Credit: ESO/B. Tafreshi (twanight.org)

Accretion onto young stars in the ULLYSES era

MIAPP - 26.10.2021

ODYSSEUS

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Credit: ESO/B. Tafreshi (twanight.org)

Accretion onto young stars in the ULLYSES era

Catherine Espaillat
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MIAPP - 26.10.2021

ker

Antonio Frasca
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Manuele Gangi
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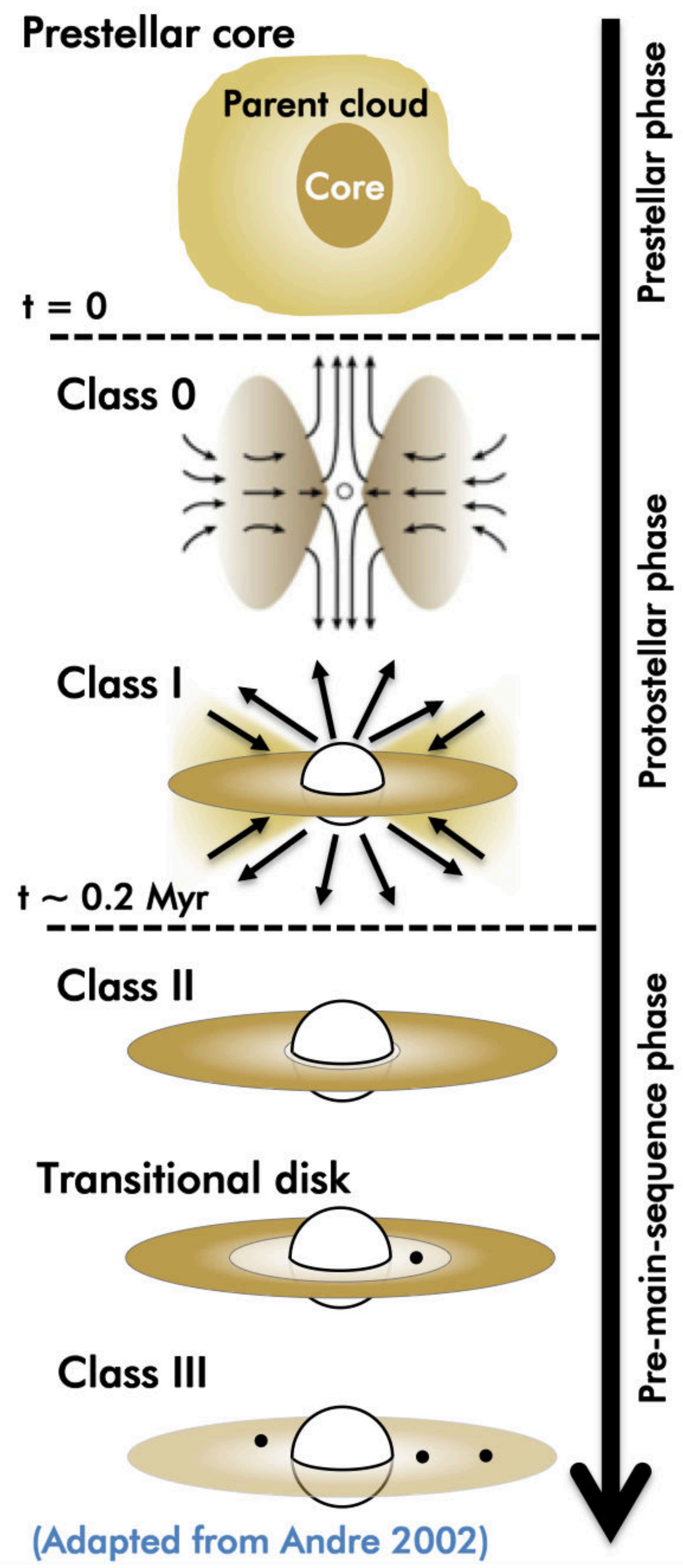
Rik Claes
J. Alcala
J. Campbell-White
PENELLOPE Team

Within your disks there might be a planet, but there surely is a star!

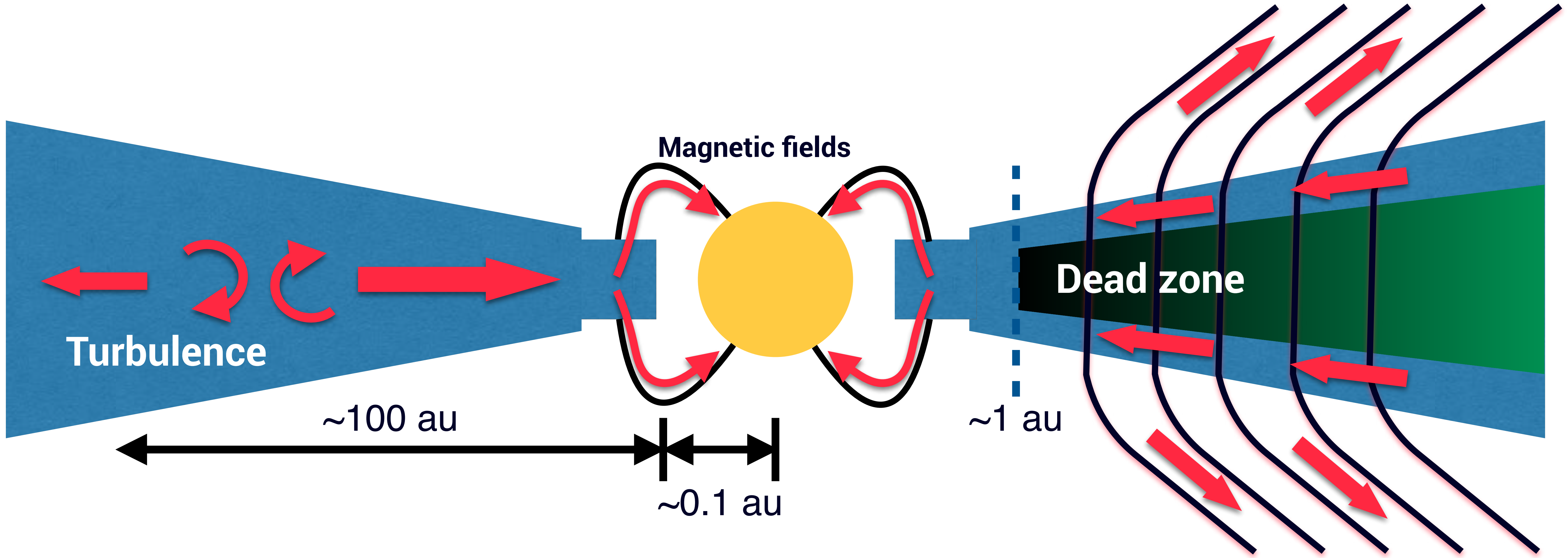
Artist impression for R. Garcia Lopez, GRAVITY et al. 2020. Credits: Mark A. Garlick

The evolution of protoplanetary disks



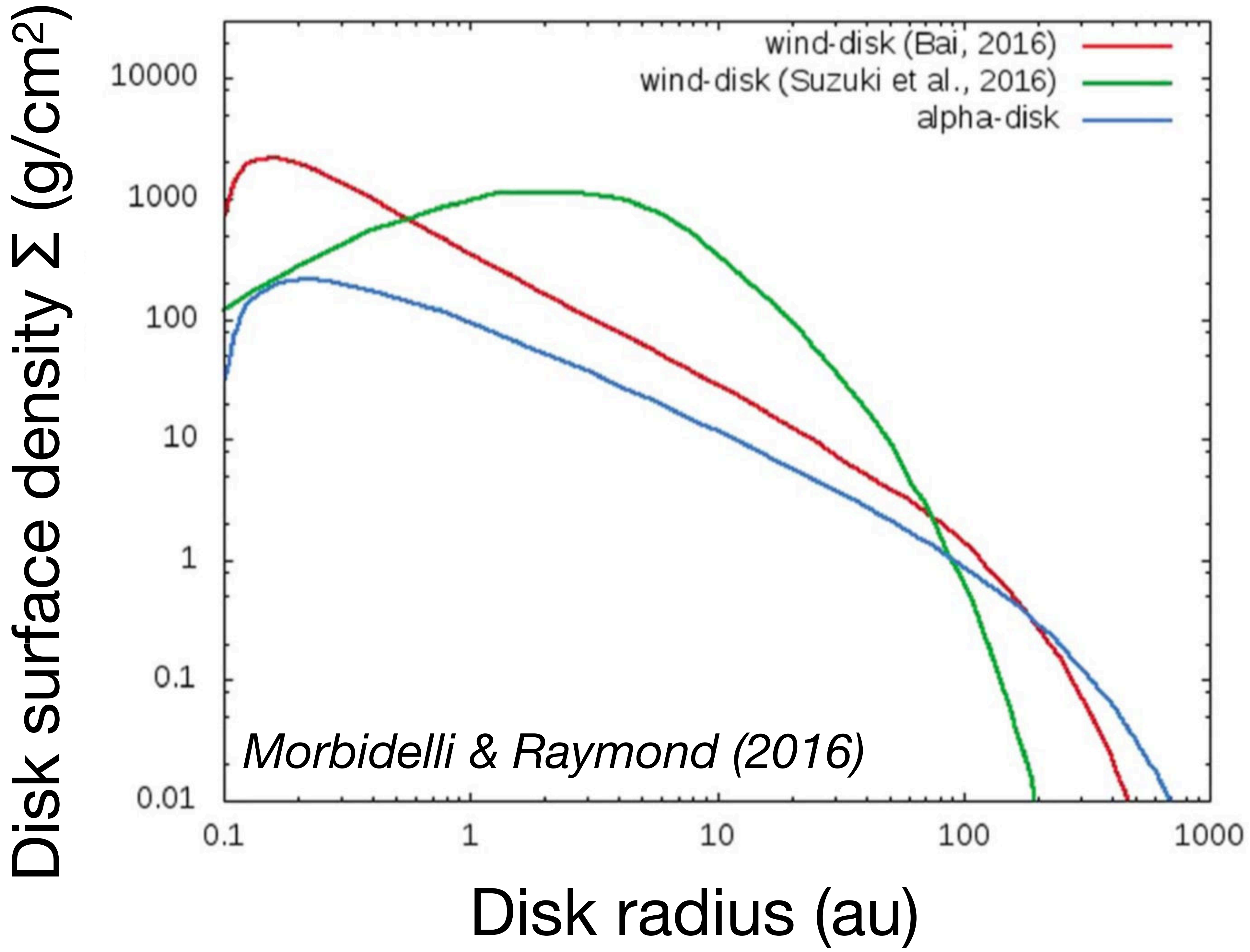
Viscous evolution (α-disk)

e.g., Lynden-Bell & Pringle 1974, Hartmann et al. 1998

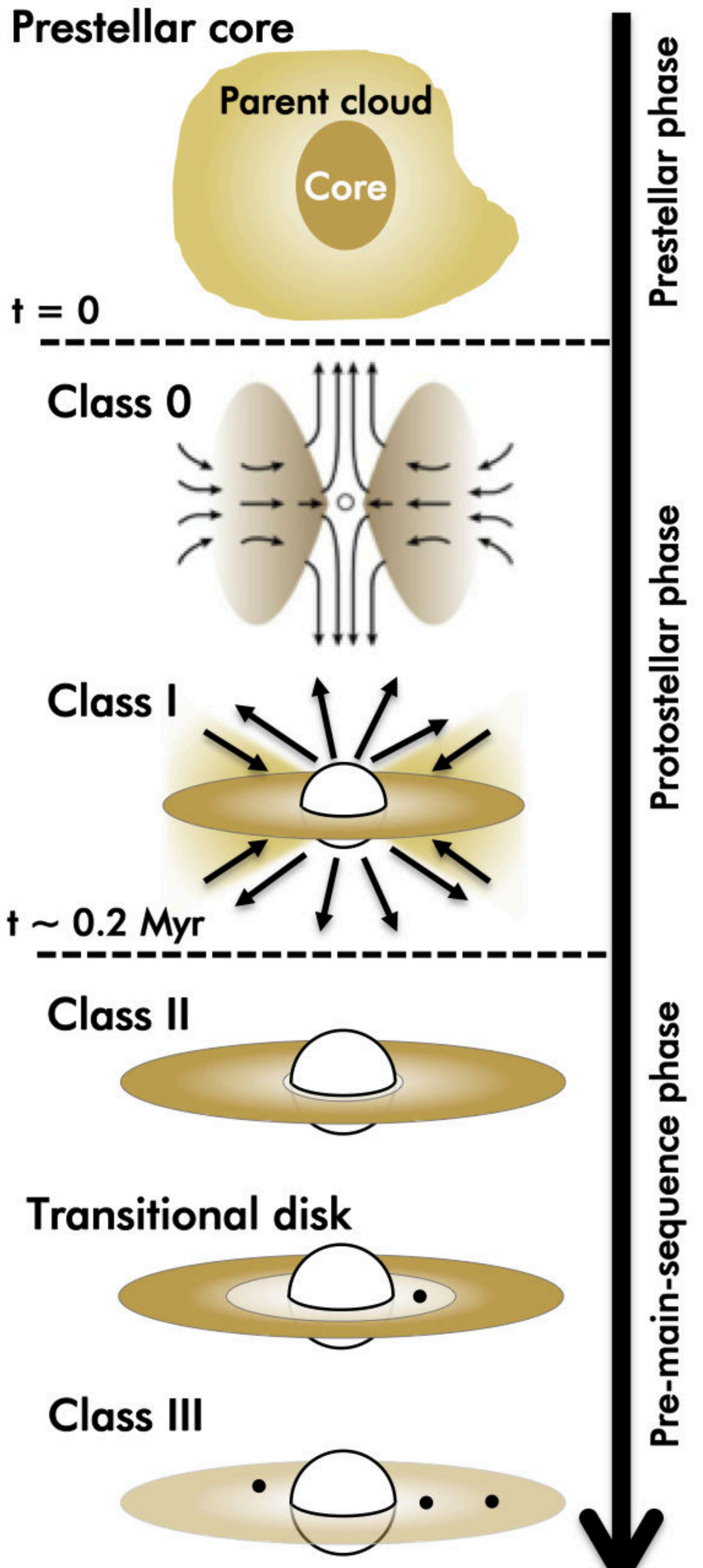


Wind-driven evolution

e.g., Armitage et al. 2013, Bai et al. 2014, 2015, 2016, Gressel et al. 2015, Simon et al. 2015



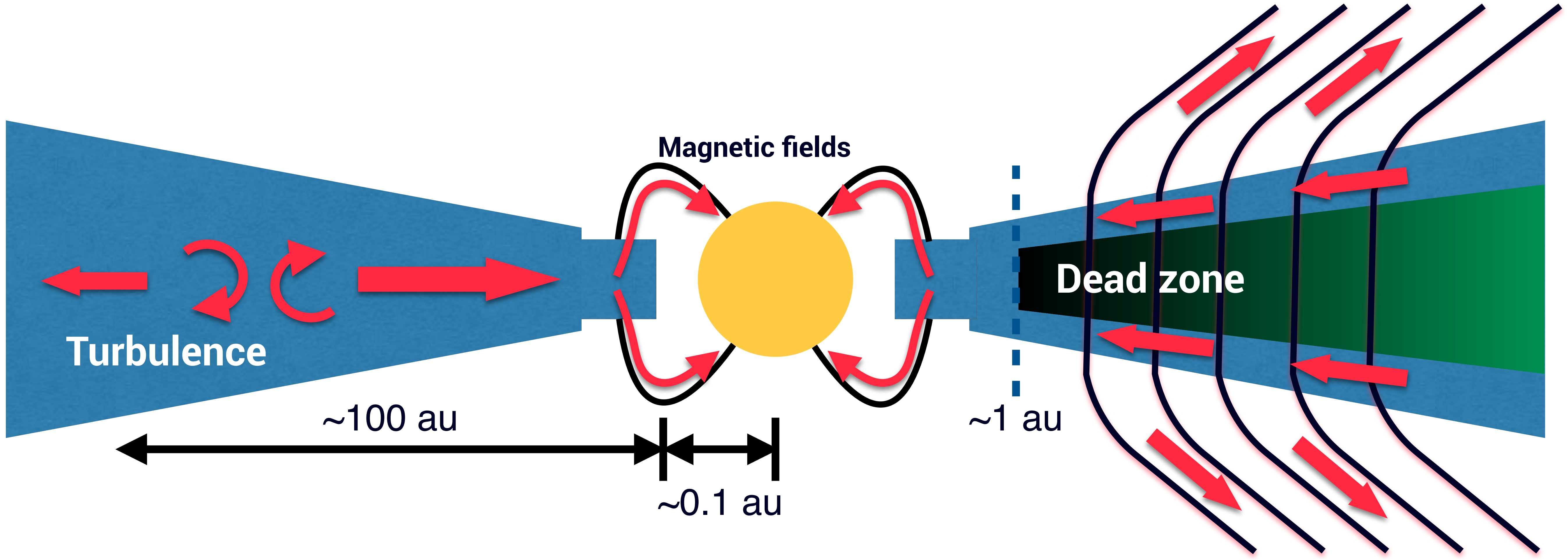
The evolution of protoplanetary disks



(Adapted from Andre 2002)

Viscous evolution (α-disk)

e.g., Lynden-Bell & Pringle 1974, Hartmann et al. 1998



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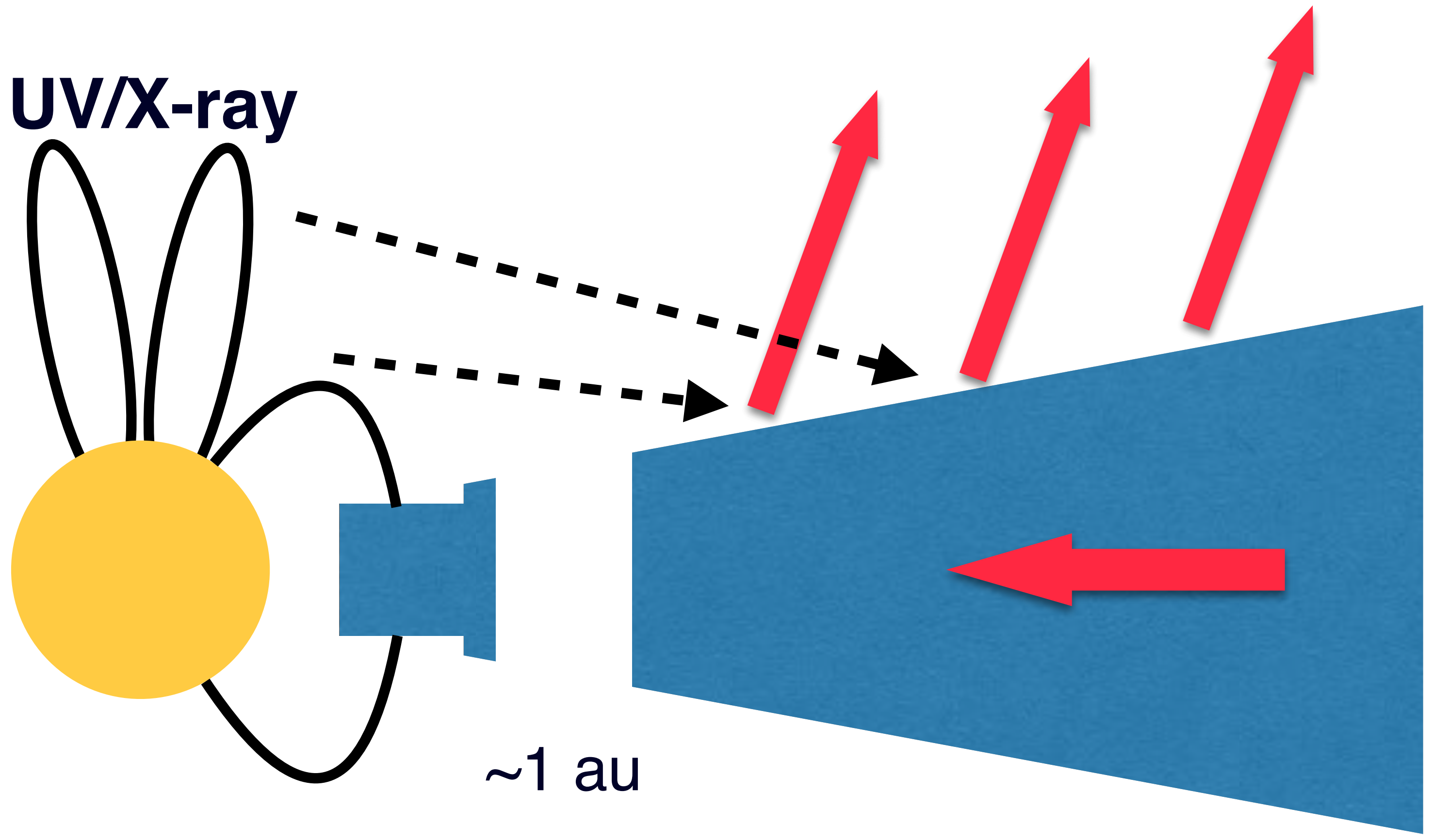
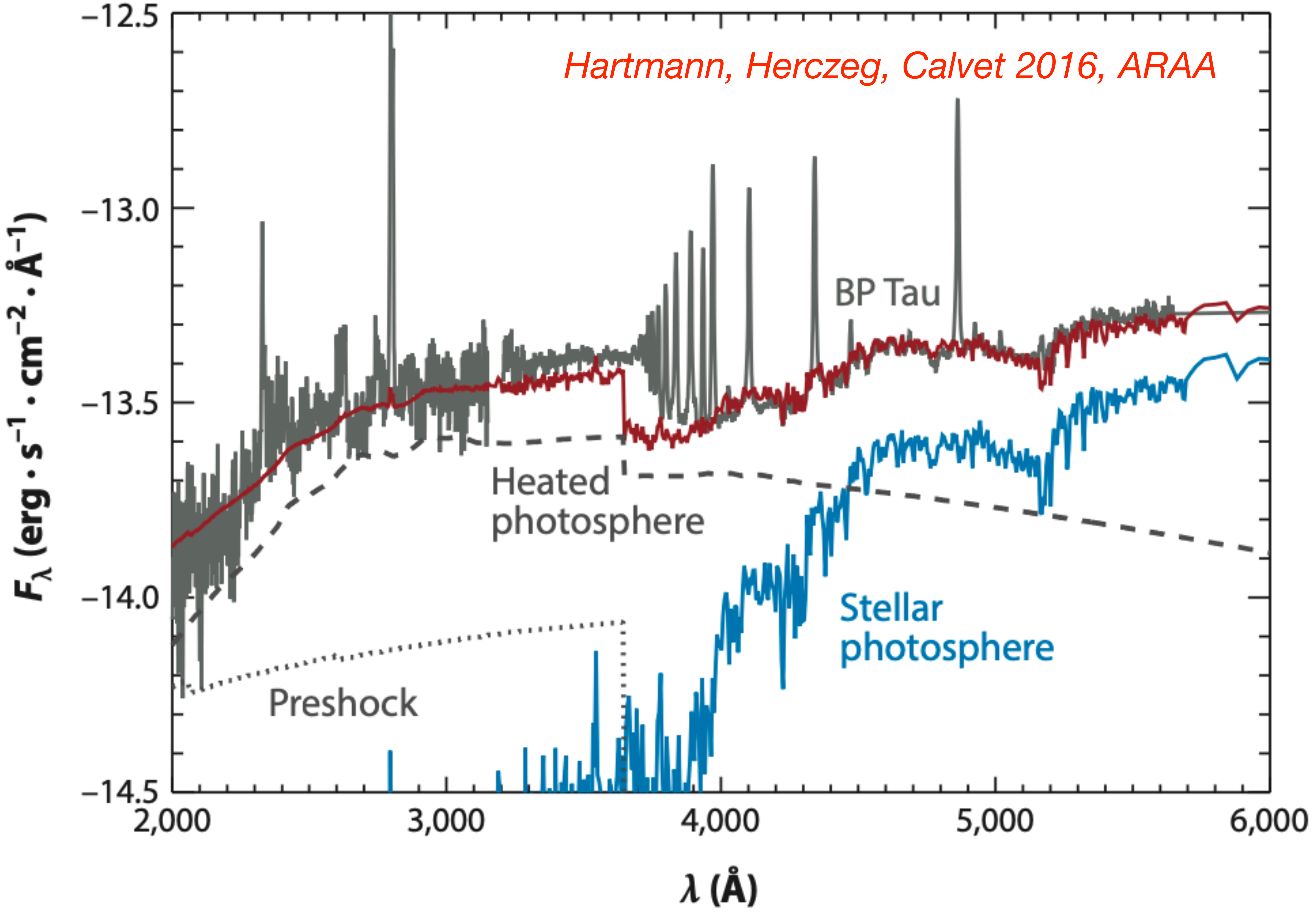
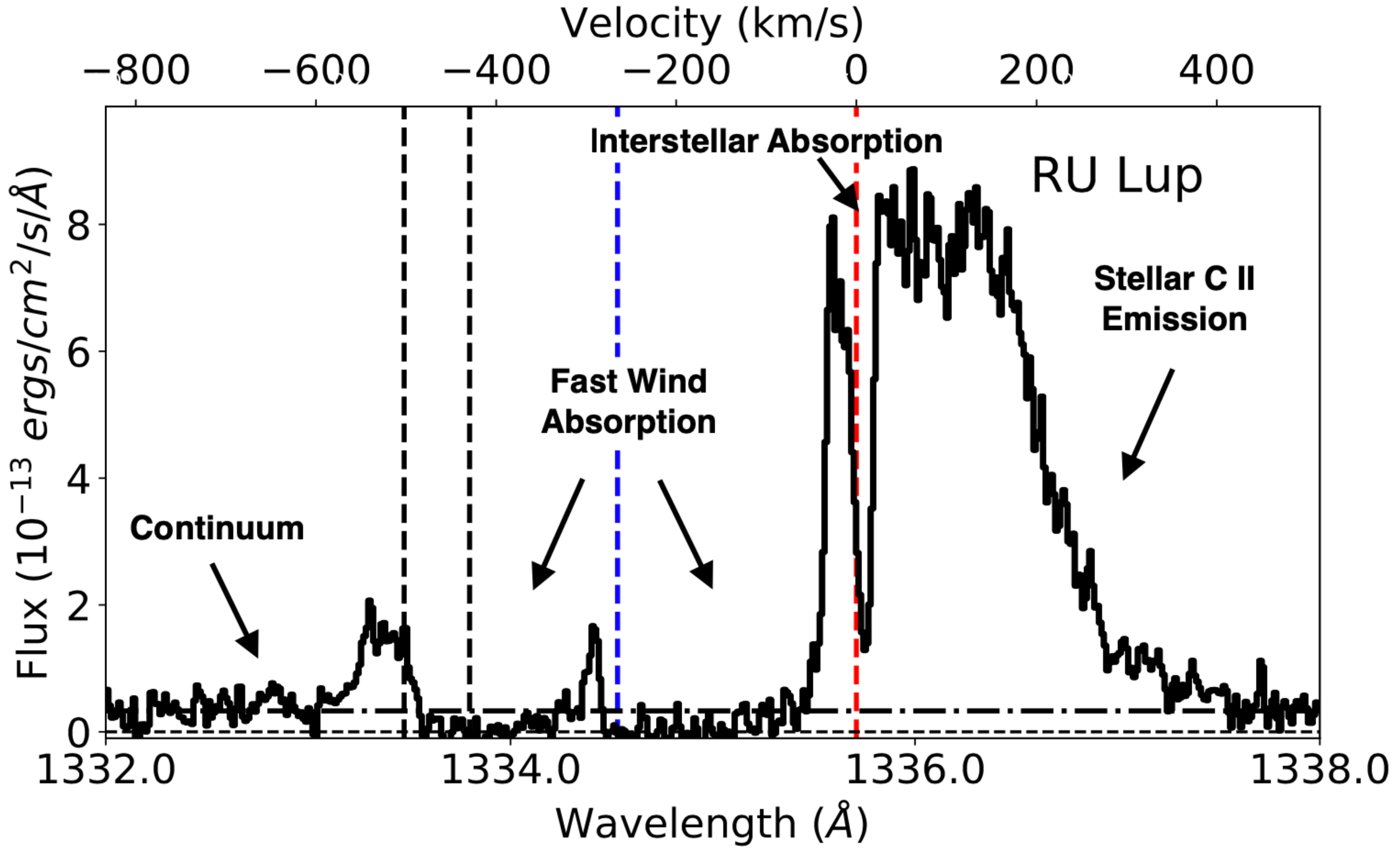


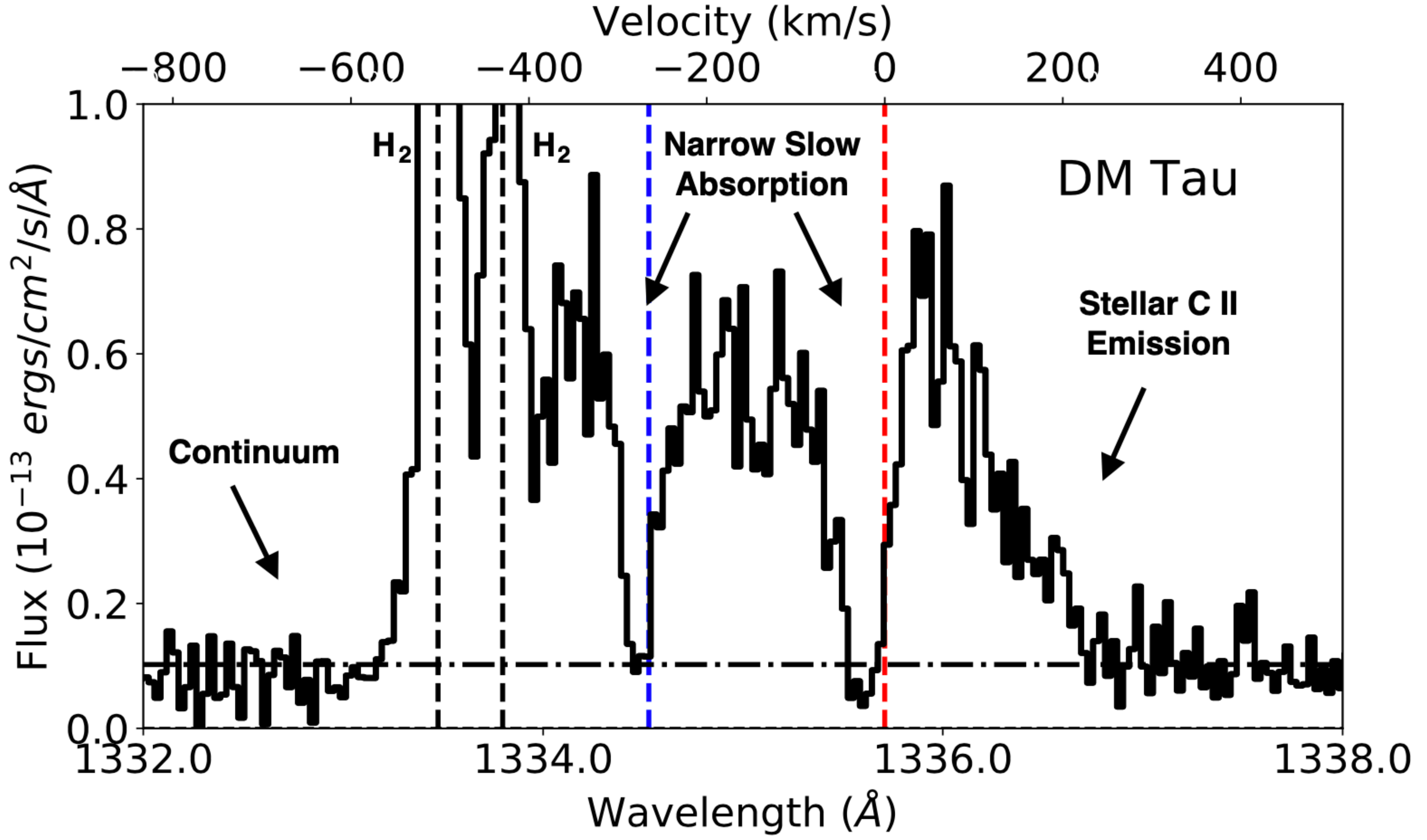
Photoevaporation

e.g., Alexander et al. 2014, Ercolano & Pascucci 2017

Studies of accretion and winds with HST





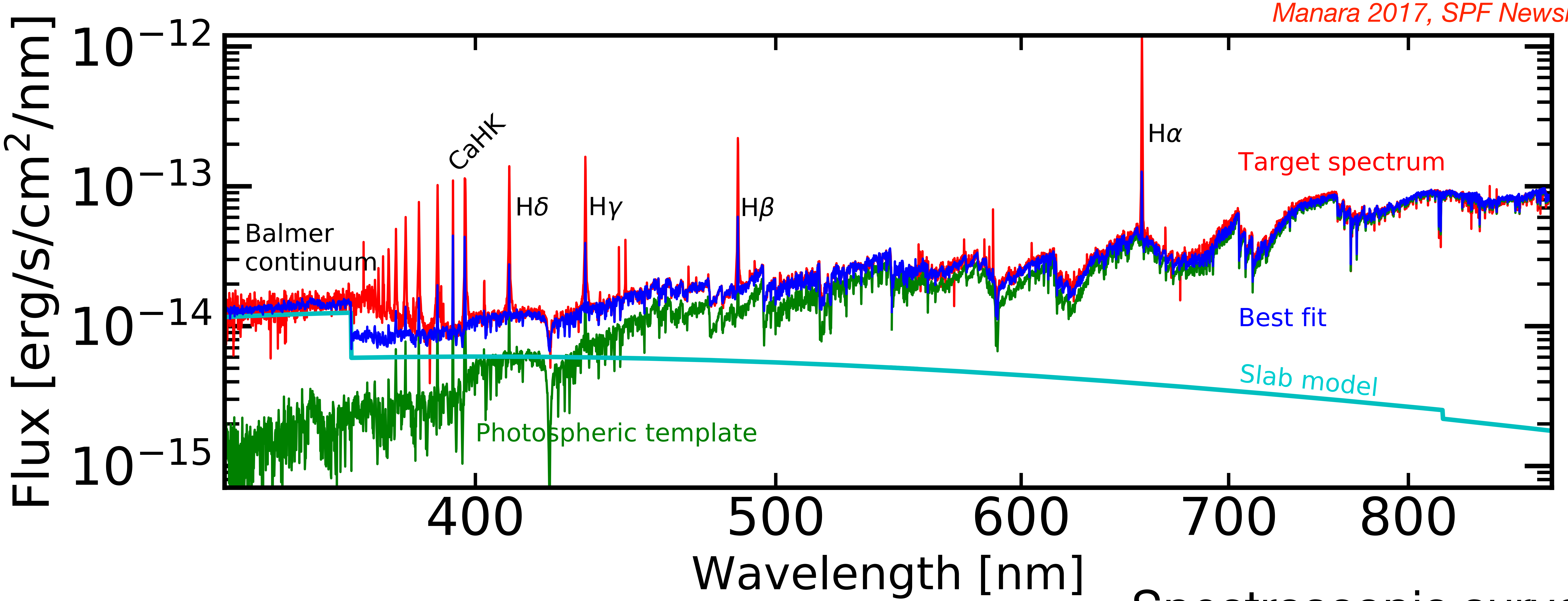


Xu, Herczeg, Johns-Krull, France 2021

HST gives access to the most direct probes of accretion and disk winds

Stellar and accretion properties from the ground

Manara 2017, SPF Newsletter

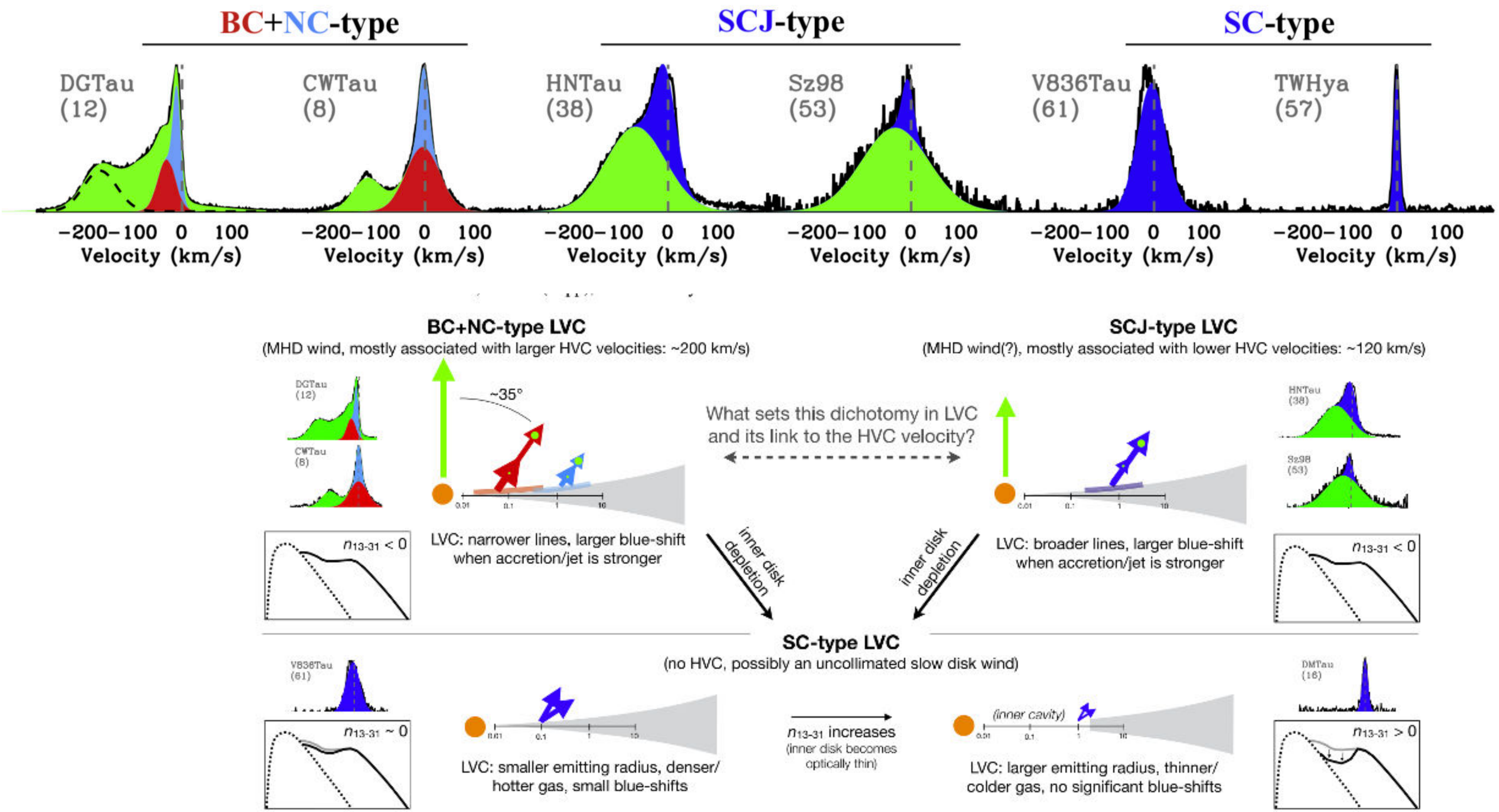


- Photospheric templates: Class III YSOs (*Manara et al. 2013a, 2017b*) ➜ SpT, $L_\star$
- Isothermal hydrogen slab model for the accretion shock spectrum ➜ L_{acc}
- Extinction values + reddening law ➜ A_V

Spectroscopic surveys:

Lupus: *Alcala et al. 2014, 2017, 2019*
Chamaeleon I: *Manara et al. 2016, 2017*
Upper Scorpius: *Manara et al. 2020*
ρ-Ophiucus: *Manara et al. 2015*
σ-Orionis: *Rigliaco et al. 2012*
Taurus: *Herczeg & Hillenbrand 2008, 2014, in prep.*
TWA*: Venuti et al. 2019*
NGC1333: *Fiorellino, Manara et al. 2021*

Studies of disk winds from the ground



Banzatti et al. 2019

See also Rigliaco et al. 2013, Natta et al. 2014, Simon et al. 2016, Nisini et al. 2018, McGinnis et al. 2019, Pascucci et al. 2020, Weber et al. 2020

A world-wide collaboration

Hubble UV Legacy Library of Young Stars as Essential Standards

500 orbits of HST COS/STIS for low-mass stars (Director's Discretionary program)
PI Roman-Duval

Outflows and Disks around Young Stars: Synergies for the Exploration of Ullyses Spectra

Team of over 50 international T Tauri star experts who are **using the ULLYSES data** to study accretion, outflows, and inner disk composition, and **coordinating complementary data collection** efforts.

Lead: G. Herczeg (KIAA Beijing), C. Espaillat (Boston University)

PENELLOPE

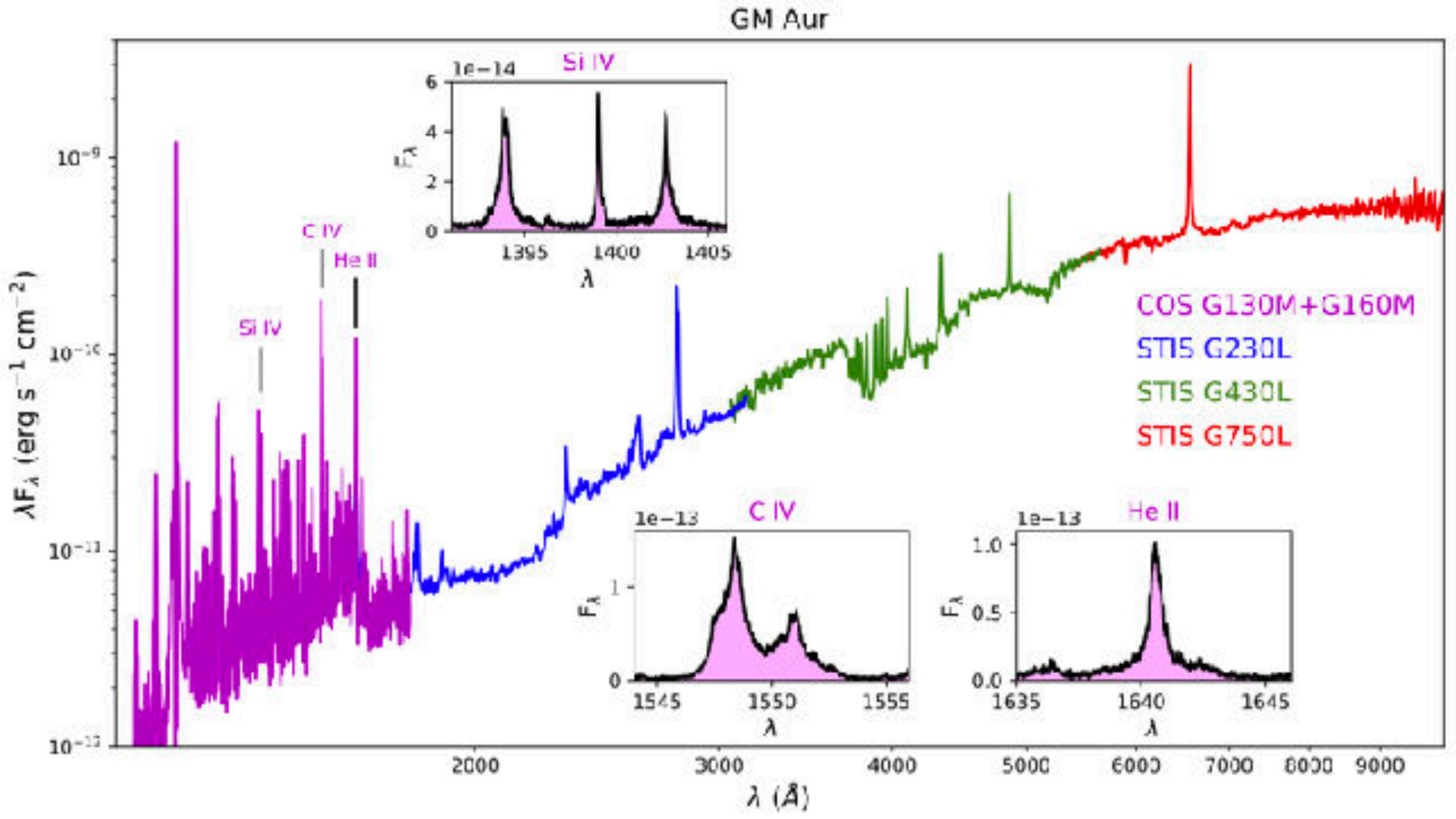
Large international team acquiring complementary data with a ~**250h Large Program** at the ESO Very Large Telescope (VLT).

PI: C.F. Manara (ESO)
Data public

Several other teams are collecting **photometry**, **high-resolution spectra** and more. Observations are coordinated with **TESS**.

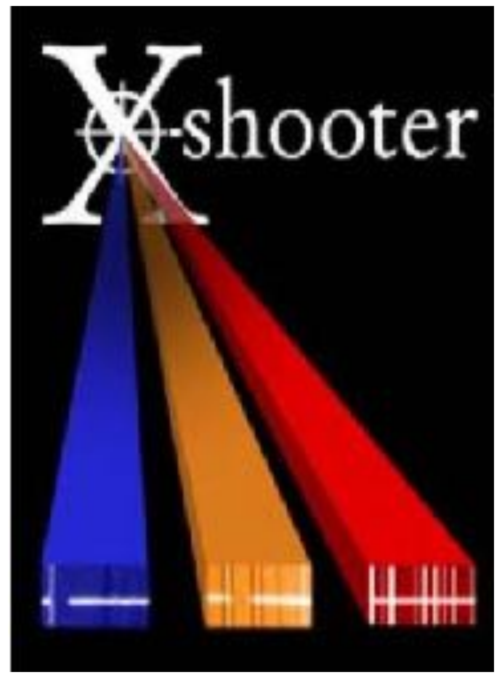
PROGRAMME STRATEGY: contemporaneous observations

λ~113–180 nm, R~18,000
λ~150–570 nm, R~500
λ~165–315 nm, R~3,000



HST COS/STIS:
NUV/FUV spectra, hot gas lines, Balmer continuum…
(*Espaillat, Herczeg et al. subm.*)

λ~300–2500 nm, R~15,000



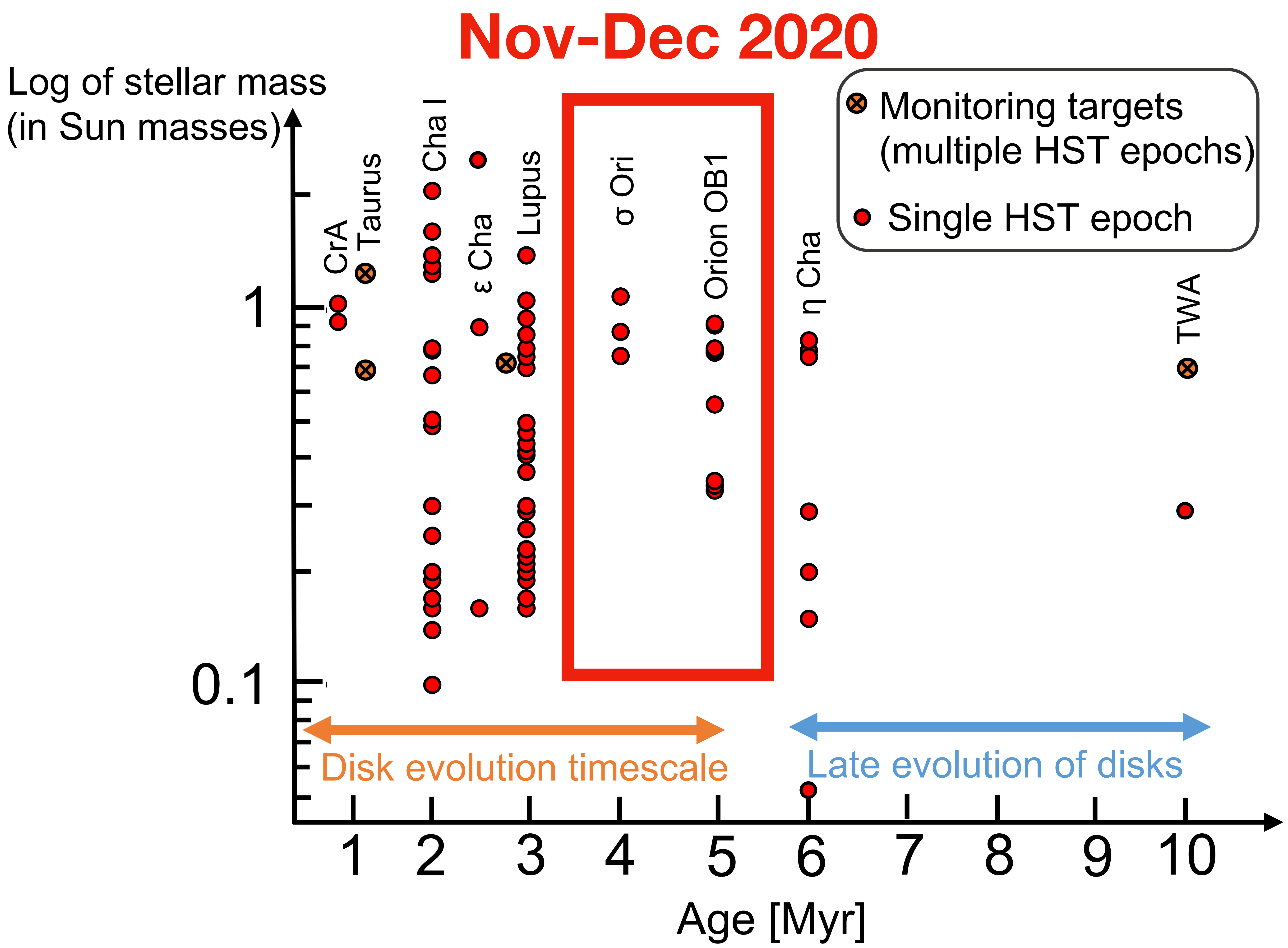
X-Shooter (absolute flux calibrated):
Stellar and accretion properties, extinction, emission lines down to 2.5 micron
Manara et al. 2021

λ~380–788 nm, R~140,000,
Δv~2 km/s
Alternative: UVES
λ~330–680 nm, R~70,000,
Δv~4 km/s

ESPRESSO/UVES:
Photospheric properties (logg, vsini, RV, veiling…) and line kinematics (with variability) to study accretion and outflows

-1/2 days — **day(s) of the HST observation** — **+1/2 days**

Sample properties

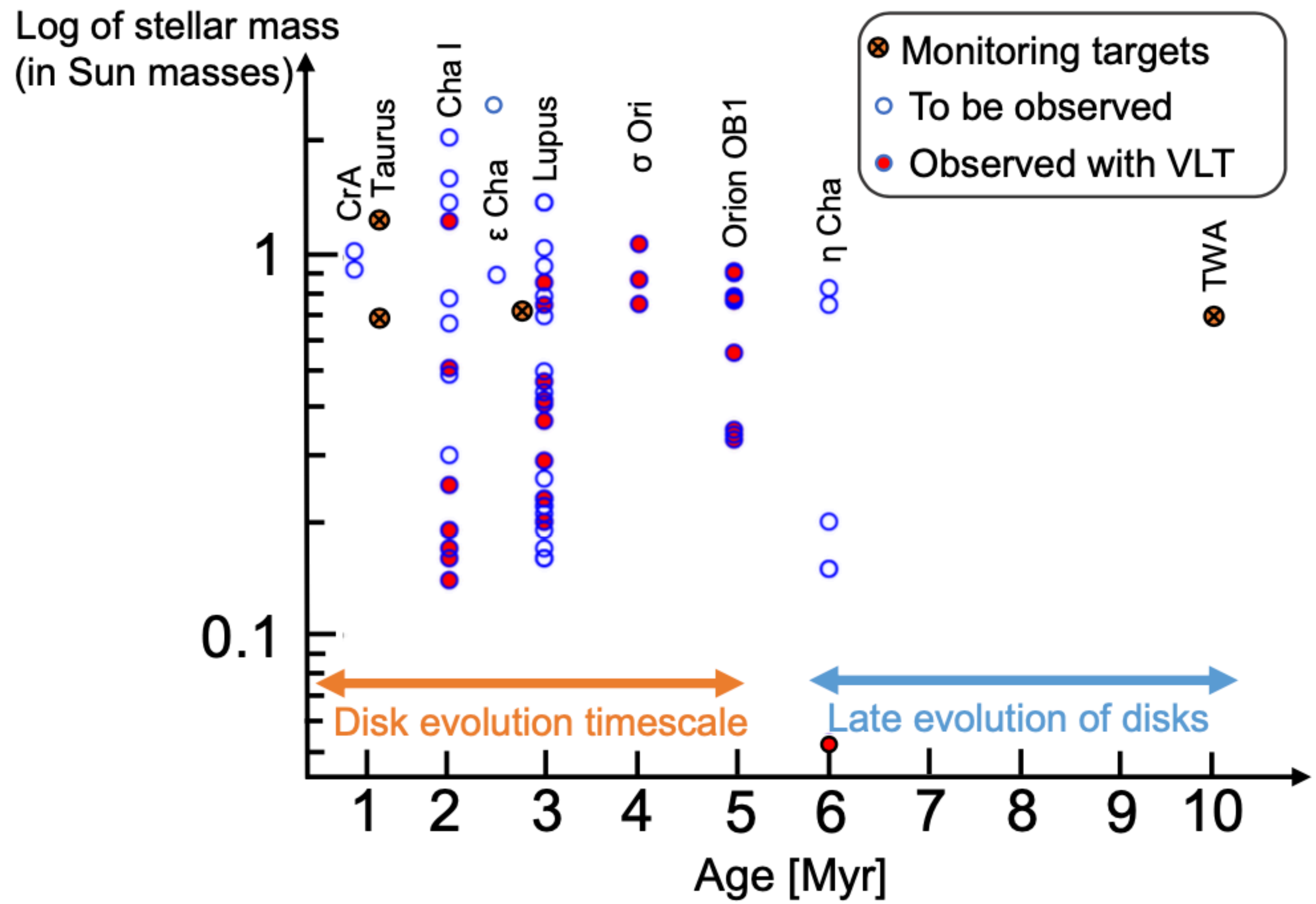


TARGETS FROM HST/ULLYSES

Total ~ 70 targets

- Nine nearby star-forming regions
- Ages from ~1 to ~10 Myr
- Masses from ~0.1 to 2 Msun
- Mainly accreting targets
- Different disk types (e.g., transition disks, full disks)
- Four targets will be monitored for three consecutive rotation periods for two times in two different years

Sample properties



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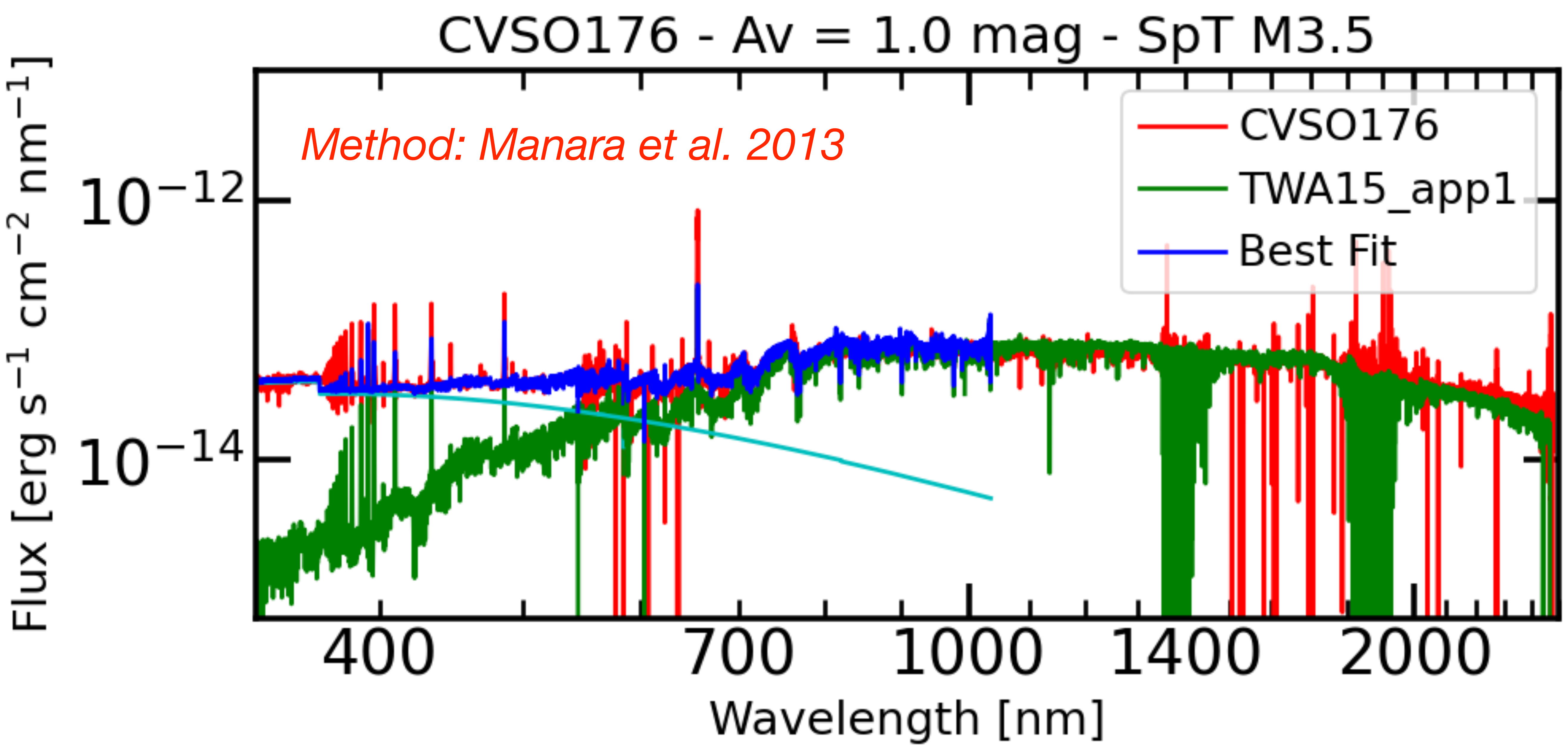
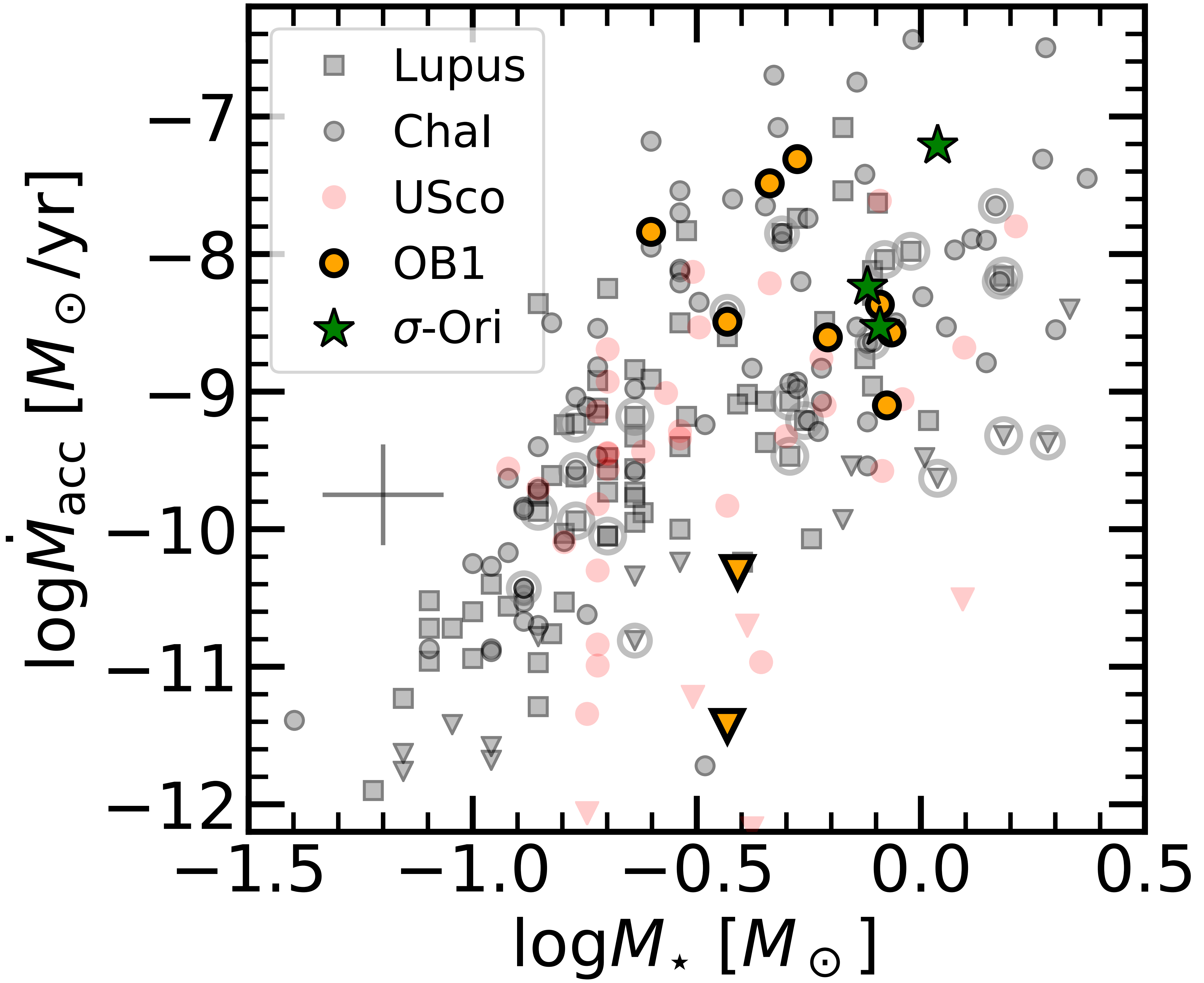
SCIENCE: stellar and accretion properties





Manara, Frasca and the PENELLOPE team, 2021

Literature Data: Manara et al. 2016a,2017b,2020
Alcala et al. 2014,2017

Derived mass accretion rates in line with those in other star-forming regions with age ~1 - 5 Myr. Large spread, larger than variability.

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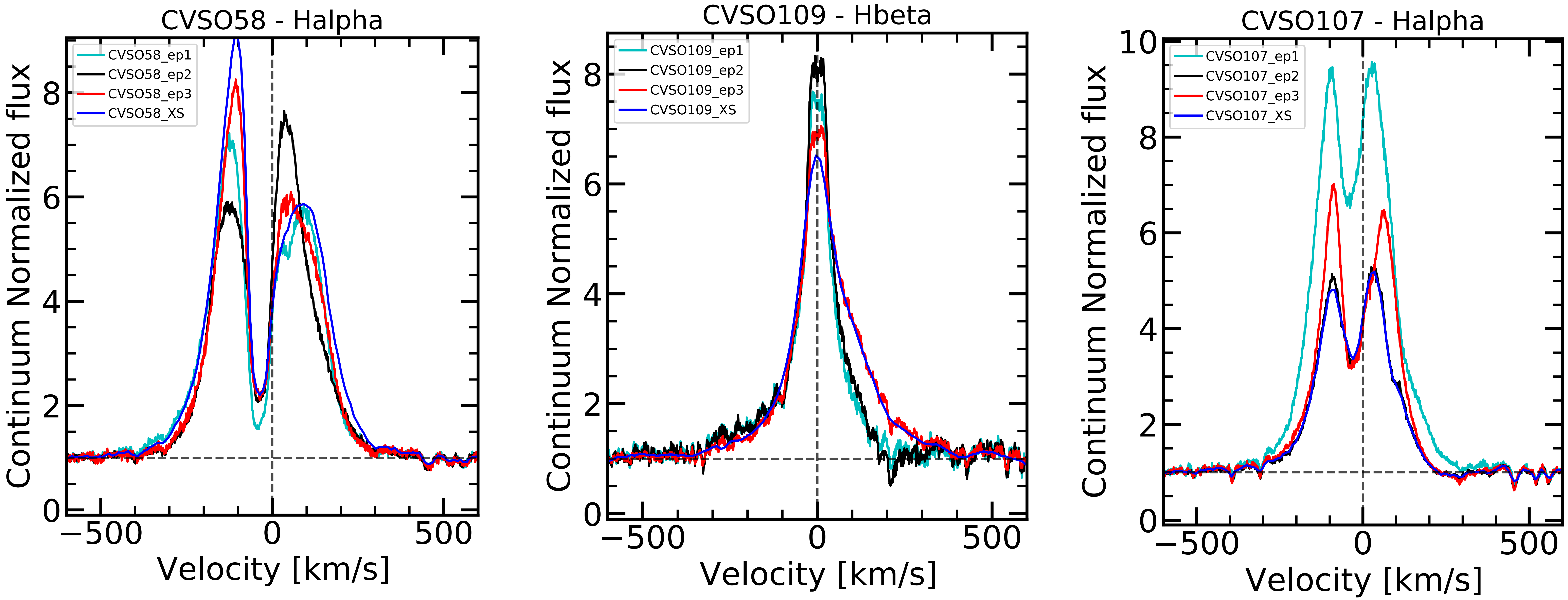
SCIENCE: accretion variability



Manara, Frasca and the PENELLOPE team, 2021

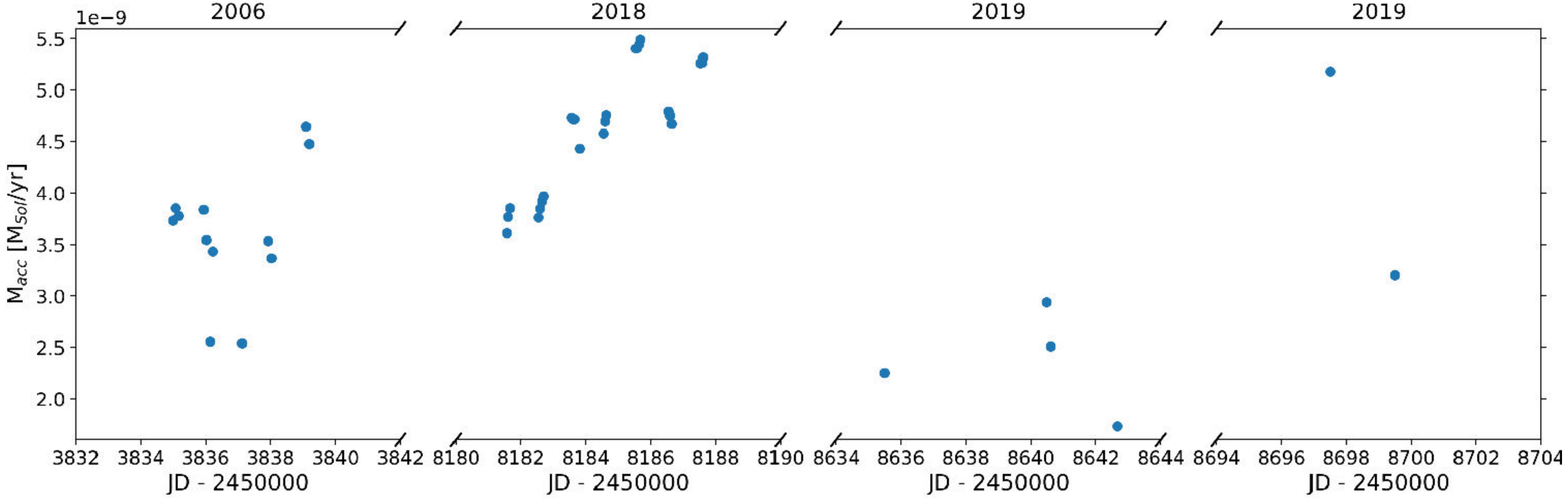
Little EW/flux variations in the line emission on timescales of ~3-4 days, but more important variations in the line profiles:

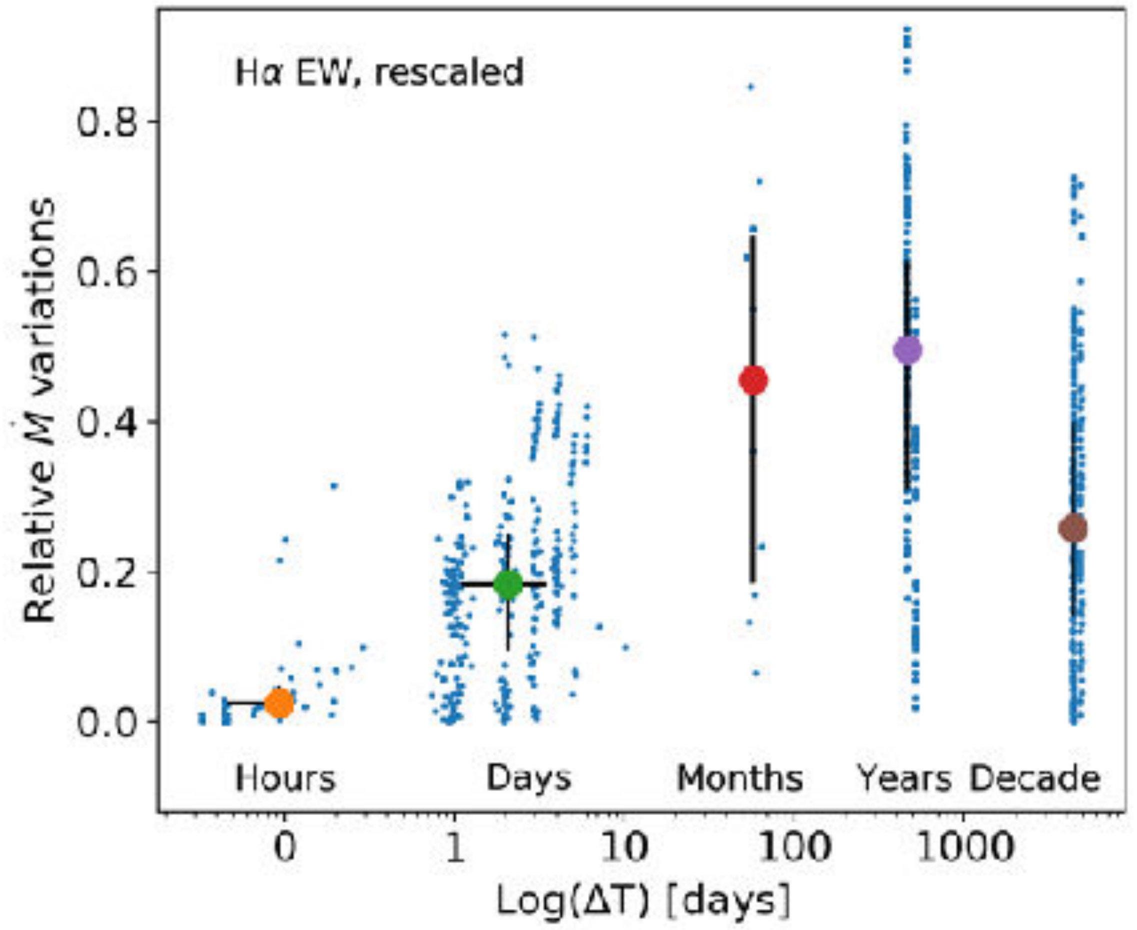
- variability of accretion rates less than factor ~3 (e.g., Costigan et al. 2014, Venuti et al. 2014)
- complex and varying structure of the accretion flow on short timescales *(see also Campbell-White et al. 2021)*

What about variability?

Accretion variability from minutes to decade timescales in the classical T Tauri star CR Cha★

G. Zsidi[1,2,4★★], C. F. Manara[1], Á. Kóspál[2,3,4], G. A. J. Hussain[1,5], P. Ábrahám[2,4], E. Alecian[6], A. Bódi[2,7], A. Pál[2], and P. Sarkis[3]

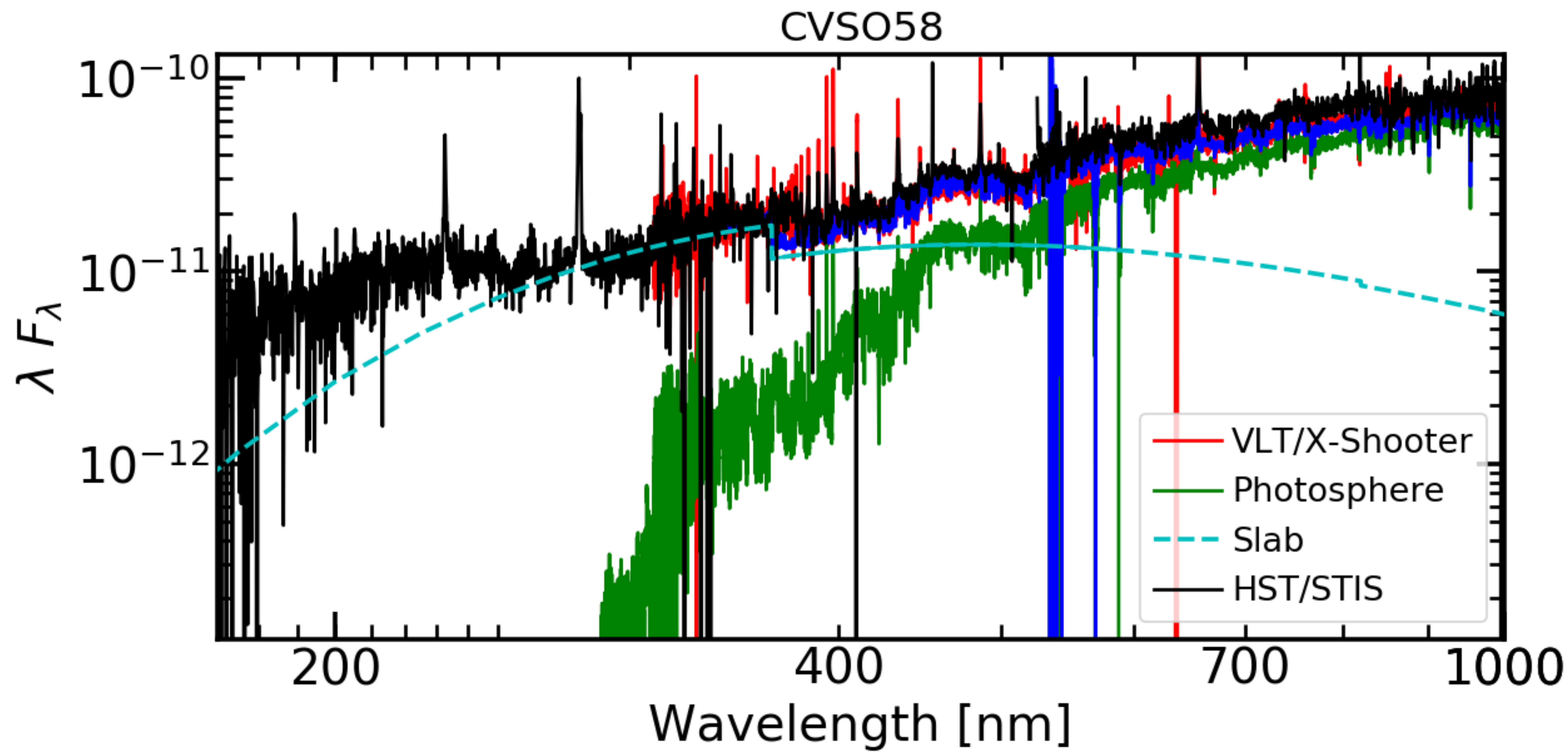




Accretion variability is within a factor ~3 on timescales of a decade

See also: Costigan et al. 2012, 2014; Venuti et al. 2014; Espaillat et al. 2019
FIscher et al. PPVII subm.

SCIENCE: slab model in the UV range

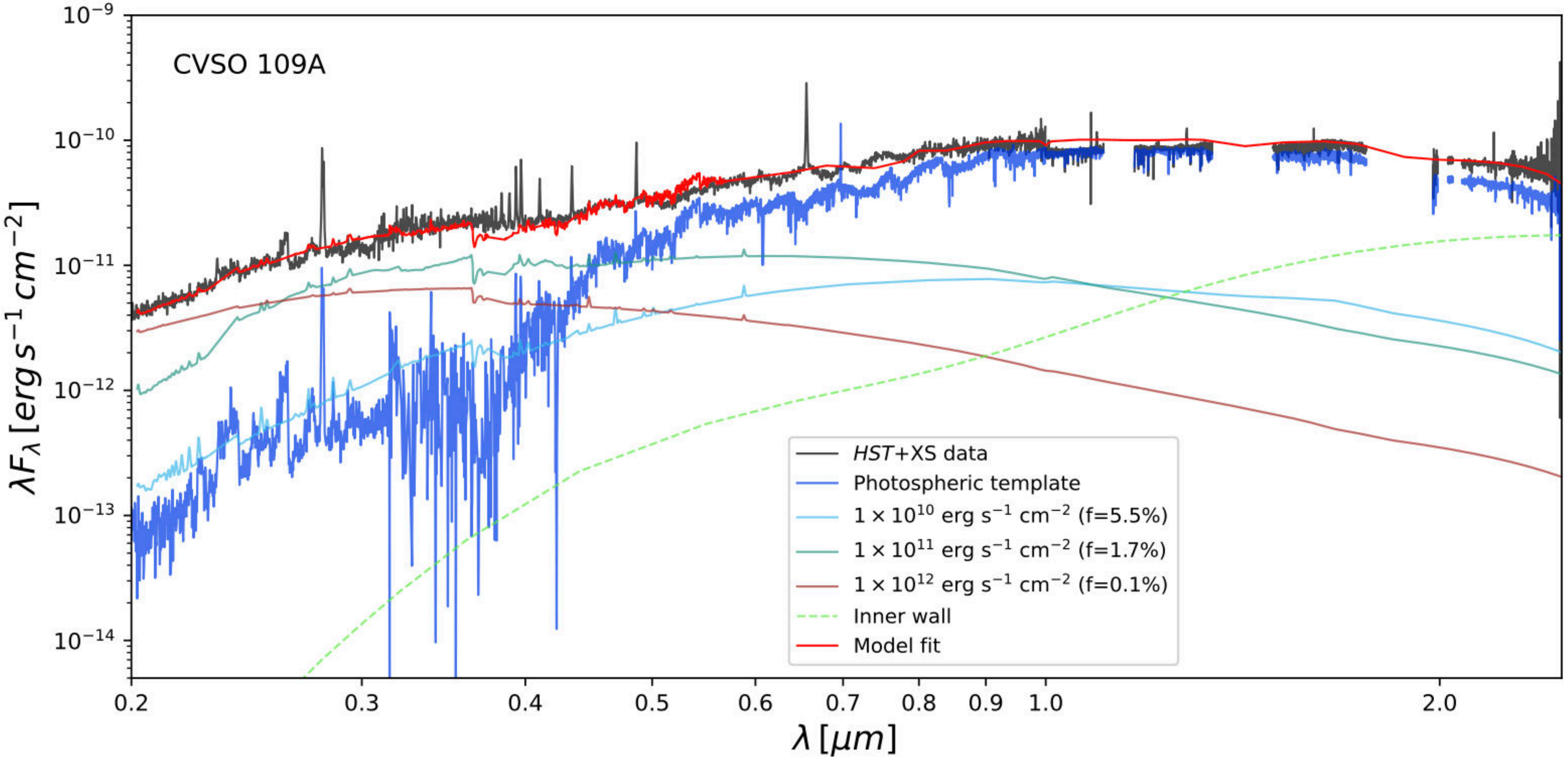


Manara, Frasca and the PENELLOPE team, 2021

The UV flux from the slab is slightly lower (~10%) than in the HST spectra in this first set of data. Possibilities:

- wrong extinction curve in the UV?
- too simplistic assumptions of the slab (e.g., single temperature)

SCIENCE: accretion on the HST side

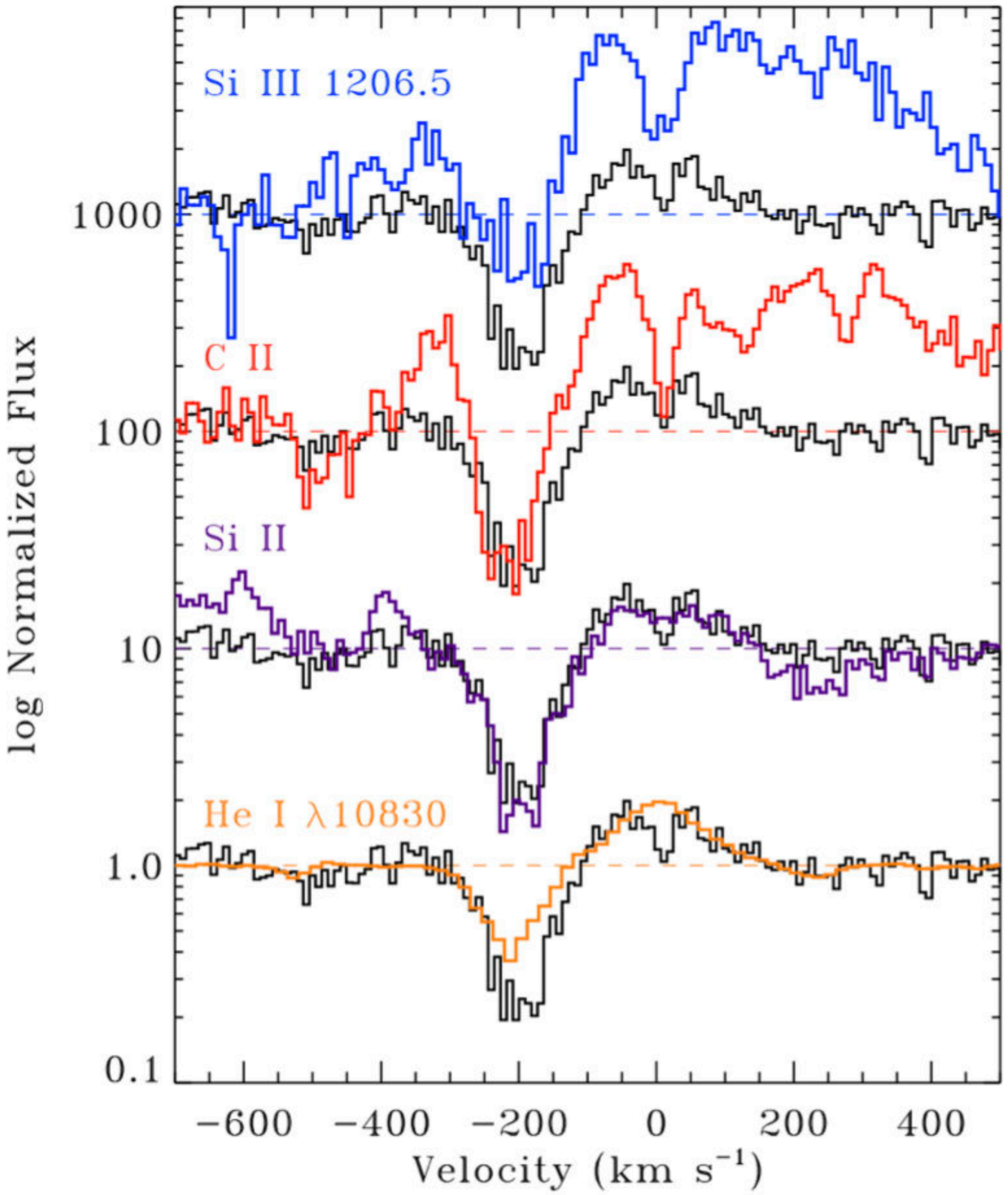


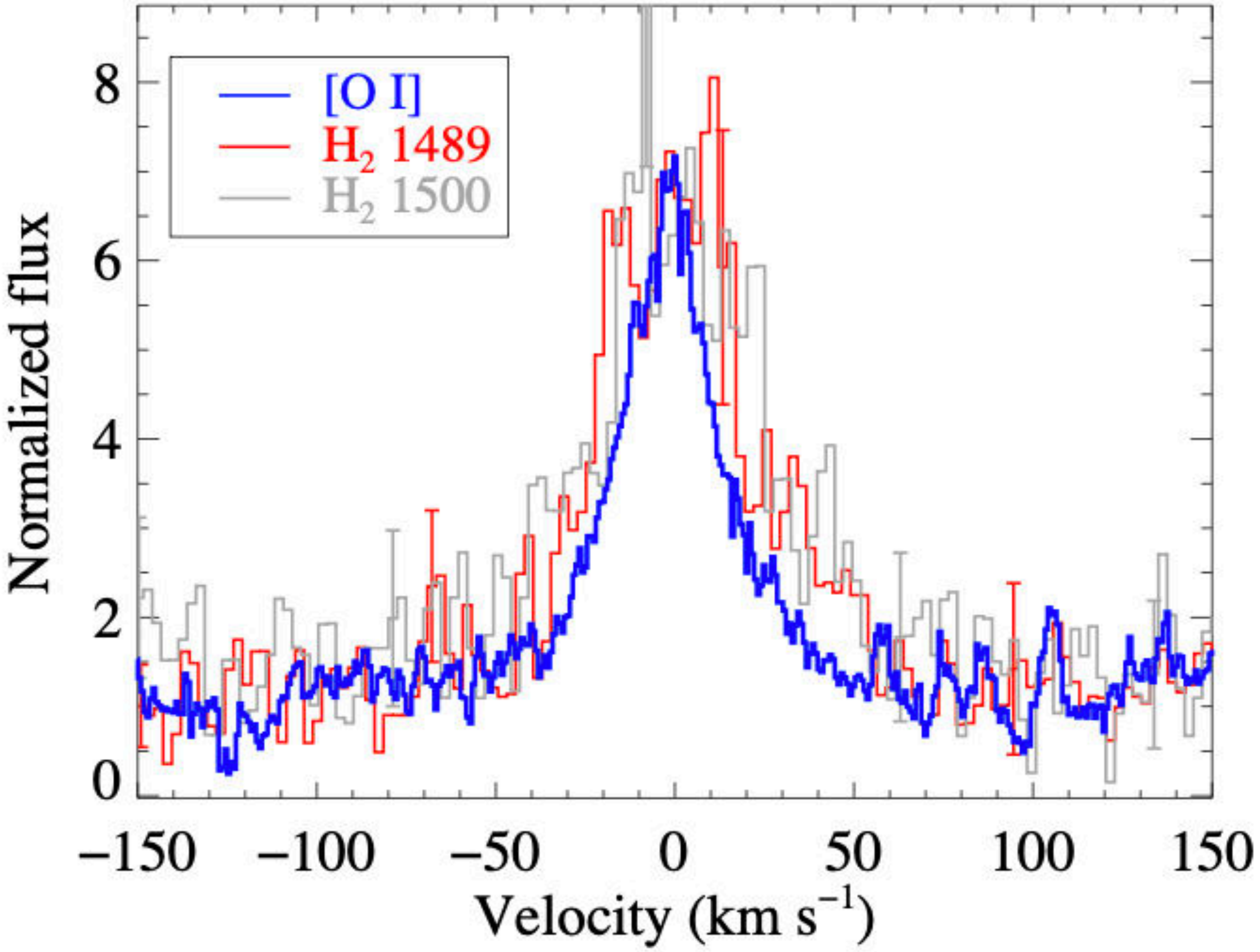
Espaillat, Herczeg and the ODYSSEUS team, subm.

Multiple components are needed to fit the spectrum from UV (HST) to NIR (X-Shooter)

Typically a factor ~1.5-5 difference wrt single component fits

SCIENCE: winds on the HST side





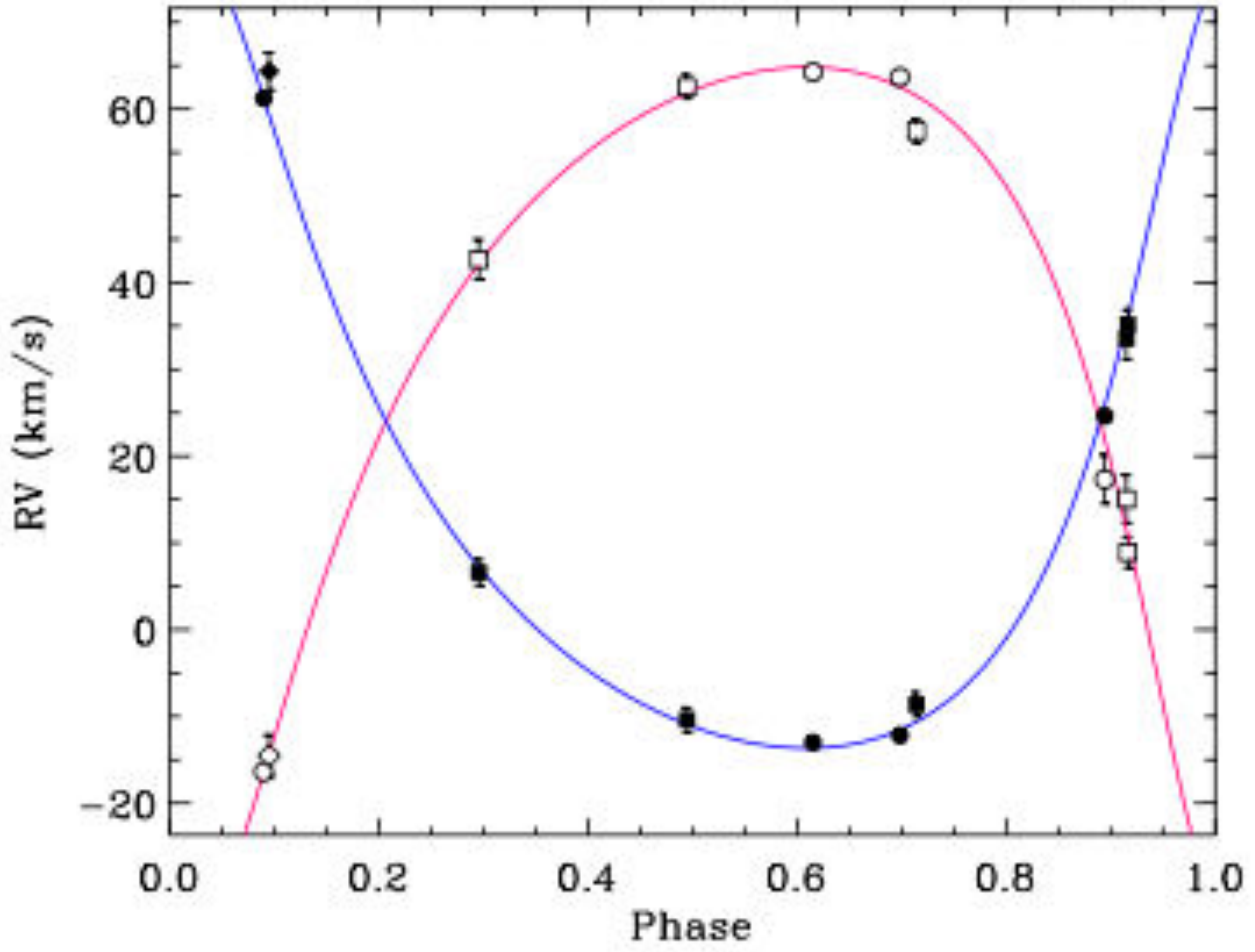
Espaillat, Herczeg and the ODYSSEUS team, subm.

New possibility to combine high-resolution optical spectra with UV spectra to trace fast, cool winds (Si III, C II…) and cooler winds ([OI], H2)

PENELLOPE - Science results

PENELLOPE II. CVSO 104: a pre-main sequence close binary with an optical companion in Ori OB1★

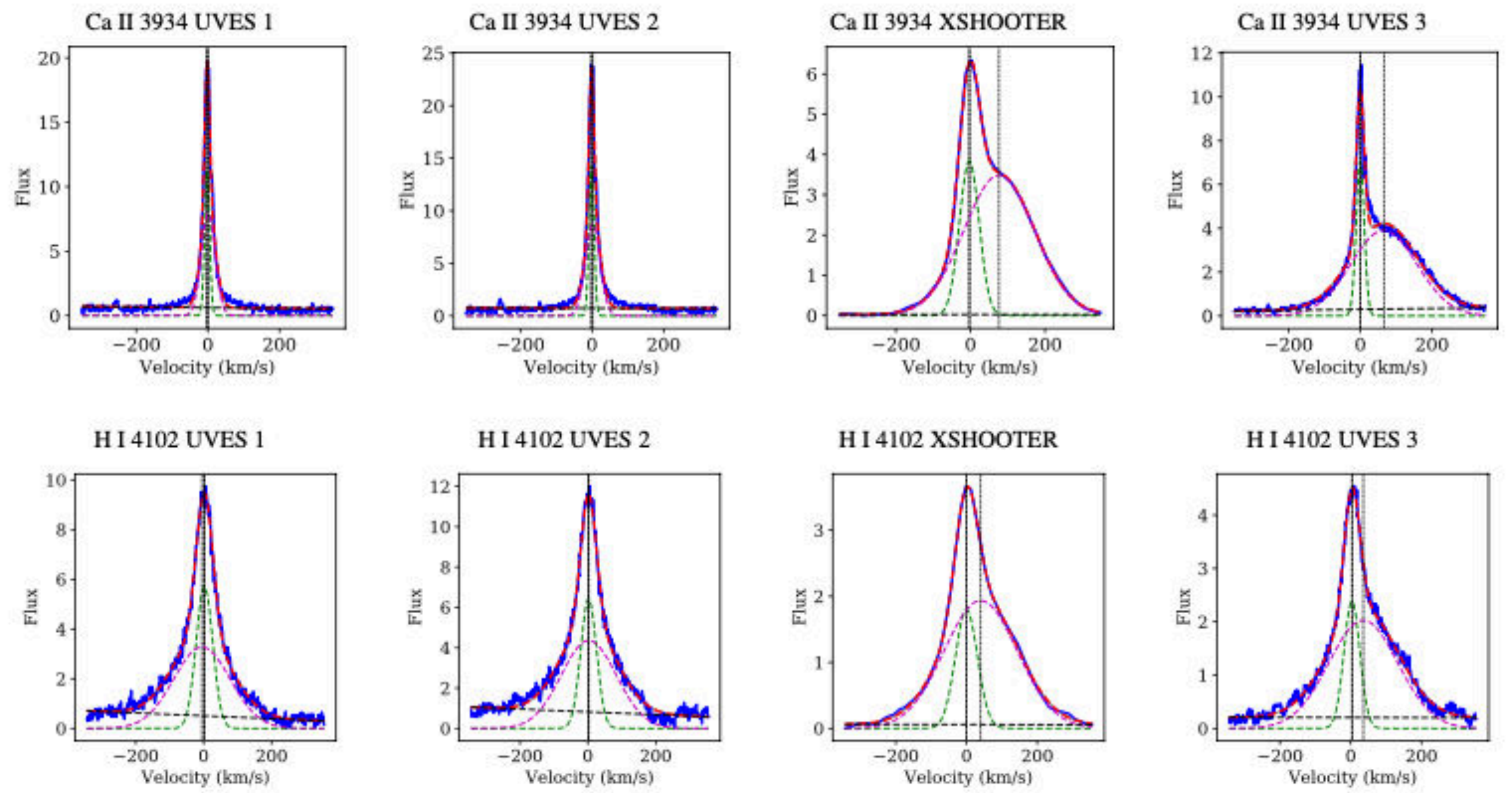
A. Frasca[1], H. M. J. Boffin[2], C. F. Manara[2], J. M. Alcalá[3], P. Ábrahám[4,5], E. Covino[3], M. Fang[6], M. Gangi[7], G. J. Herczeg[8], Á. Kóspál[4,5,9], L. Venuti[10], F. M. Walter[11], J. Alonso-Santiago[1], K. Grankin[12], M. Siwak[4], E. Alecian[13], and S. Cabrit[14]



A new spectroscopic binary

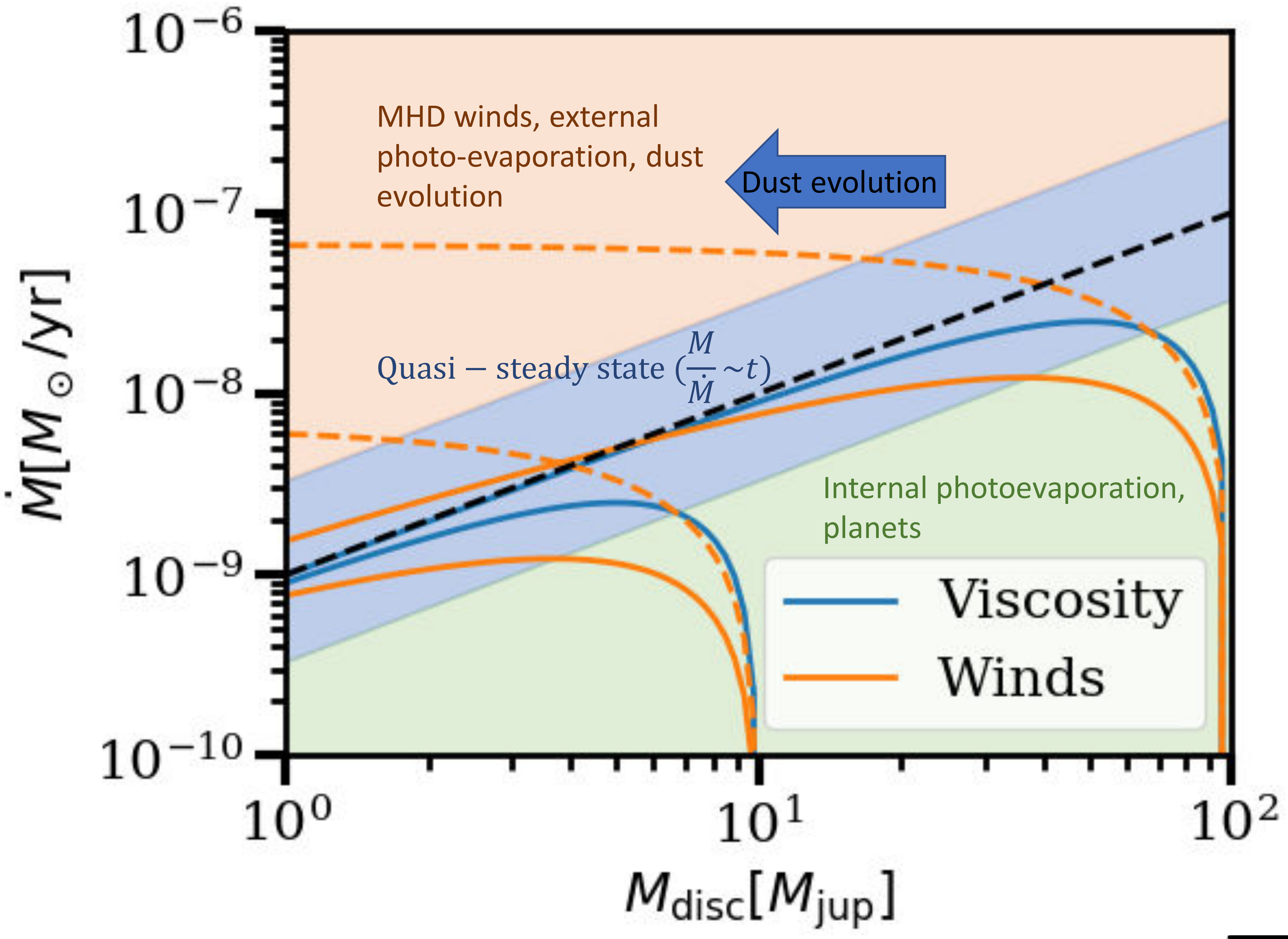
The STAR-MELT Python package★ for emission line analysis of YSOs†

Justyn Campbell-White,[1]‡ Aurora Sicilia-Aguilar,[1] Carlo F. Manara,[2] Soko Matsumura,[1] Min Fang[3], Antonio Frasca,[4] and Veronica Roccatagliata[5,6,7]



Rotating and infalling material in the inner disk of CVSO109

Disk mass - accretion rates relation

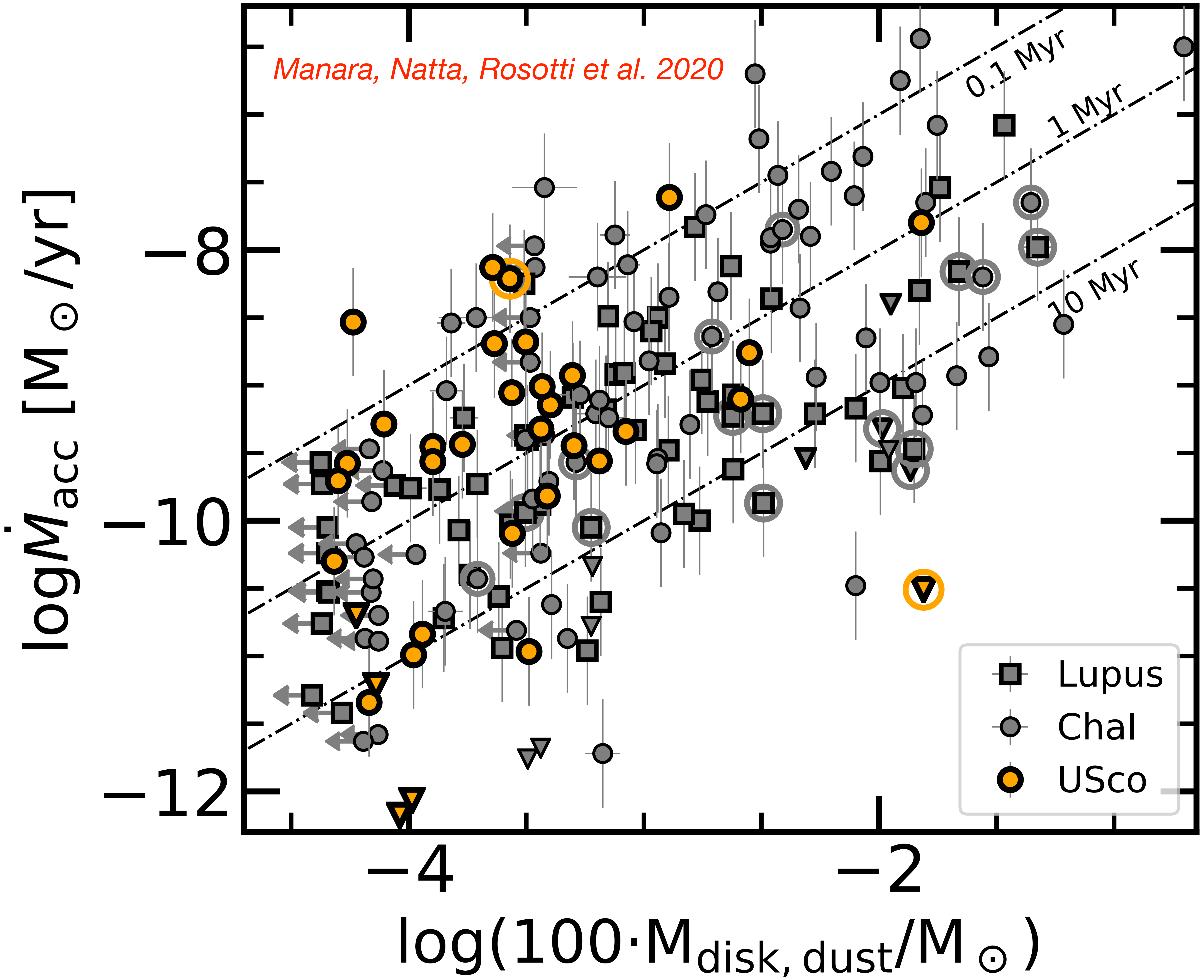


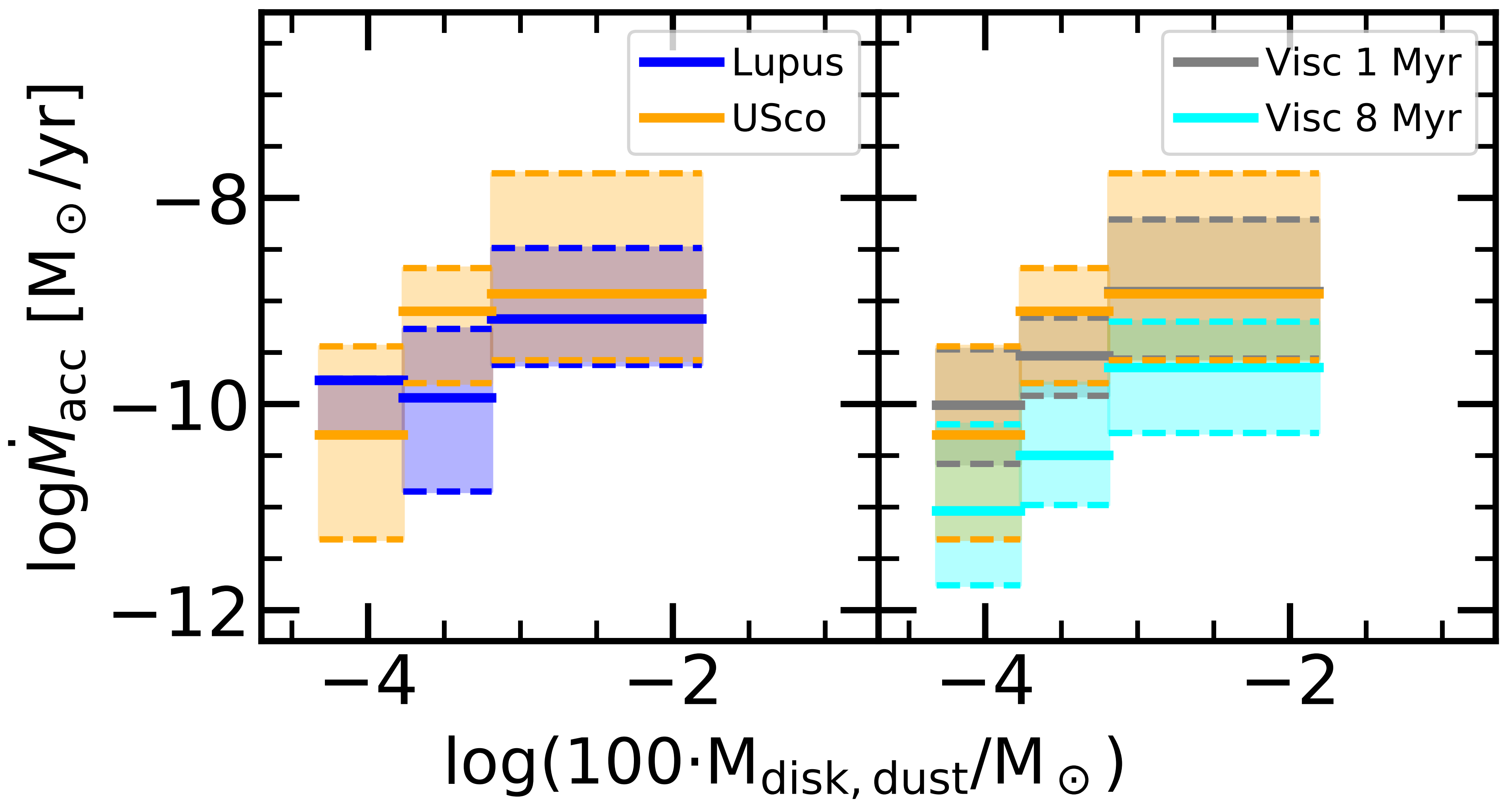
Viscous models predict a **tight correlation** between mass accretion rates and disk masses

See also Hartmann et al. 1998, Jones et al. 2012, Lodato et al. 2017, Rosotti et al. 2017, Mulders et al. 2017, Somigliana et al. 2020, Tabone et al. subm.

Manara, Ansdell, Rosotti et al. PPVII, submitted

Disk mass - accretion rates relation at ~10 Myr



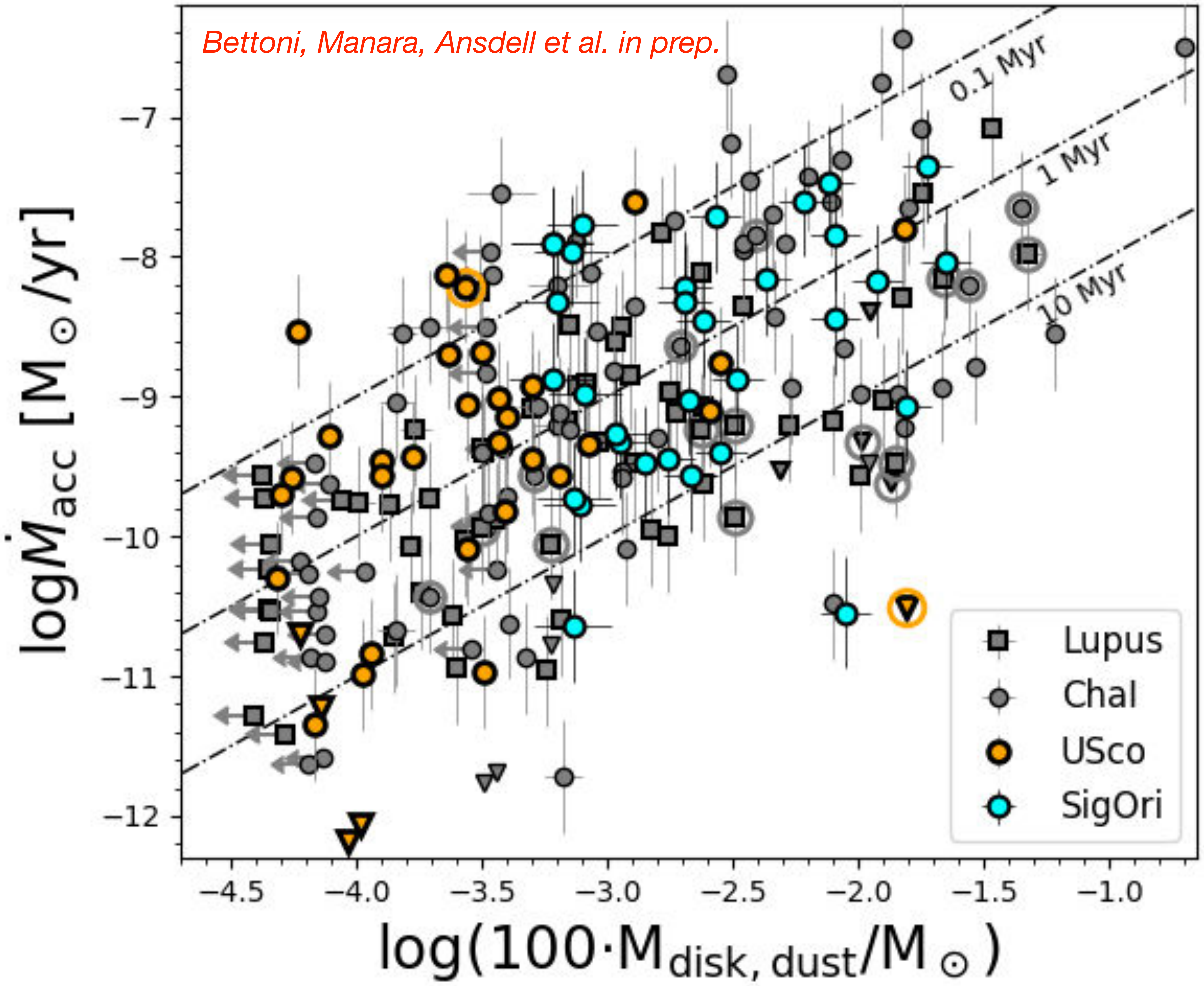


Current data are in tension with pure viscous evolution:

- wider spread of Macc
- little (no?) evolution with time
- an effect of *dust* evolution?

Manara et al. 2016b, Mulders et al. 2017, Lodato et al. 2017, Rosotti et al. 2017, Manara et al. 2020, see also Sellek et al. 2020a,b; read also Hartmann & Bae 2018

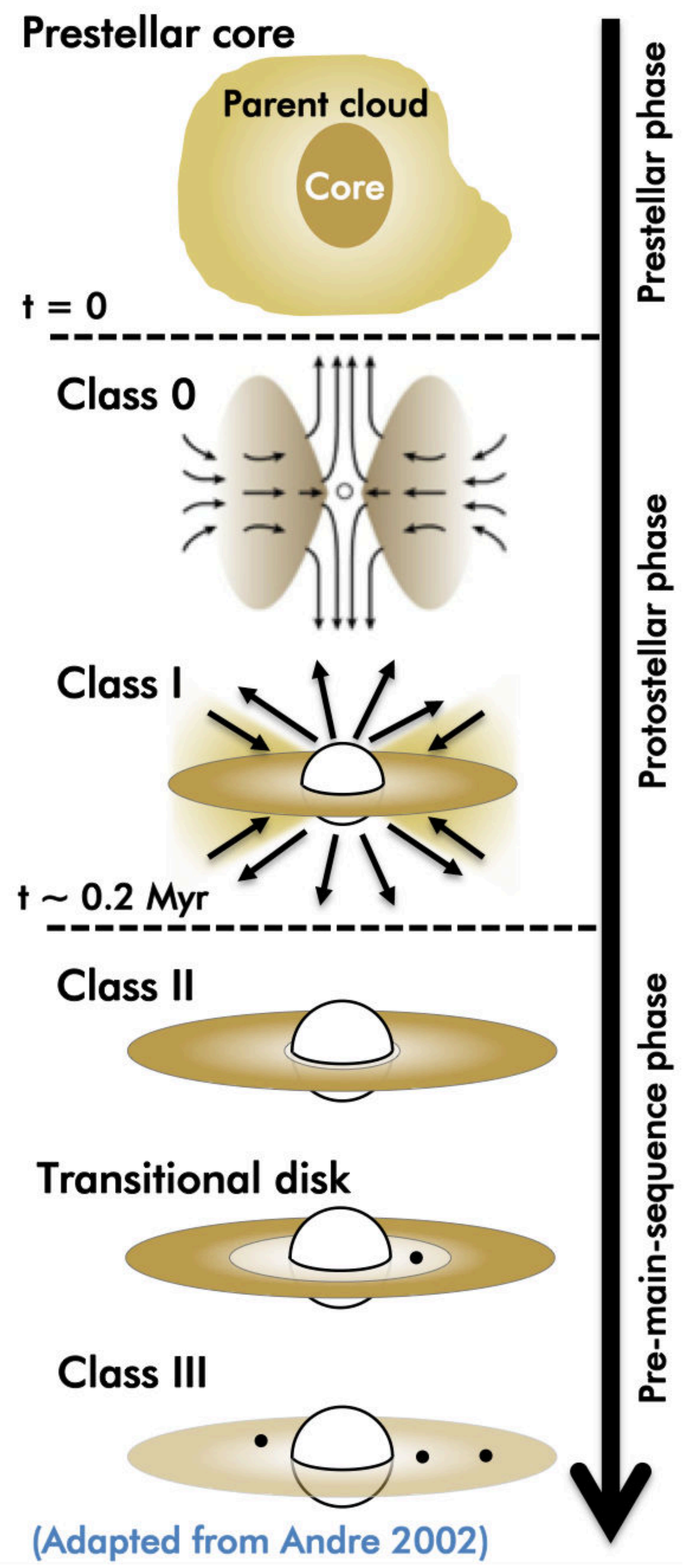
Disk mass - accretion rates relation in σ-Ori

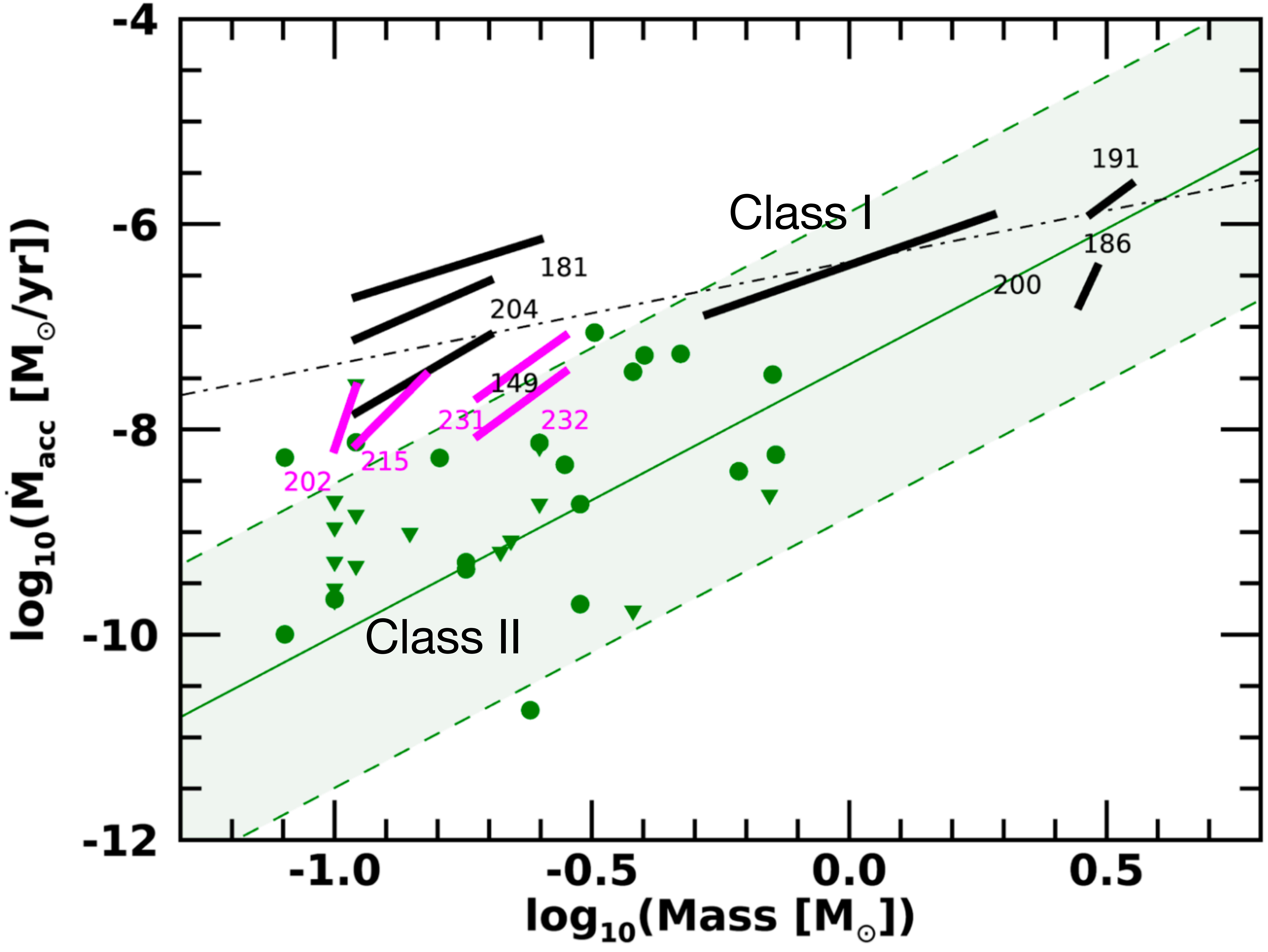


Highest accretion rates measured closer to σ-Ori together with strong forbidden lines: external photoevaporation?

Manara et al. 2016b, Mulders et al. 2017, Manara et al. 2020, see also Sellek et al. 2020a,b

Exploring accretion in the earlier phases





Class I from the same star-forming region (*coeval*) have higher Macc than Class II by ~10-100

Fiorellino, Manara, Nisini et al., 2021


Credit: ESO/B. Tafreshi (twanight.org)

TAKE HOME POINTS:

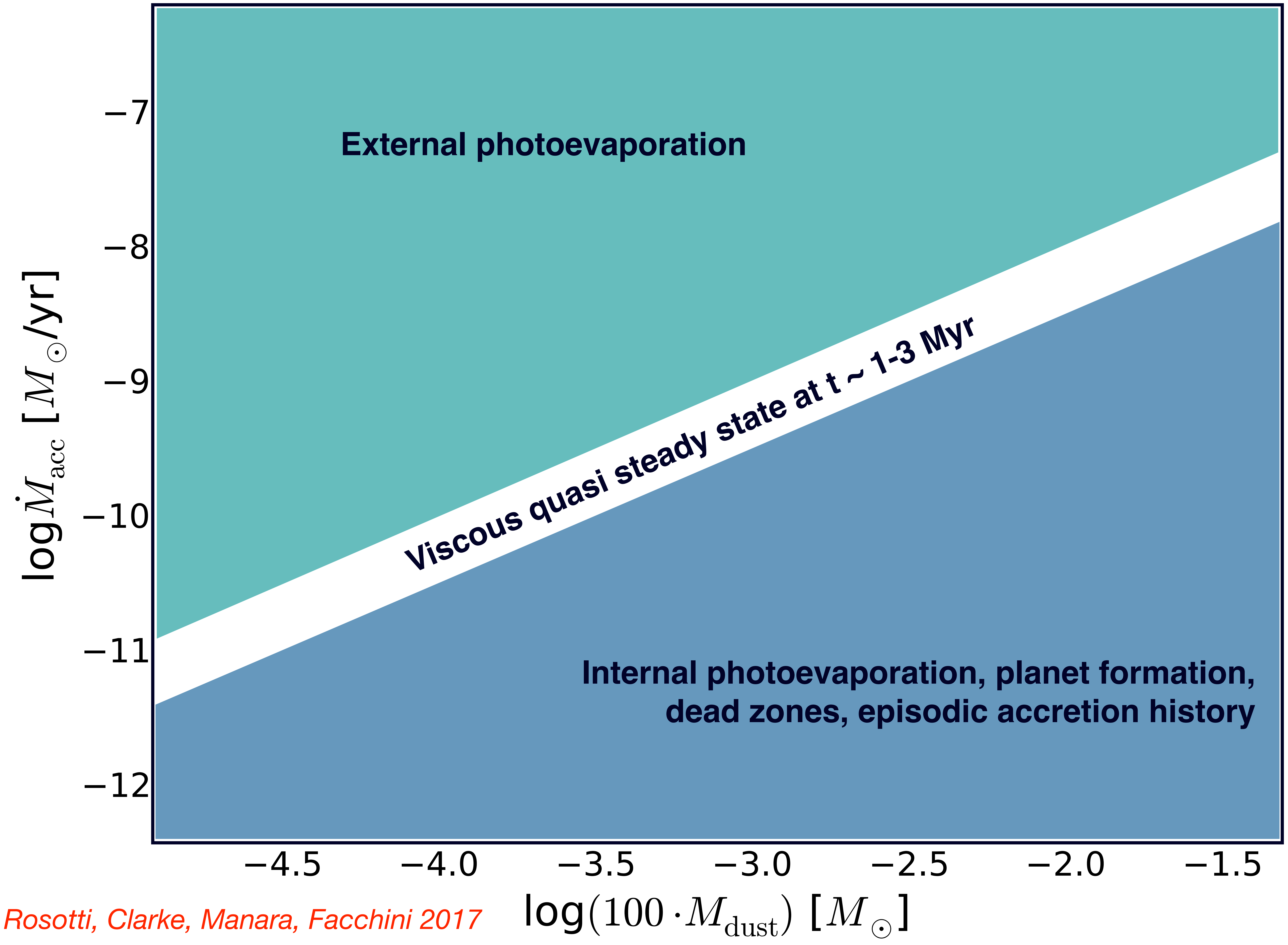
1 Accretion and ejection processes are key to understand how disks evolve.

2 Combined efforts (e.g., ULLYSES/ODYSSEUS/PENELLOPE) will allow us to better constrain accretion/ejection mechanisms

GREGORY J. HERCZEG
Associate Director of Science, Associate Professor, Associate Speaker

CARLO F. MANARA
User Support Astronomer
@cfmanara

Disk mass - accretion rates relation

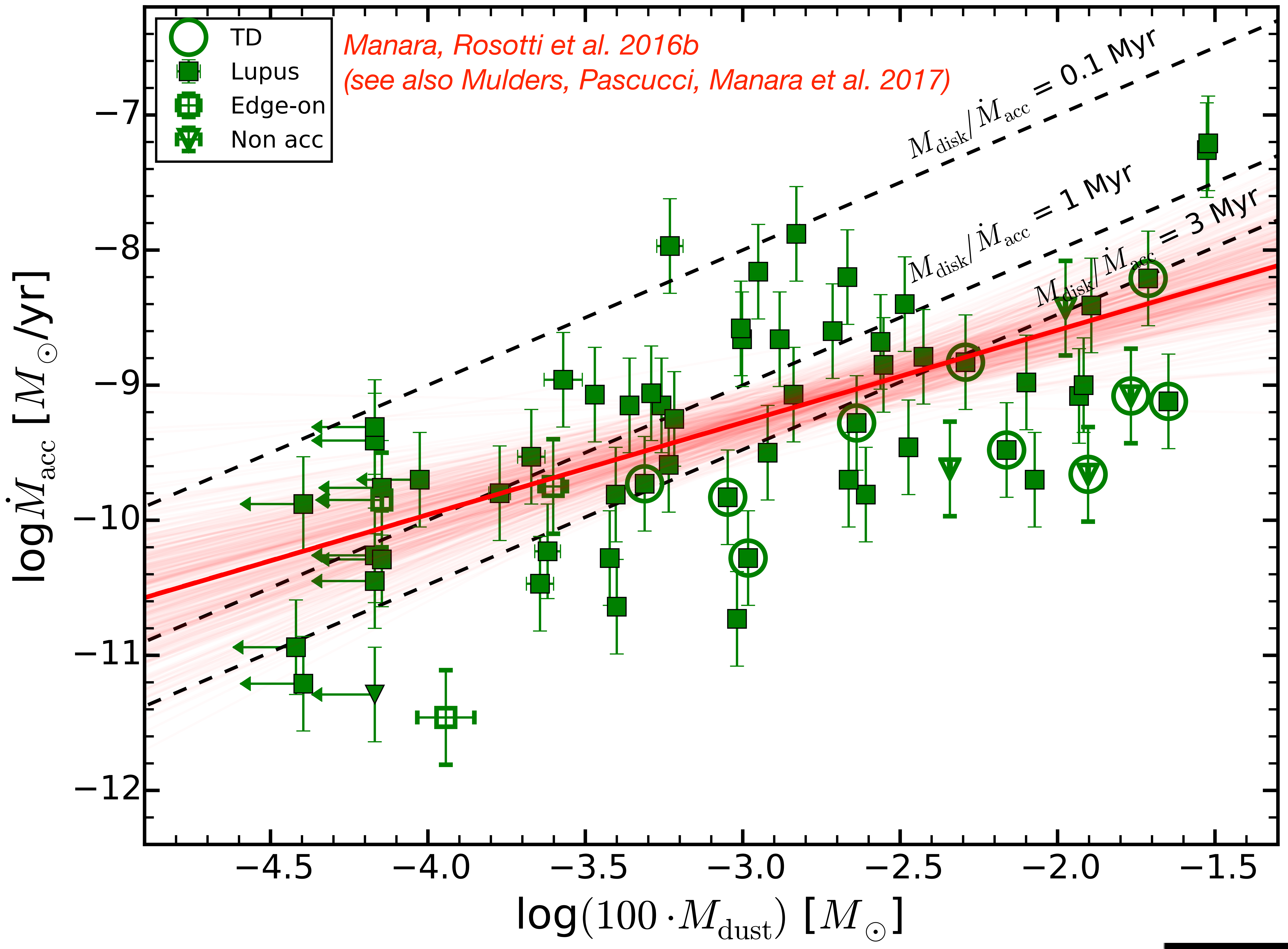


Rosotti, Clarke, Manara, Facchini 2017

Viscous models predict a **tight correlation** between mass accretion rates and disk masses

See also Hartmann et al. 1998, Jones et al. 2012, Lodato et al. 2017, Mulders et al. 2017, Somigliana et al. 2020

Disk mass - accretion rates relation at ~1-3 Myr

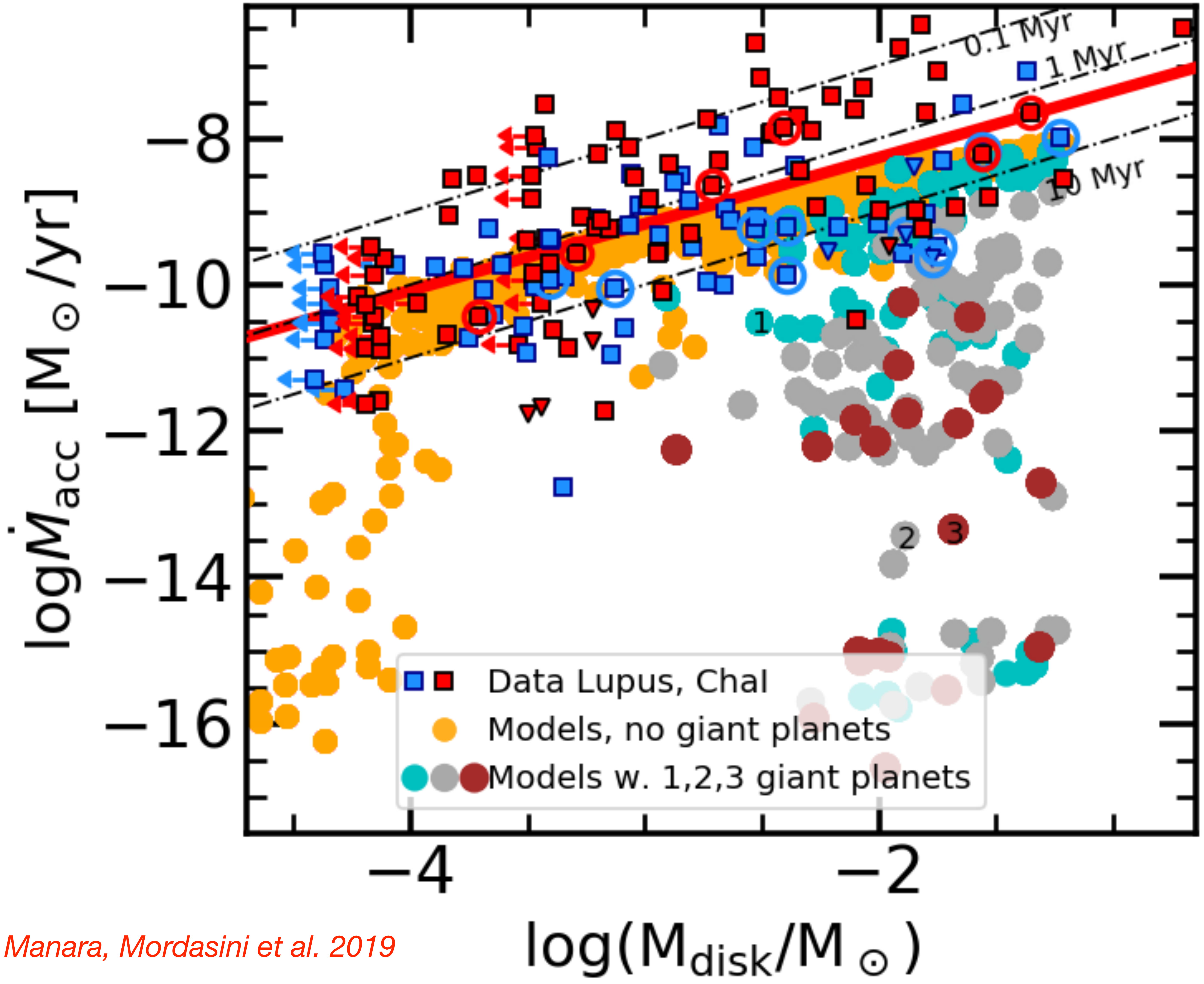


M_{acc} correlates ~ linearly with M_{dust}, no correlation with M_{CO}. With a gas-to-dust ratio of 100 the results are in *general agreement* with viscous evolution models

…only if the viscous timescale is ~1 Myr

Mulders, Pascucci, Manara et al. 2017
Lodato, Scardoni, Manara et al. 2017
Rosotti, Clarke, Manara et al. 2017

Disk models in planetary population models



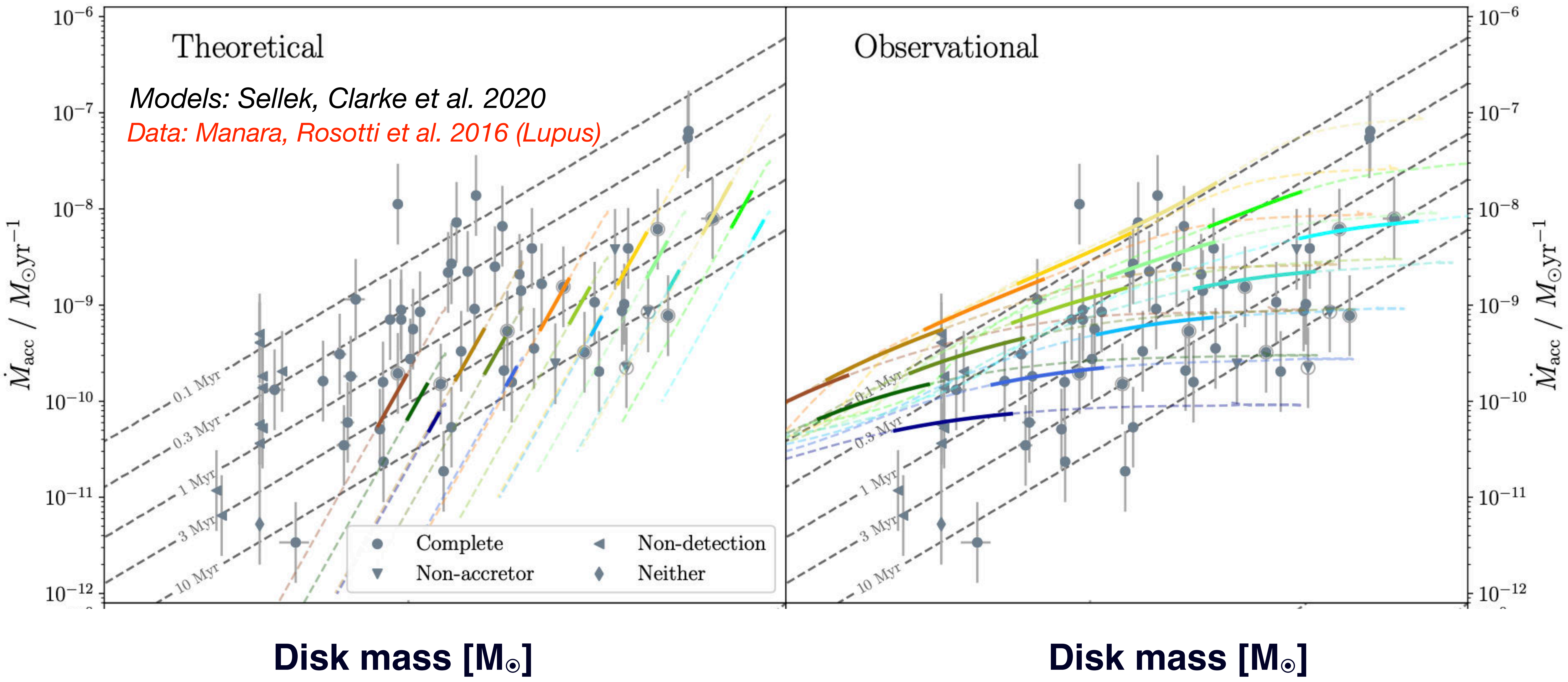
Manara, Mordasini et al. 2019

Current *disk* models used to *predict* the observed exoplanet populations are to be revised based on the outcome of our observations:

+ general agreement between models and data

- small spread, too many low accretors at high disk masses (too high accretion rates on planets?)

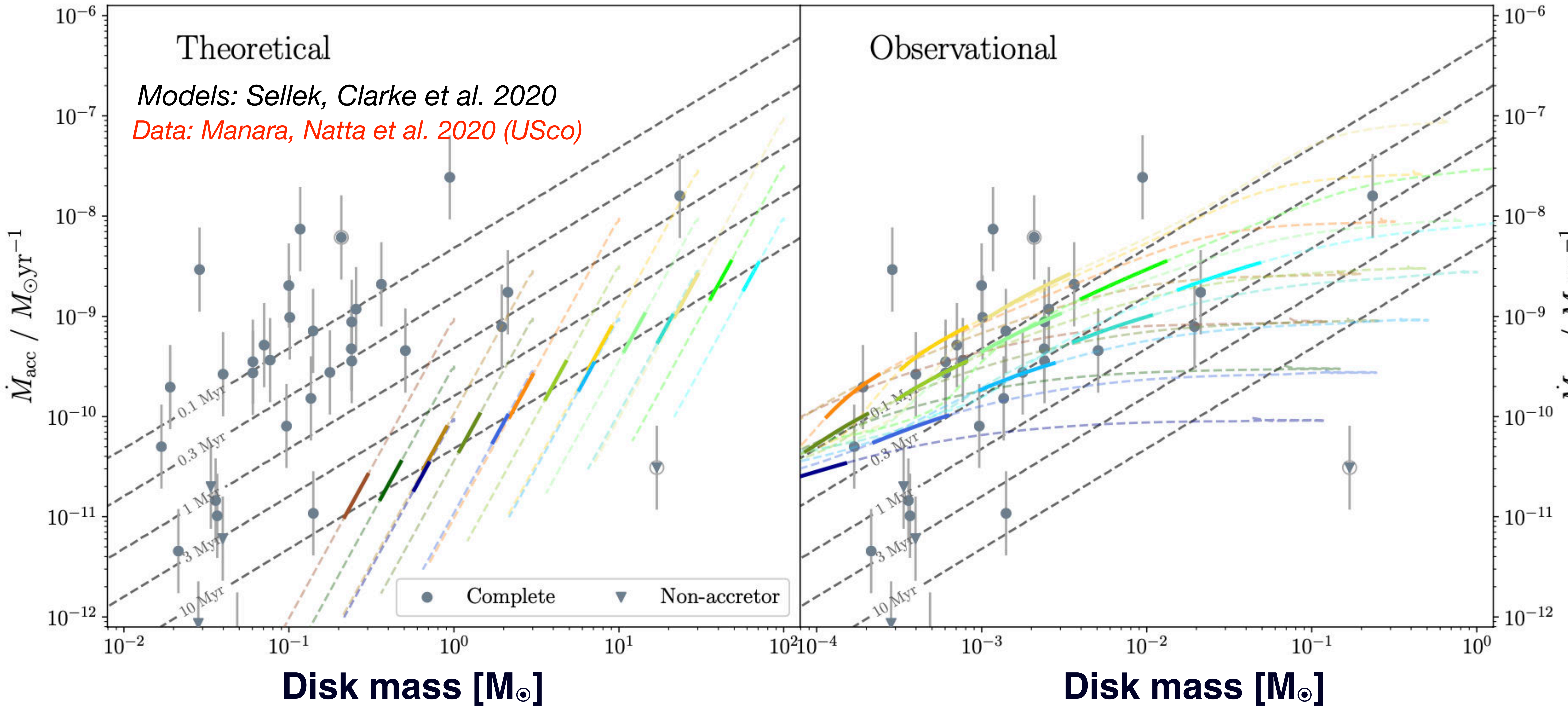
Disk mass - accretion rates relation



Including dust evolution the (viscous) models are in better agreement with observations

Sellek, Clarke et al. 2020

Disk mass - accretion rates relation



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