X-SHOOTER STUDY OF THE M_{ACC} VS M_{STAR} RELATIONSHIP

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ESTEC - 29.10.2015

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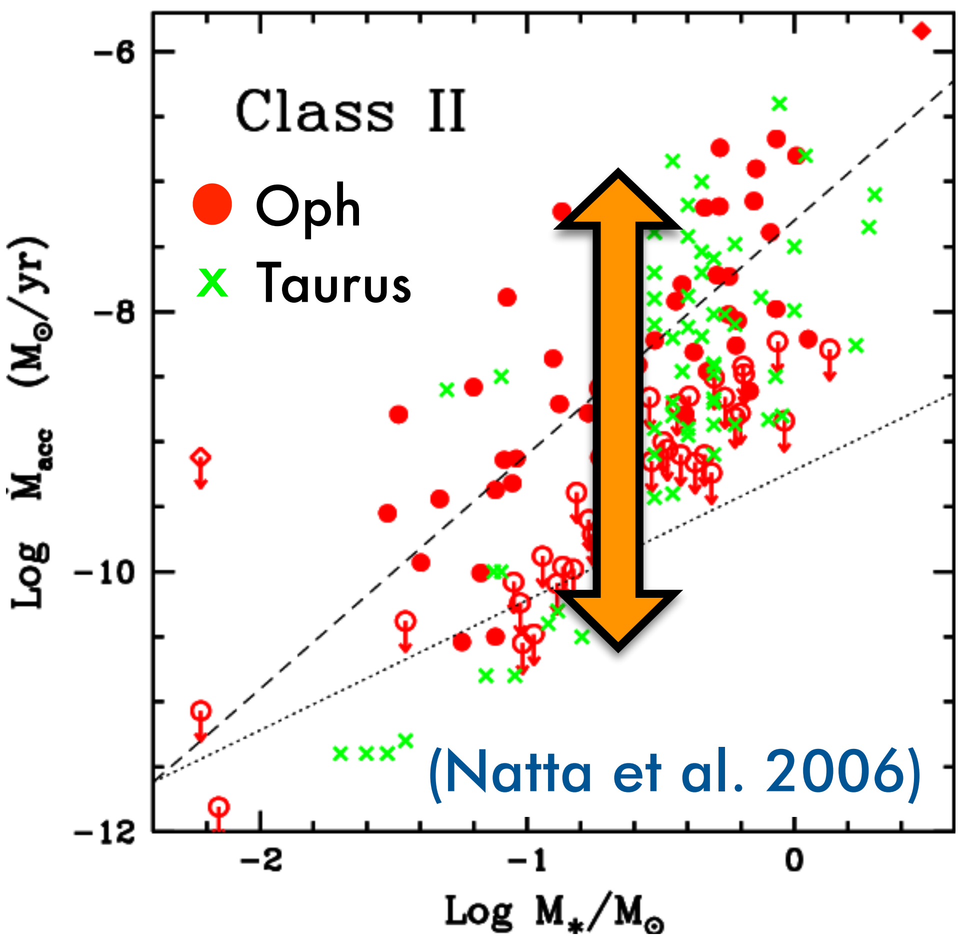
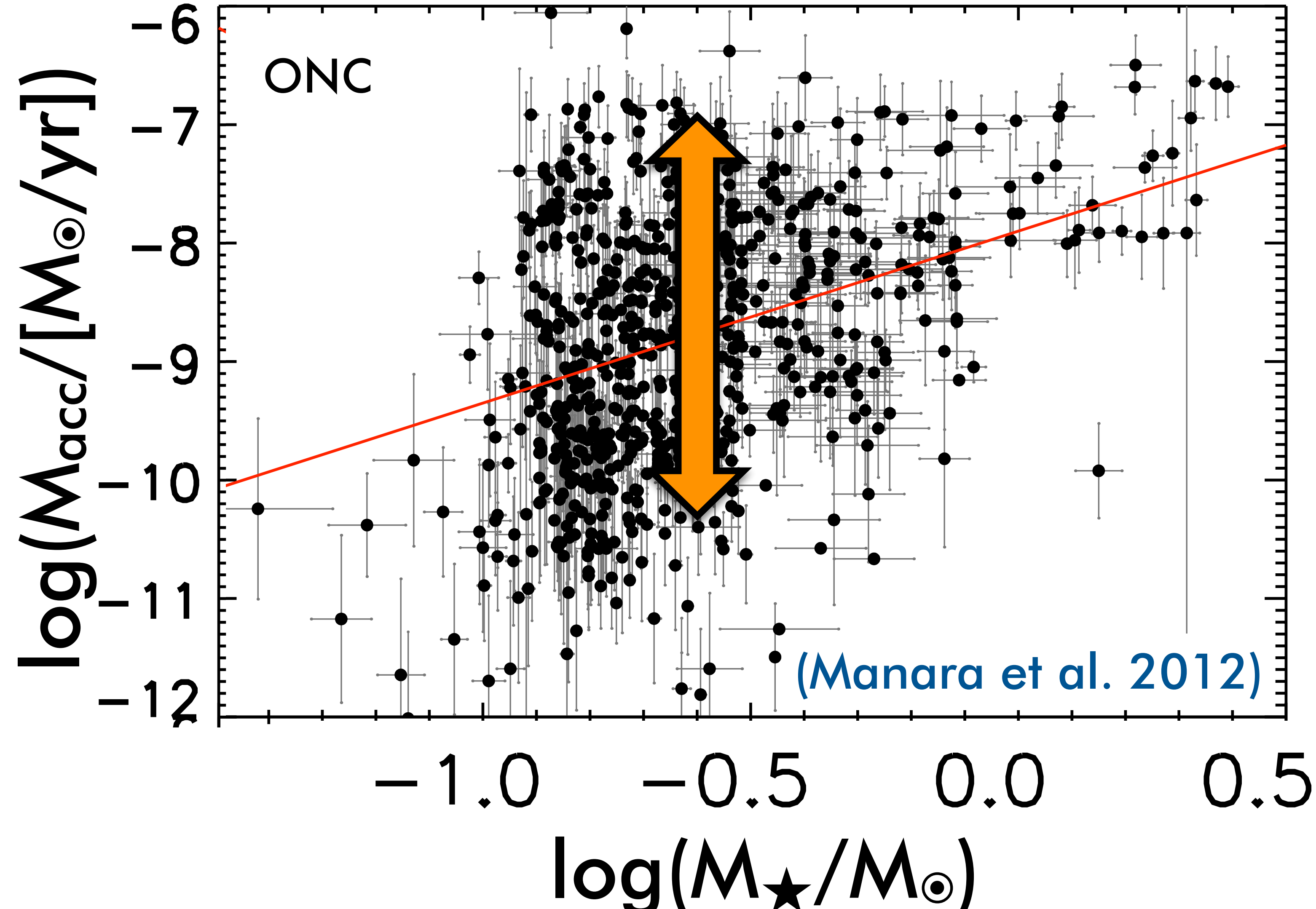
JEDI JEts & Disks @ Inaf

Accretion is a tracer of disk evolution





SLOPE: ($M_{acc} \sim M_\star^\alpha$; $\alpha \sim 2$)

1. Initial conditions (Dullemond+06,Alexander+06)
2. Photoevaporation (Clarke&Pringle 06,Ercolano+14)
3. Environment (Padoan+05)
4. Disk self-gravity (Vorobyov & Basu 08,09)

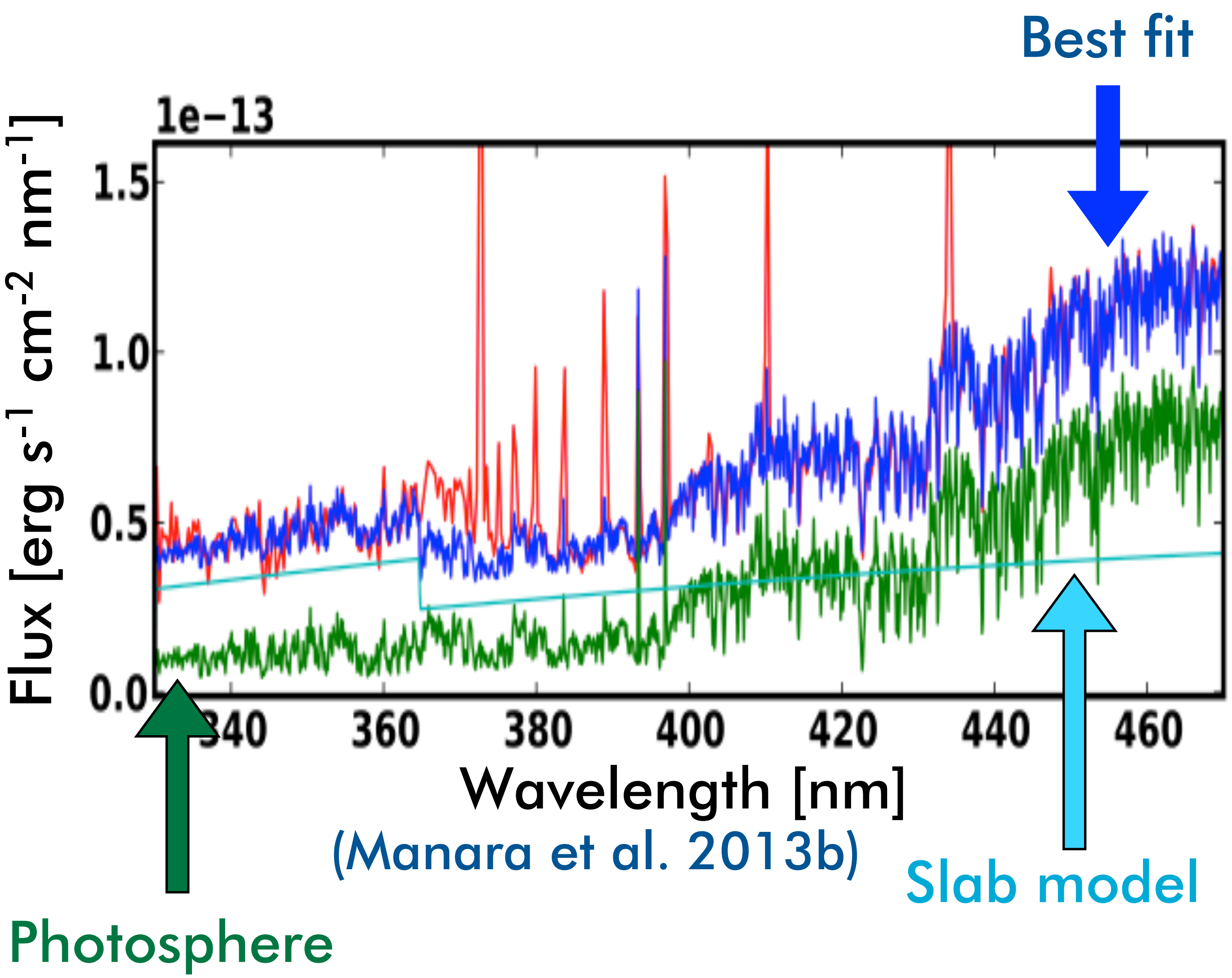
SPREAD:

1. Variable accretion (Costigan+14, Venuti+14), evolution
2. Methods to measure accretion

See also:
Muzerolle et al. 1998, 2003,
Calvet et al. 2004,
Mohanty et al. 2005,
Natta et al. 2004
Hartmann 2009,
Rigliaco et al. 2011,
Da Rio et al. 2014,
Ercolano et al. 2014,
Venuti et al. 2014 …

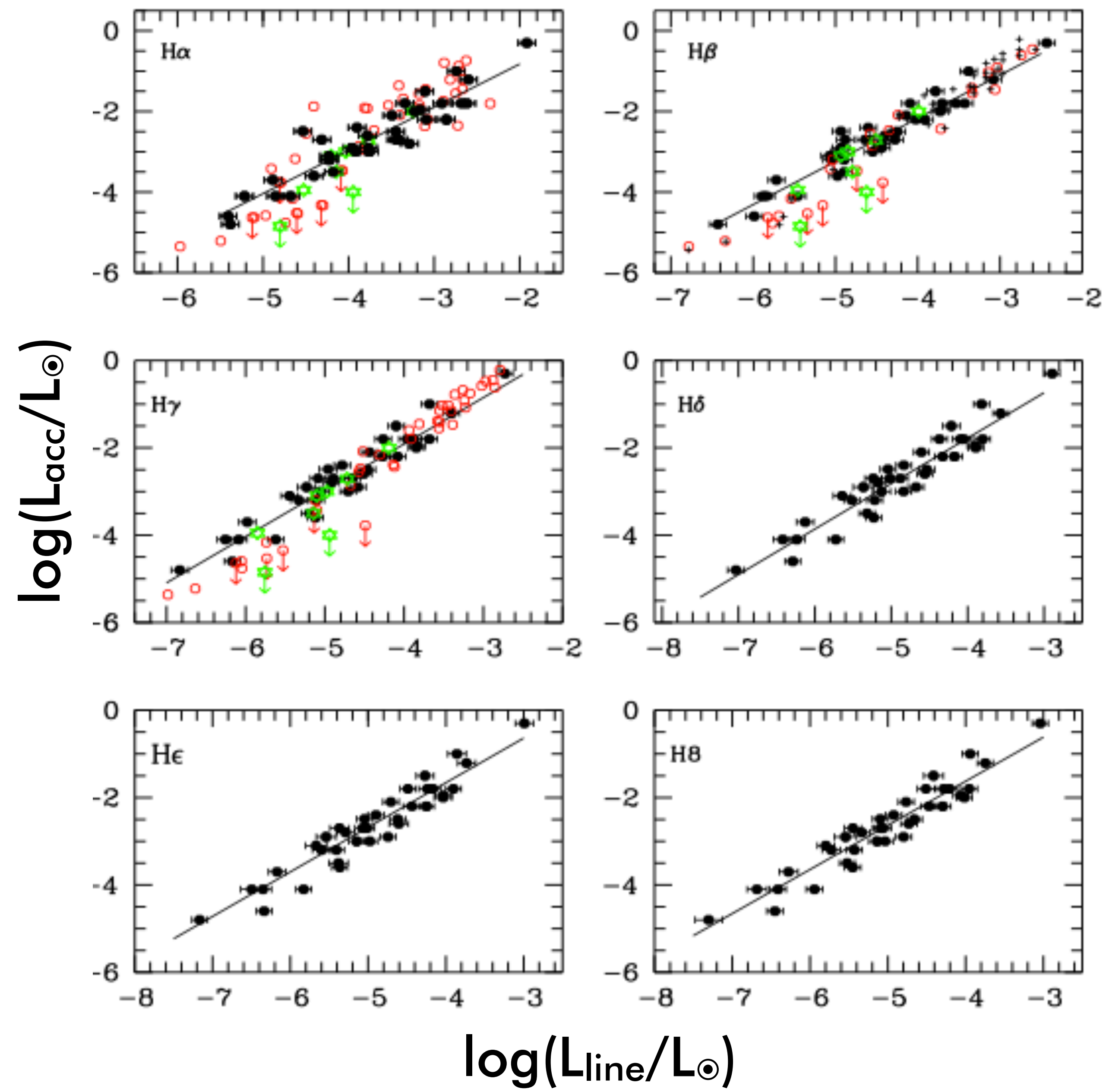
How to measure accretion

UV - excess



(Manara et al. 2013b)

Line luminosity

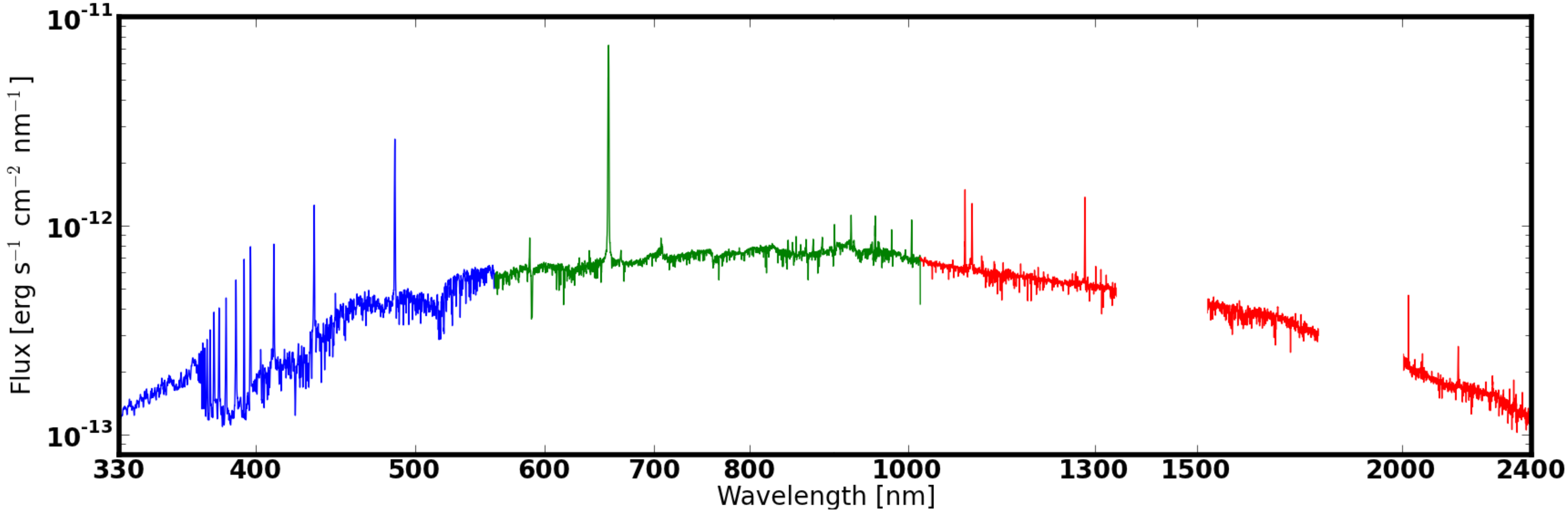


(Alcala, Natta, Manara et al. 2014)

See also:

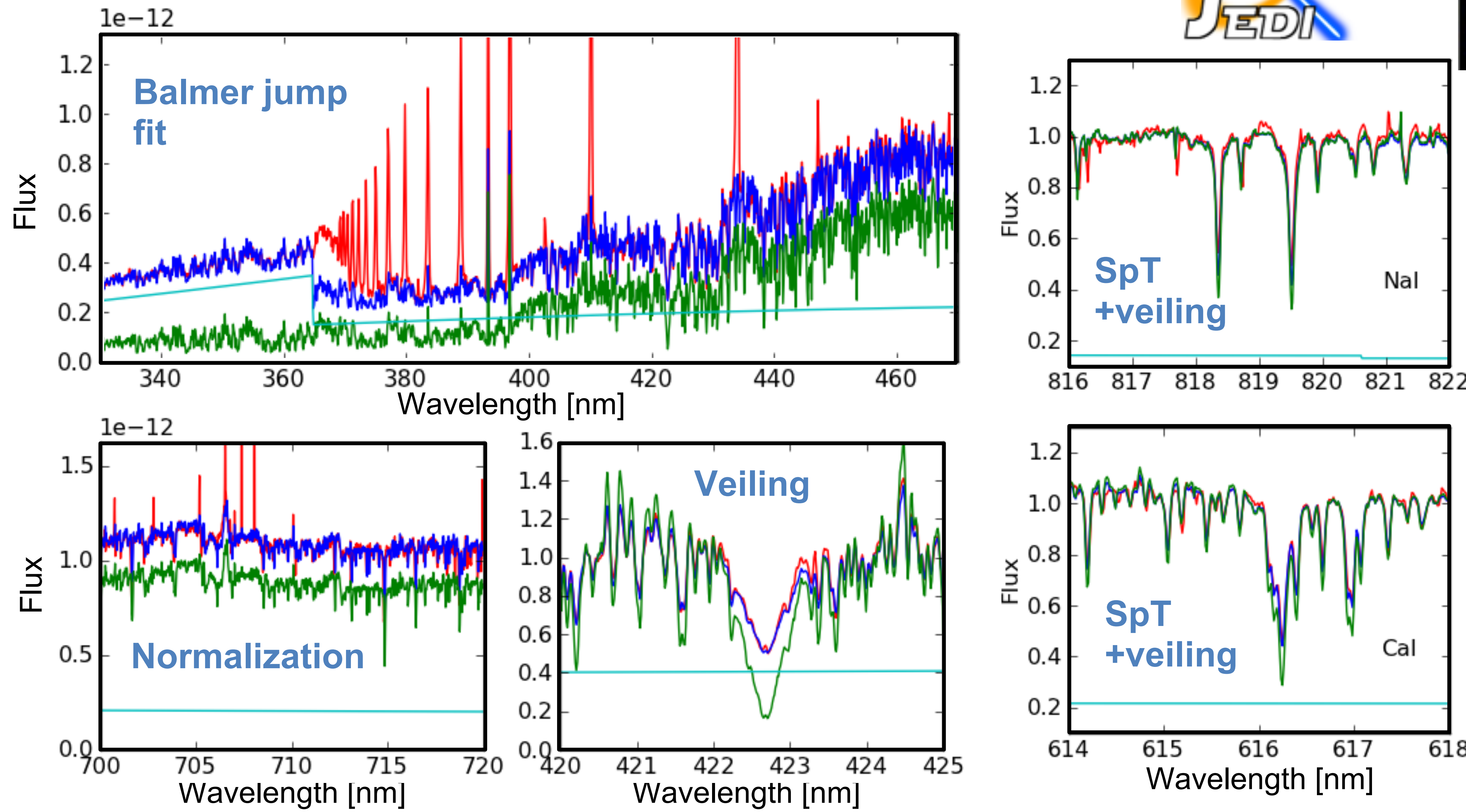
Valenti et al. 1993, Calvet&Gullbring 1998, Muzerolle et al. 2000, Calvet et al. 2004, Dahm et al. 2004, Natta et al. 2004, 2006, Herczeg & Hillenbrand 2008, Fang et al. 2009, Biazzo et al. 2012, Rigliaco et al. 2012, Ingleby et al. 2013

VLT/X-Shooter



- Medium resolution and high-sensitivity
- Simultaneous observation from ~300 nm to ~2500 nm
  - UV-excess
  - Many accretion diagnostics
  - Photospheric features

Accretion and stellar properties determination



Manara et al. 2013b

- Photospheric templates: Class III YSOs (Manara et al. 2013a) ➜ SpT, $L_\star$
- Isothermal hydrogen slab model for the accretion shock spectrum ➜ L_{acc}
- Extinction values + reddening law ➜ A_V

ACCRETION & STELLAR PROPERTIES DETERMINATION

X-Shooter surveys

σ-Orionis
Age ~ 3-5 Myr
$0.08 < M_\star/M_\odot < 0.3$
8 Class II YSOs
(Rigliaco et al. 2012)

Lupus
Age ~ 2-3 Myr
$0.1 < M_\star/M_\odot < 1.2$
36 Class II YSOs
(Alcala, Natta, Manara+2014)

TW Hyadrae
Age ~ 5-10 Myr
$M_\star/M_\odot < 0.6$
<10 Class II YSOs
(Stelzer et al. in prep)

Italian GTO (PI Alcala)

+

ρ-Ophiucus (PI Testi)
Age ~ 1 Myr
$M_\star/M_\odot < 0.2$
17 Class II YSOs
(Manara, Testi, Natta & Alcalá 2015a)

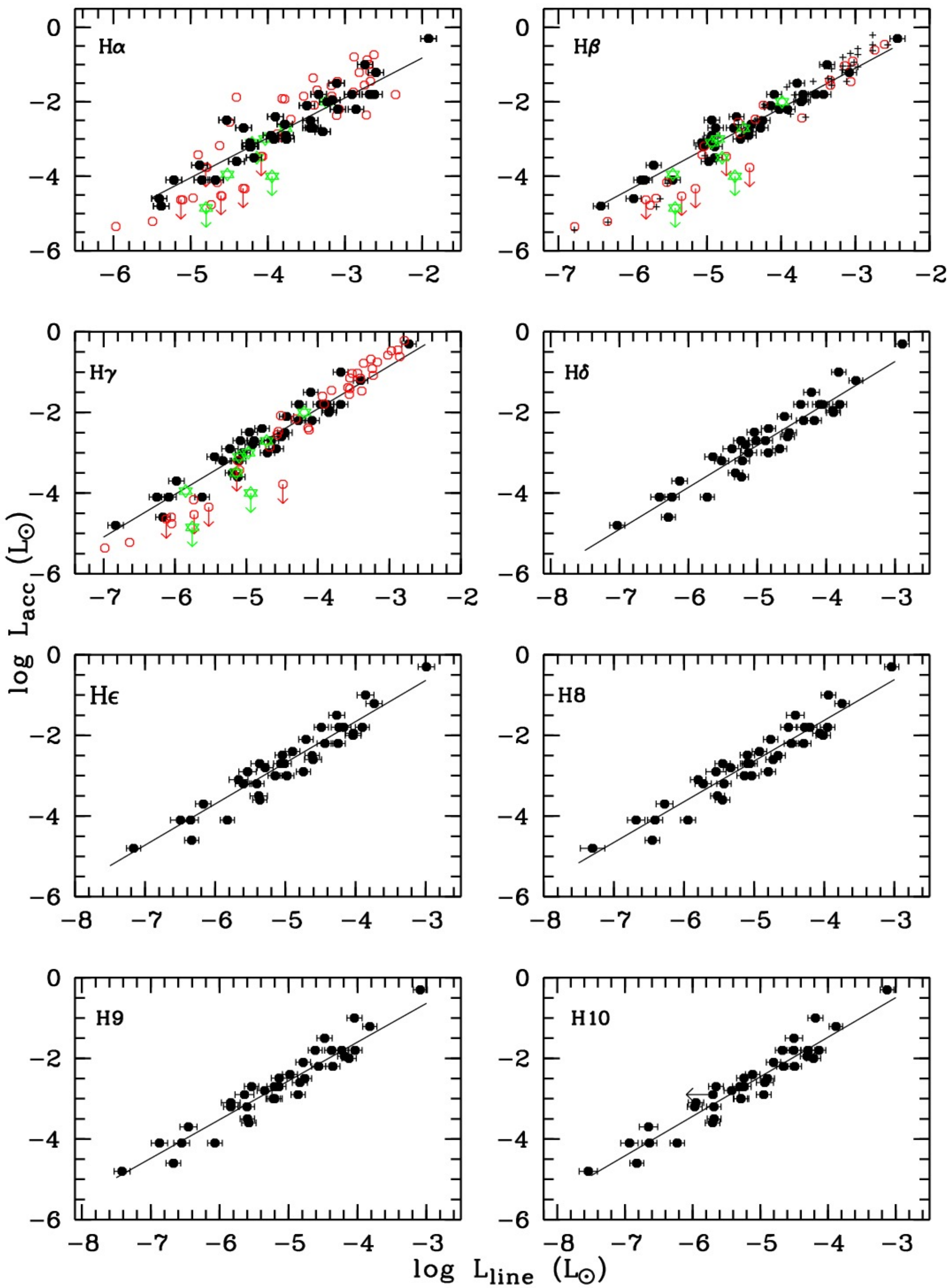
Chamaeleon I (PI Herzceg)
Age ~ 2-3 Myr
$0.1 < M_\star/M_\odot < 2$
31 Class II YSOs
(Manara, Fedele, Herczeg & Teixeira 2015b)

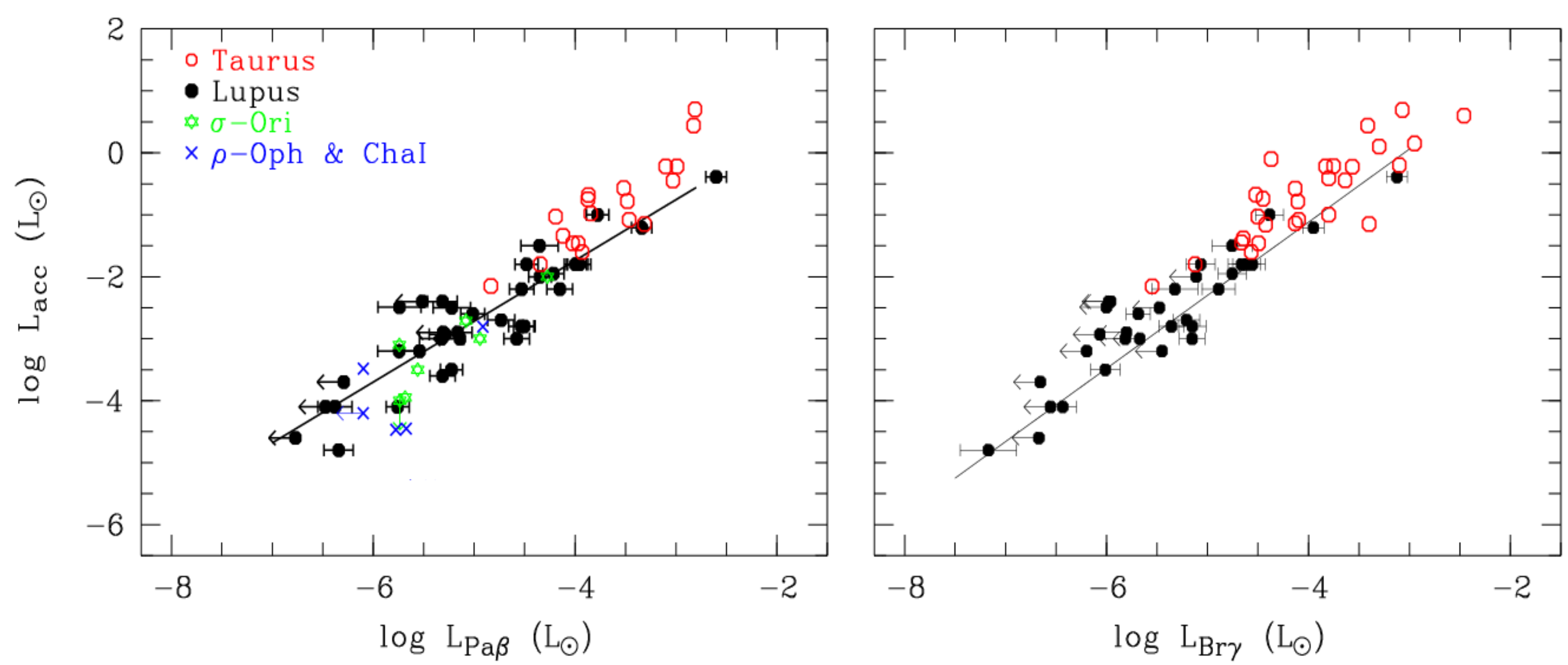
GTO survey: L_{acc} vs L_{line} relationships

$L_{acc} \propto L_{line}^{\eta}$ ($0.9 < \eta < 1.18$)

to zero order linear over 5 orders of magnitude in L_{acc}

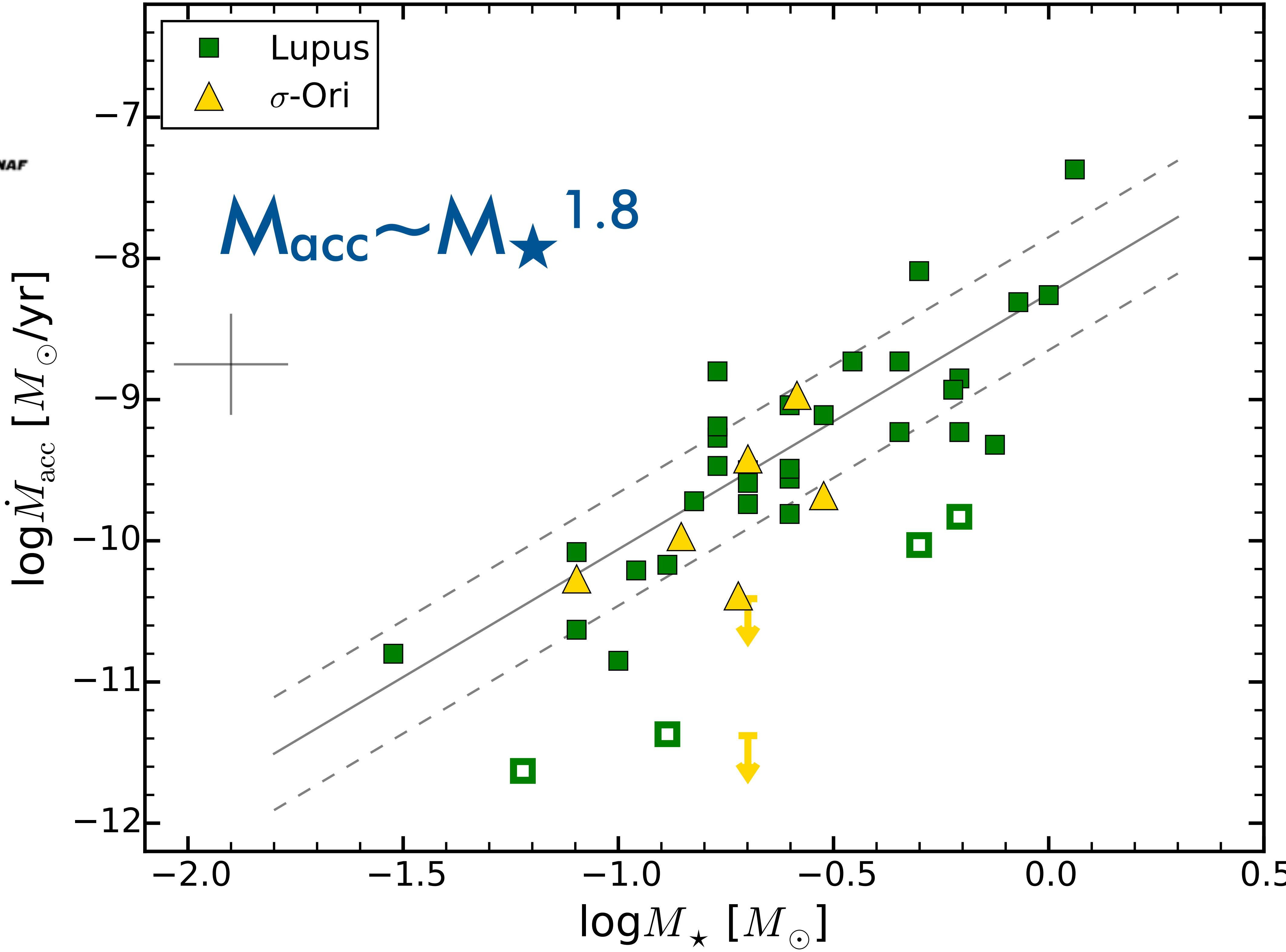
- Balmer lines up to H15
- Pa5 - Pa10 & Br7
- He I & He II (10 lines)
- Ca II (H & K, IRT)
- Na I D lines





Alcalá, Natta, Manara et al. 2014

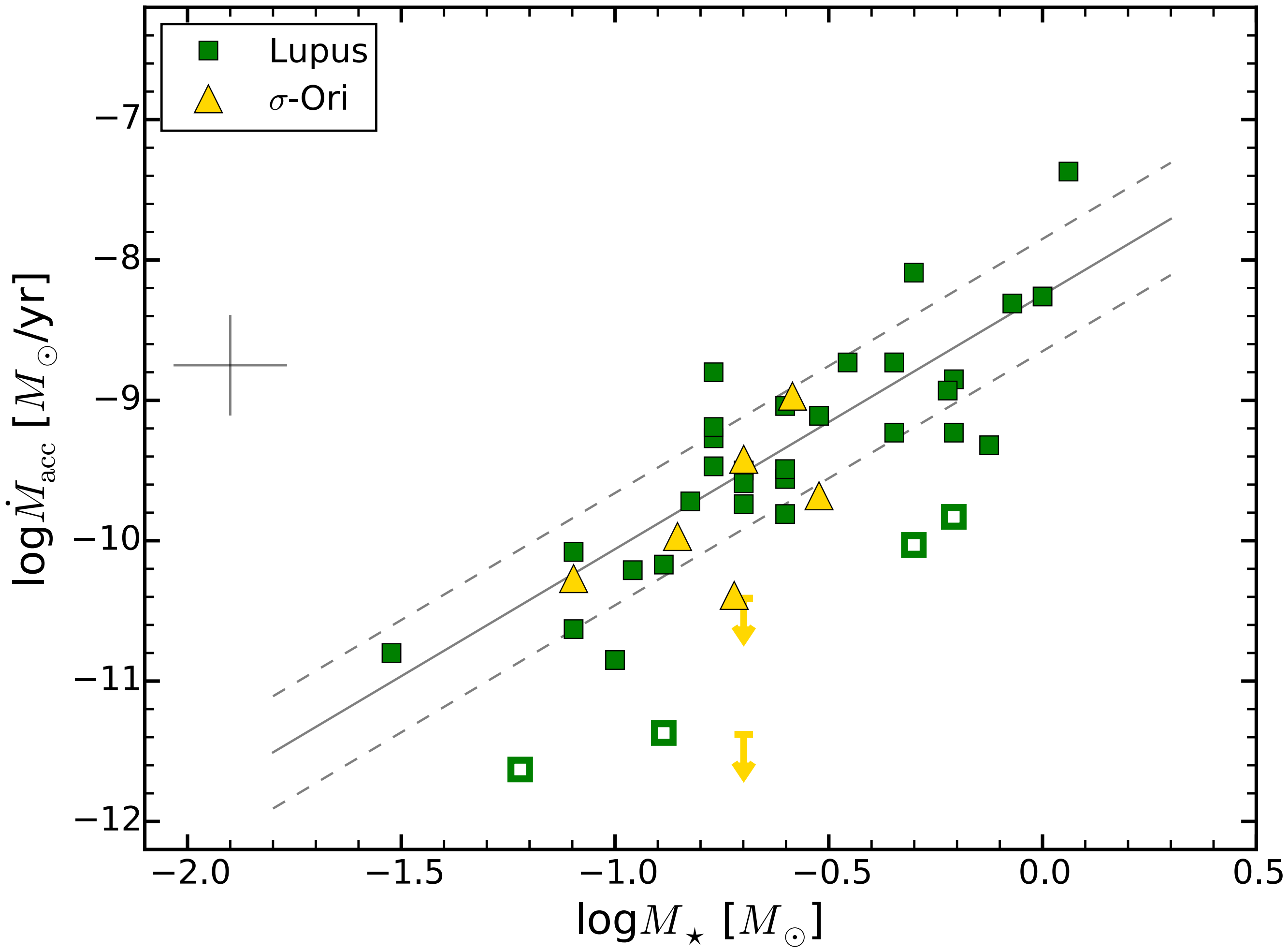
GTO survey: Lupus & σ-Ori



(adapted from) Alcalá, Natta, Manara et al. 2014 and Rigliaco et al. 2012

Low dispersion in comparison with other SFRs

GTO survey: Lupus & σ-Ori

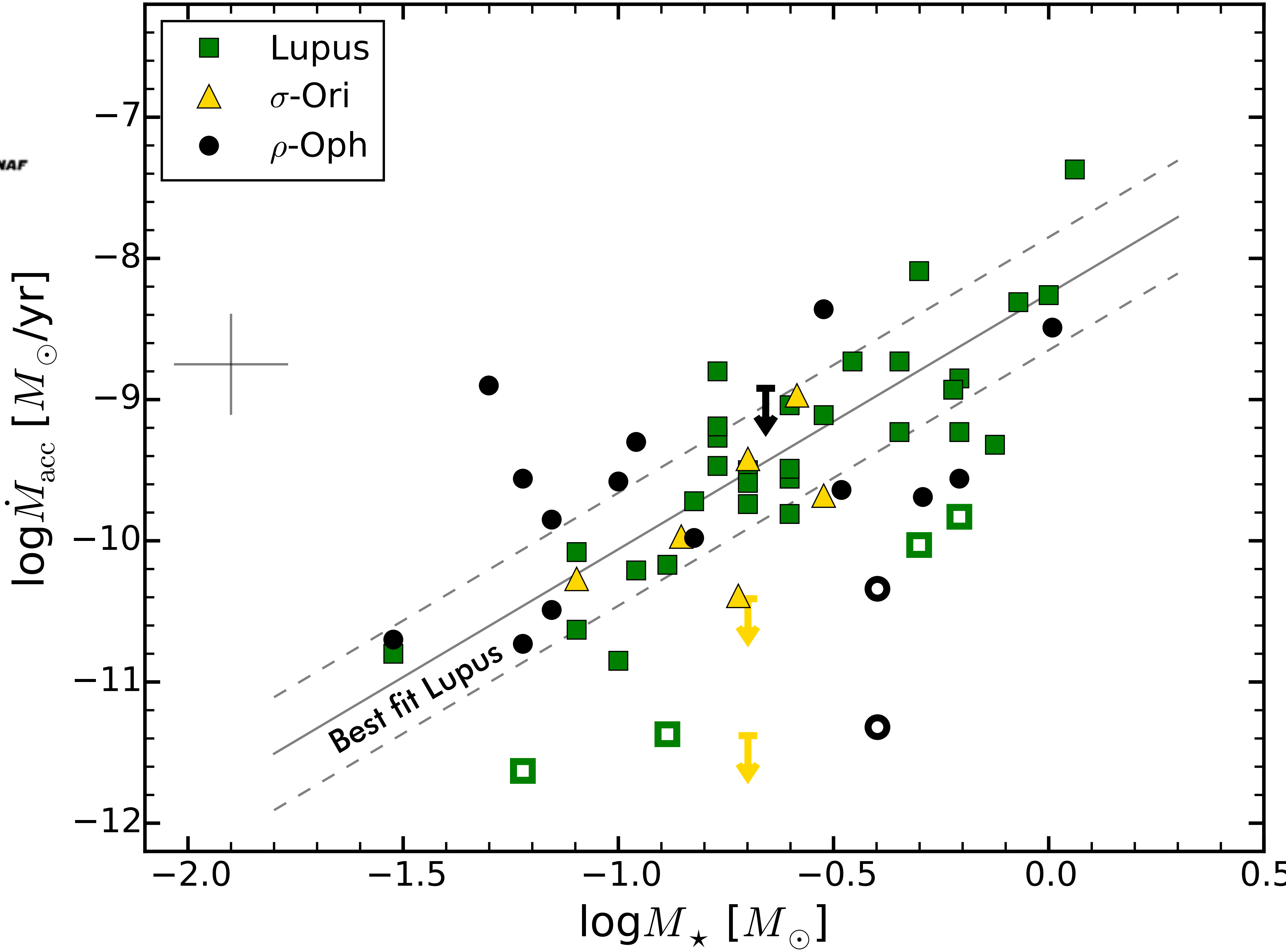


(adapted from) Alcalá, Natta, Manara et al. 2014 and Rigliaco et al. 2012

Low dispersion in comparison with other SFRs

- much better quality of data (homogeneity)?
- Lupus different than other SFRs: particular initial conditions of SF ?

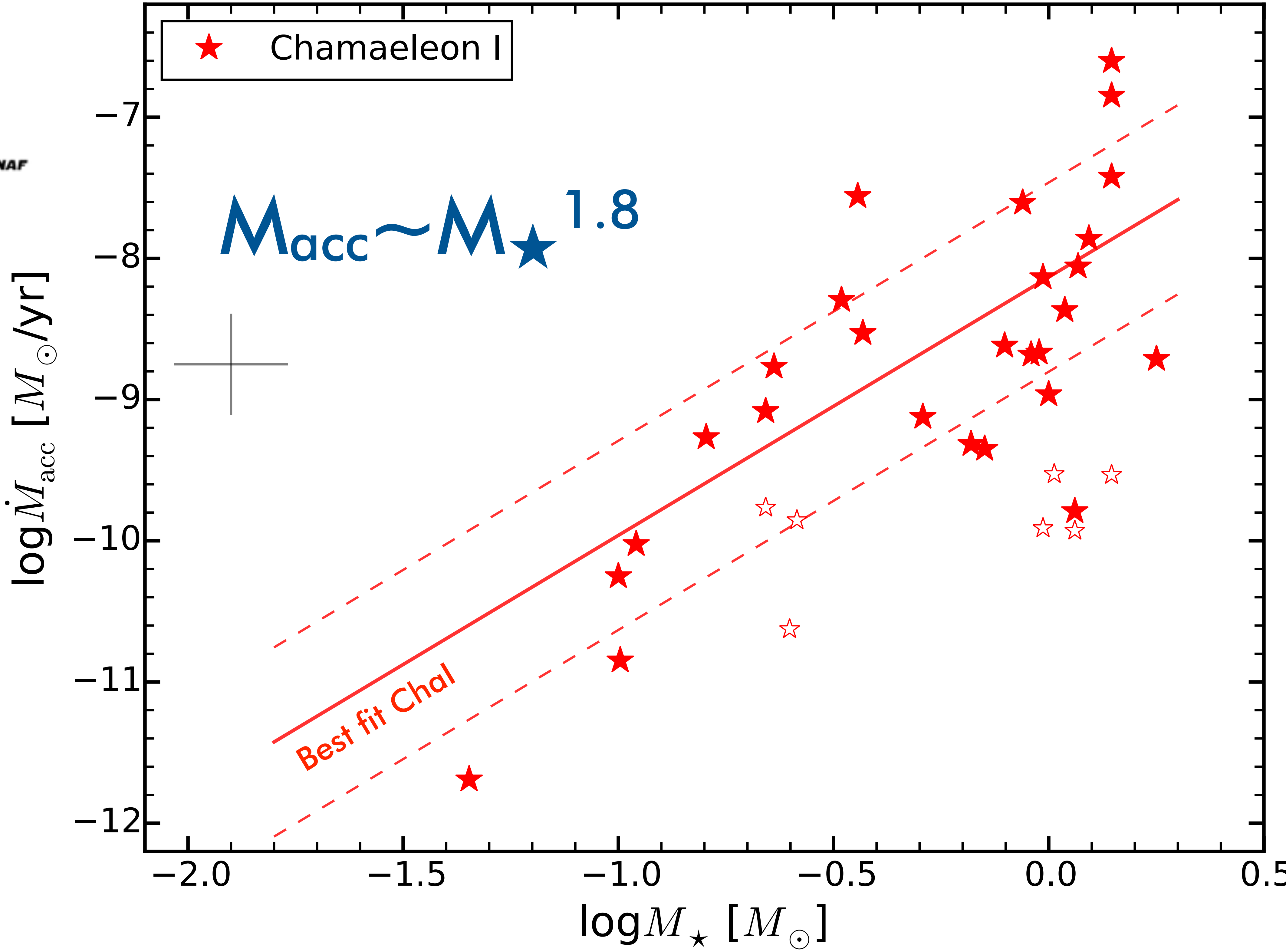
X-Shooter surveys



Manara, Testi, Natta, & Alcalá 2015a

Relation still valid in the brown dwarf regime

X-Shooter surveys

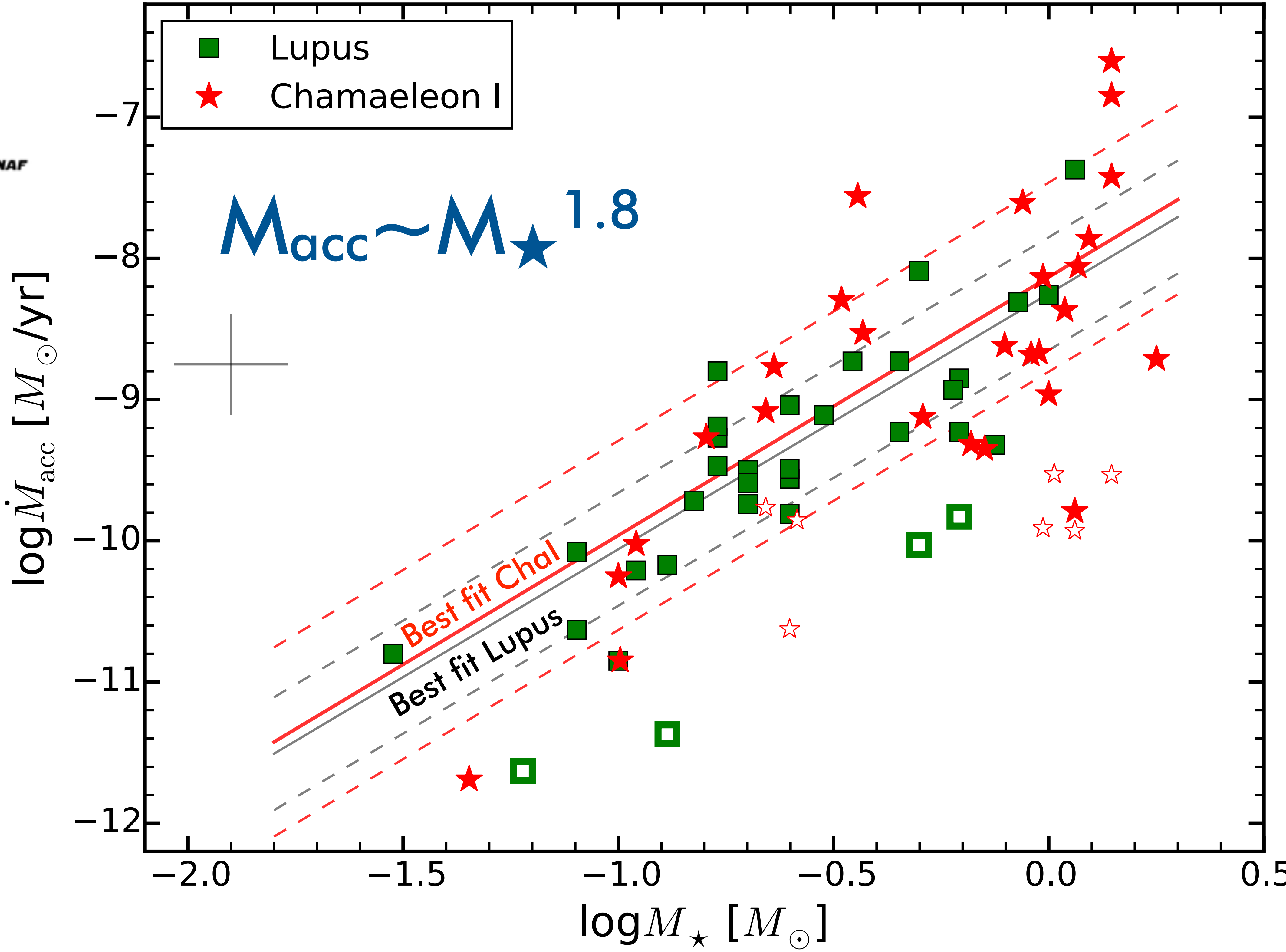


$M_{acc} \sim M_\star^{1.8}$

Manara, Fedele, Herczeg & Teixeira 2015b

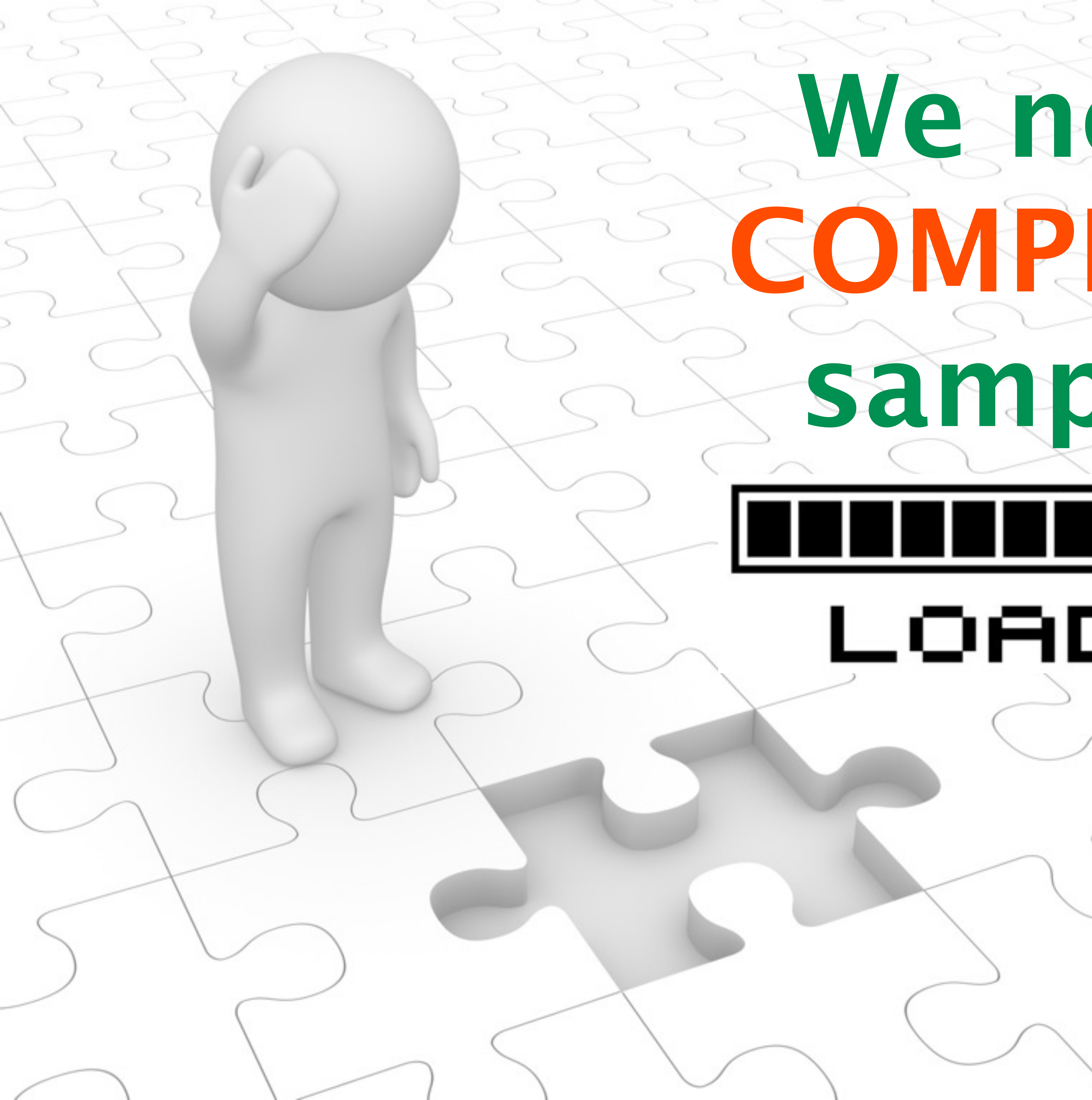
Low dispersion, correlation between M_{acc} and $M_\star$

X-Shooter surveys: Lupus vs Chamaeleon I



Manara, Fedele, Herczeg & Teixeira 2015b

Different initial/environmental conditions?



We need COMPLETE samples

LOADING

X-Shooter surveys: the show goes on

σ-Orionis	Lupus	TW Hyadrae
Age ~ 3-5 Myr	Age ~ 2-3 Myr	Age ~ 5-10 Myr
$0.08<M_\star/M_\odot<0.3$	$0.1<M_\star/M_\odot<1.2$	$M_\star/M_\odot<0.6$
8 Class II YSOs	36 Class II YSOs	~10 Class II YSOs
(Rigliaco et al. 2012)	(Alcala, Natta, Manara+2014)	(Stelzer et al. in prep)

ρ-Ophiucus (PI Testi)	Chamaeleon I (PI Herzceg)
Age ~ 1 Myr	Age ~ 2-3 Myr
$M_\star/M_\odot<0.2$	$0.1<M_\star/M_\odot<2$
17 Class II YSOs	31 Class II YSOs
(Manara, Testi, Natta, & Alcala 2015a)	(Manara, Fedele, Herczeg & Teixeira 2015b)

Lupus (PI Alcala)	ChaI (PI Testi)	Upper Sco (PI Manara)
Age ~ 2-3 Myr	Age ~ 2-3 Myr	Age > 5 Myr
$0.1<M_\star/M_\odot< 2$	$0.1<M_\star/M_\odot<1$	$0.1<M_\star/M_\odot<1.2$
46 Class II YSOs	44 Class II YSOs	~70 Class II YSOs
(P95+P97 - analysis on-going)	(P95+P96 - analysis on-going)	(P97 proposal submitted)

TAKE HOME

1 A detailed METHOD leads to ACCURATE ESTIMATE of stellar and accretion properties and SMALLER SPREAD of accretion rates at a given stellar mass

2 This novel method must be now applied to large (complete) samples!

esa

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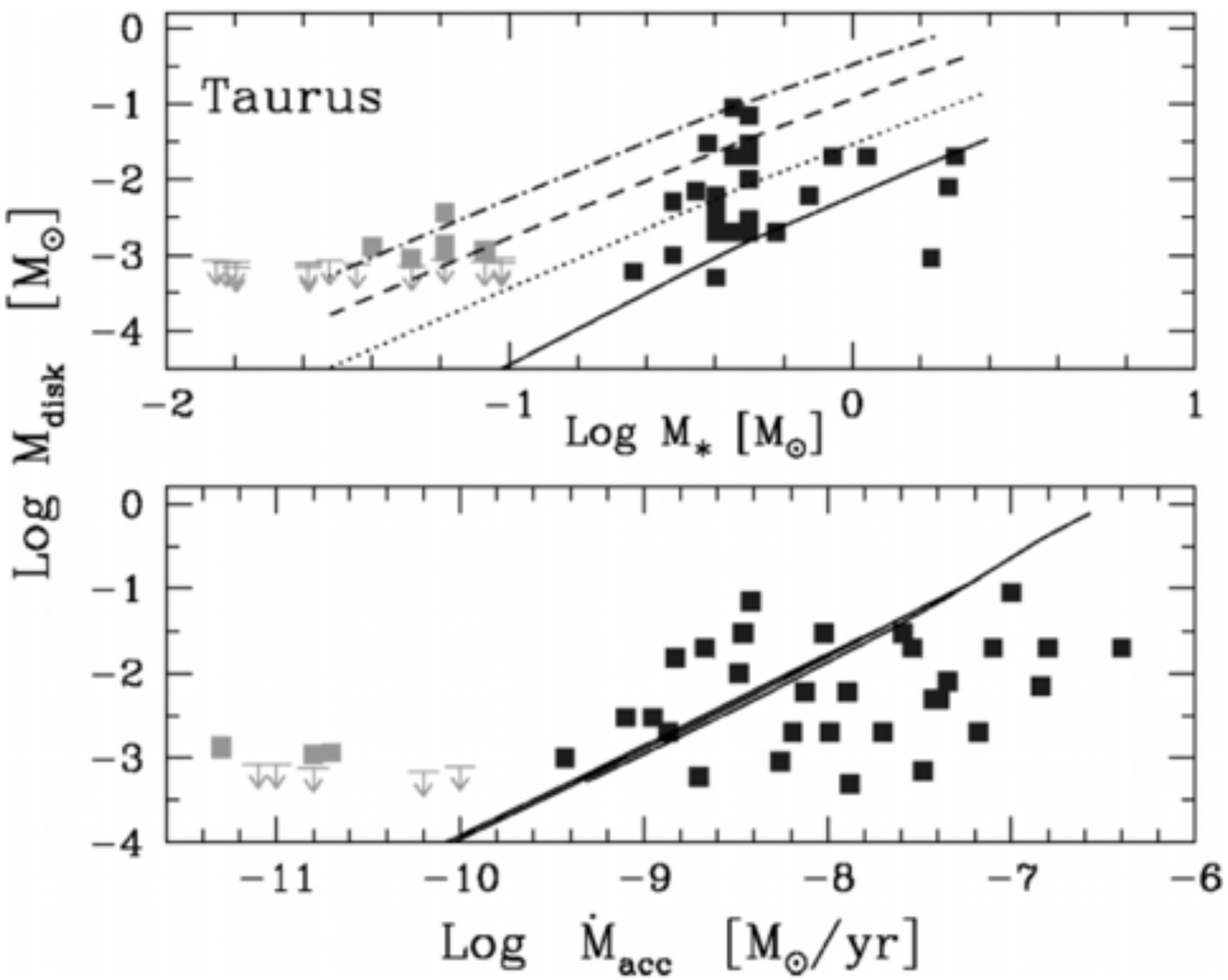
Istituto Nazionale di Astrofisica INAF

What to do with XS+ALMA

Dullemond, Natta, and Testi 2006



A tight M_{acc}-$M_\star$ relation can be due to initial conditions at formation. If true, this implies a tight M_{disk}-M_{acc} relation. ALMA+XS: Lupus & Chamaeleon I

AND DISK INCLINATIONS
AND DYNAMICAL MASSES
FOR THE STARS…

Other X-Shooter works by Jedi

- Mass accretion rate in nearby young clusters (Rigliaco et al. 2012, A&A, 548, A56; Alcala et al. 2014, A&A, 561, A2; Manara et al. 2014, A&A, 568, A18; 2015a, A&A, 579, A66; 2015b, A&A, in press; POSTER by B. Stelzer)
- Photospheric templates of young stellar objects (Manara et al. 2013, A&A, 551, A107) and studies of their chromosphere (Stelzer et al. 2013, A&A, 558, A141)
- Determination of atmospheric parameters of young stellar objects (T_{eff}, logg, vsini, RV; Frasca et al. in prep.)
- Studies of jets from young stellar objects (Bacciotti et al. 2011, ApJ, 737, L26; Whelan et al. 2014, A&A, 565, A80; Giannini et al. 2015, ApJ, in press)
- Studies of peculiar brown dwarfs and ultracool dwarfs (Rigliaco et al. 2011, AN, 332, 249; A&A, 526, L6; Stelzer et al. 2012, A&A, 537, A94; 2013, A&A, 551, A106)
- Slow winds in young stellar objects in Lupus and σ-Ori (Natta et al. 2014, A&A, 569, A5)
- Connection between jets and winds in YSOs in Lupus/Chamaeleon/σ-Ori (POSTER by B. Nisini) and accretion and winds (POSTER by M. Vincenzi)
- Accretion/ejection connection in ISO-ChaI 217 (Whelan et al. 2014, A&A, 570, A59)
- Diagnostics of jets with Fe lines (Giannini et al. 2013, ApJ, 778, 71)
- Determination of Einstein A-coefficients ratios of [FeII] (Giannini et al. 2015, ApJ, 798, 33)
- Studies of Balmer and Paschen decrements (Antoniucci et al. in prep)

JEDI booklet arXiv:1506.07073; Alcala et al. 2011, AN, 332, 242
http://www.oa-roma.inaf.it/irgroup/JEDI/JEDI/Home.html

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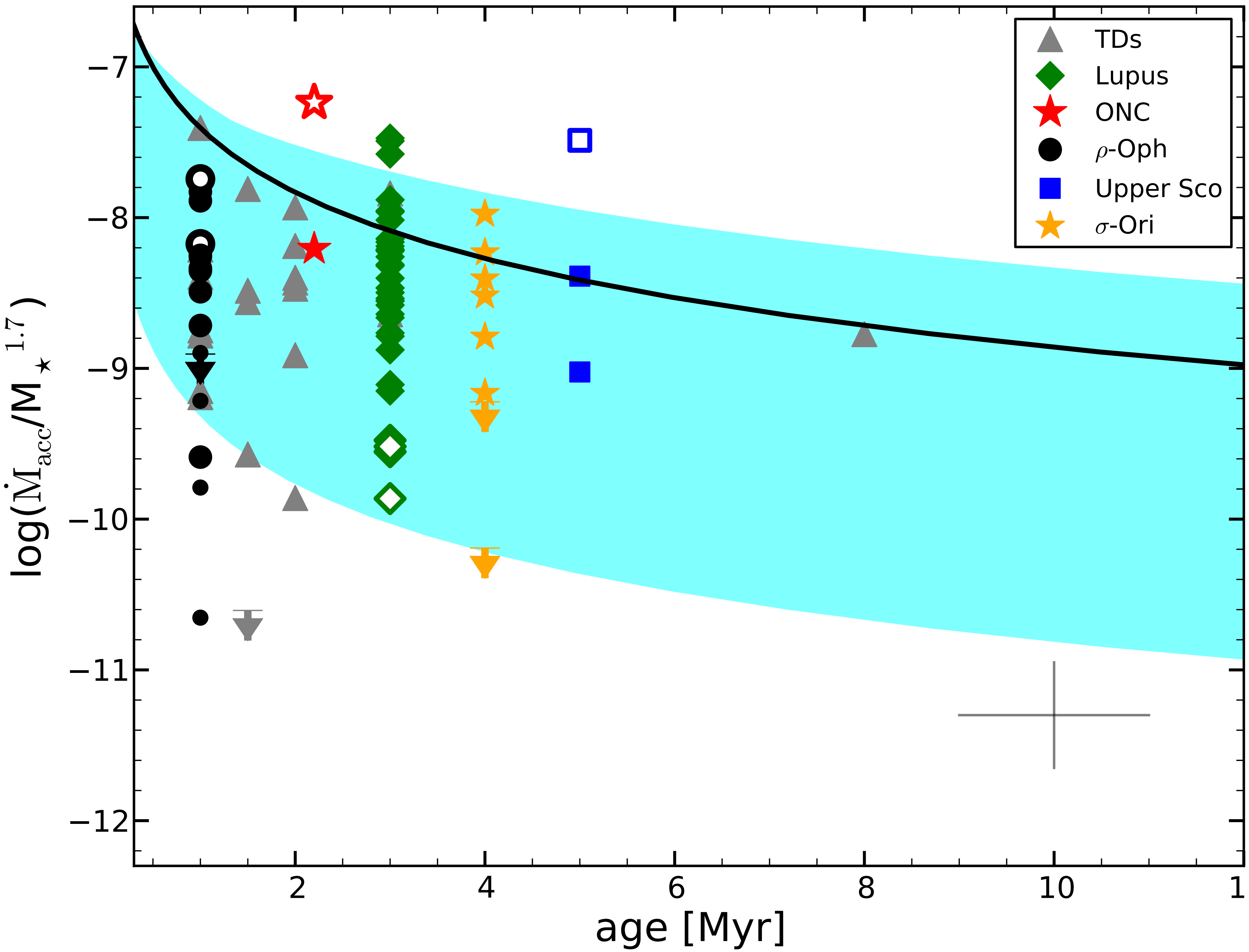
ADDITIONAL SLIDES

Accretion as a function of age



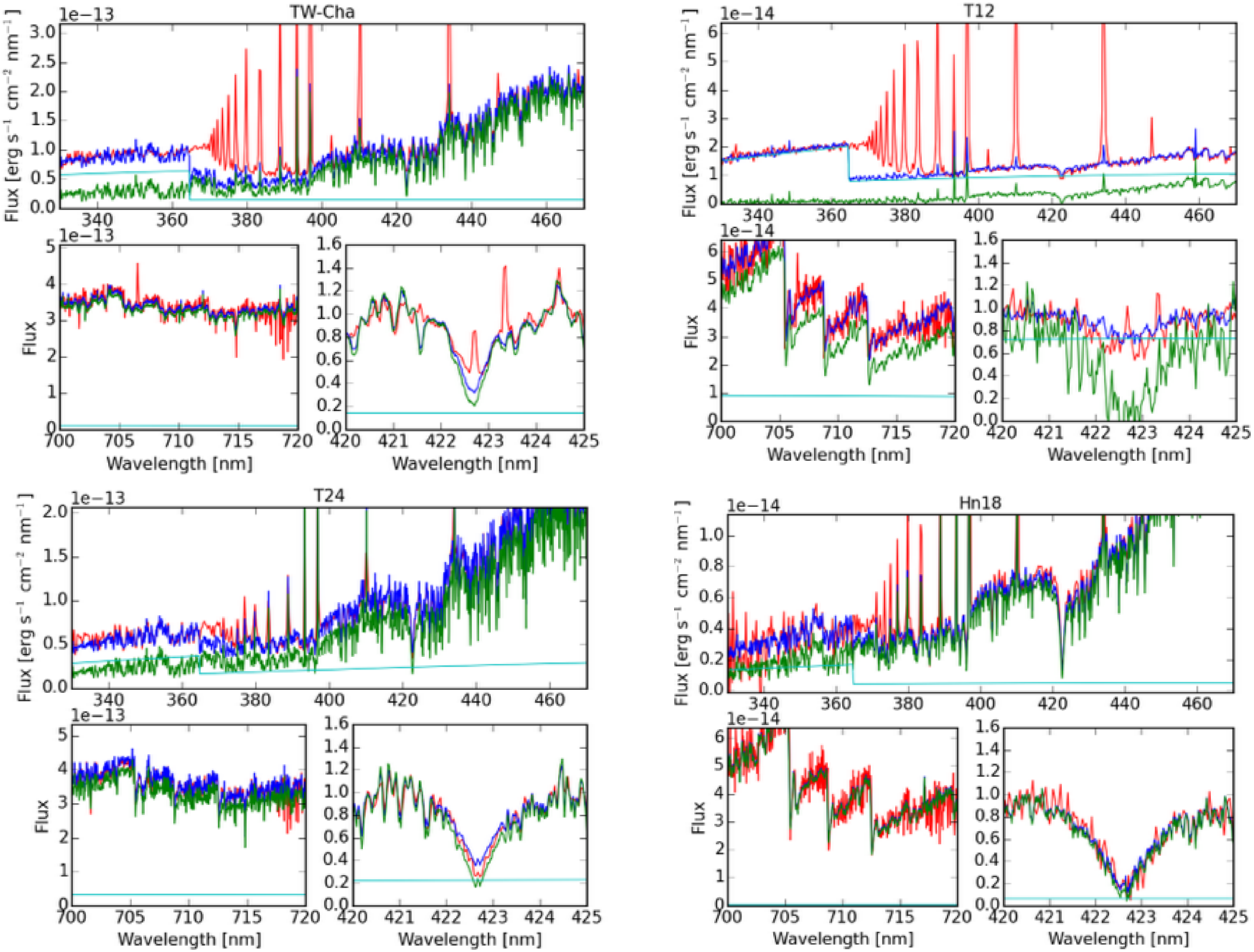
Manara, PhD Thesis, 2014

$10^{-3} < \alpha < 10^{-1}$

$0.005 < M_d(0)/M_\odot < 0.1$

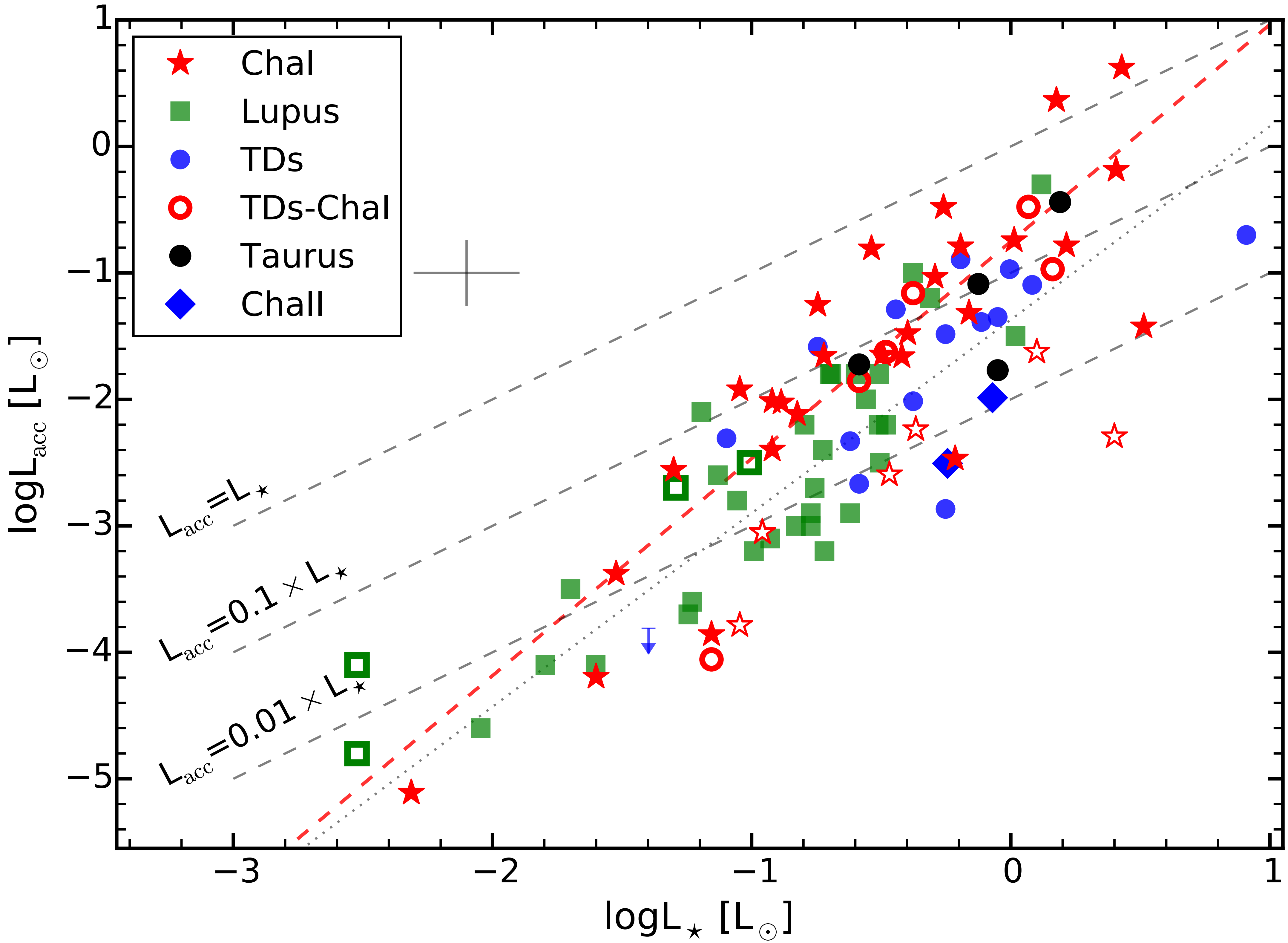
$5 < R_0$ [AU] < 15

Accretion disk properties in nearby clusters - ChaI



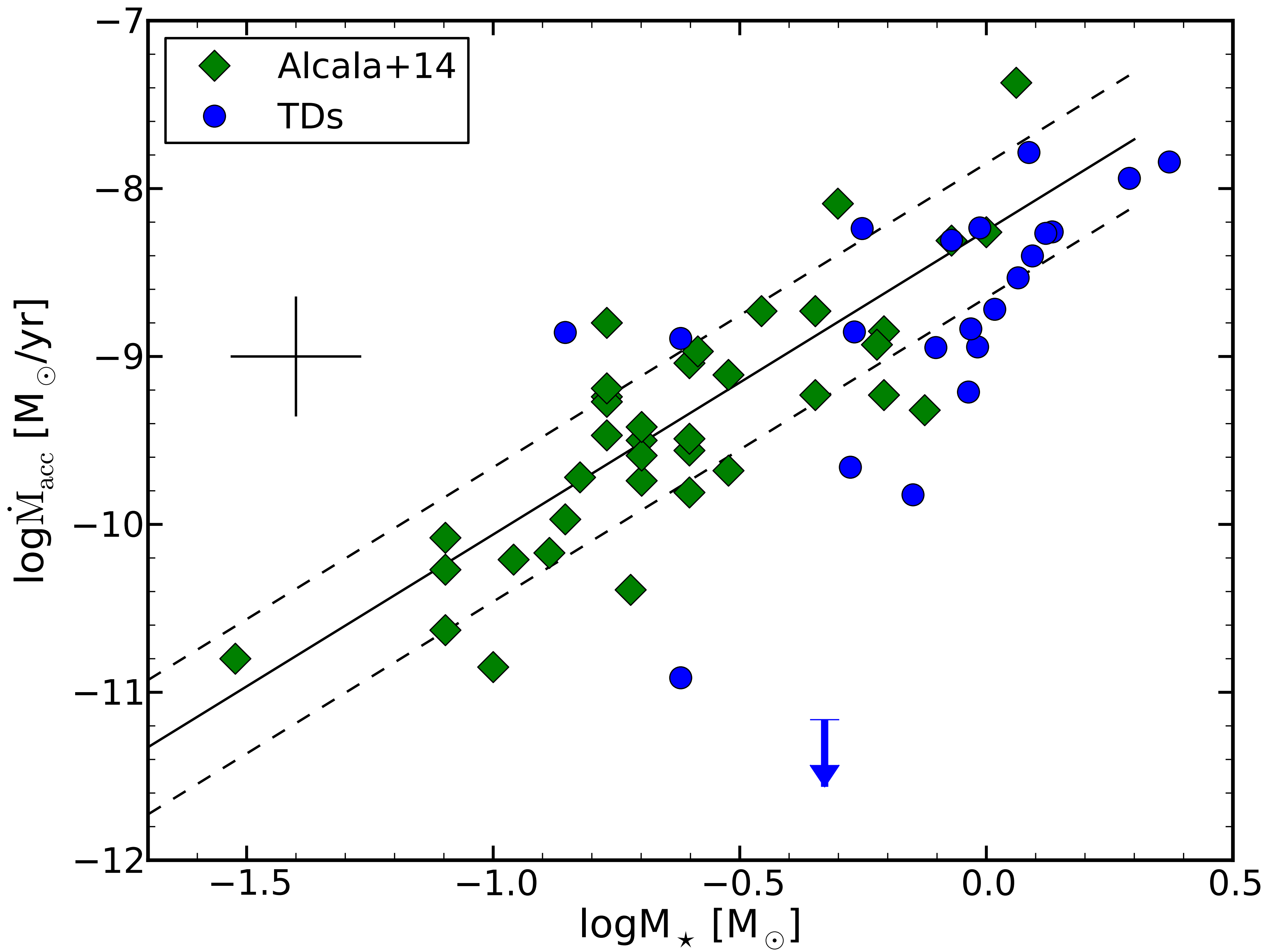
Manara, Fedele, Herczeg, and Teixeira 2015b, in press

Accretion disk properties in nearby clusters - ChaI



Manara, Fedele, Herczeg, and Teixeira 2015b, in press

Accretion in transitional disks



Manara, Testi, Natta et al. 2014

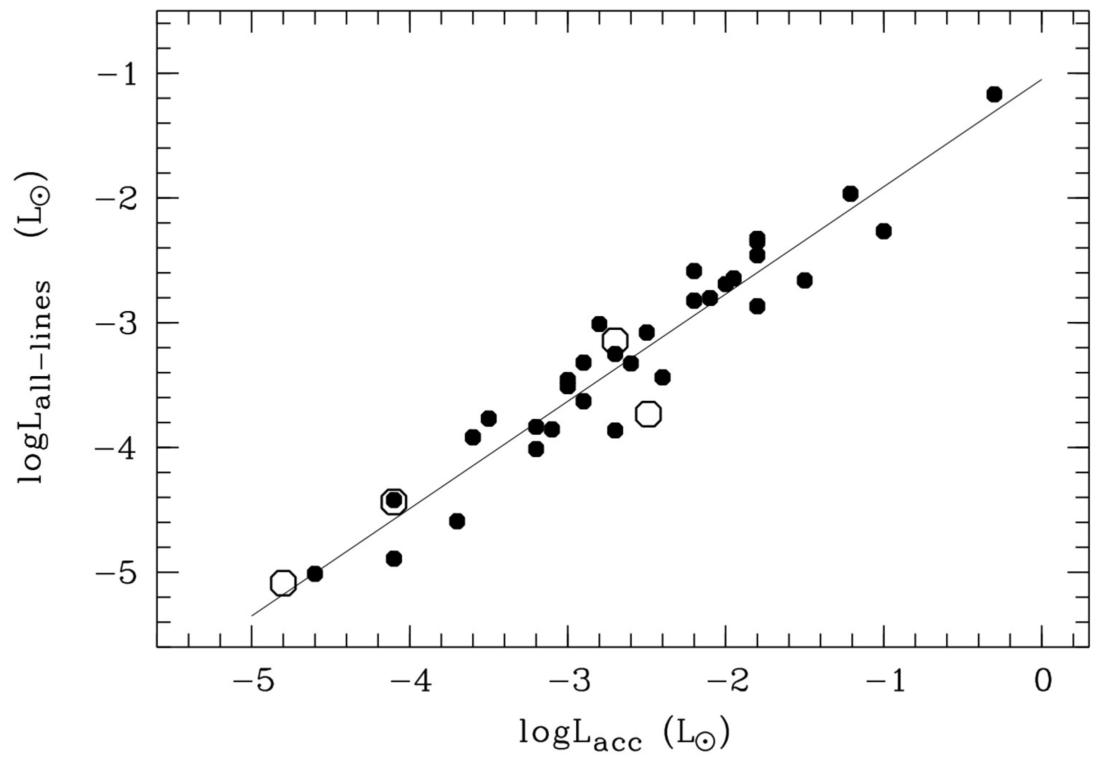
Similar accretion rates as classical disks

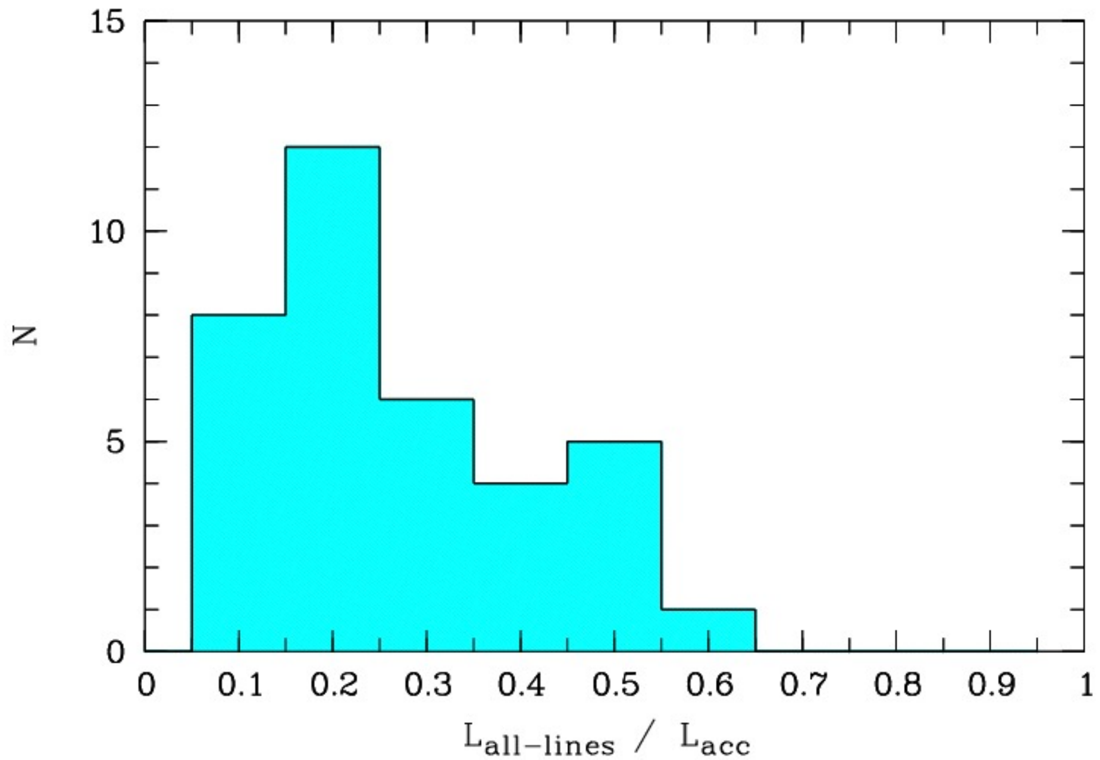
(at least some objects)

$L_{all\text{-}lines}$ vs L_{acc}

$L_{all\text{-}lines}$: sum of all permitted lines (H, Ca II, He) + $L_{pseudo\text{-}continuum}$

- > 70% of integrated line luminosity is in Balmer lines
- in most (90%) YSOs L_{Balmer} > 60% of $L_{all\text{-}lines}$
- in some YSOs (Sz73, Sz83, Sz88A & Sz113) emission in other lines is up to 50%





$L_{all\text{-}lines}$ is a fraction of L_{acc}