School of Physics and Astronomy
FACULTY OF MATHEMATICS AND PHYSICAL SCIENCES

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Formation and evolution of the intermediate mass Herbig Ae/Be pre-main sequence stars

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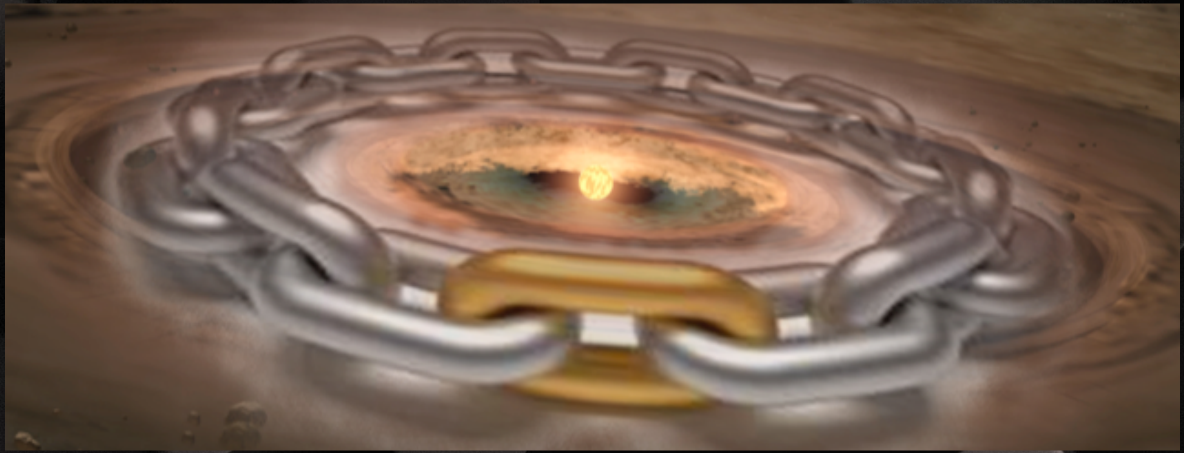
(Leeds, UK)



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STARRY
STARS THAT 'R' YOUNG

Low mass vs. high mass star formation
Is magnetospheric accretion acting?

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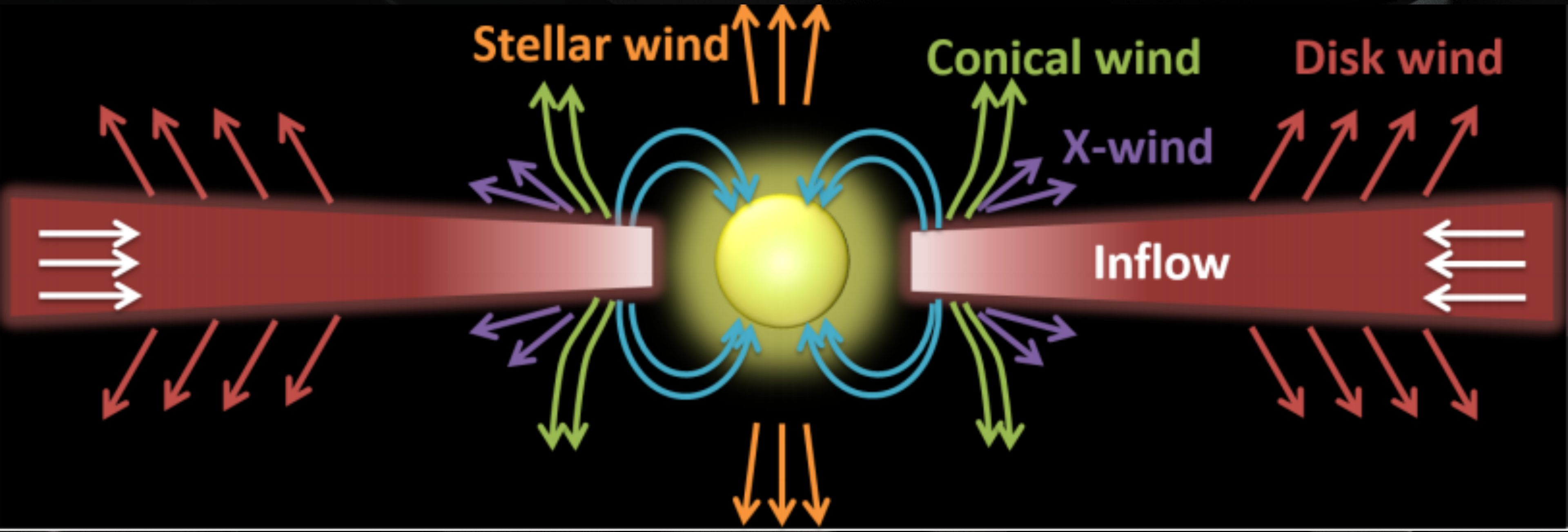


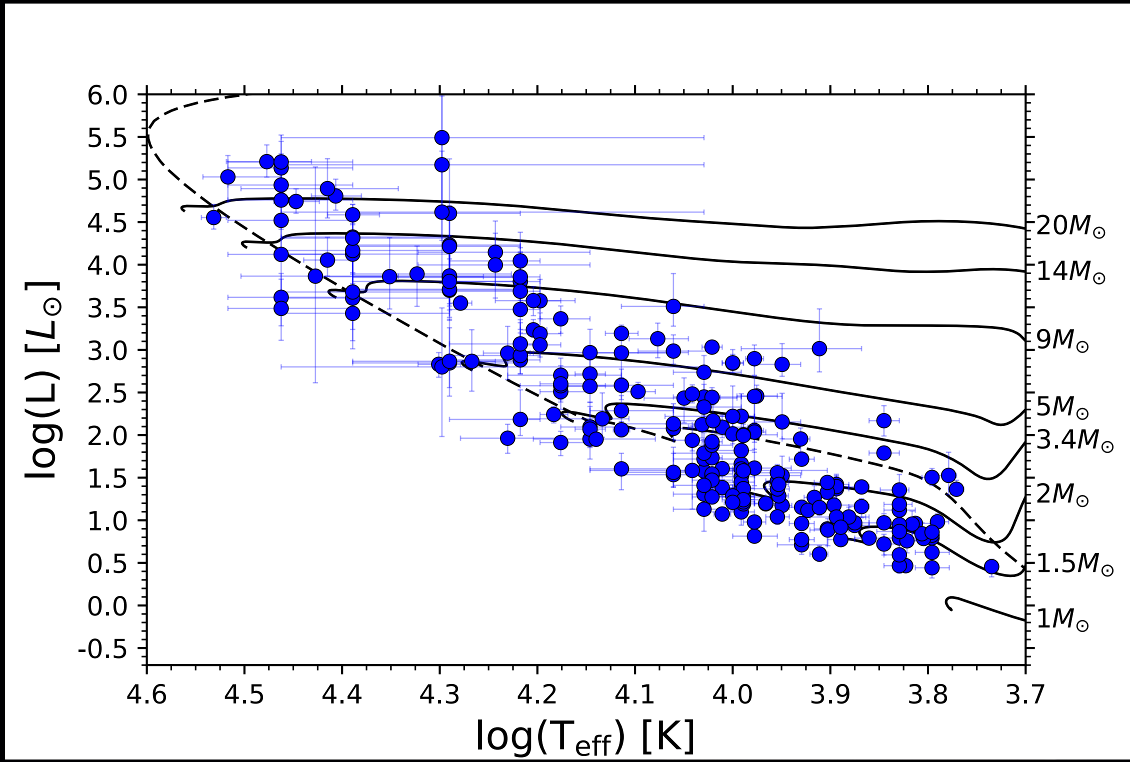
- Stars of spectral type A and earlier have radiative envelopes, so no magnetic dynamo expected
- Only about 10% of intermediate mass stars found to have *B*-fields (Alecian+ 2013 – no difference in emission properties Reiter+ 2018)
- How does matter accrete onto more massive stars?

Pre-main sequence stars

T Tauri stars : solar mass, magnetically controlled accretion, veiling, optically visible

Herbig Ae/Be stars : intermediate mass,

optically visible



GAIA DR2 Vioque+ 2018

Massive Young Stellar Objects : massive, rare, elusive, obscured (Leeds RMS, see talk Lumsden)

Herbig Ae/Be stars even host planets

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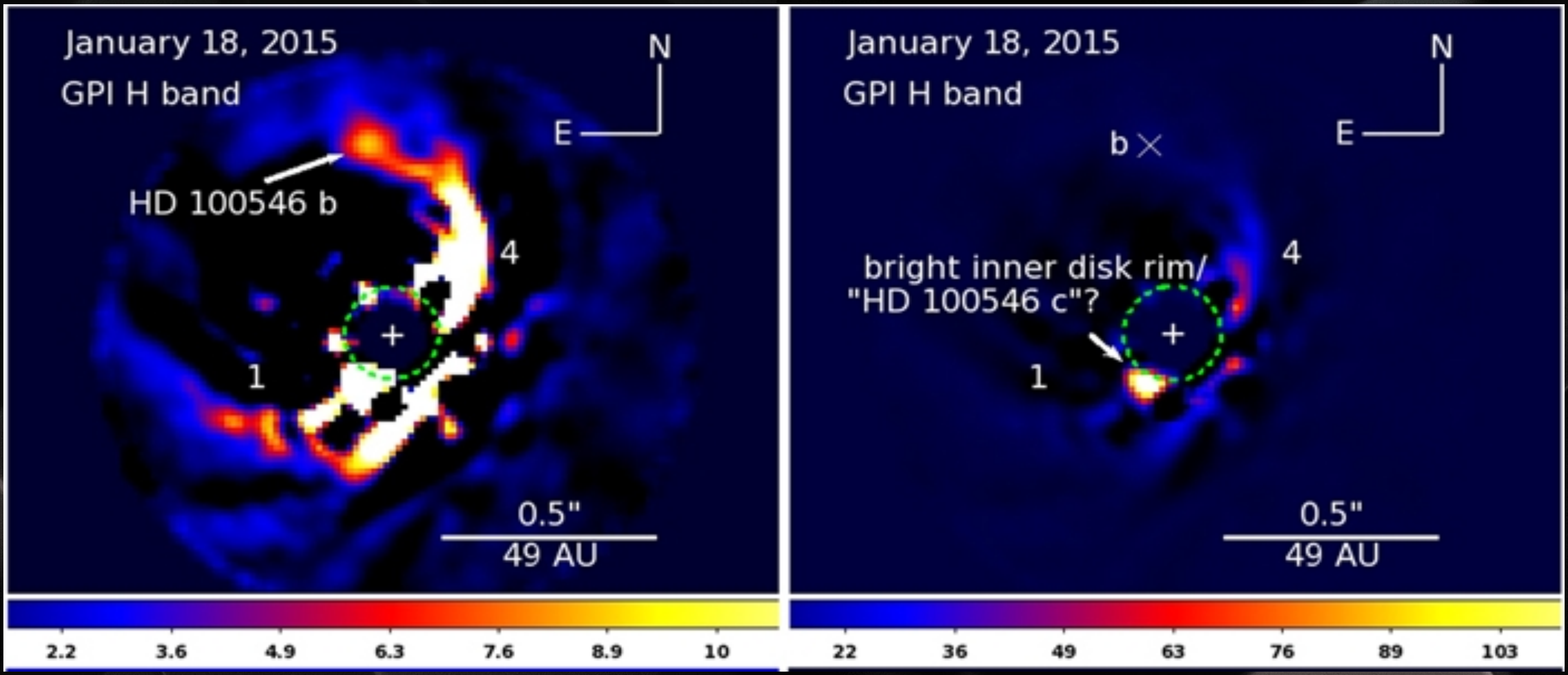


HD 100546 : Thayne Currie+ 2015, see also Mendigutia+ 2015, 2017

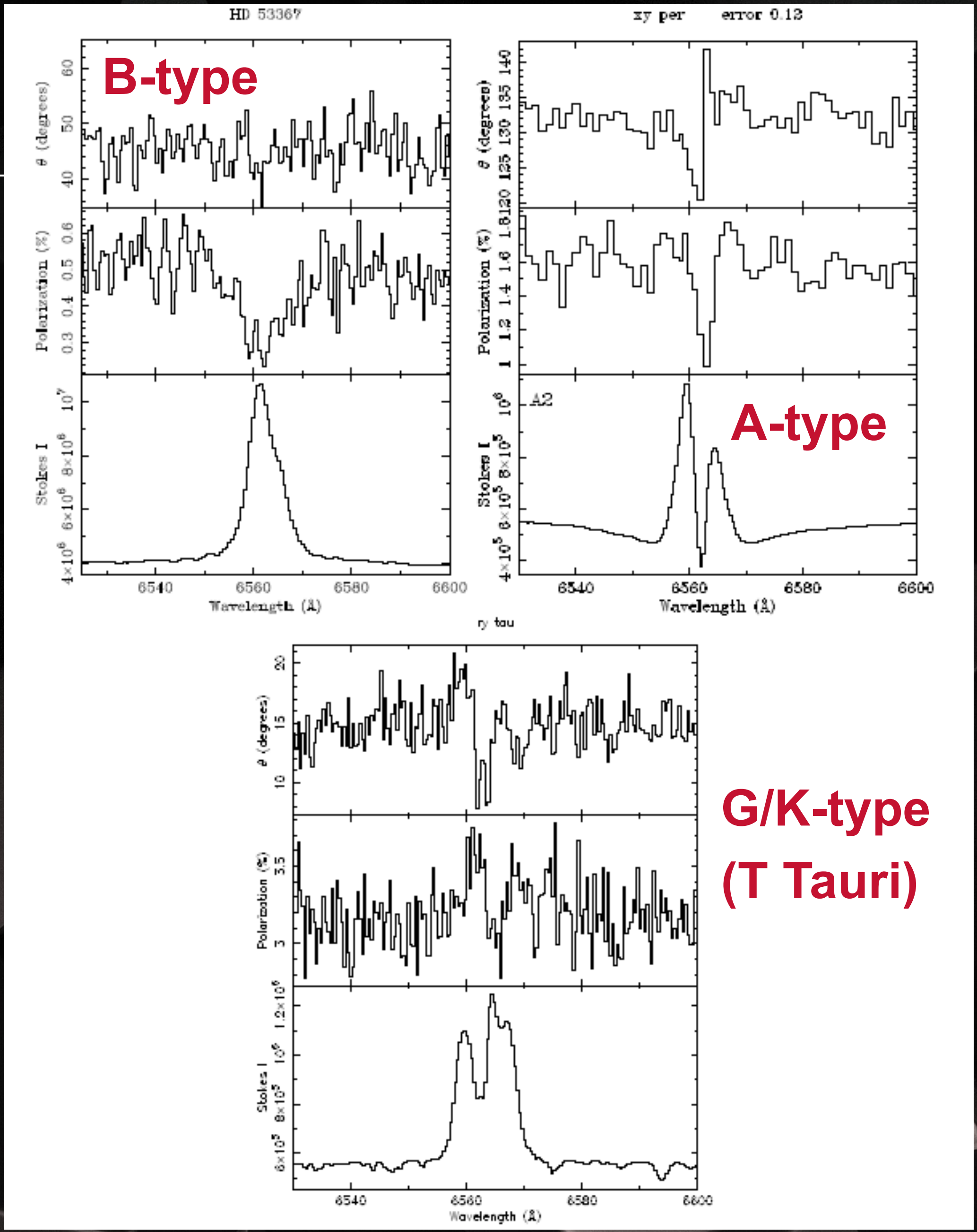
Linear Spectropolarimetry

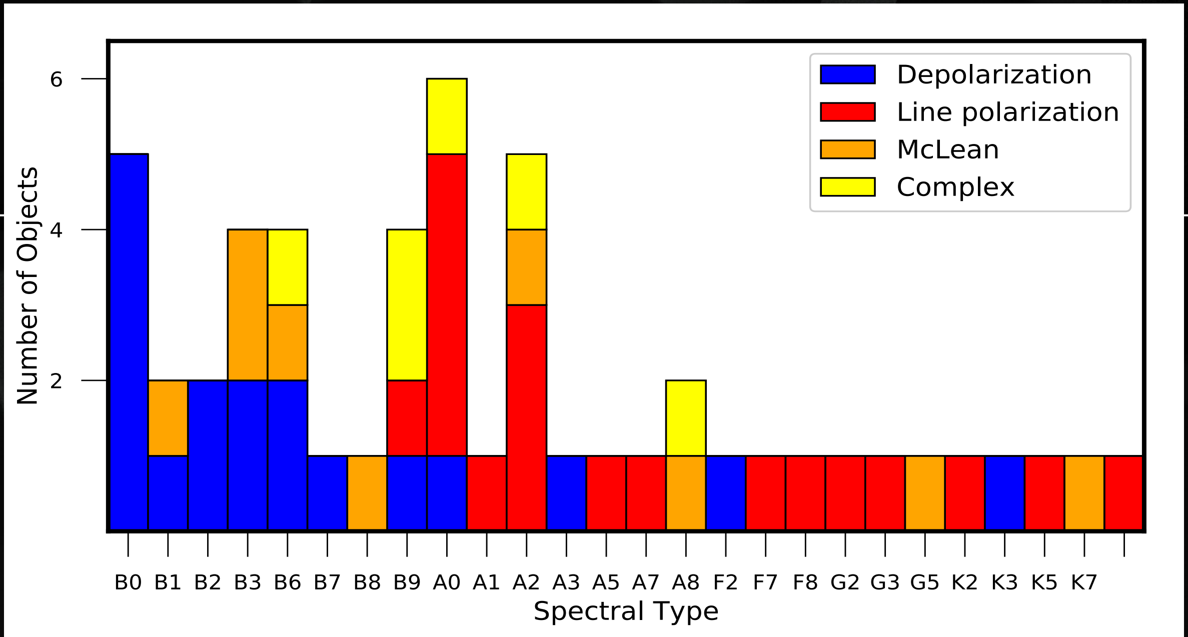
Reveals presence of small scale disks

Herbig Be stars consistent with disk reaching to close to star

Herbig Ae stars similar to the T Tauri stars with inner disk hole of several stellar radii

(Vink+ 2003, 2005, Mottram+ 2007, Ababakr+ 2017)





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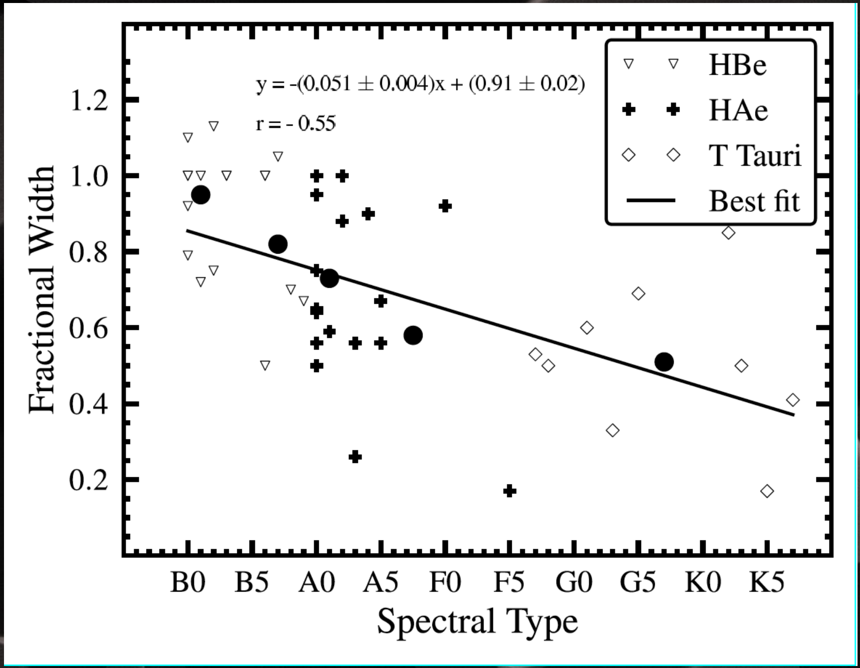
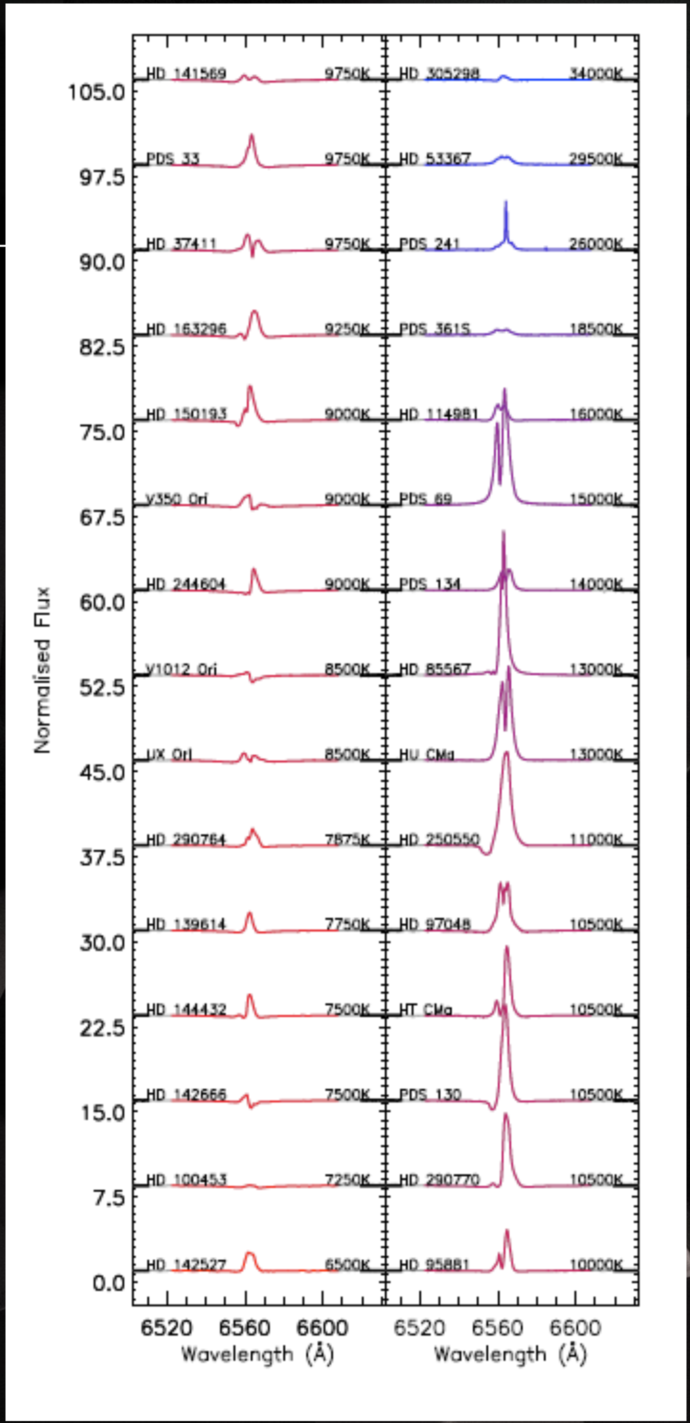
Large sample of 56 objects:
Trend with spectral type (Ababakr+ 2017)

Break/change in properties around $3M_{\odot}$.



Investigate accretion properties across mass range

- Obtained X-Shooter data of a large sample of 90 Herbig Ae/Be stars
- Spectra cover optical – near-infrared wavelength range (400nm – 2.4micron) in one shot, no issue with variability
- Determined stellar parameters in homogeneous manner for all objects
- Worked out accretion rate.
- Fairlamb+ 2015



A large sample: accretion rates

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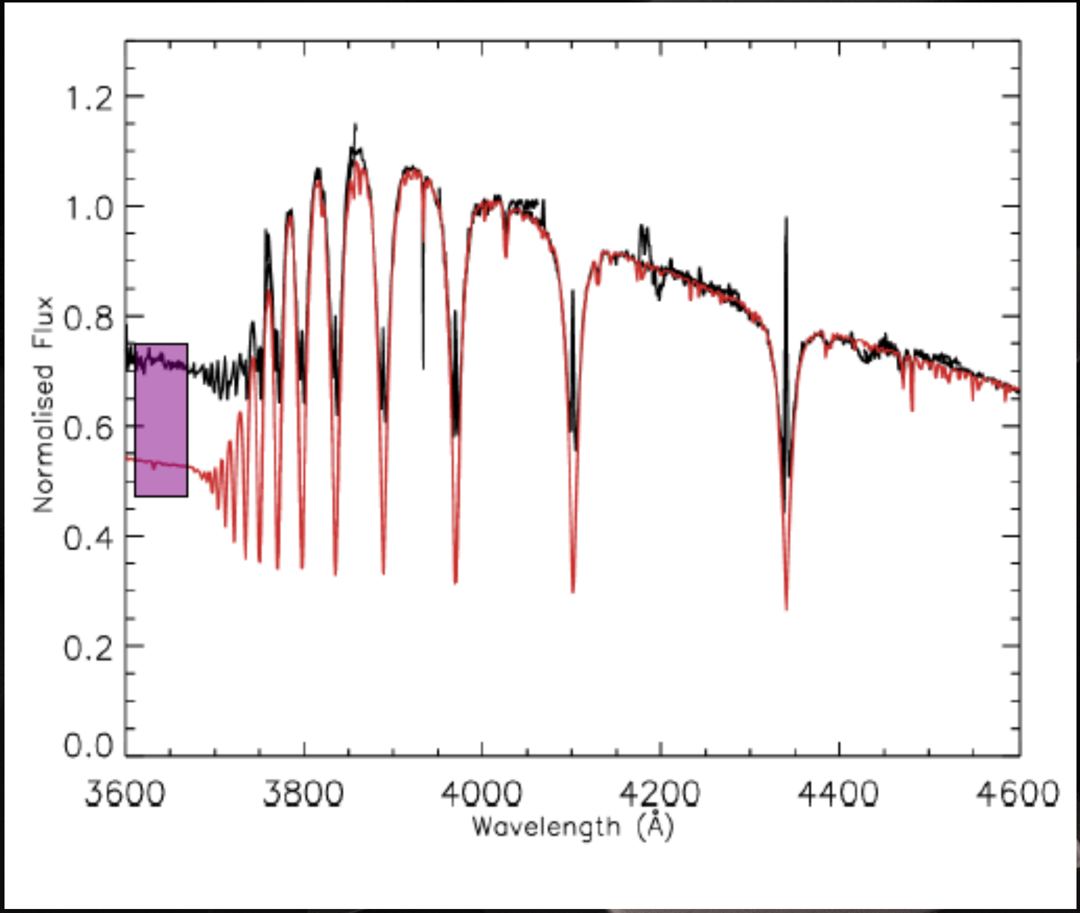
Only “direct” measure: Balmer excess: continuum emission due to accretion shock

- ➢ Determine UV excess
- ➢ Magnetospheric accretion model: accretion luminosity
- ➢ Stellar radius and mass: accretion rate

- ➢ Cf. Calvet & Gullbring 1998 (T Tauri) Muzerolle+2004, Donehew & Brittain 2011 (Herbig Ae/Be)



Accretion rate correlates with mass

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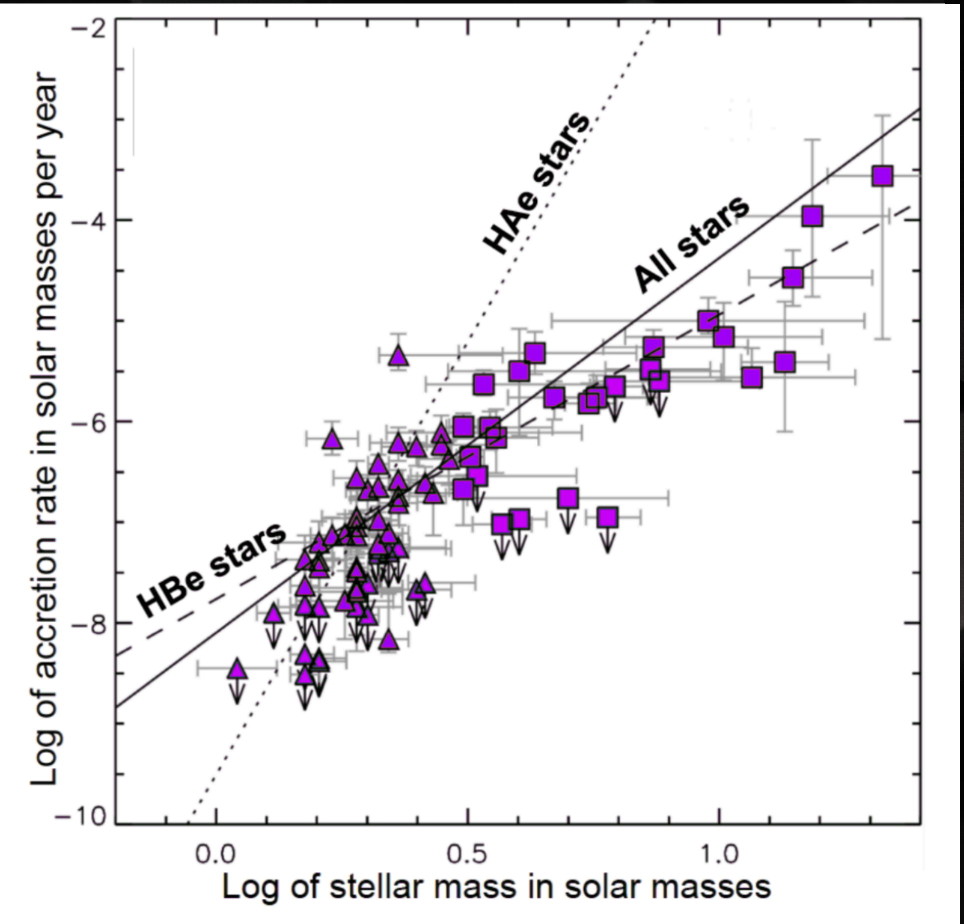


But: different slope Ae and Be objects

Break at around 3 solar masses

Occurs at similar mass as other such findings Vink+ 2002 (see also Muzerolle+ 2004, Grady+ 2010, Oudmaijer+ 2011, Cauley & Johns-Krull 2015, Scholler+ 2016)

Also, some early B-types have UV excesses that can not be reproduced with magnetospheric accretion

Need another mechanism.

Boundary layer accretion instead?

Mendigutia+ in prep; Fairlamb+ 2015

See poster 4C by Wichittanakom

Emission line luminosities correlate with accretion luminosity.

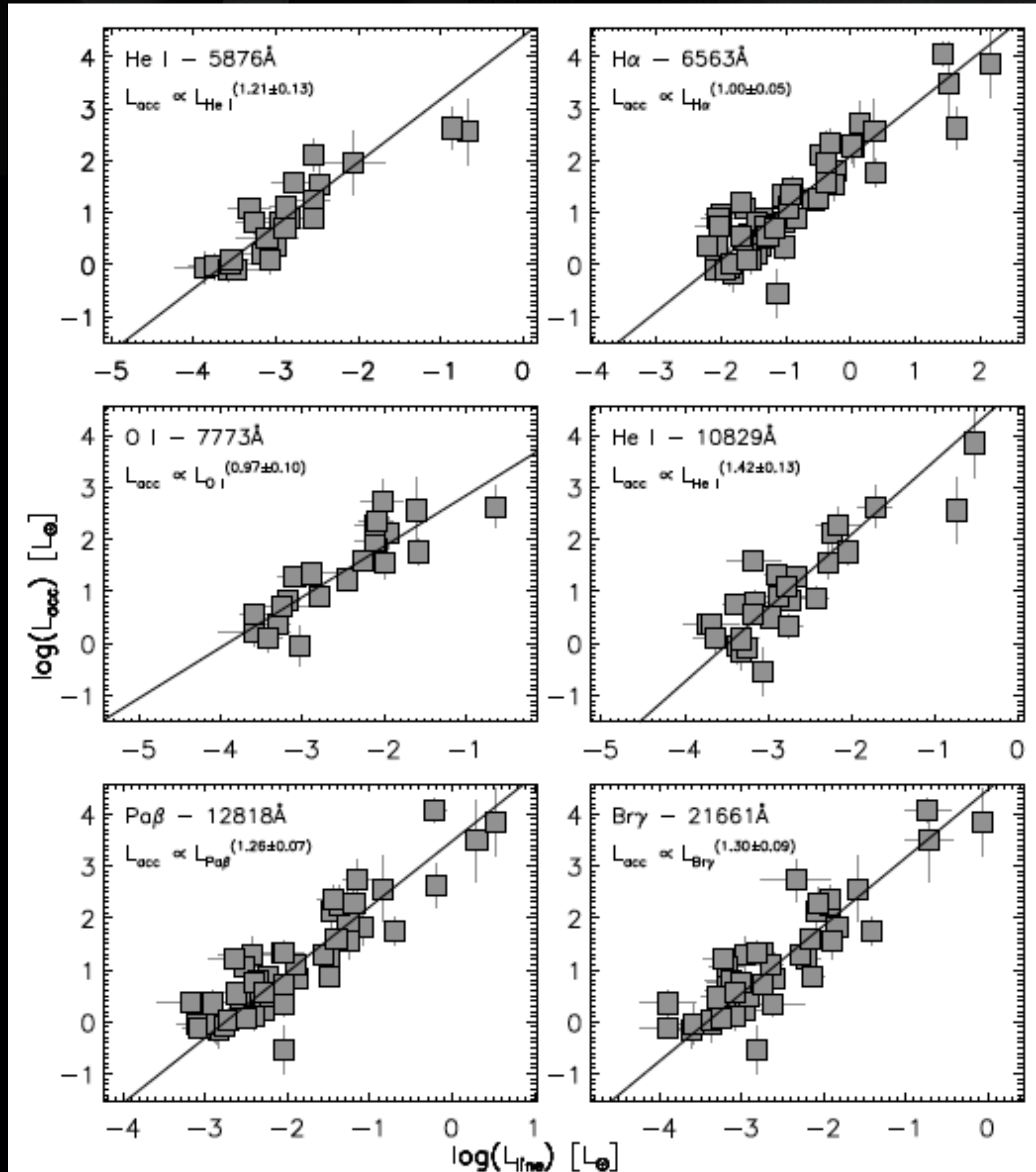
Can be used as accretion diagnostic

L_{acc} determination much easier than using UV excess

Extended the number of calibrated lines to entire X-Shooter spectral range

Fairlamb+ 2017

Mendigutia+2011, Garcia-Lopez+ 2005, Muzerolle+2004, Donehew & Brittain 2011, Rigliaco+2012



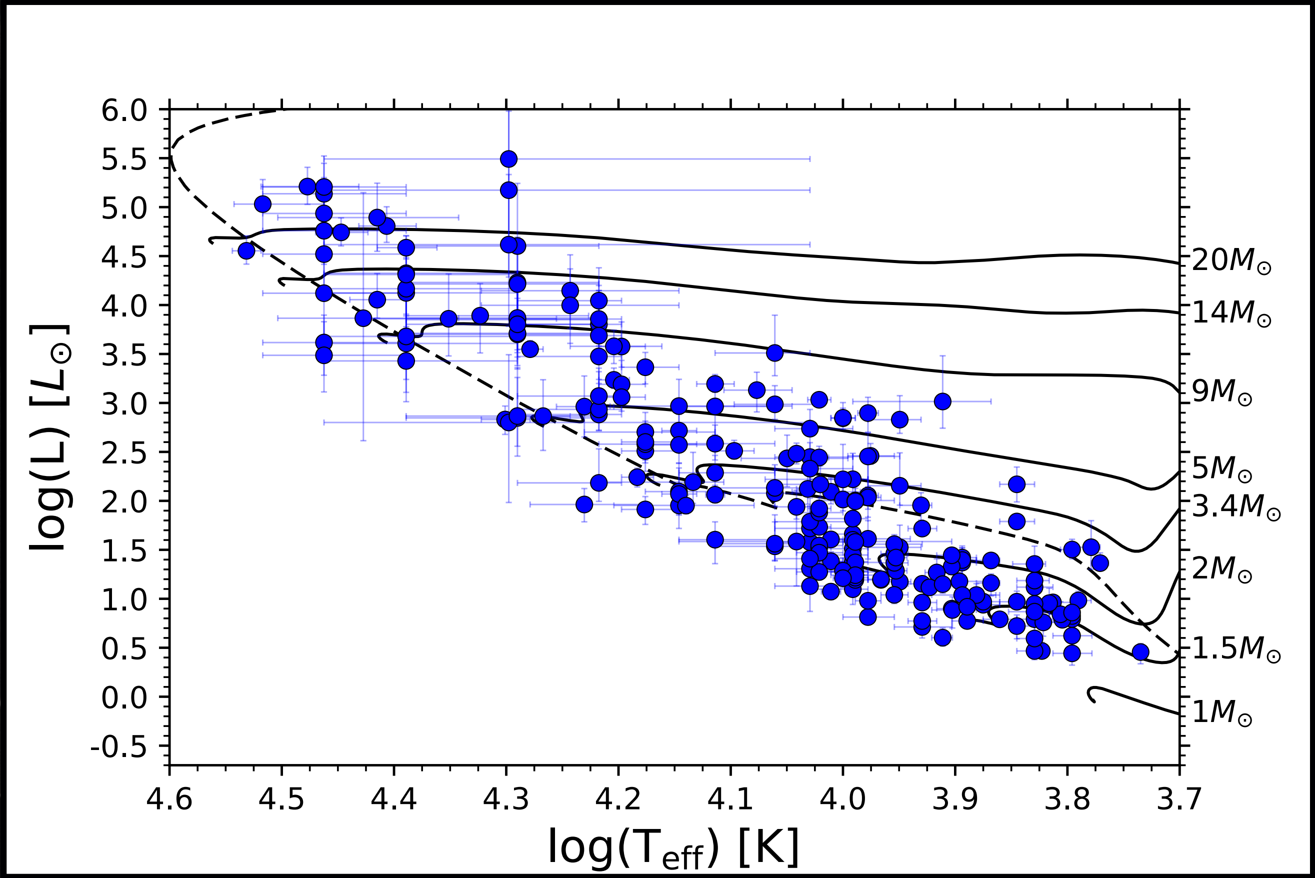
The HR diagram – GAIA DR2 results

Parallaxes + Total Fluxes → Luminosities

200+ objects could be placed on HR diagram.

PMS tracks → Masses

& Isochrones → Ages



Vioque+ 2018

Infrared excess vs. mass

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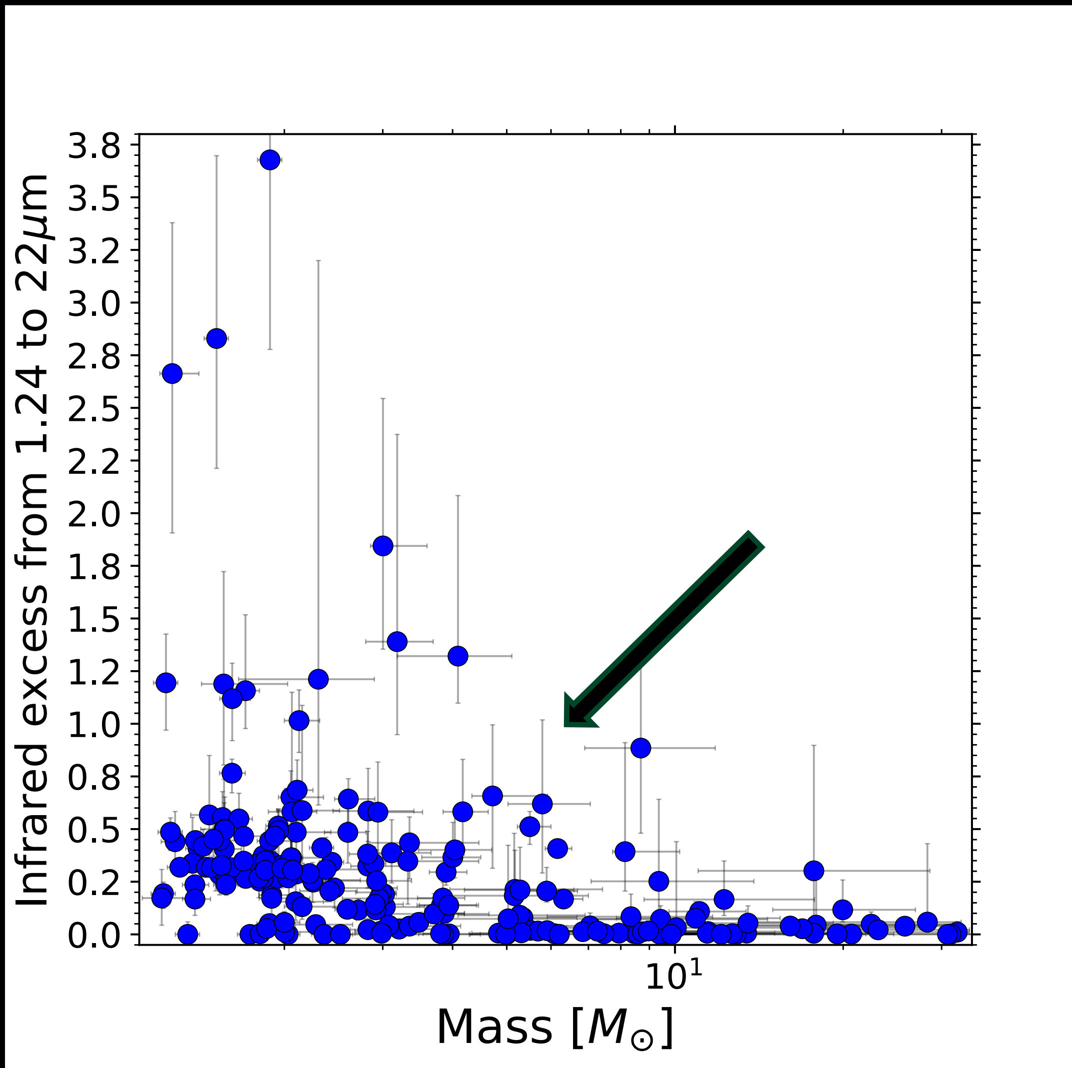

There appears a break at $7M_\odot$. Dusty environment different for early Herbig Be stars.

Related to more efficient dust evaporation at higher temperatures/ brightnesses.

See also Albi+ 2009, Gorti+ 2009

Variability derived from GAIA data vs. Mass

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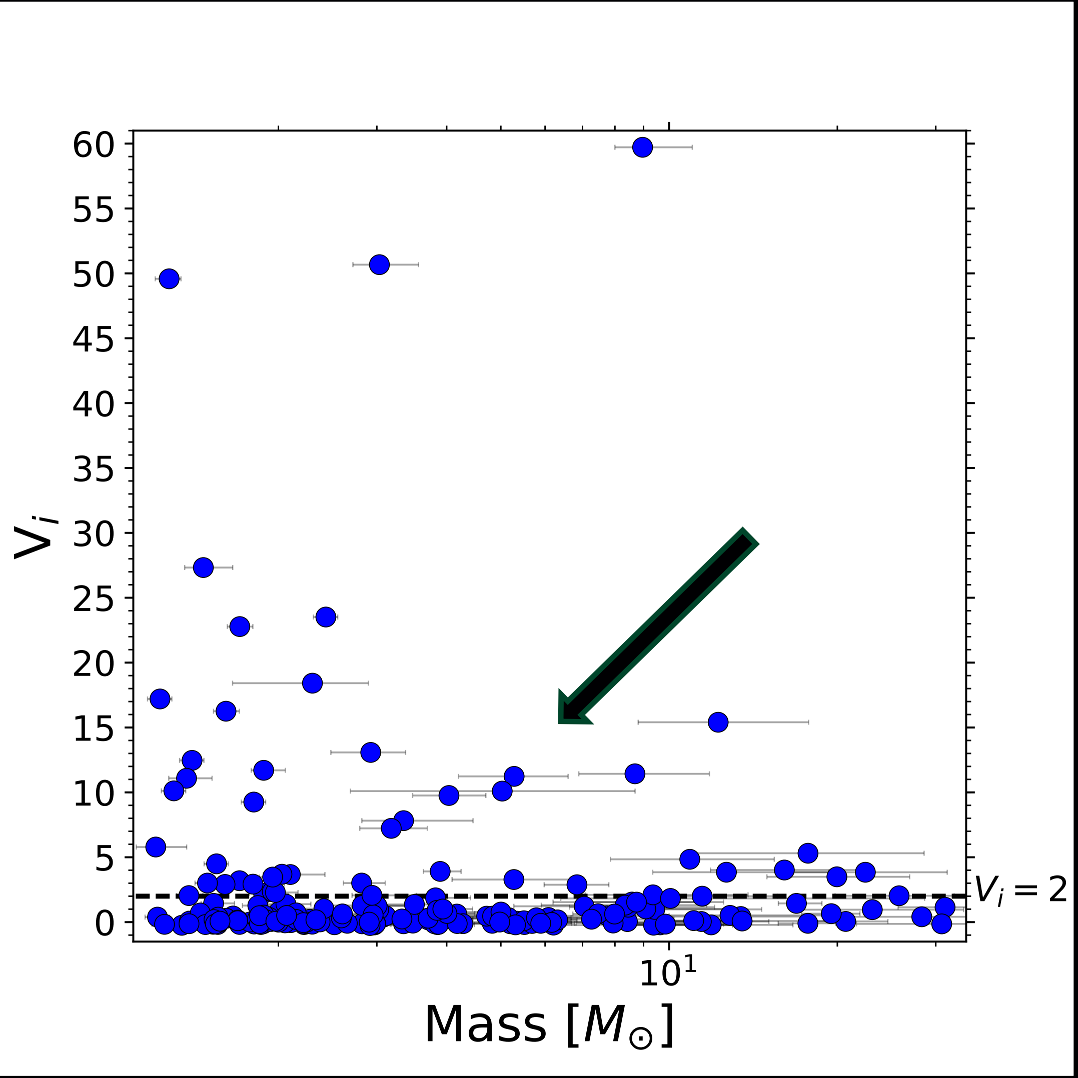

Same break at around 7 solar masses.

25% of all Herbig Ae/Be stars strongly variable.

Variability vs. Infrared excess

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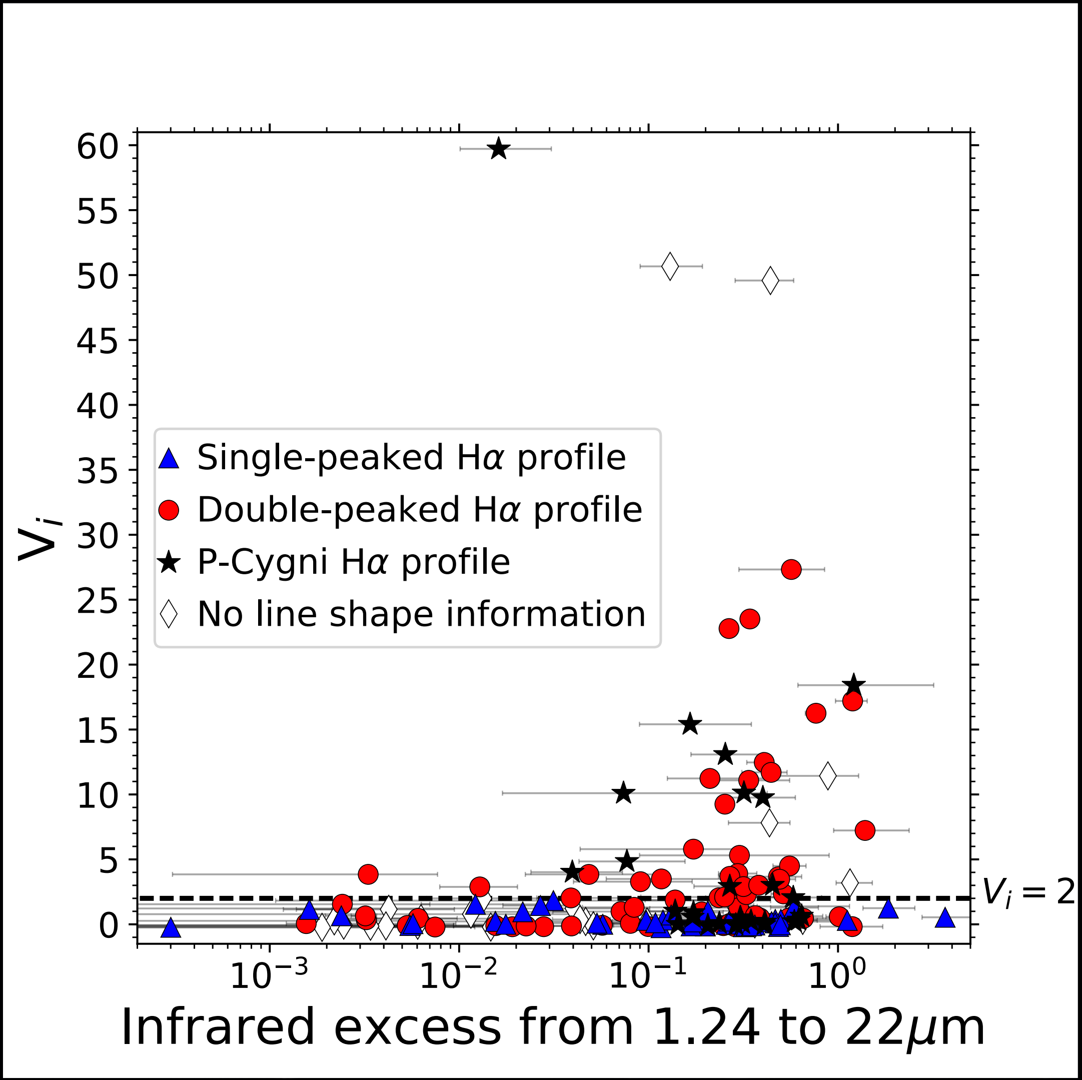

of the strongly variable Herbig Ae/Be stars show double-peaked Hα emission. None show a single-peaked line profile.

UXOR phenomenon

Grinin+ 1996, 2000

Ongoing: GAIA: Herbig Ae/Be stars as link between low and high mass stars – Clusters stats: Testi, Palla+ 97, 98, 99

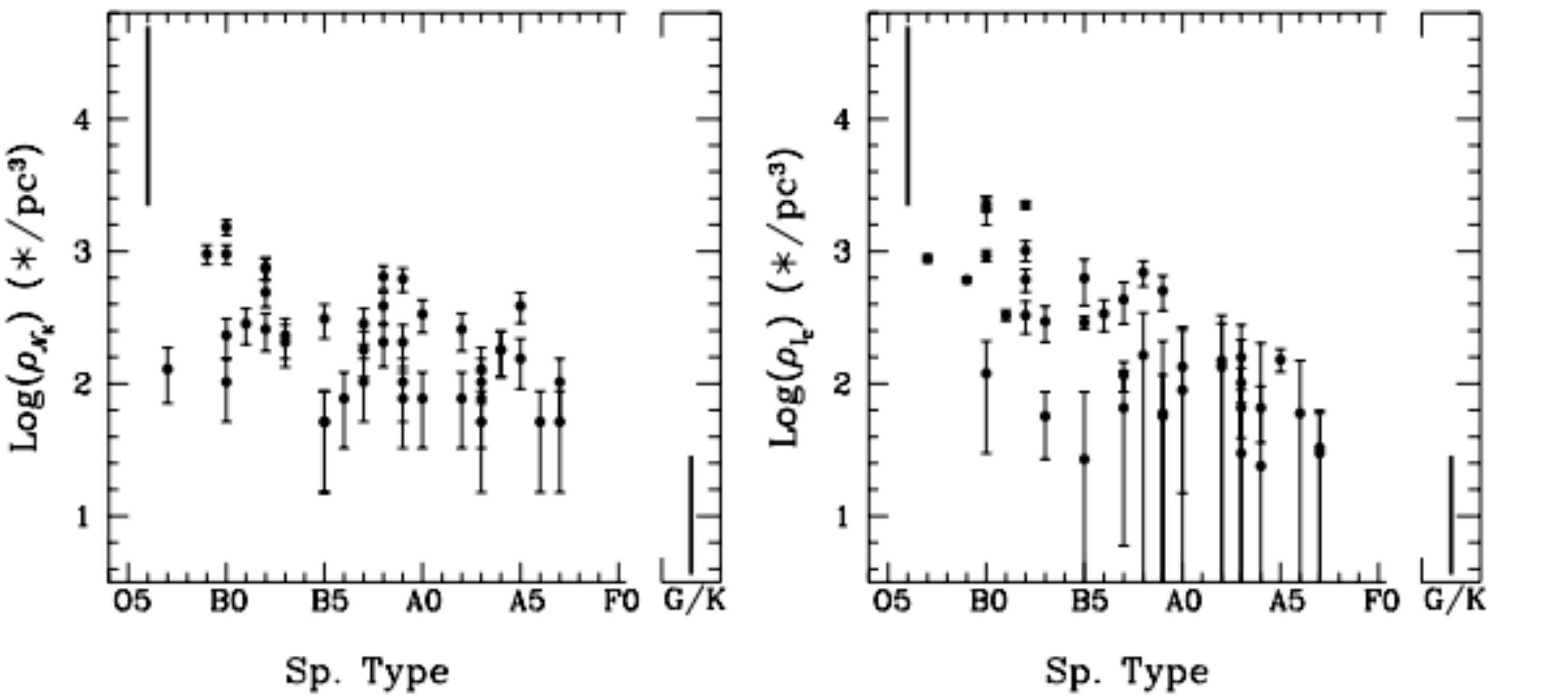

Fig. 7. Stellar volume densities derived from $\mathcal{N}_K$ (*left*) and from I_C (*right*) versus spectral type of the central star. Stars with $I_C < 0$ have been excluded. The heavy vertical line at O6 represents the range of stellar densities found in the Trapezium cluster, whereas that at G/K (not to scale) represents the densities of stellar groups in Taurus-Auriga.

See Poster 1G by Perez

Conclusions

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- Herbig Ae/Be stars bridge the gap between low and high mass young stars and cover the mass where change in accretion occurs.
- Collected largest dataset of linear spectropolarimetry (56 objects)
- Conducted largest spectral survey – 0.4 – 2.4 micron of 90 objects
- GAIA DR2 200+ objects in HR Diagram
- Herbig Ae stars similar to T Tauri stars in spectropolarimetry
- Specpol + M_{acc}: tracing gas close to star: change **at around 3 solar masses** (mid to late B-type). Different accretion mode?
- GAIA – dust tracing material further from star: change at 7 solar mass (photo-evaporation).
- Variability linked to edge-on disks – UXOR phenomenon
- Disk accretion mechanism in massive objects – Boundary Layer?

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