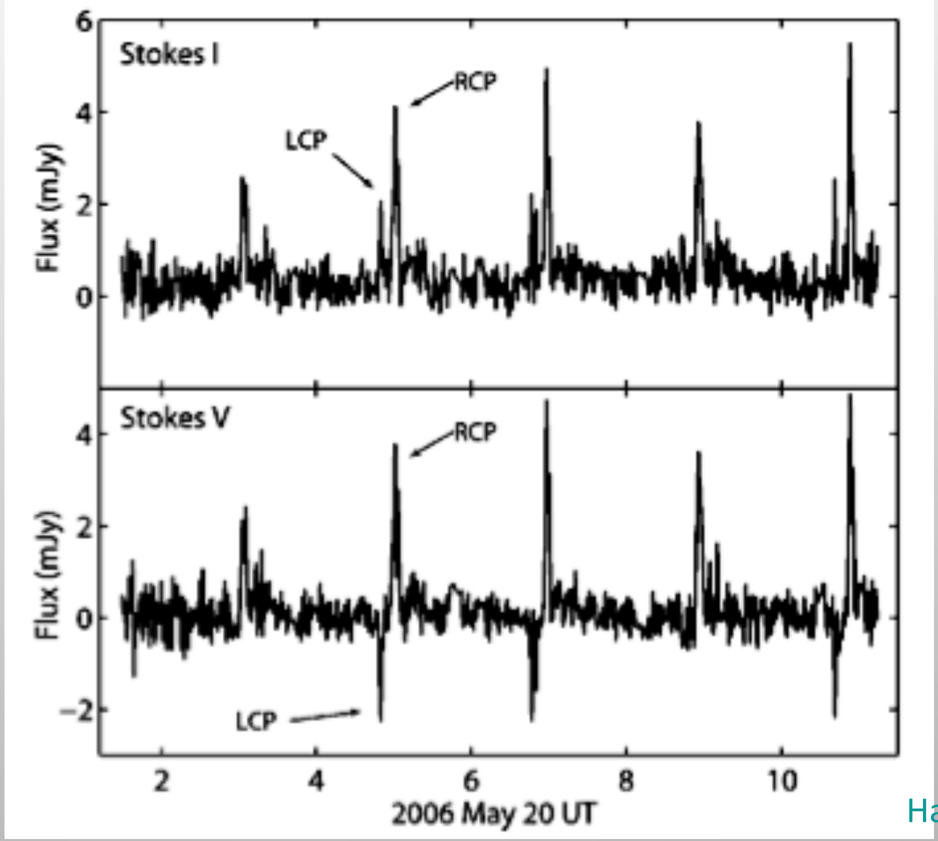
20 ksec XMM-Newton from Jan 2010

X-Shooter spectrum from Apr 2010

Stelzer et al., A&A subm.

The testcase ultracool radio dwarf: TVLM513-46546

SpT M8.5
D = 10.6 pc
Vsini ~ 60 km/s
Log ($L_{h\alpha}$ /L_{bol}) = -4.6…-5.1
Log (L_x /L_{bol}) = -5.1



Hallinan et al. (2007)

Observations:
- periodic 100% LH + RH polar. Bursts in both bands; stronger @ 8.44GHz
- unpolarized persistent emission
- 2 bursts per rotation @ 4.88 GHz

→ need for beamed mechanism that produces polarized emission

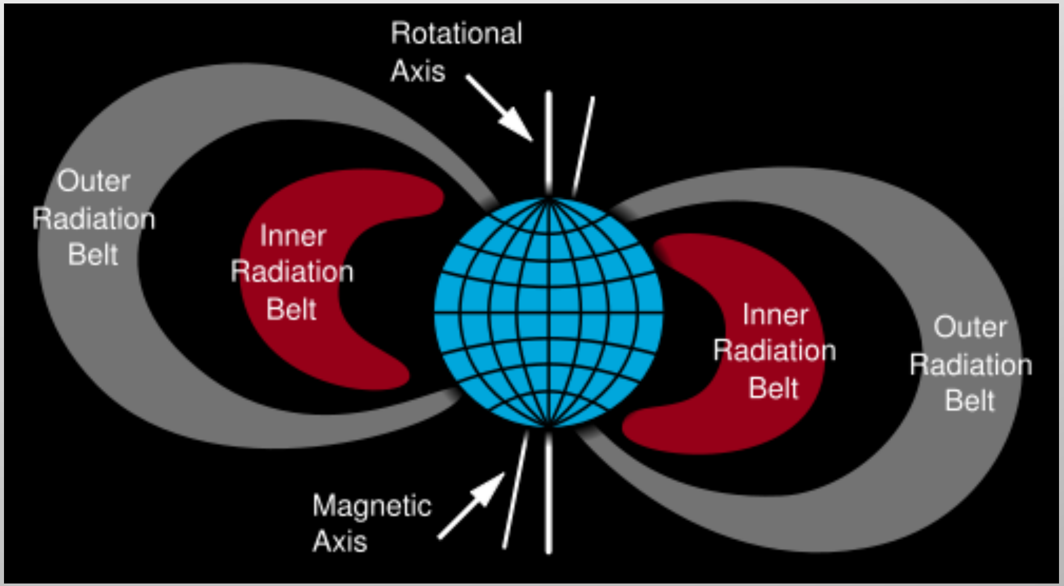
Electron cyclotron maser
Application to the ultracool dwarf TVLM 513-46

Electron cyclotron maser
= instability caused by resonance
between gyrating electrons
and el.magn wave

→ ECM works if there is

1) an anisotropic electron velocity distribution

2) strong magnetic field or low density:



Van Allen radiation belts on Earth (Fig. from Wikipedia)

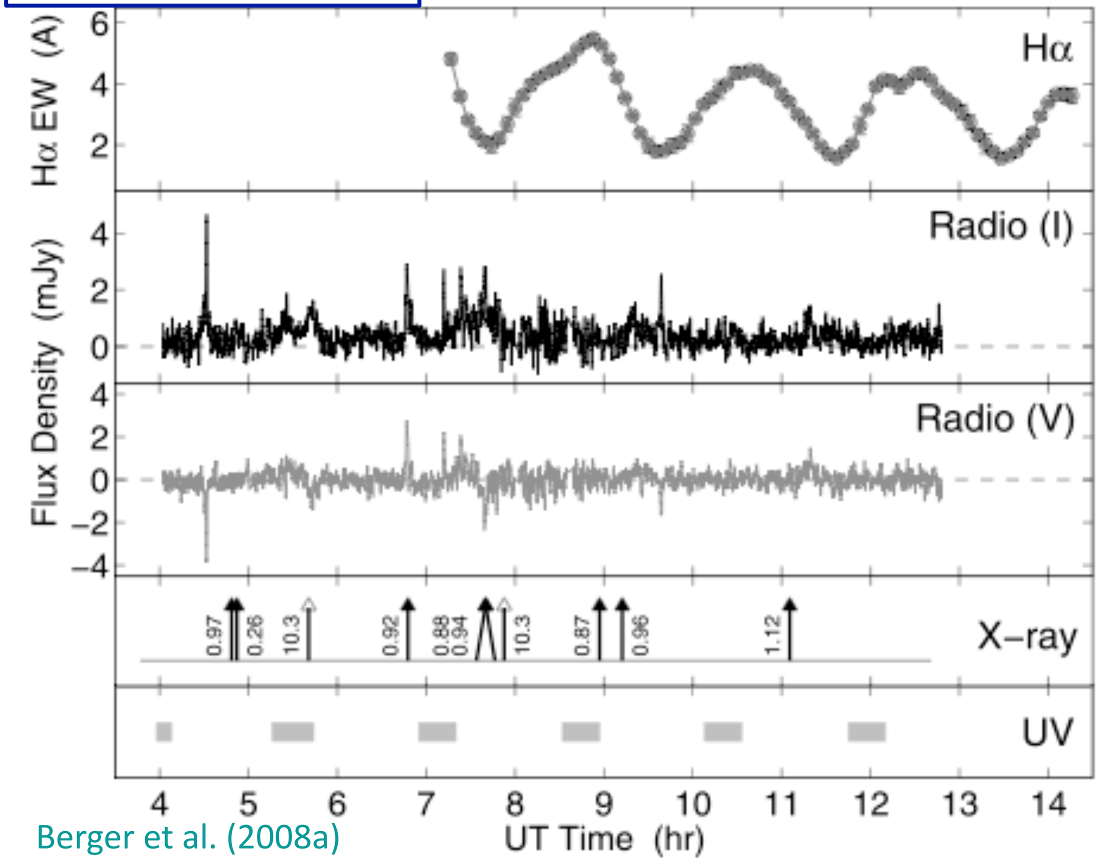
Scenario for ECM on TVLM513:
plasma trapped at low latitudes in radiation belts,
plasma cavity near poles ("coronal holes"): $\nu_{cyc} = 2.8 \cdot 10^6 B >> \nu_{pl} = 9000\sqrt{n_e}$
electric field parallel magnetic field injects trapped electrons into cavity,
e.g. by potential drop of ions and electrons mirroring at different locations

Hallinan et al. (2006)

→ polarized, broad-band radio emission

Simultaneous multi-λ observations of TVLM513-46546

SpT M8.5
D = 10.6 pc
Vsini ~ 60 km/s
Log ($L_{h\alpha}$ /L_{bol}) = -4.6…-5.1
Log (L_x /L_{bol}) = -5.1



Berger et al. (2008a)

Periodic Hα emission

Non-periodic polarized radio bursts superposed on unpolarized quiescent emission

Weak X-ray detection:

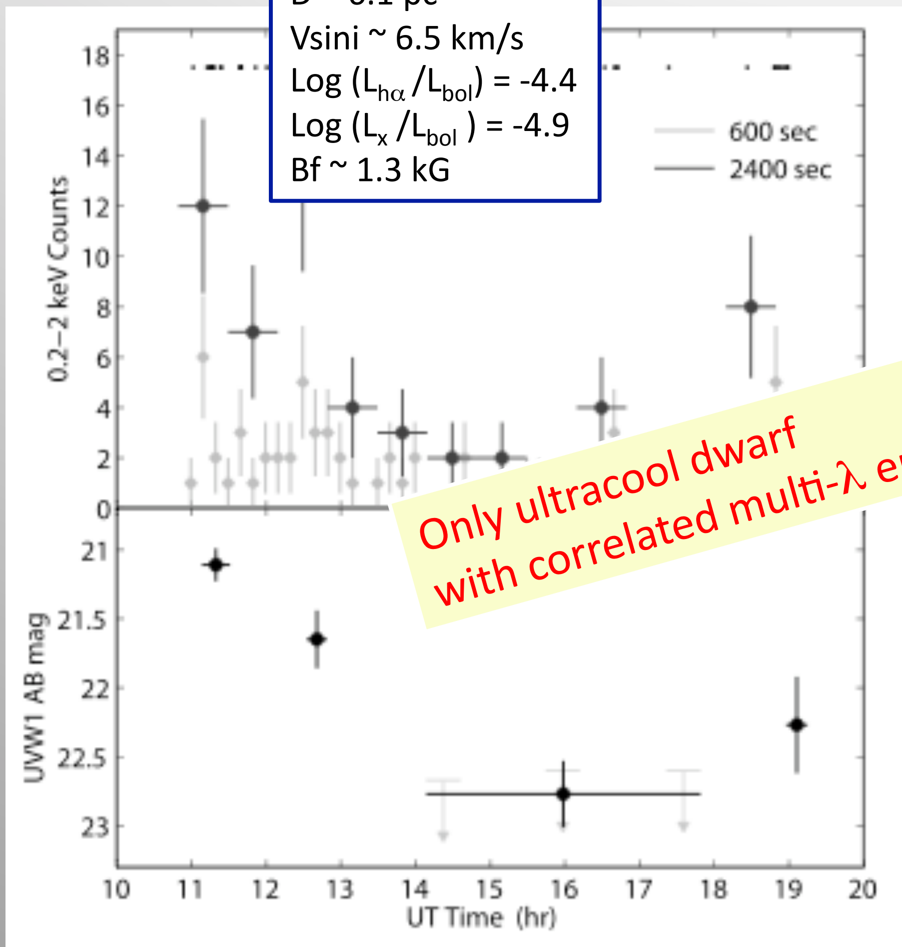
$$L_x \sim 1.2 \cdot 10^{25} erg/s$$

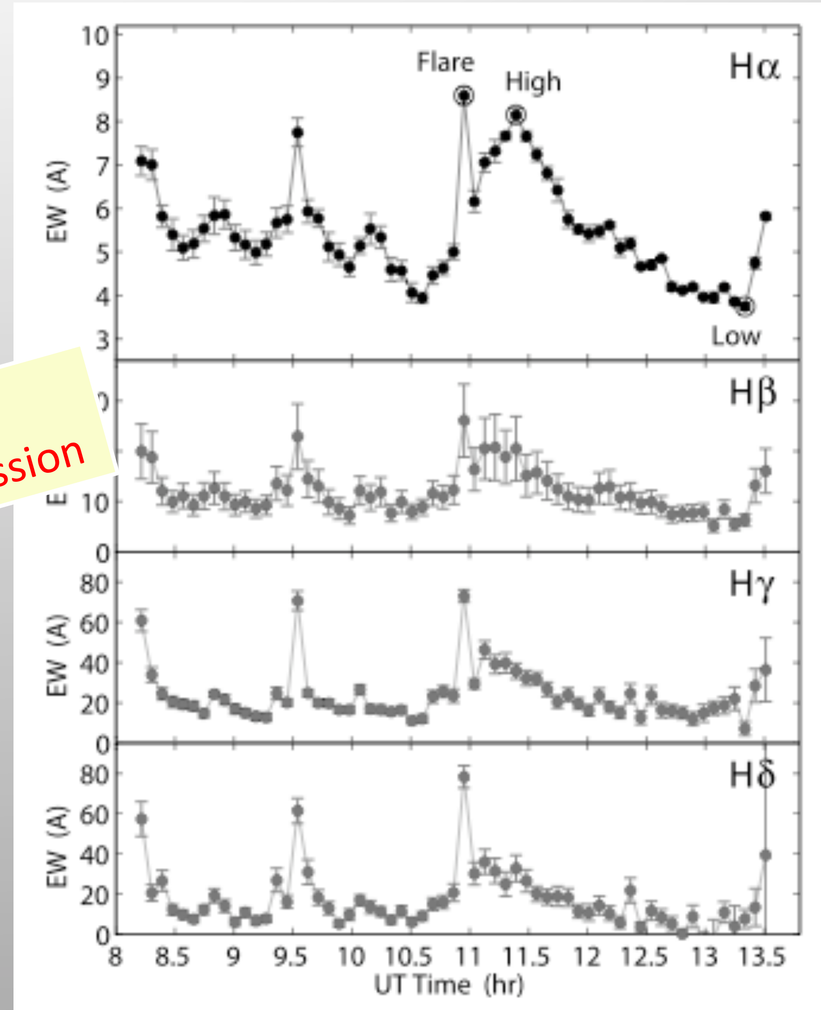
No UV detection

No clear evidence for correlation between emission in different bands; likely both dipolar and multi-polar field components present.

Simultaneous multi-λ observations of vB 10

SpT M8.5
D = 6.1 pc
Vsini ~ 6.5 km/s
Log ($L_{h\alpha}$ / L_{bol}) = -4.4
Log (L_x / L_{bol}) = -4.9
Bf ~ 1.3 kG





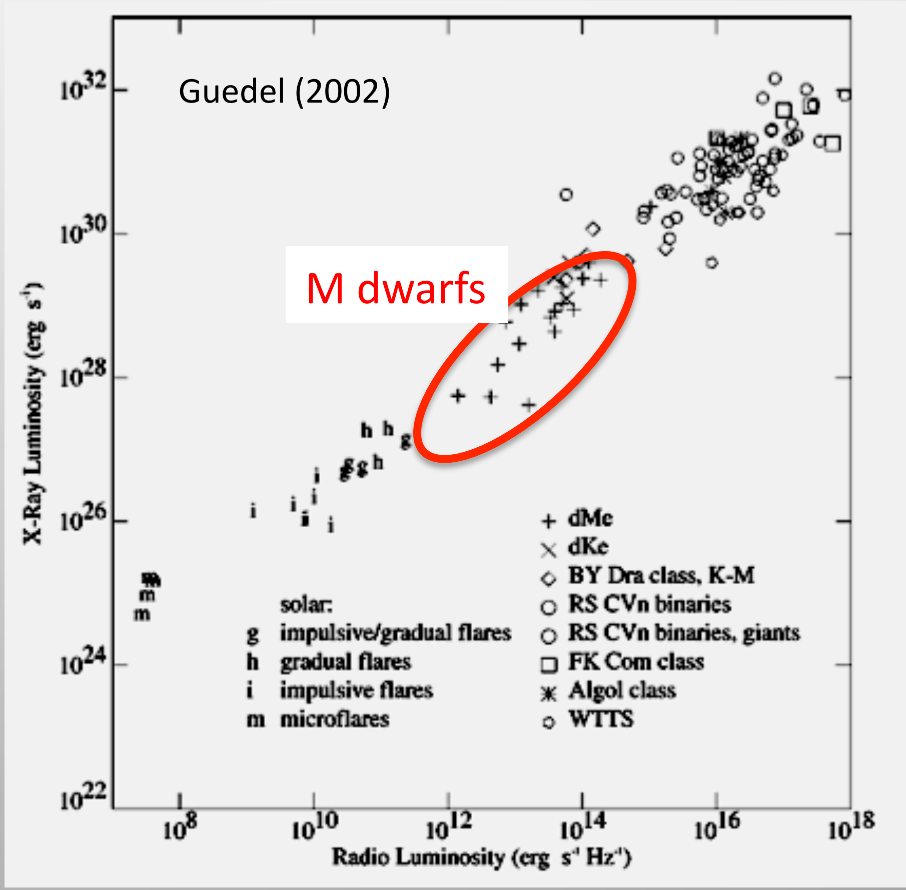
Only ultracool dwarf
with correlated multi-λ emission

Berger et al. (2008b)

- frequent emission line flaring
- variable UV correlated with X-rays
- minimum UV flux ~ 1 dex higher than photospheric level → persistent transition region

The Guedel-Benz relation
(Correlation of L_R and L_X)

$$\log L_X \approx \log L_R + 15.5$$



Assume gyrosynchrotron for radio,
Power-law electron distribution with δ~3

→compute fraction of total input energy that goes into particle acceleration (“a”) and
that goes into X-ray luminosity (“b”):

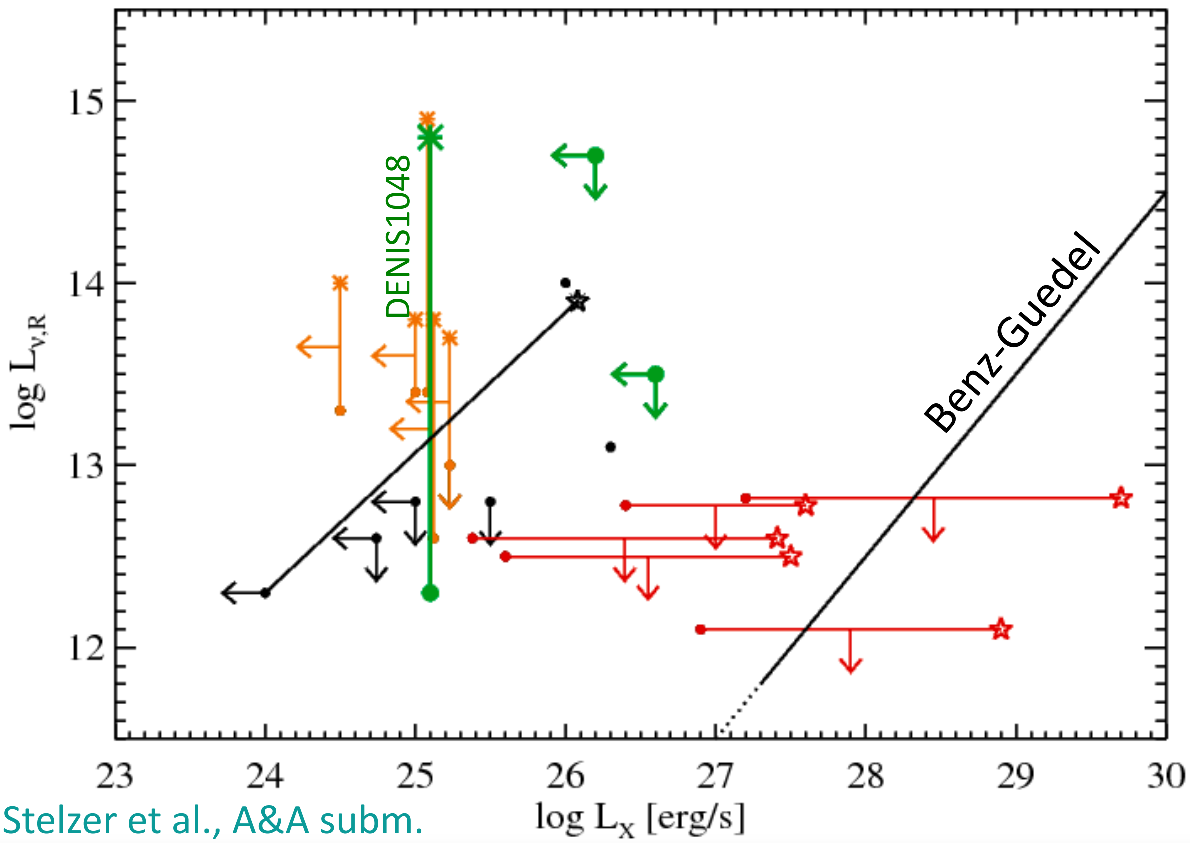
$$\dot{E} = \frac{1}{a}\int_{\epsilon_0}^{\infty} \dot{N}(\epsilon)\epsilon\, d\epsilon = \frac{1}{b} L_X$$

→ $$L_R = 9.6 \times 10^{-26} B^{2.48} \frac{a}{b} \tau_0(\alpha + 1) L_X$$

= constant for all stars !

X-ray and radio luminosities correlated over 6 dex for various types of stars (independent on age,spectral type, binarity, rotation, chromospheric activity)

L_R and L_X of ultracool dwarfs



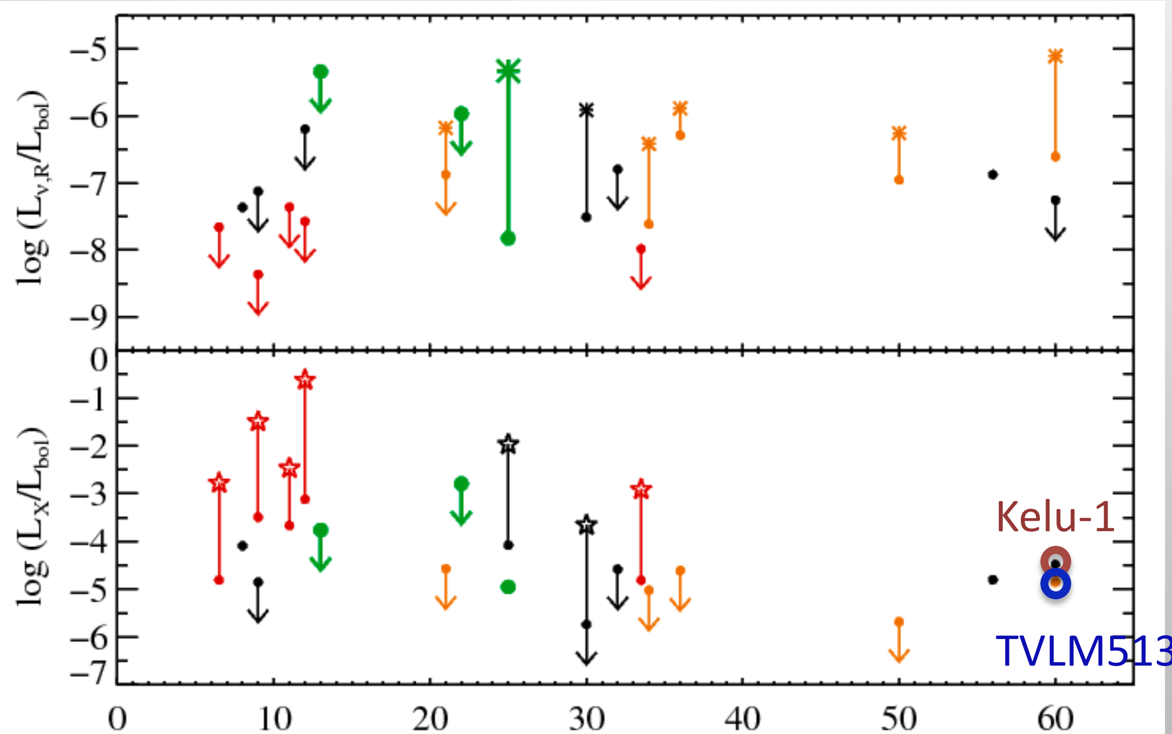
Stelzer et al., A&A subm.

Benz-Guedel relation
is violated (e.g. Berger et al. 2002)

- UCDs with bright radio emission show radio bursts
  → Electron Cyclotron Maser
  (Hallinan et al. 2006; 2008)
  but no or very weak X-rays
- UCDs without detectable radio emission but with X-ray flares
- LP944-20 has both radio spikes and X-ray flares

DENIS1048:
New X-ray detection (1 dex deeper than previous upper limit)
....fits into radio-bursting group
(no X-ray flare observed yet, but Hα flare Fuhrmeister & Schmitt 2004)

Rotation-activity connection for ultracool dwarfs ?



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Fast rotators violate Benz-Guedel relation more than slow rotators (Berger et al. 2008)

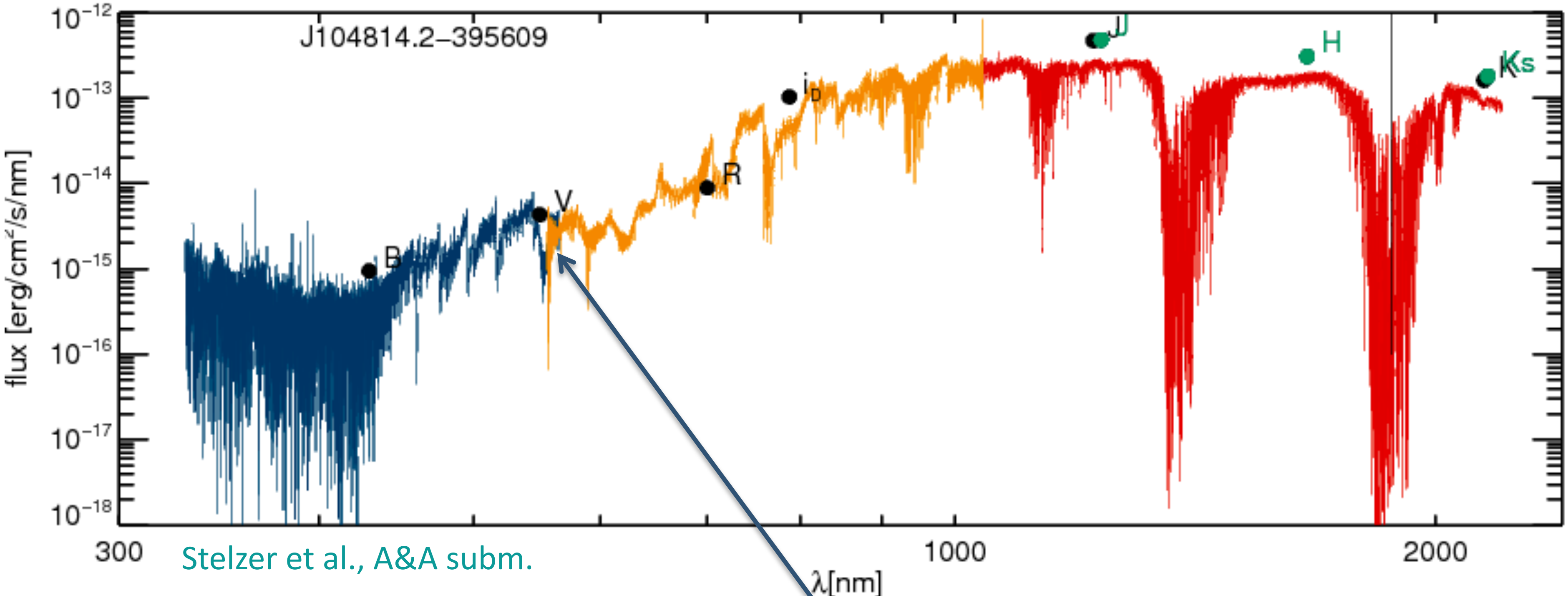
- radio ruled by rotation, but X-rays not ?

OR

- selection effect: radio bursts not yet identified on slow rotators ?

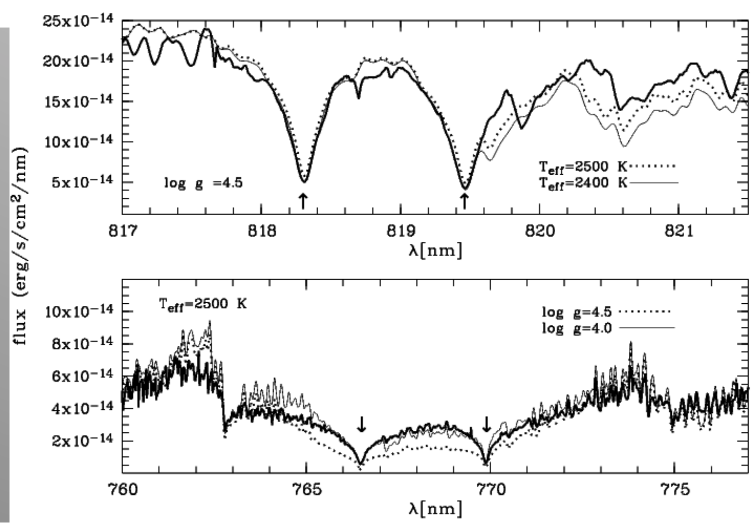
lated to their longer rotation periods. For $v \sin i \sim 10$ km/s and a 'canonical' radius of $0.1\,R_\odot$ the maximum period is ~ 0.5 d, much longer than the typical duration of the radio observations

X-Shooter spectrum of DENIS1048-3956



Stelzer et al., A&A subm.

XMM Optical Monitor

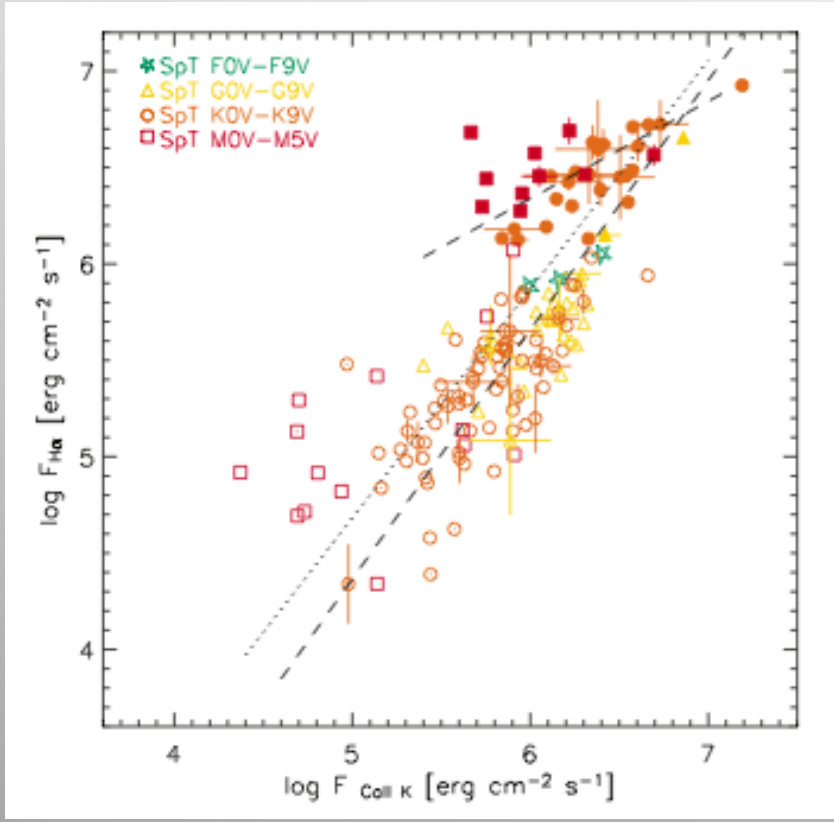


Comparison with synthetic spectra:

- T_{eff} = 2450 K (SpT M9)
- log g = 4.3 → young disk population
- vsini ~ 25 km/s

Flux-flux relations for chromospheric activity

Martinez-Arnaiz et al. (2011)



<u>Sample:</u>
300 single F…M dwarfs
incl. `normal' dwarfs
and emission line stars

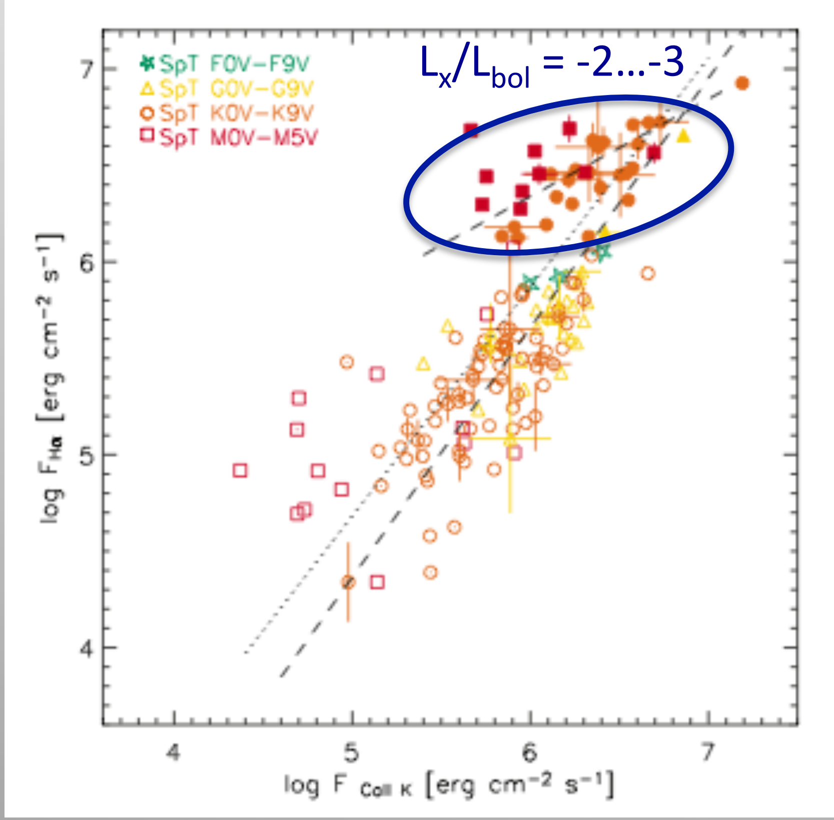
Simultaneous data for many activity diagnostics

Results:

- Power-law relations between pairs of line fluxes
  with slope depending on difference of atmospheric height for the two emitting regions

Flux-flux relations for chromospheric activity

Martinez-Arnaiz et al. (2011)



Sample:
300 single F…M dwarfs
incl. `normal' dwarfs
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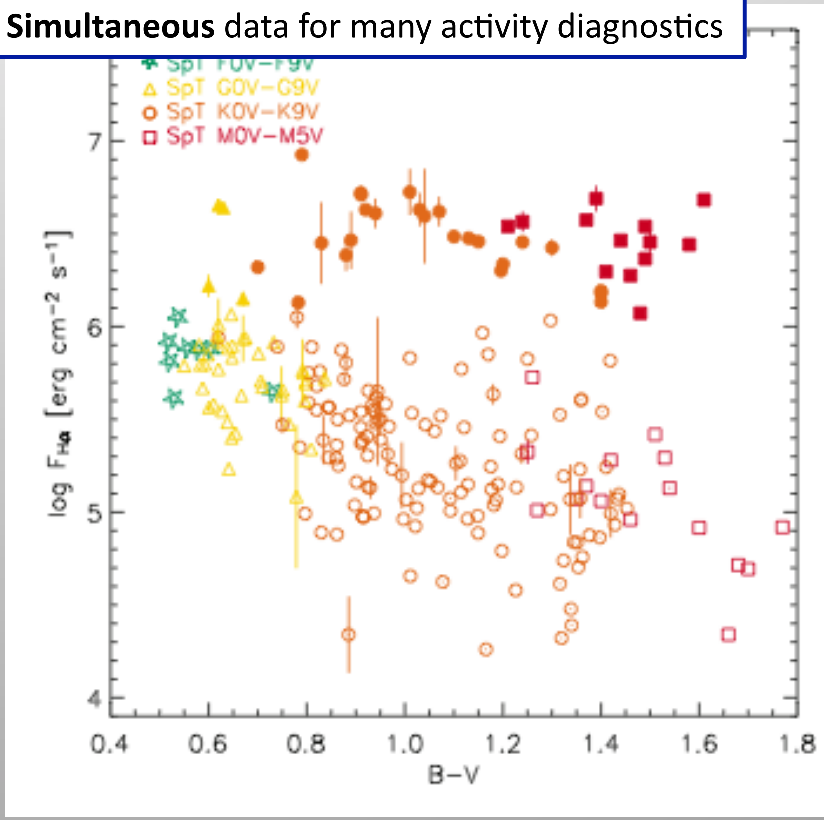
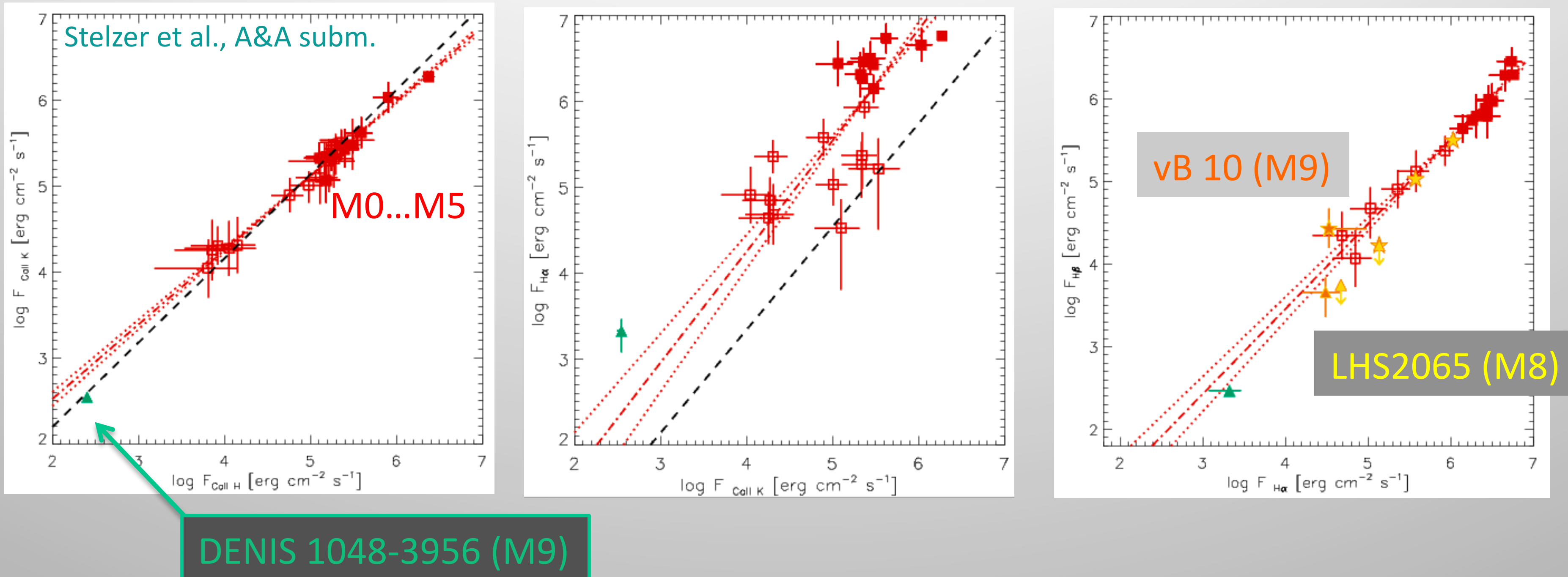
Simultaneous data for many activity diagnostics



Results:

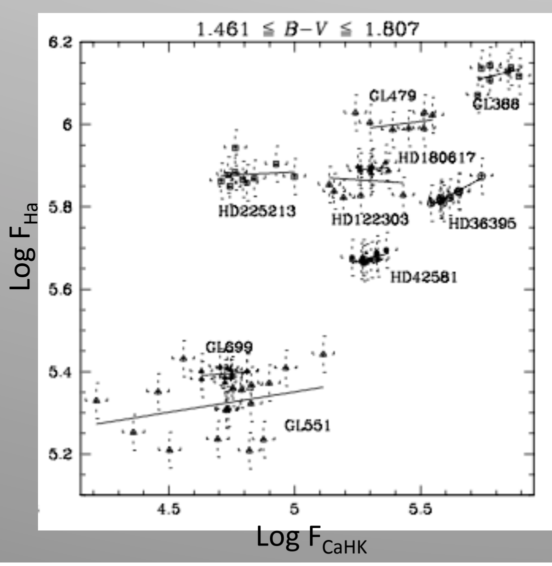
- Power-law relations between pairs of line fluxes with slope depending on difference of atmospheric height for the two emitting regions
- X-ray saturated K…M stars have Hα excess + are distinguished in Hα vs. B-V diagram → younger age ? [14/39 member of young associations + 16/39 have high Li abundance]

Chromospheric flux-flux relations for ultracool dwarfs



Cincunegui et al. (2007):

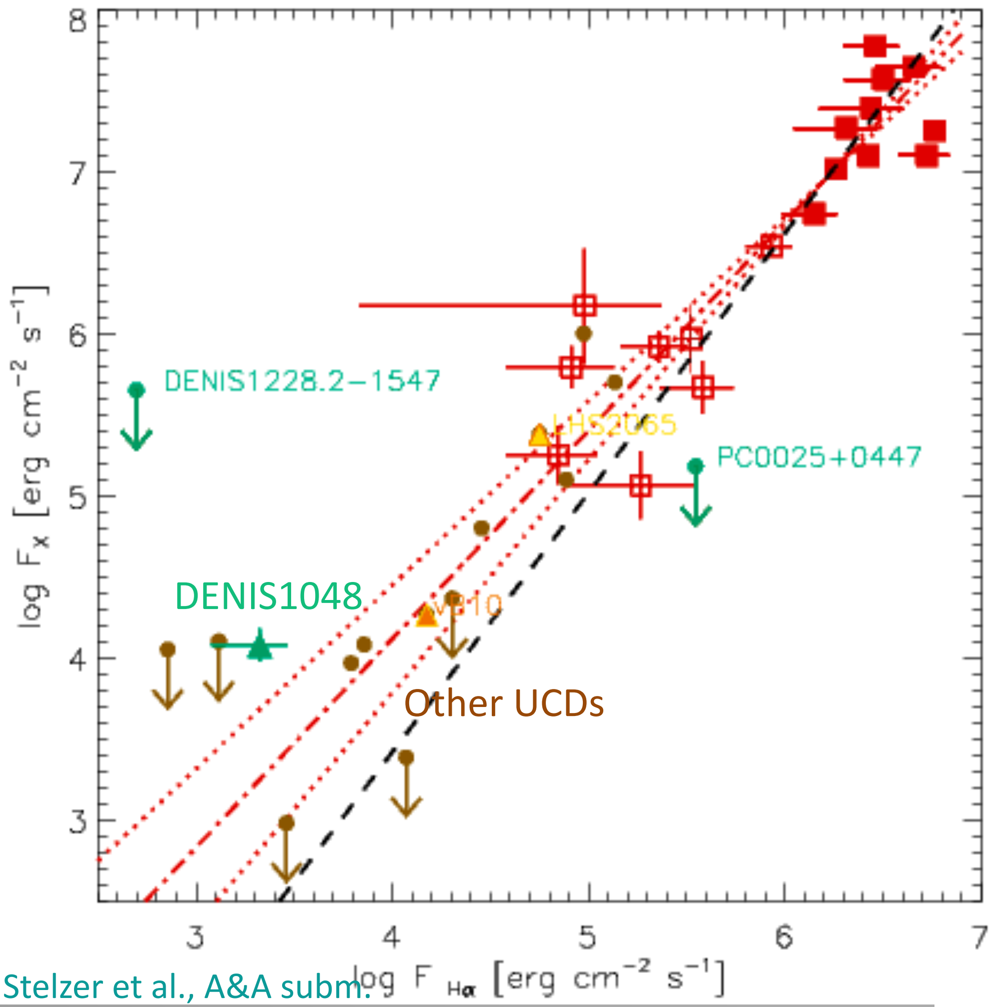
For a given individual star in different activity States no universal flux-flux relation



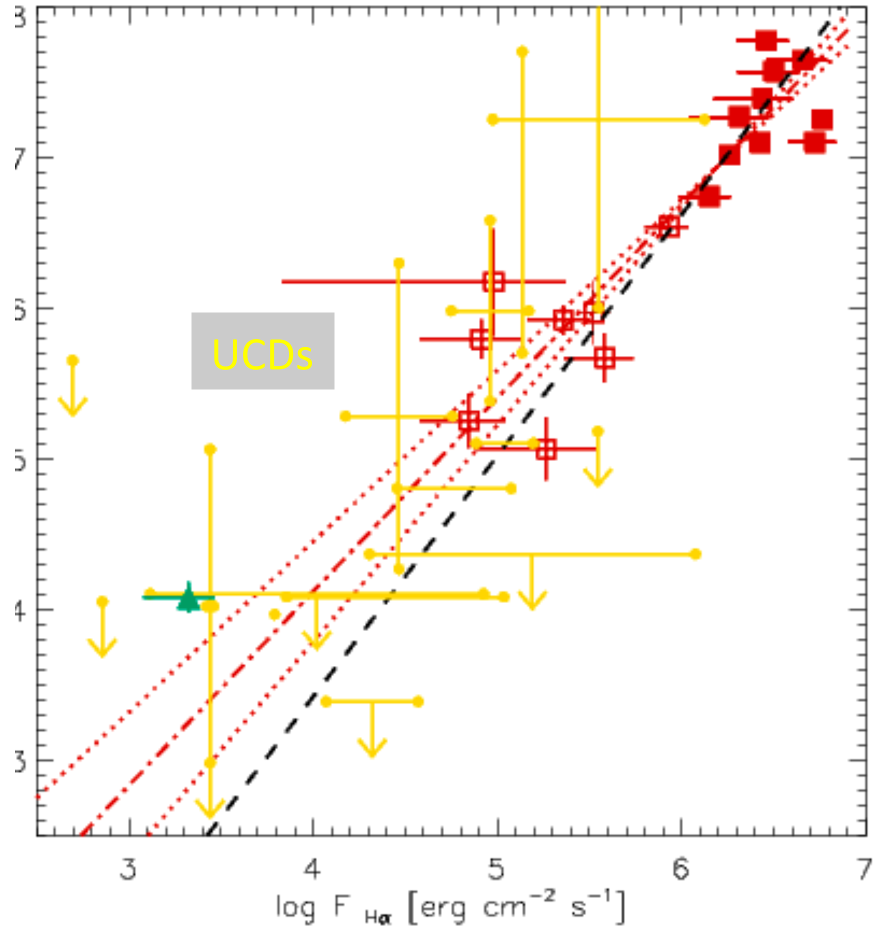
- UCDs roughly compatible with extrapolation of flux-flux relations
- LHS2065: Balmer measurements during flare line up along the flux-flux relation

First extension of chromospheric flux-flux relations to late-M SpT

X-ray vs. Hα flux
(coronal vs. chromospheric radiative loss)



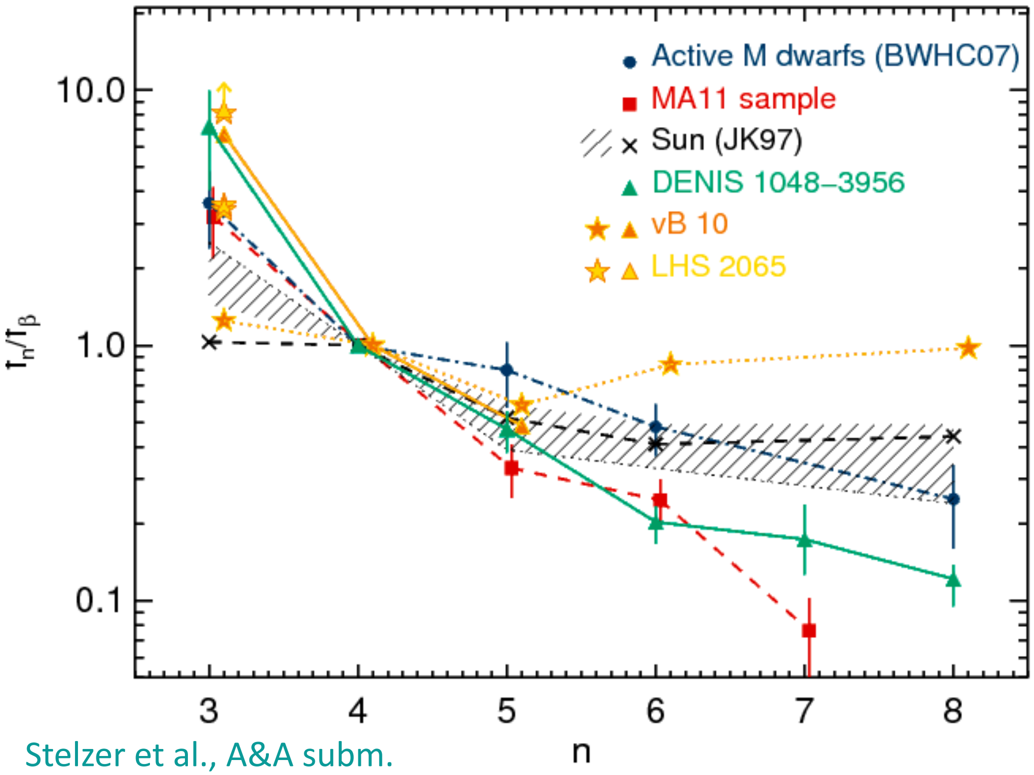
Stelzer et al., A&A subm.



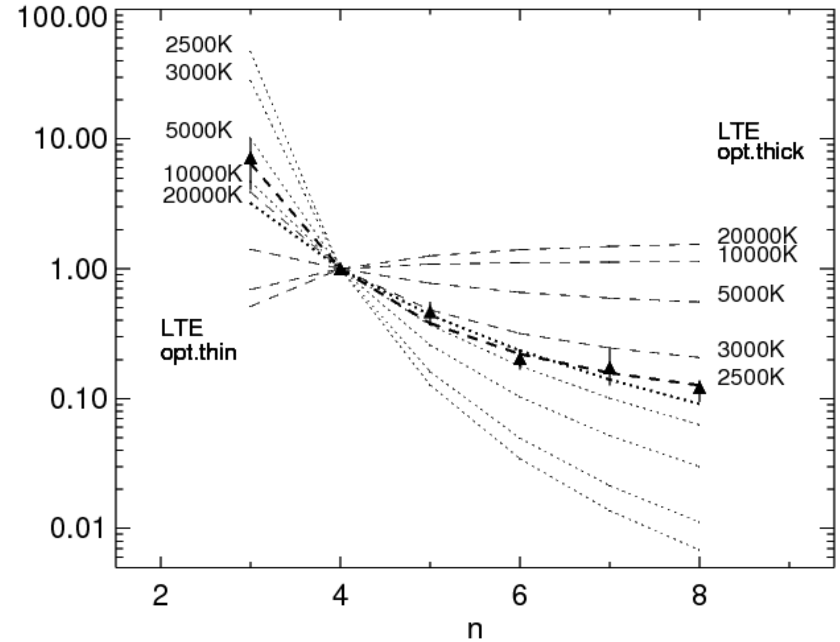
UCDs represented by `quiescent' emission follow the early-M dwarf relation

Huge amplitudes of variability in UCDs (due to bias?)

Physical conditions of emitting plasma
Balmer decrements



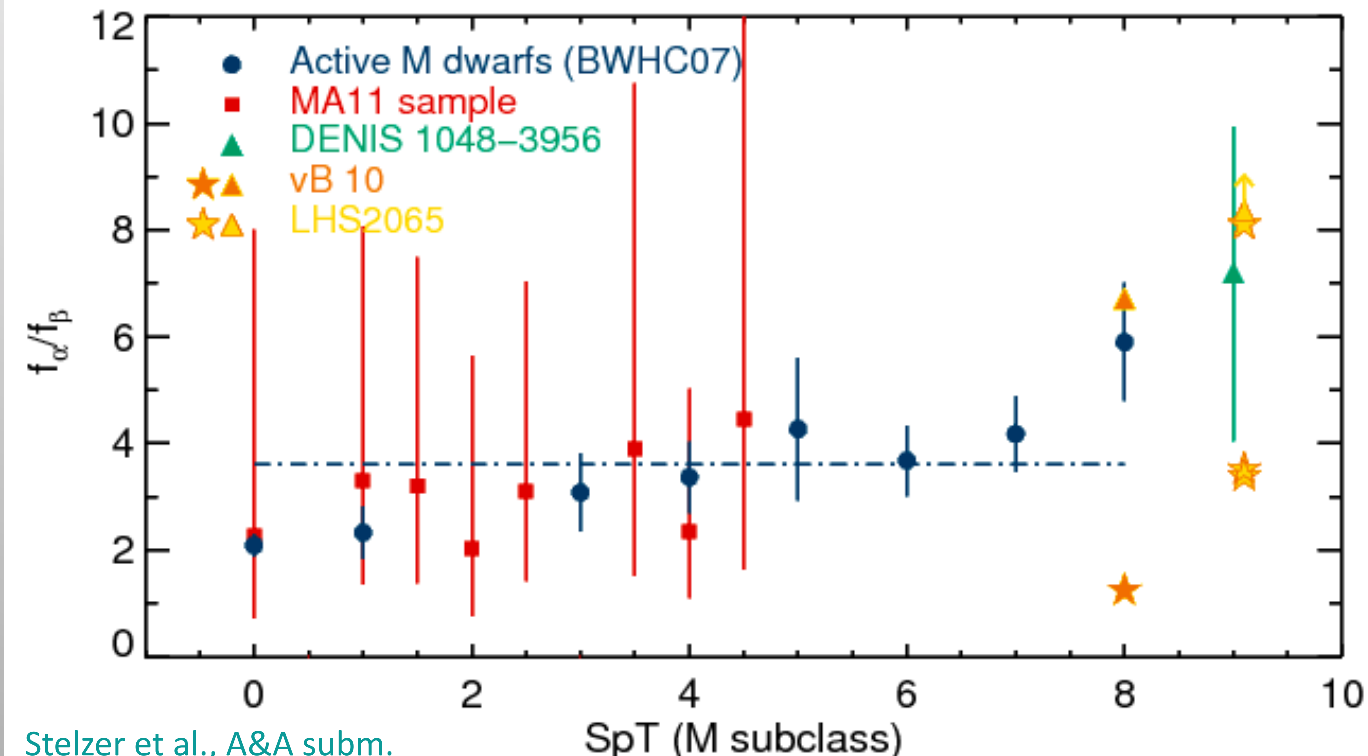
Stelzer et al., A&A subm.



Comparison of DENIS1048 to LTE plasma:
A) opt.thick: ✓ for 2500 K
B) opt.thin: ✓ for 20000 K

- DENIS1048 vs. Sun: resembles solar flare not quiet Sun
- UCDs have high Hα/Hβ
  (with flare/quies. trend opposite to Sun)

Physical conditions of emitting plasma
Hα/Hβ decrements



Stelzer et al., A&A subm.

Increasing Hα decrement with later SpT confirmed by DENIS1048 LHS2085 + vB10

Conclusions for DENIS1048-3956

DENIS1048-3956 ....

....is a bursting radio and quiescent X-ray source („ECM group“)

....has (weak) optical chromospheric emission line spectrum:

roughly consistent with flux-flux relations of early-M dwarfs

but high $H\alpha/H\beta$ ratio
possibly typical for UCDs