School of Physics and Astronomy
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UNIVERSITY OF LEEDS

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

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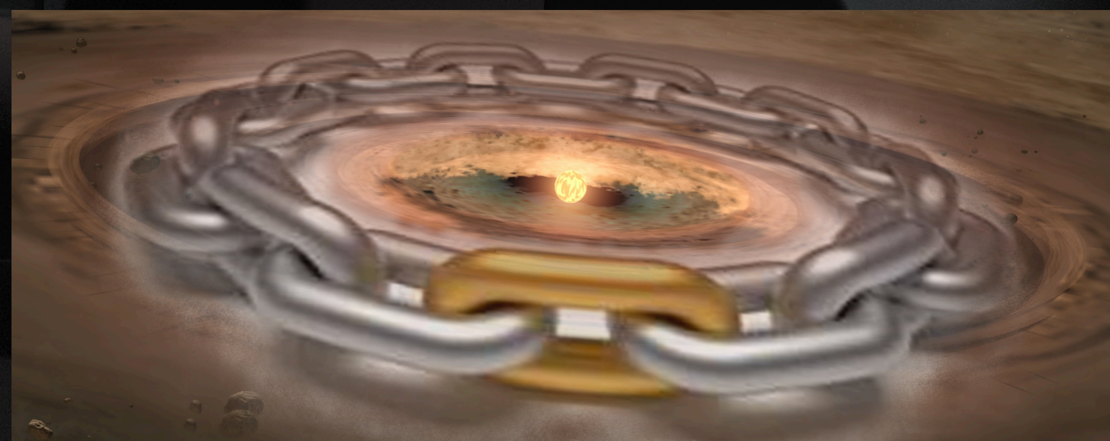
(Leeds, UK)



Karim Ababakr, Miguel Vioque, Alice Perez (Leeds), Ignacio Mendigutia, Deborah Baines (Madrid), John Fairlamb (IfA), Mario van den Ancker, Willem-Jan de Wit (ESO), Jorick Vink (Armagh), John Ilee (IoA)

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STARS THAT 'R' YOUNG

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

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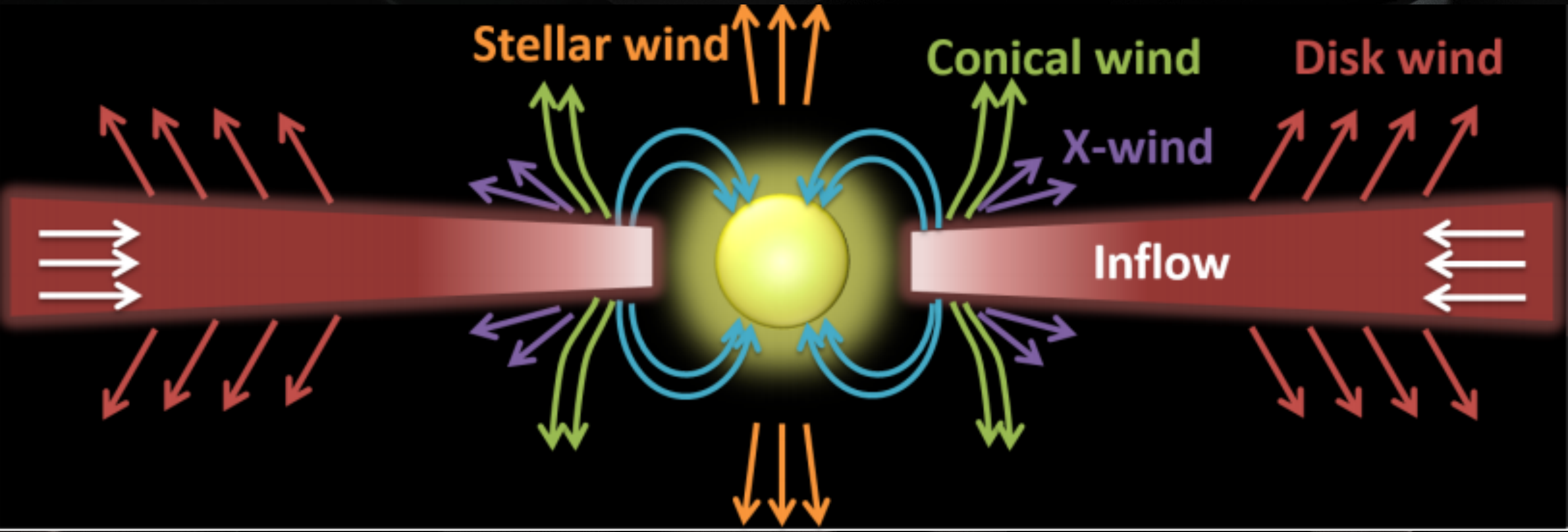

- Stars of spectral type A and earlier have radiative envelopes, so no magnetic dynamo expected
- Only about 10% of intermediate mass stars found to have *B*-fields (Alecian+ 2013 – no difference in emission properties Reiter+ 2018)
- How does matter accrete onto more massive stars?

Pre-main sequence stars

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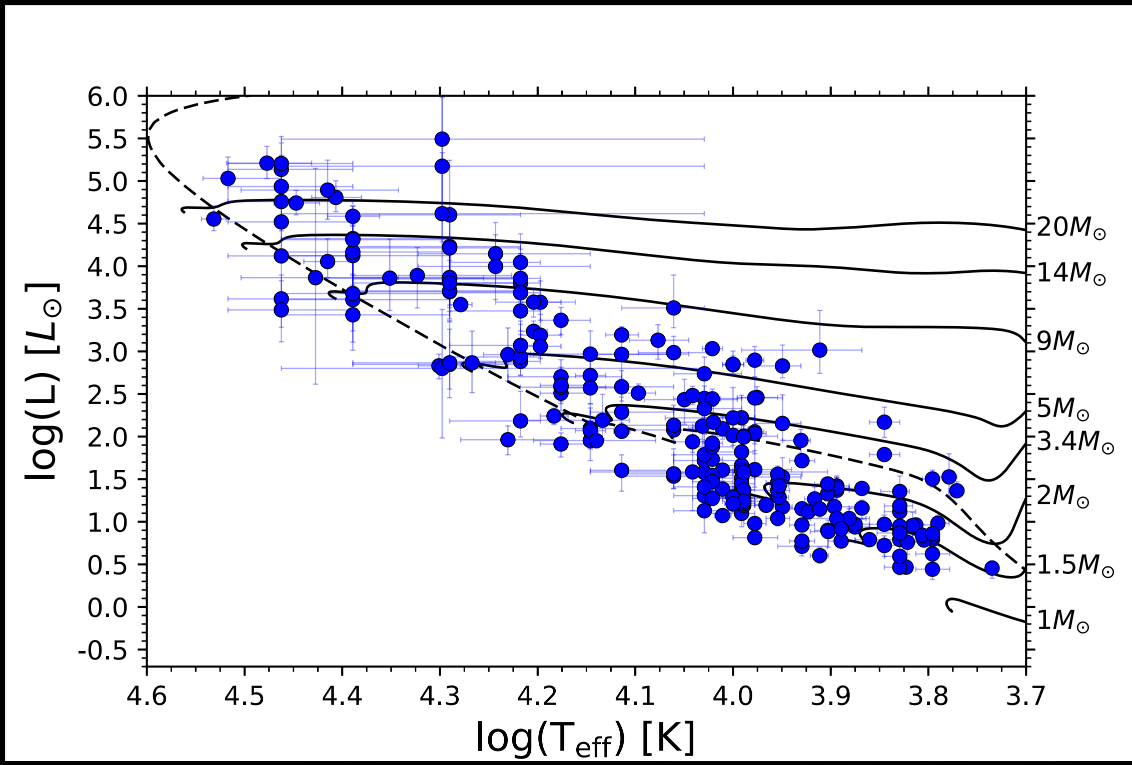
T Tauri stars : solar mass, magnetically controlled accretion, veiling, optically visible

Herbig Ae/Be stars : intermediate mass,

optically visible

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



GAIA DR2 Vioque+ 2018

Herbig Ae/Be stars even host planets

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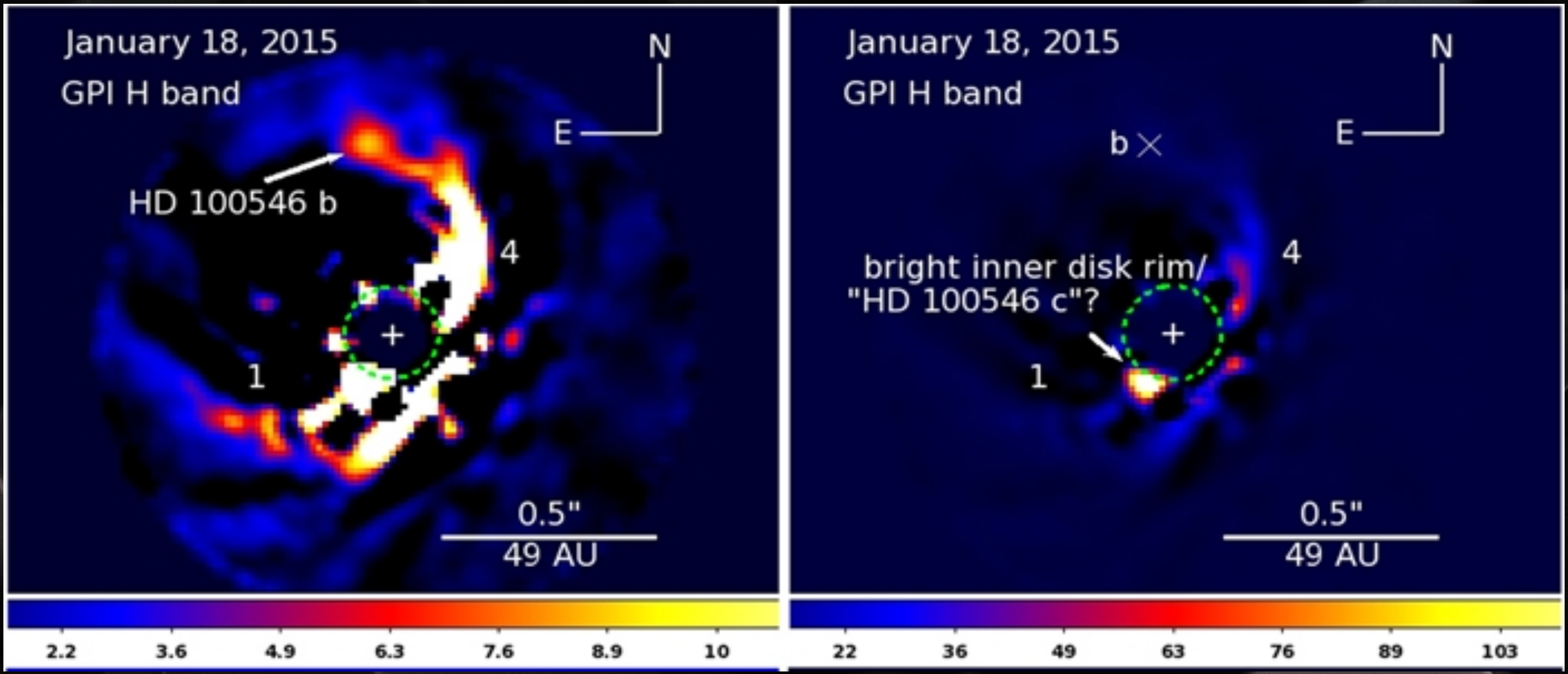

HD 100546 : Thayne Currie+ 2015, see also Mendigutia+ 2015, 2017

Herbig Ae/Be stars even host planets
HD 100546:

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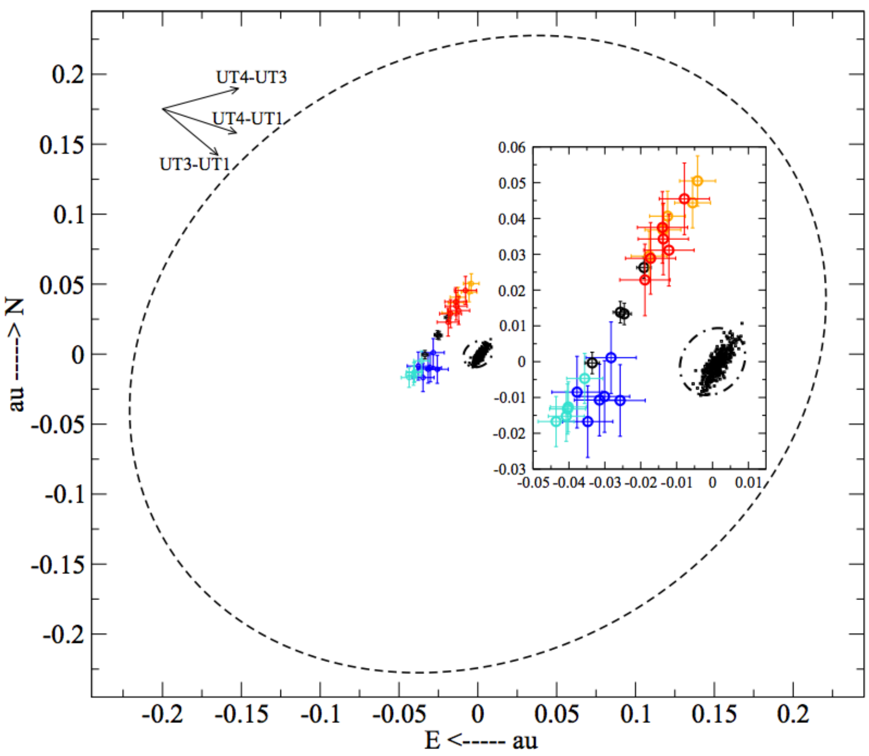
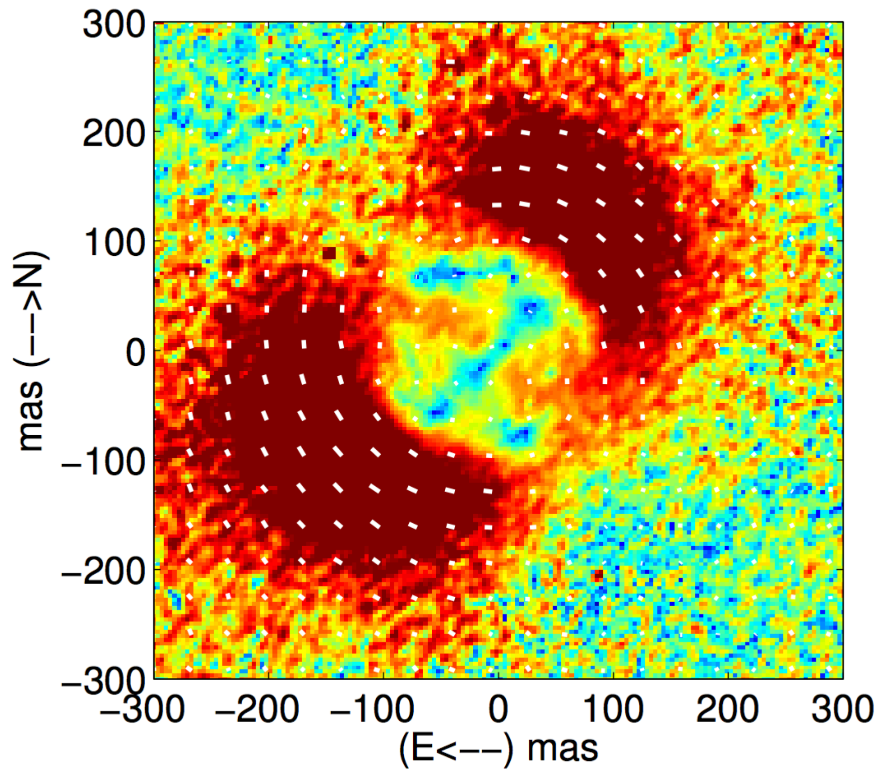




Mendigutia+ 2015 ***AMBER:***

- Much Br gamma emission from volume outside magnetosphere
- Inner disk would be depleted in < 1 yr, needs to be replenished

Mendigutia+ 2017. ***SPHERE:***

- Flow from outer to inner disk?

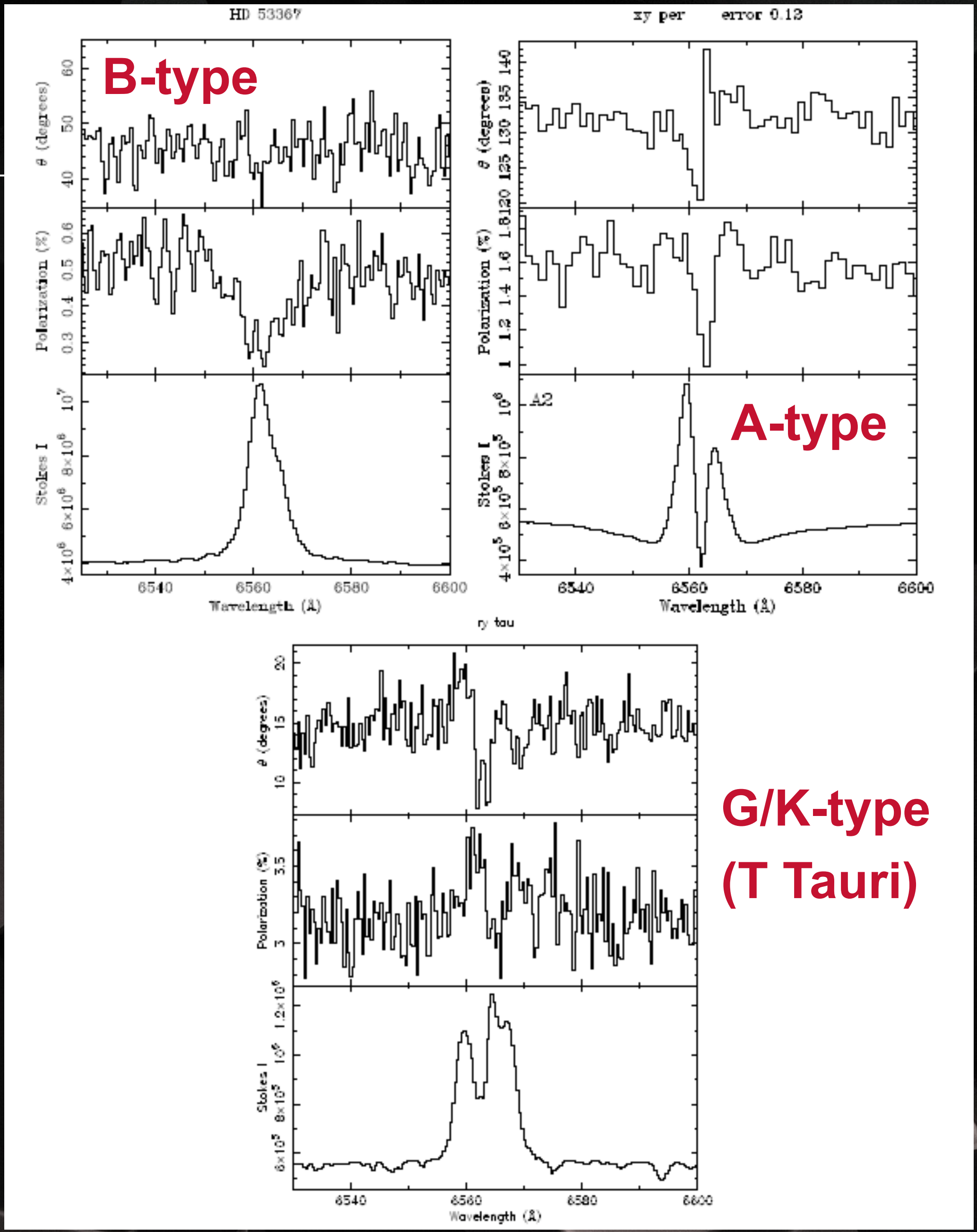
Linear Spectropolarimetry

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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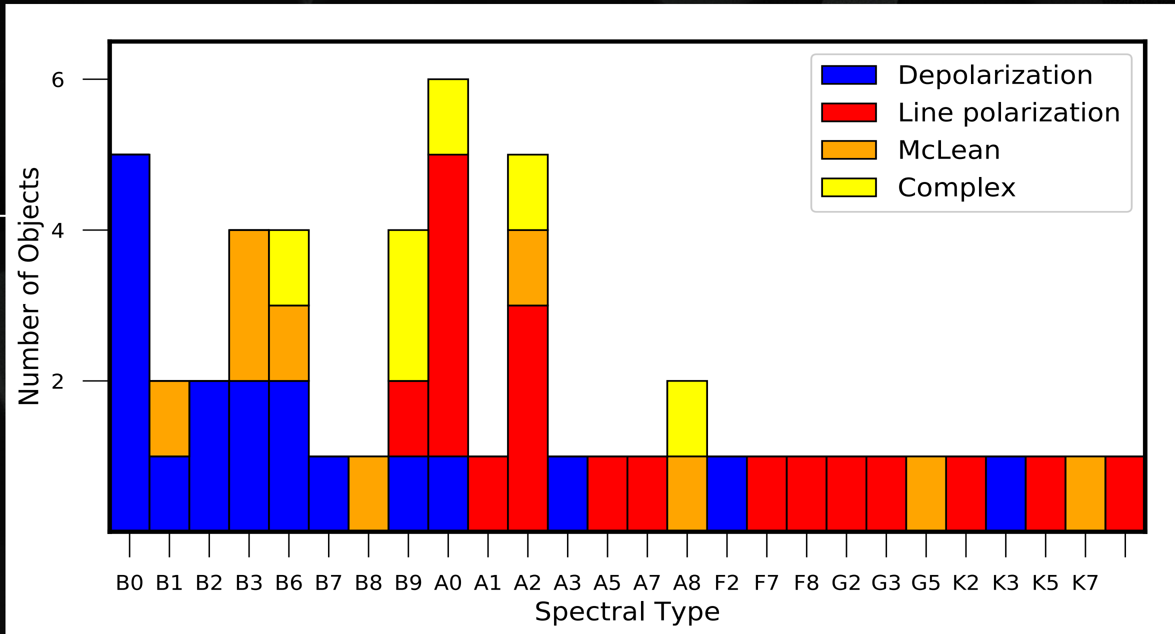
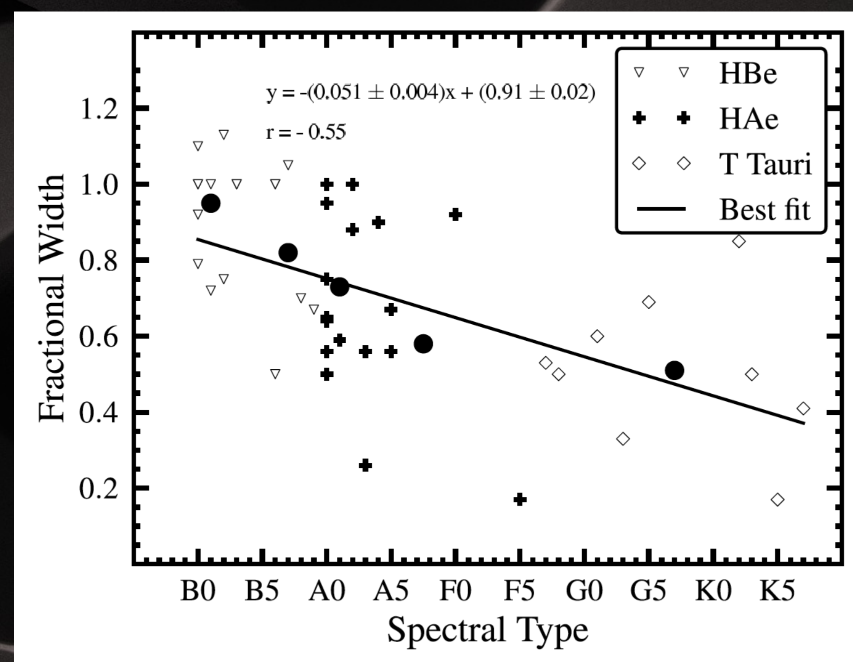


Large sample of 56 objects:

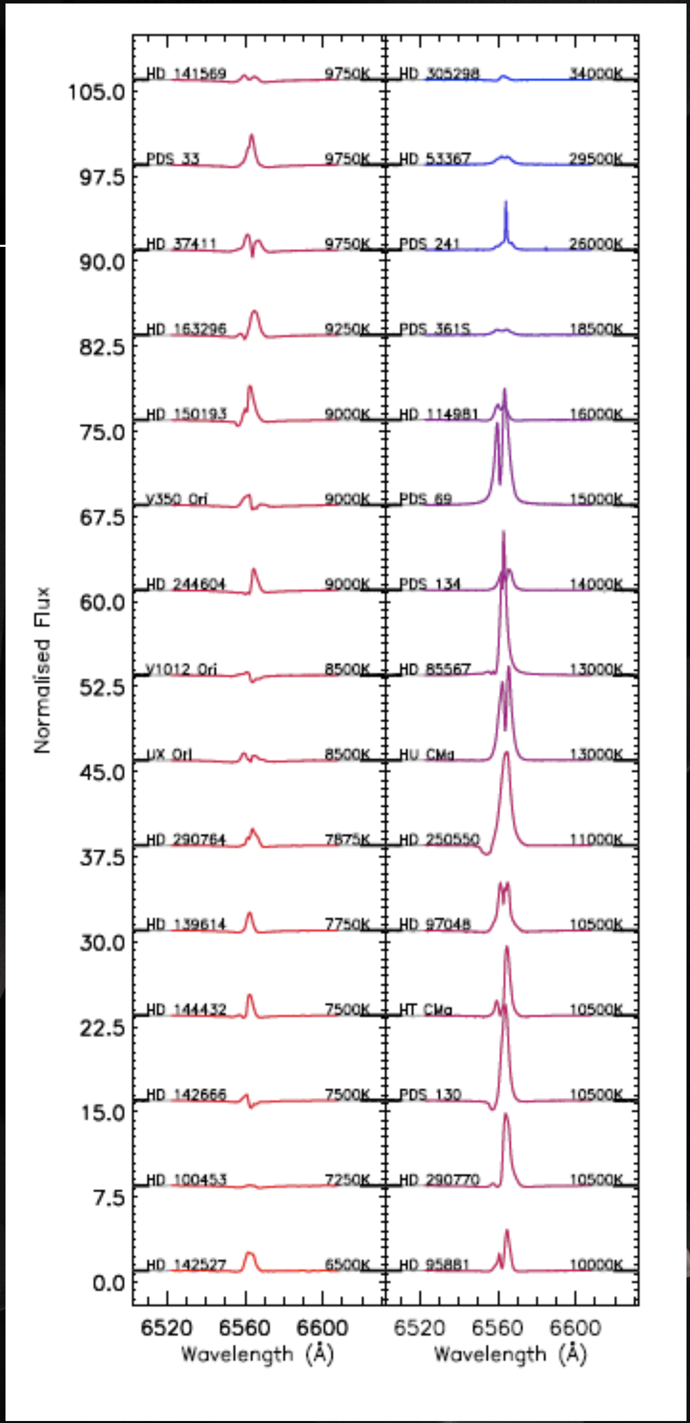
Trend with spectral type (Ababakr+ 2017)

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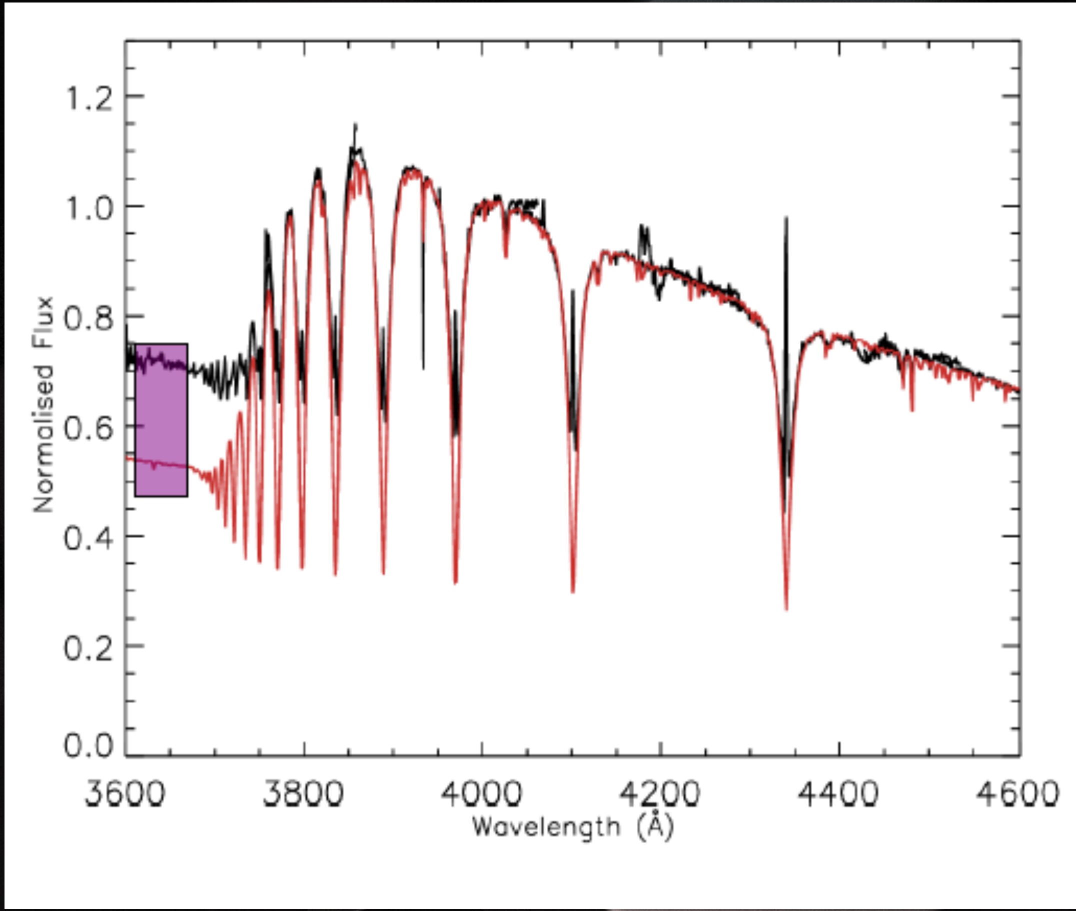
Only "direct" measure: Balmer excess: continuum emission due to accretion shock

- 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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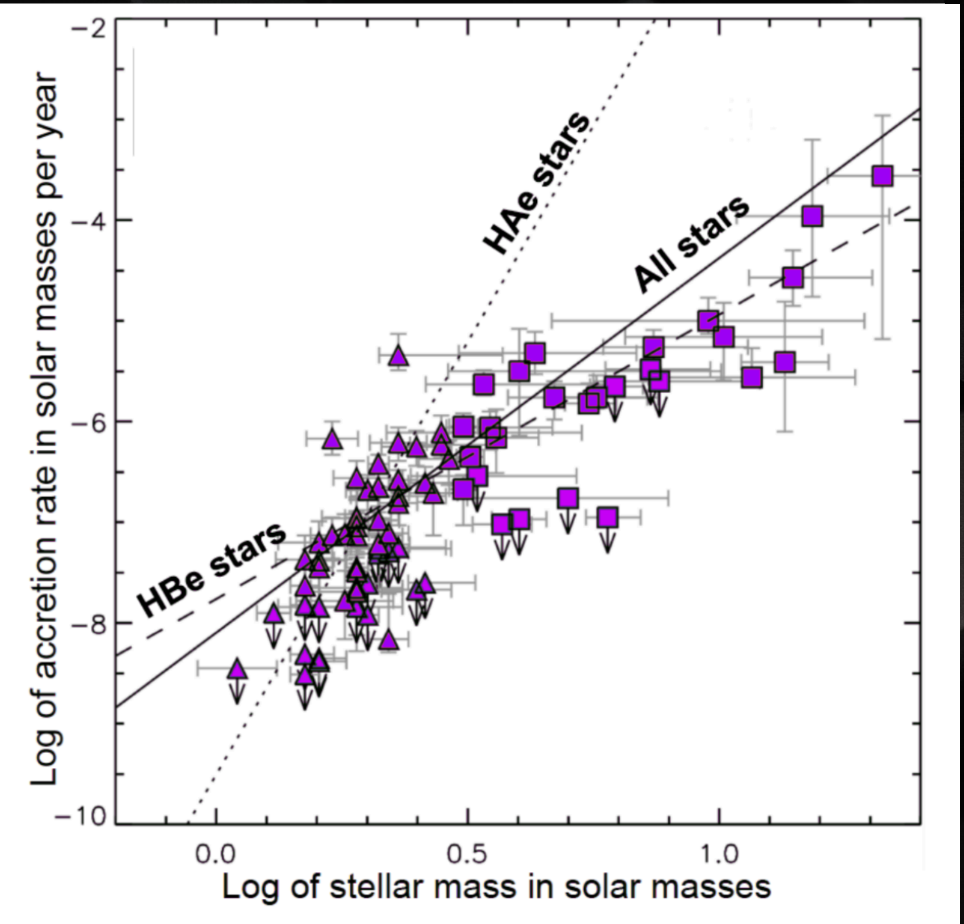


But: different slope Ae and Be objects

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.

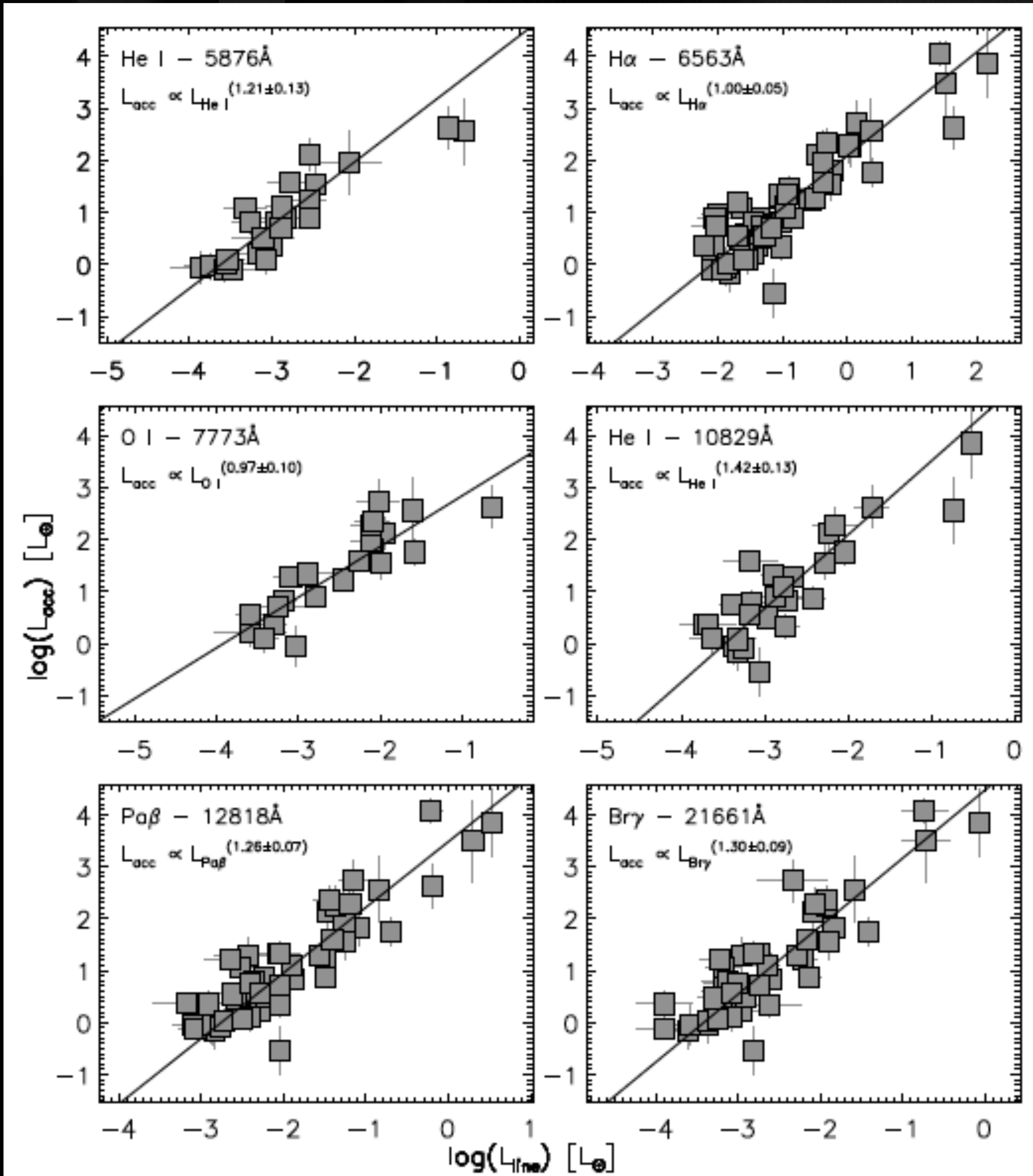
Can be used as accretion diagnostic

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



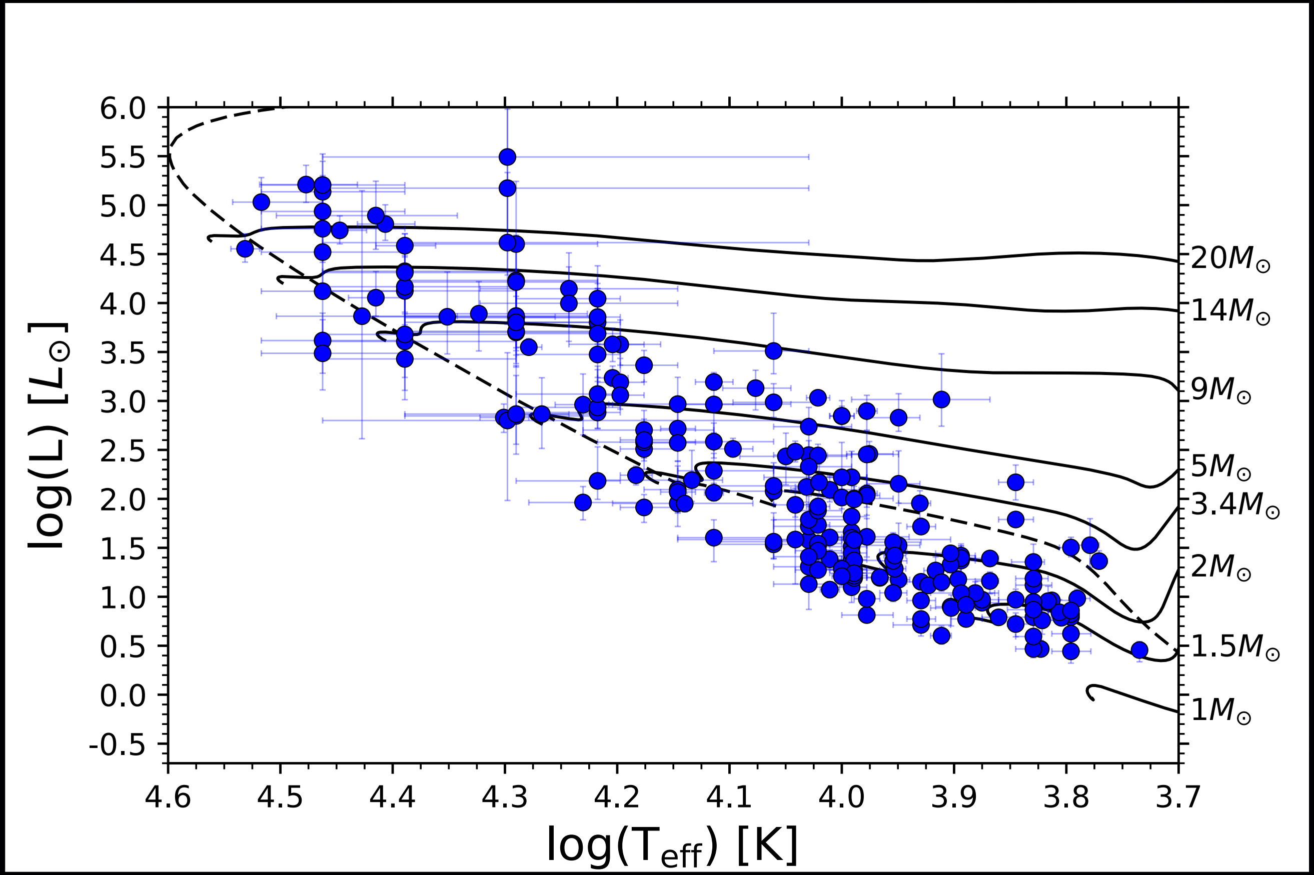
The HR diagram – GAIA DR2 results

Parallaxes + Total Fluxes → Luminosities

200+ objects could be placed on HR diagram.

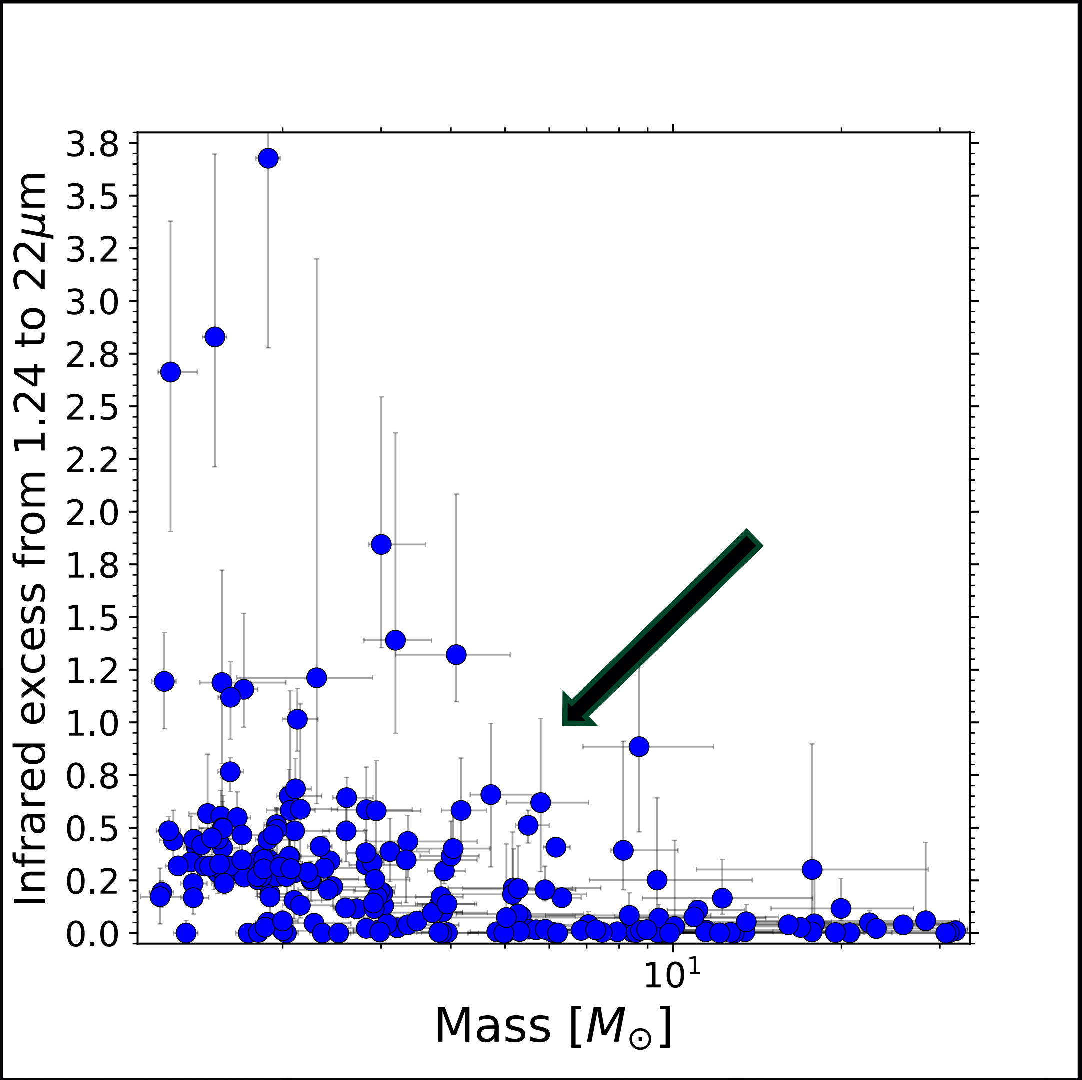
PMS tracks → Masses

& Isochrones → Ages



Vioque+ 2018

Infrared excess vs. mass



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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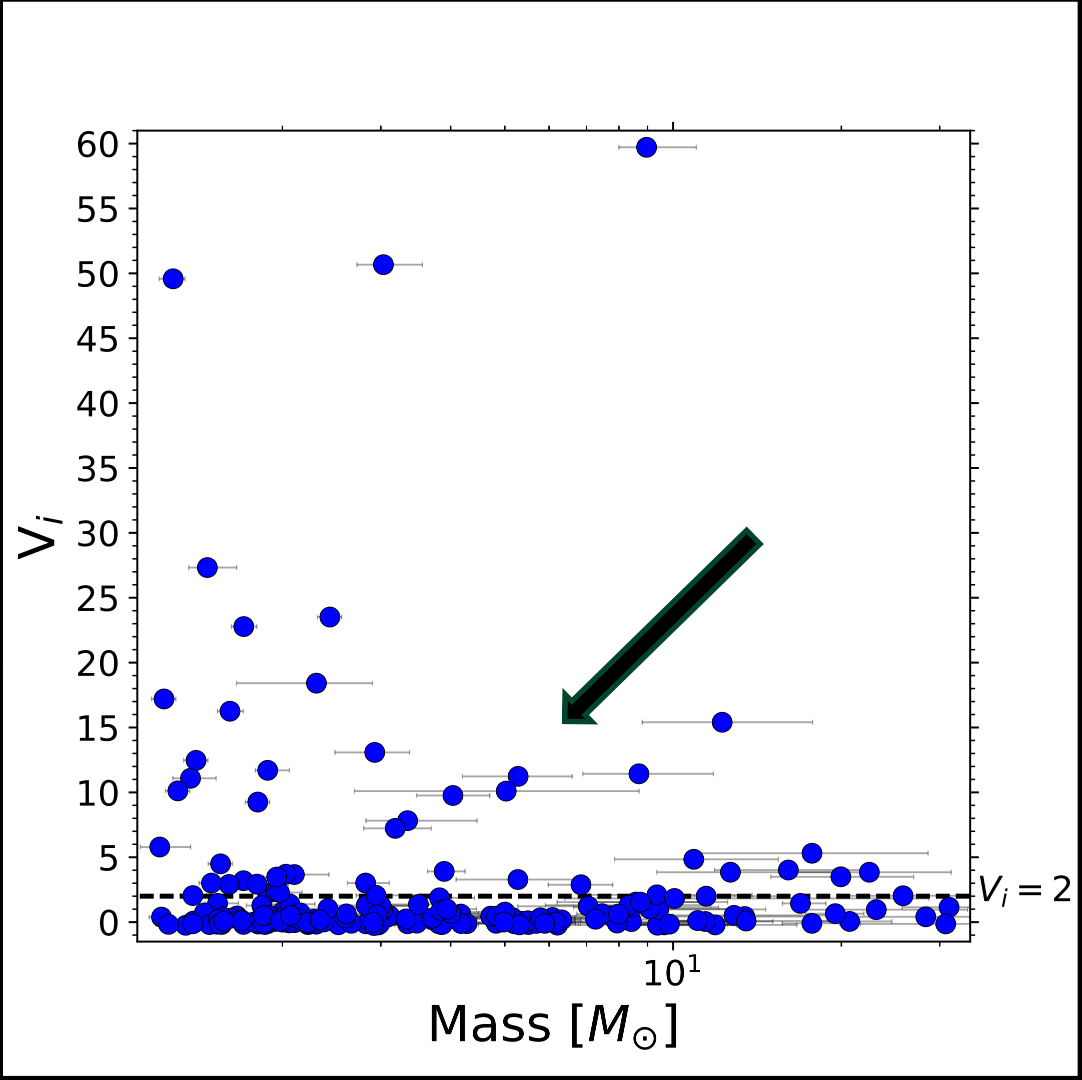

Same break at around 7 solar masses.

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

Variability vs. Infrared excess

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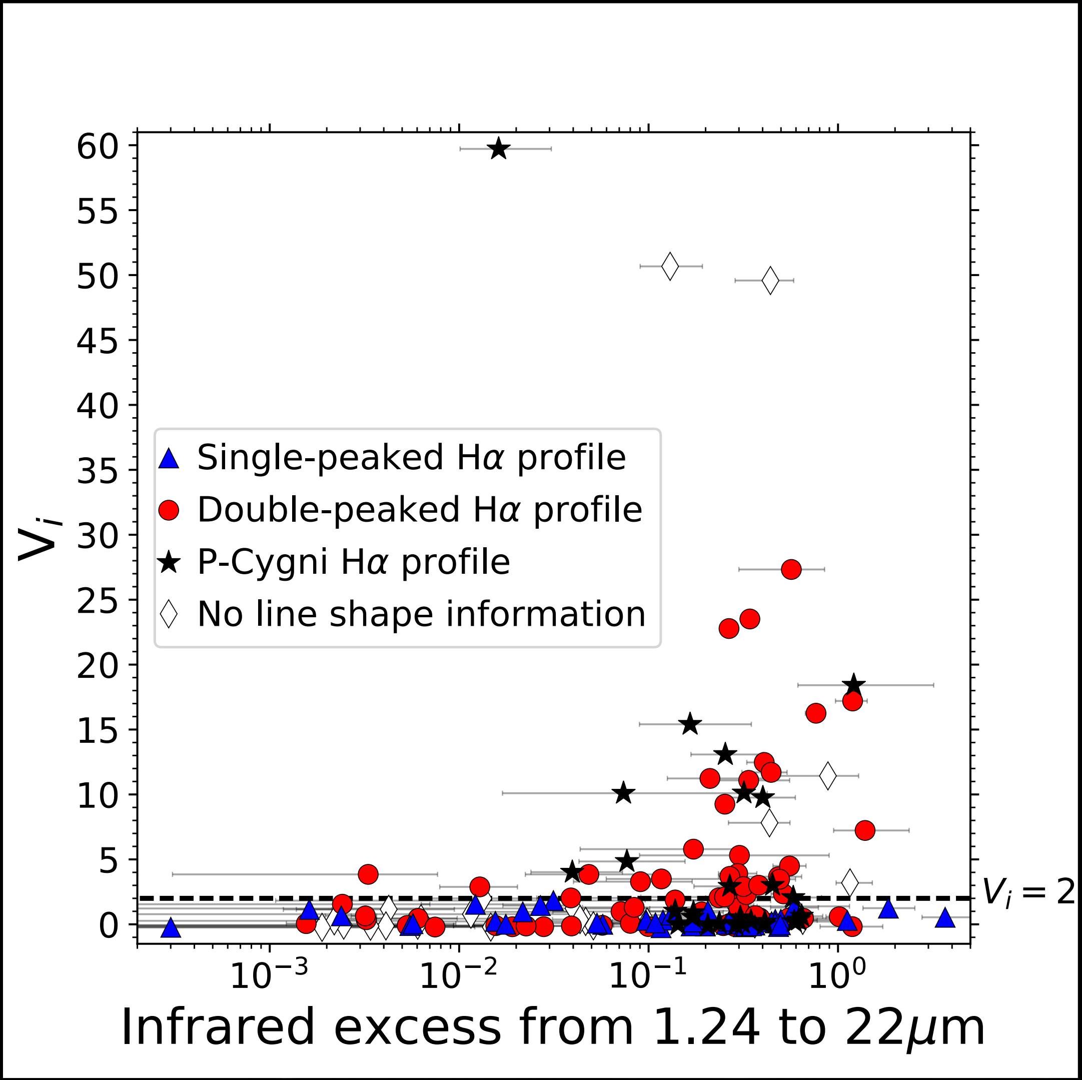

70% of the strongly variable Herbig Ae/Be stars show double-peaked Hα emission. None show a single-peaked line profile.

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

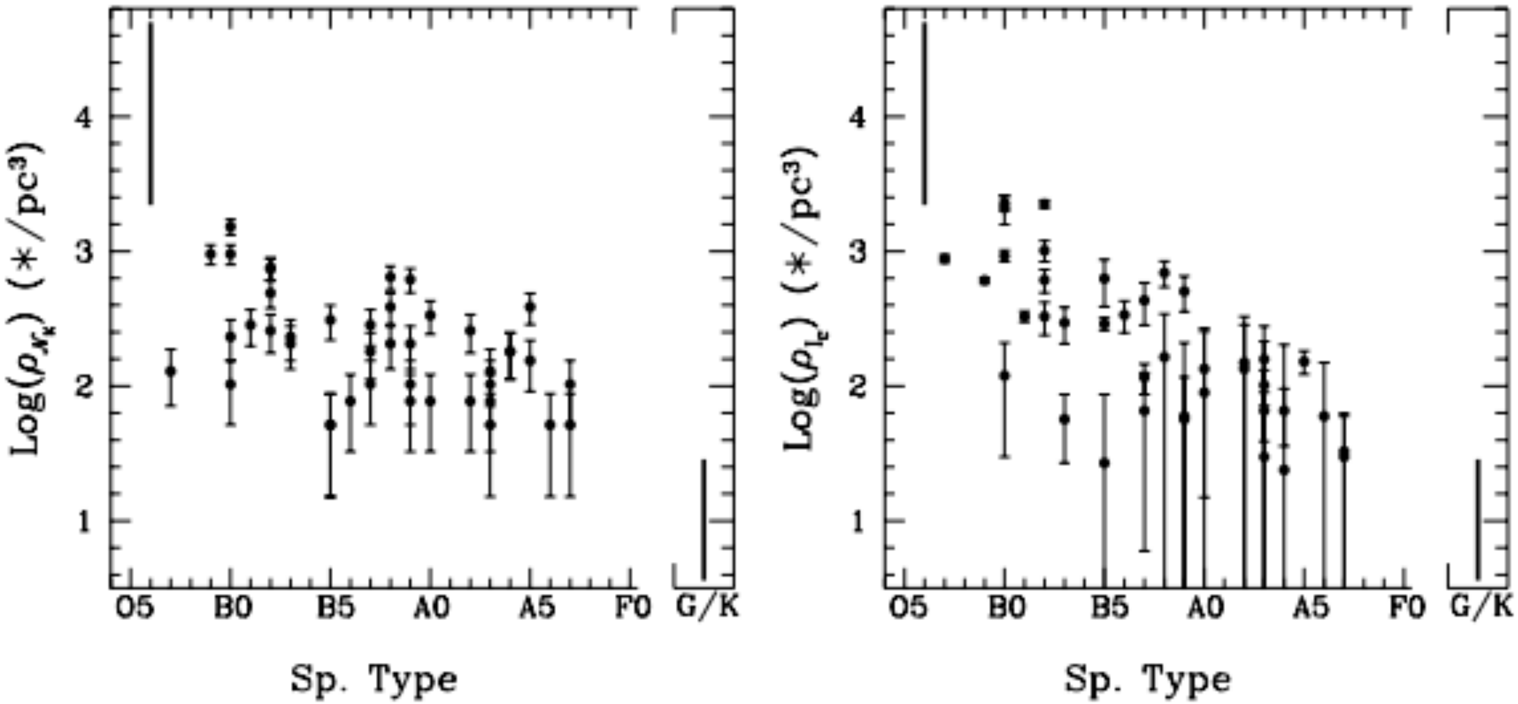

Fig. 7. Stellar volume densities derived from $\mathcal{N}_K$ (*left*) and from I_C (*right*) versus spectral type of the central star. Stars with $I_C < 0$ have been excluded. The heavy vertical line at O6 represents the range of stellar densities found in the Trapezium cluster, whereas that at G/K (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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STARS THAT 'R' YOUNG

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