Disks, accretion and ejection in BD/VLM stars

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Arcetri & DIAS

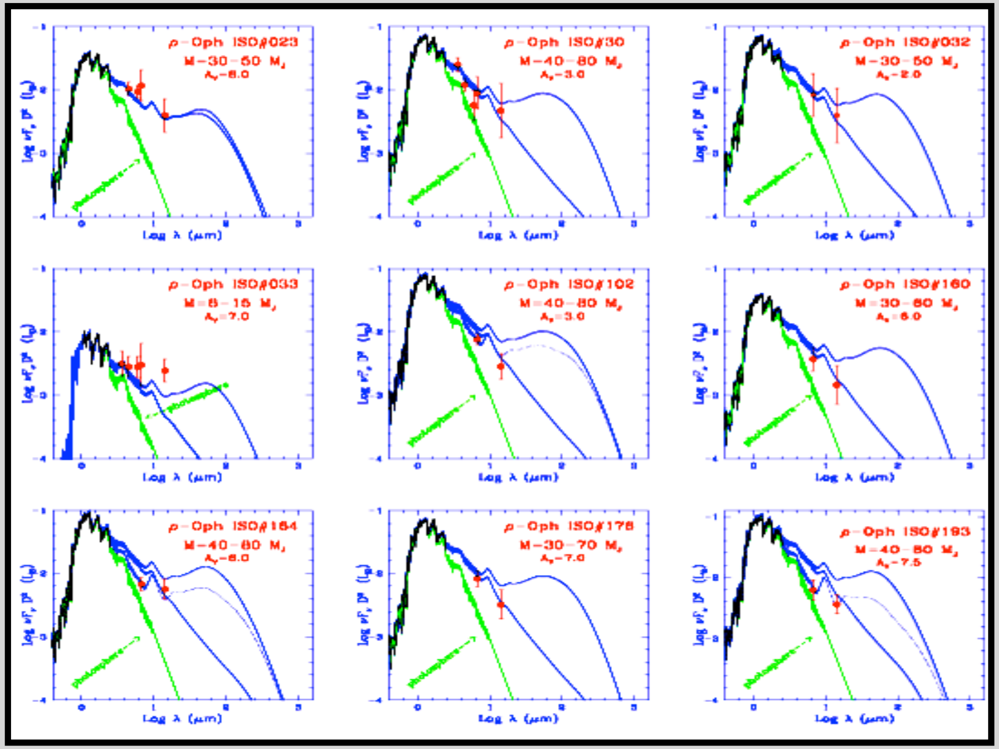
BDs/VLMS have disks, accrete and eject matter

Why is it interesting?

- ✓ Relevance for formation mechanism: same as stars?
- ✓ And for disk physics (large leverage)
- ✓ Can BDs form planets ?

First detections of <u>dusty</u> disks from near&mid-IR excess

- ✓ Ground-based & ISO



Comeron et al. 1999, 2000
Natta & Testi 2001
Natta et al. 2002

Spitzer

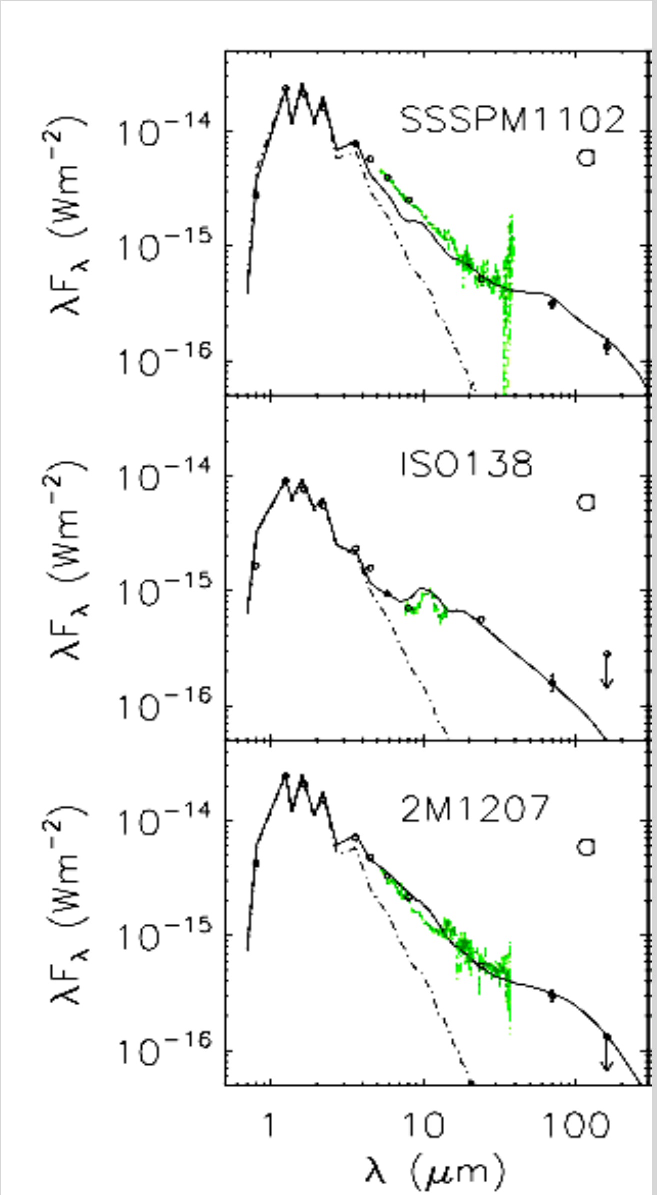
- ✓ Large samples (statistics)
- ✓ SEDs up to mid-IR
  - Complete to ~20-30 M_J (nearby star-forming regions)
  - Fraction of disks similar to TTS

No disk masses
No disk radii (R>10 AU)

Herschel

- ✓ ~ 50 BDs:
  - 80% detected at 70 mic
  - 30 % detected at 160 mic
- ✓ Masses: very low
- ✓ No need for settling

P. Harvey: GTO program (Poster #21)



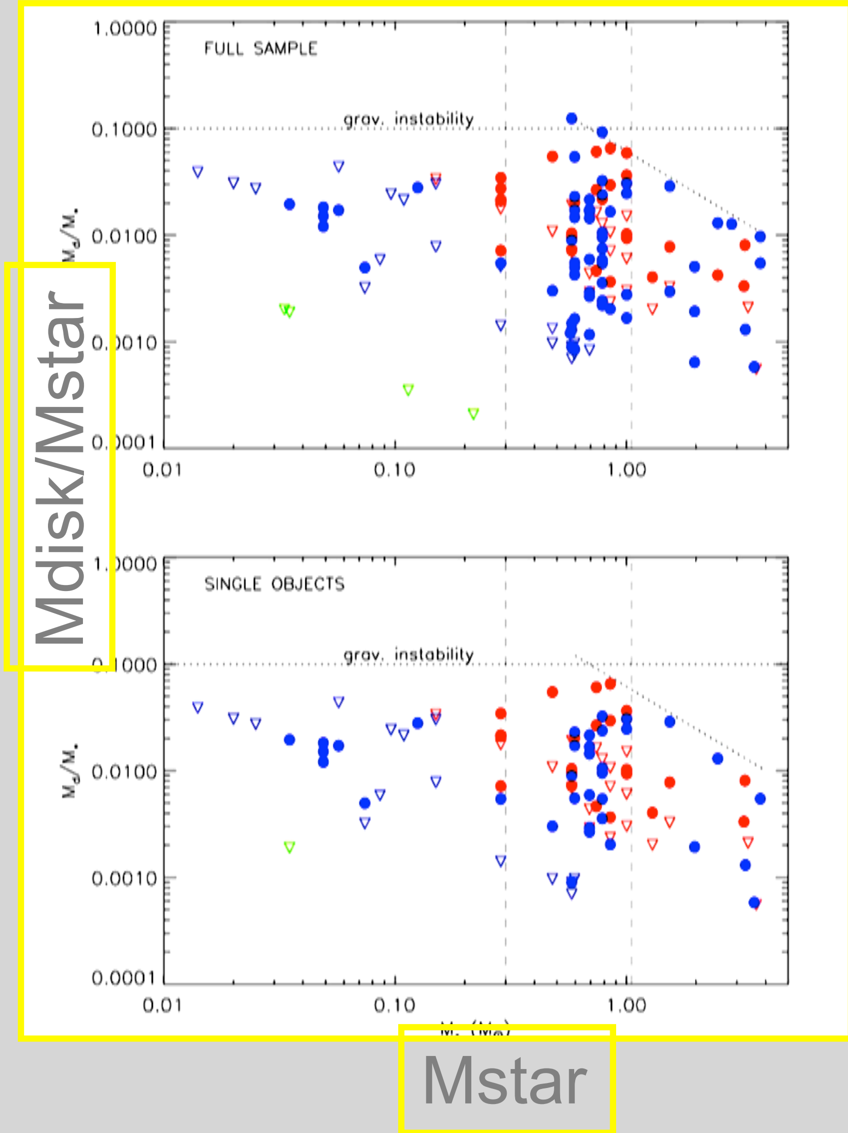
TWA
M8.5
Mdisk~10^{-5} $M_\odot$

Cha I
M6.5
Mdisk~few10^{-6} $M_\odot$

TWA
M8
Mdisk~10^{-5} $M_\odot$

Sub-mm (Scuba-2)

- ✓ 7 new objects (3 in Taurus and 4 in TWA) with SCUBA-2 (850mic)
- ✓ Detections: 2 in Taurus, 0 in TWA
- ✓ Disk masses of BDs: $M_d/M_* \ll 0.1$
- ✓ Mdisk< 1 M_J



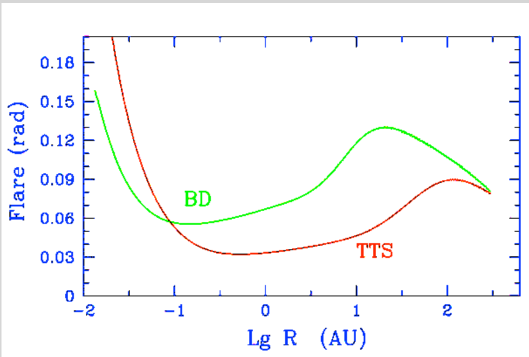
Mohanty et al. 2011 (talk)

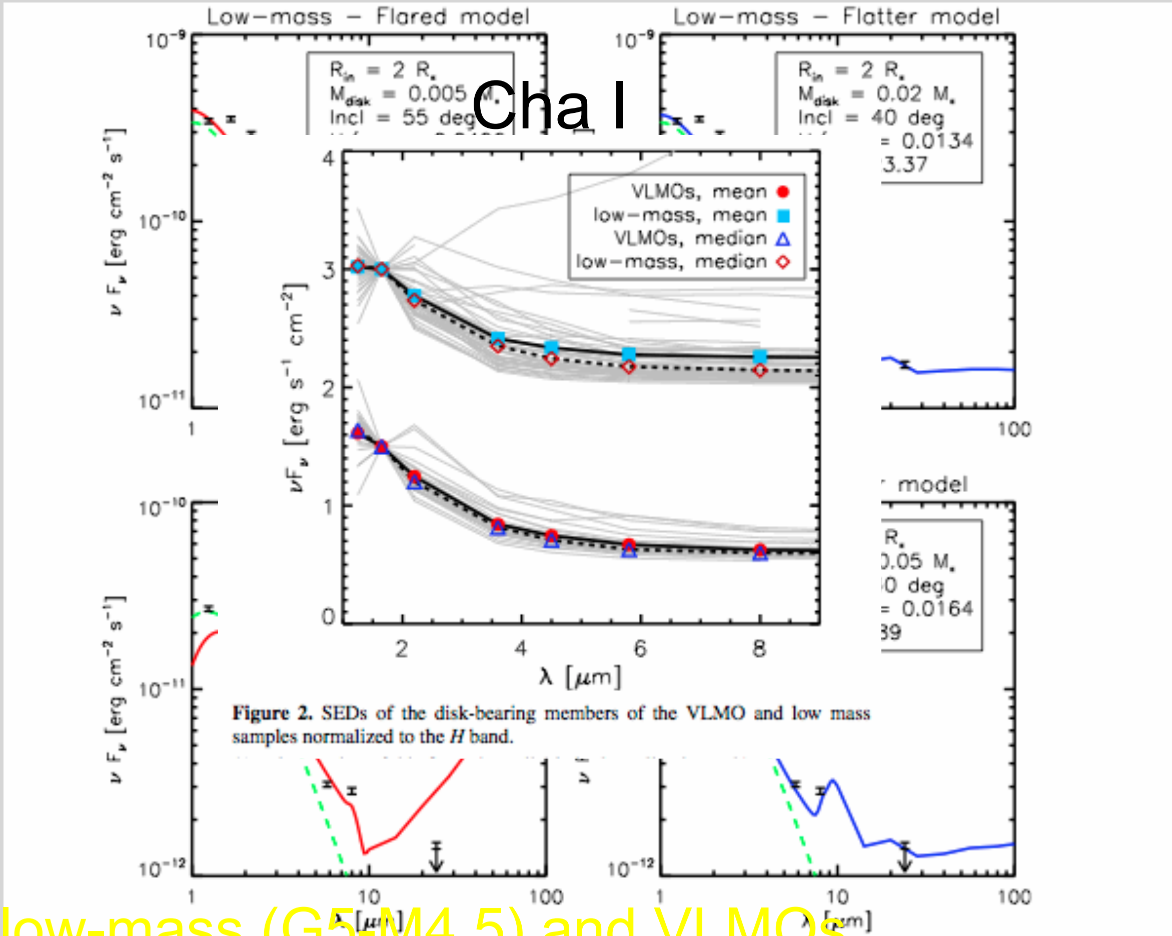
Low disk masses

- ✓ No Jupiter-mass planets
- ✓ Earths?
- ✓ Planetesimals?

Grain evolution

- ✓ From SEDs: evidence of sedimentation, faster than in TTS

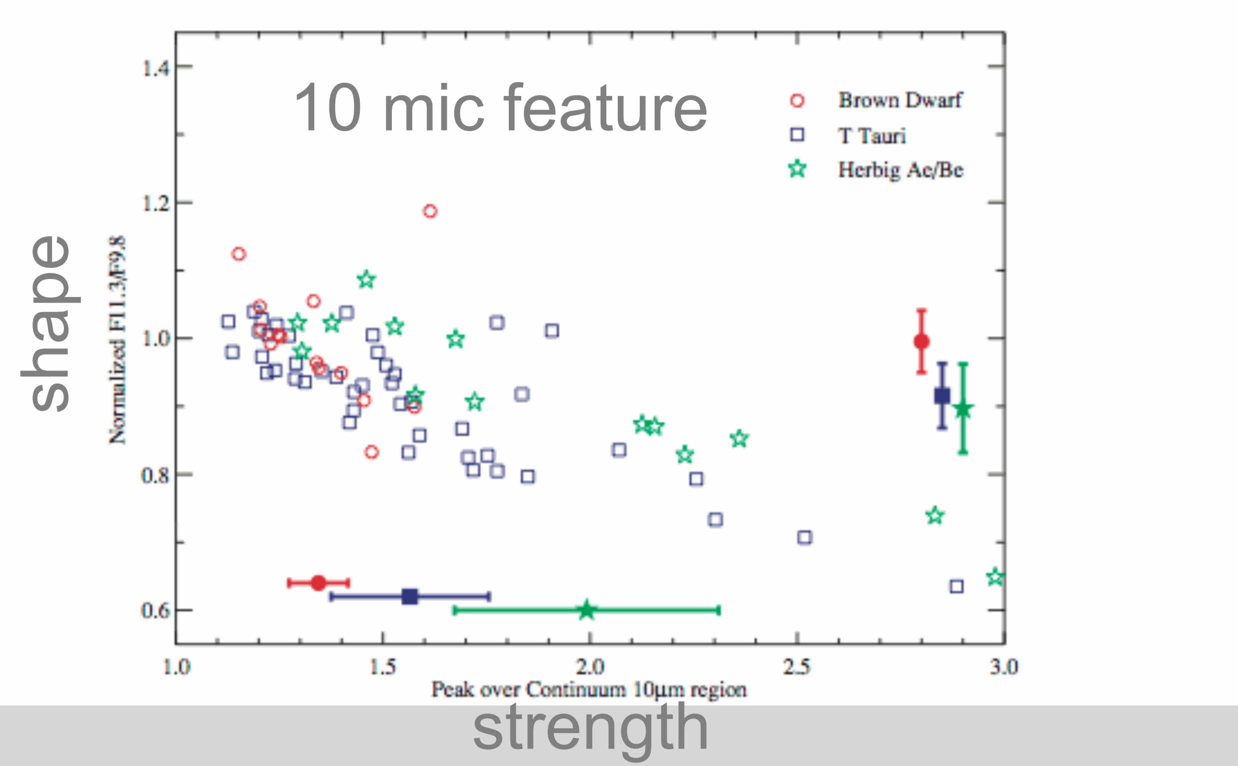




Szucs et al. 2010: both low-mass (G5-M4.5) and VLMOs (M4.75-M9.5) need grain sedimentation, VLMOs more so than low-mass stars.

Silicates

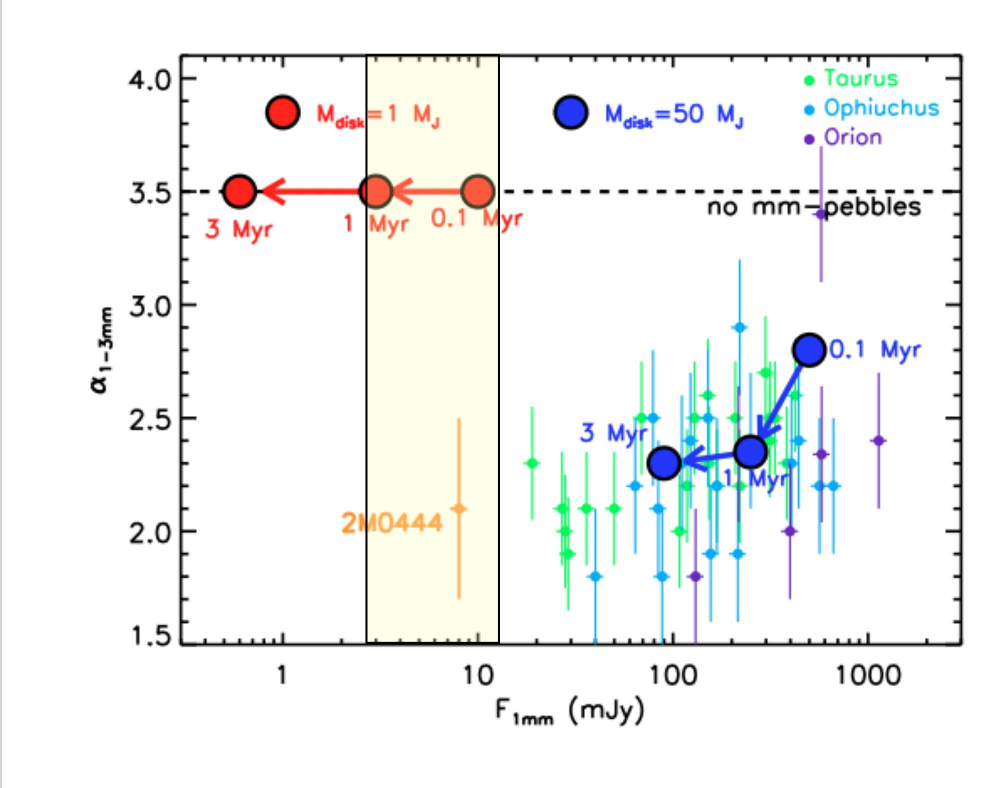
- ✓ 10 mic silicates more evolved than in TTS



Pascucci et al. 2009, see also Poster #37 by Oliveira

Pebbles in BD disks?

- ✓ Evidence of mm-size grains in the outer disks of TTS: impossible!
- ✓ Grain growth is controlled by gas-dust coupling (gas density and motions)
  - Coalescence
  - Fragmentation
  - Radial drift
- ✓ Model predictions for low-mass disks in BD: no growth!
- ✓ 2MASS 0444+2512: detected at 450,850,1.3mm, 3.47mm (see Sholz et al. 2006, Bouy et al.2008, Mohanty et al. 2011): shallow (sub)-mm spectrum



4 BDs with ALMA Early Science

Ricci et al., 2010, 2011 etc. (ESO), see poster #43 and talk by Testi
Birnstiel et al. 2010, 2011 etc., Pinilla et al. 2011 (Heidelberg)

- ✓ If BD disks have mm-size grains (as TTS disks), this is an indication that they can form planetesimals & earths
- ✓ We do not understand how

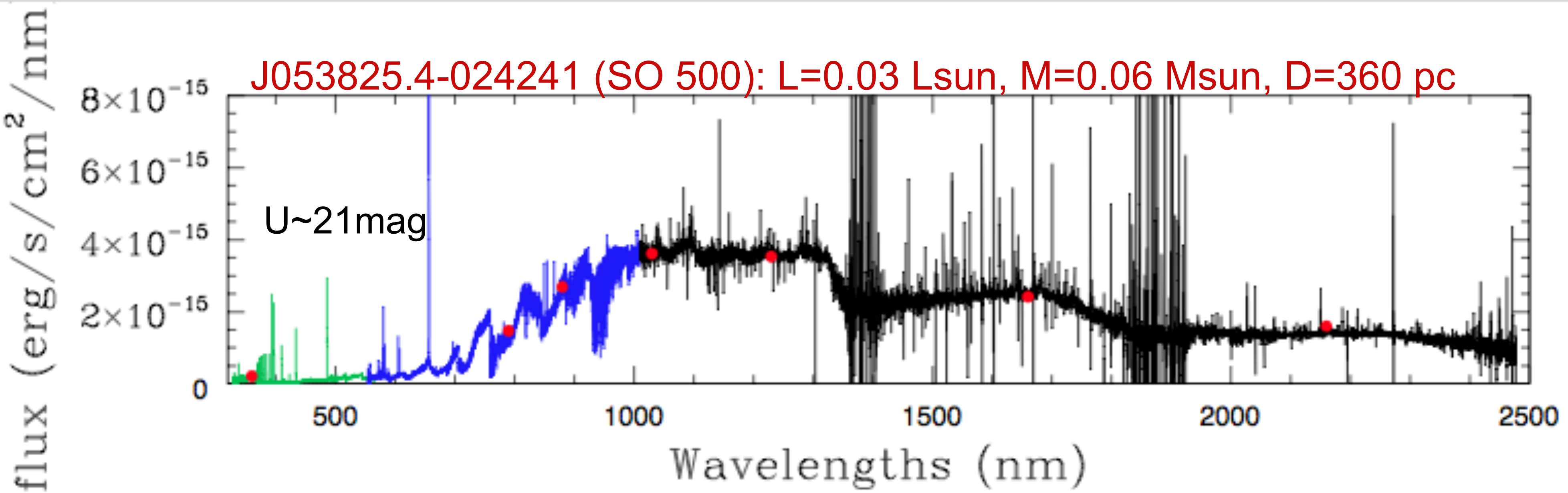
Accretion

- ✓ Many young BDs have evidence of accretion
- ✓ Macc in BDs is lower than in more massive stars: Macc $\propto$Mstar^2
- ✓ Macc decreases on average with time also for BDs
- ✓ The fraction of accreting BDs is lower in older star forming regions
- ✓ There are BDs with (relatively) high accretion rates; some very old ?

Statistics has improved, but most Macc derived from Halpha

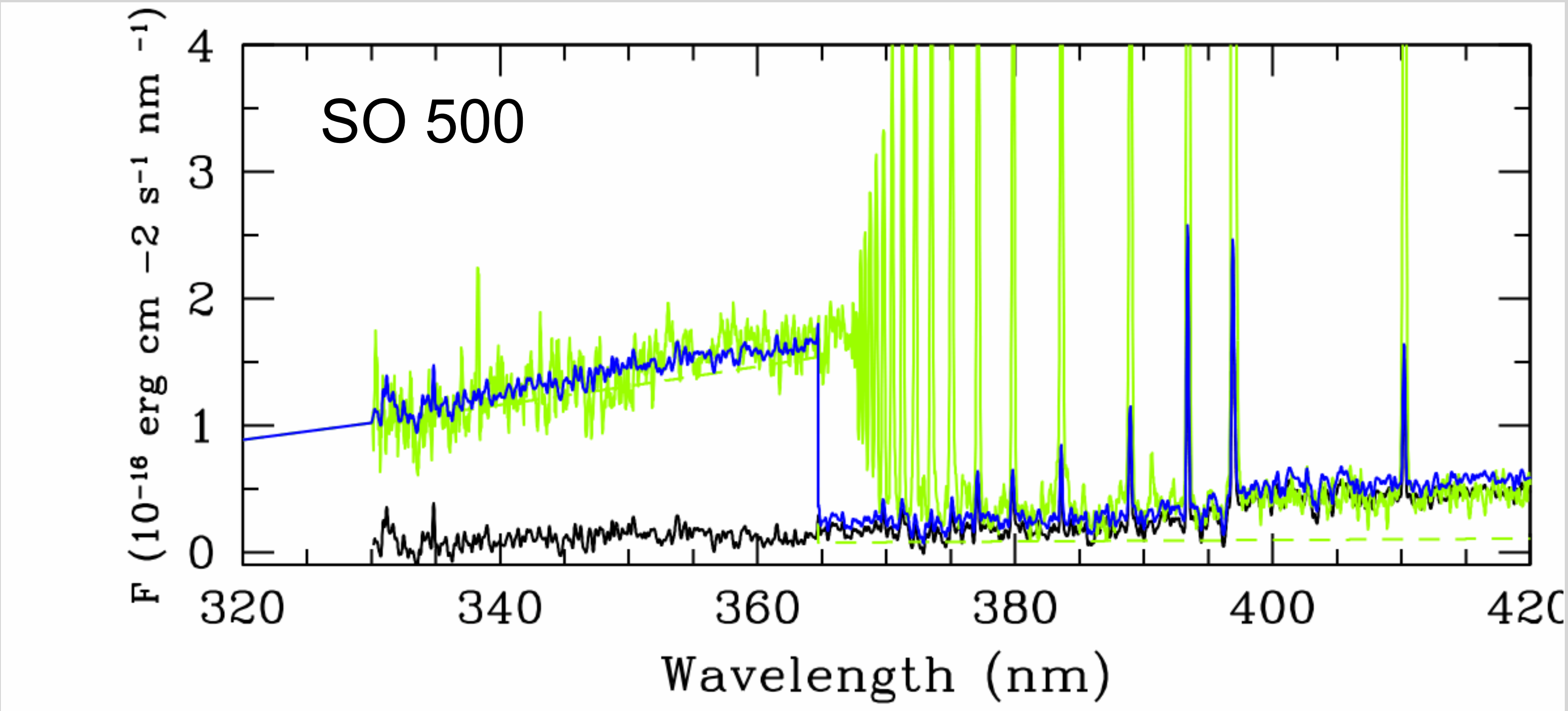
X-Shooter spectra

- Echelle spectrometer on UT2/ESO
- Resolution 4000-9000 (75-33 km/s)
- Good sensitivity
- Simultaneous coverage from 300-2400nm (U-K)



Talk by Alcala', Poster #46 (Stelzer), #44 (Rudolf)

Direct measurement of Lacc



Template (Class III) + BC from slab model

Continuum excess emission

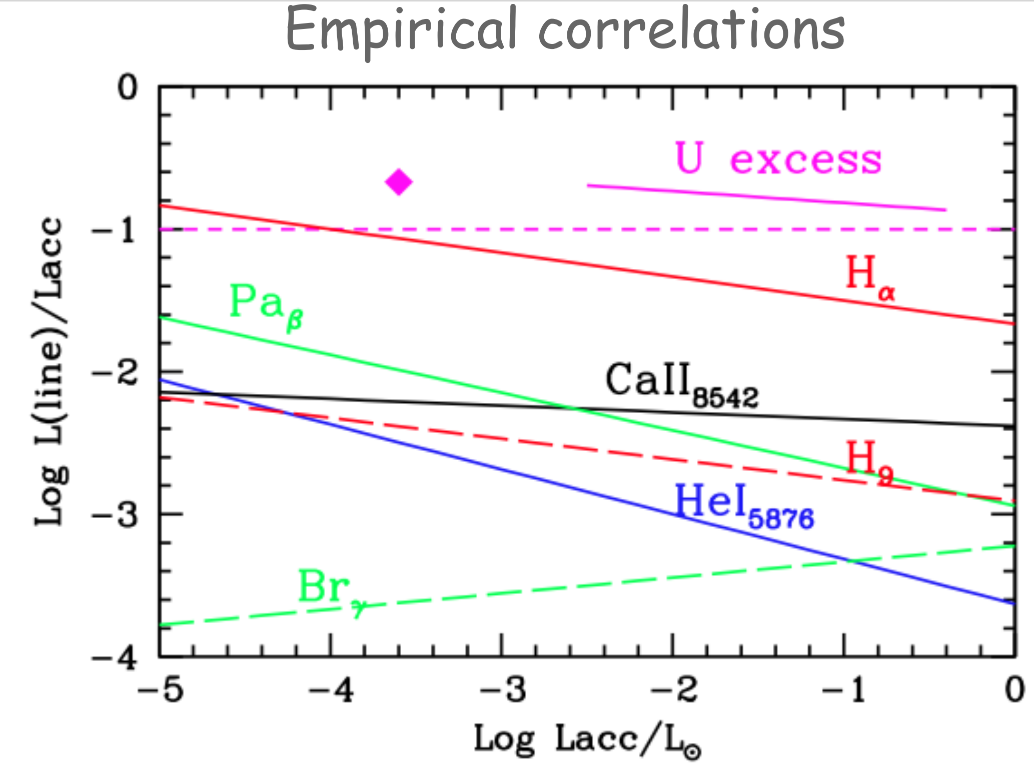
Accretion luminosity

Hydrogen lines

He lines

CaII lines

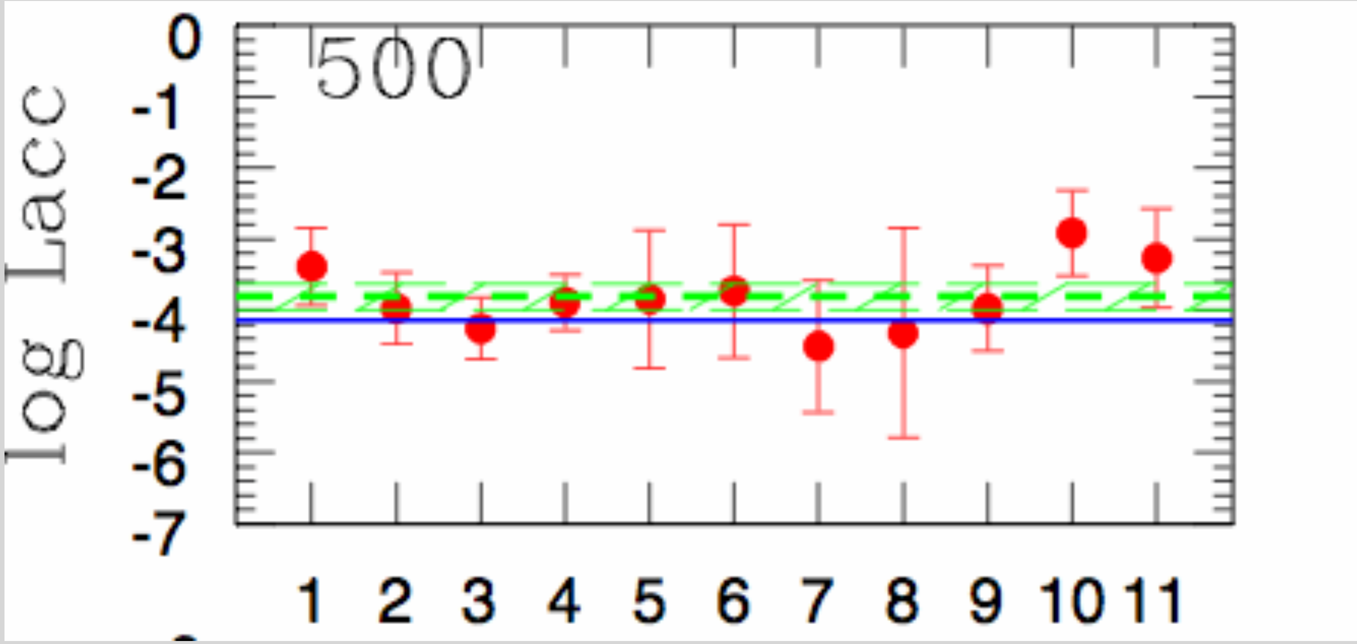
Lacc	0.1	1e-4
Hα	3%	10%
H9	0.2%	0.5%
Paβ	0.2%	1%
Brγ	0.05%	0.02%
$CaII_{8542}$	0.5%	0.6%
HeI_{5876}	0.05%	0.5%
Uexc	15%	20%



Xshooter sample: few tens TTS, ~10 BDs

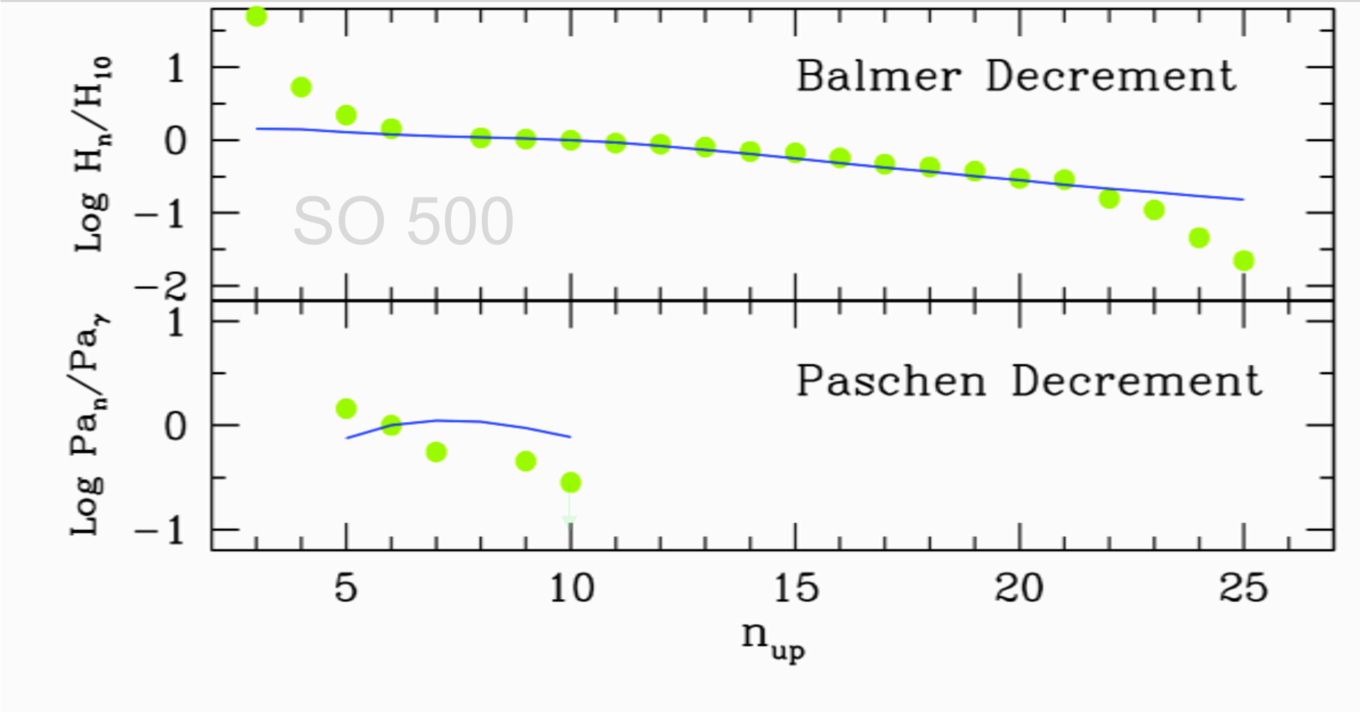
✓ Improved estimates of secondary accretion indicators into BD regimes

1: Halpha
2: Hbeta
3: Hgamma
4: H9
5: Pa_gamma
6: Pa_beta
7: HeI
8: NaI
9: CaII854nm
10: CaII866 nm
11: Uband



Rigliaco et al. 2010 and in prep.

Physical conditions of the emitting gas



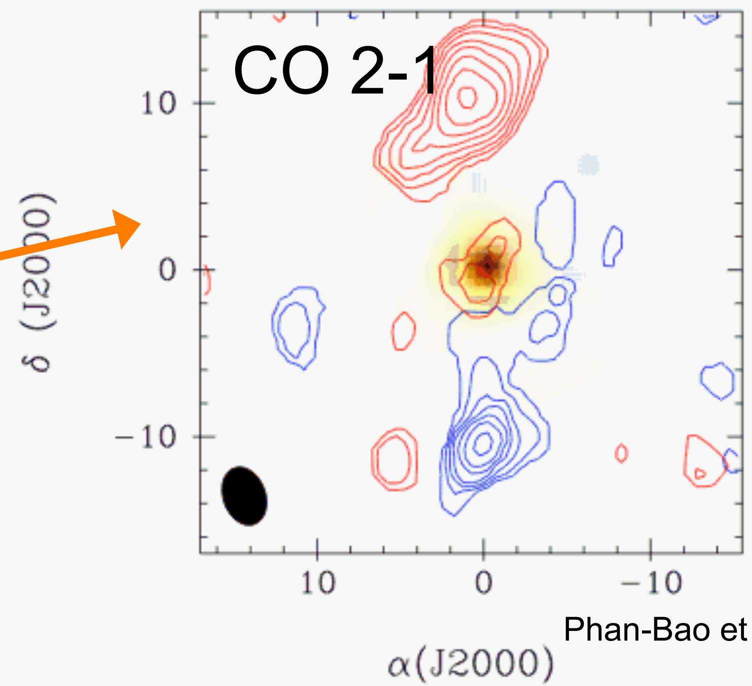
Hydrogen slab model

- ✓Electron density
- ✓Temperature
- ✓Velocity field
- ✓Slab depth
- ✓Level population
- ✓Area

We need predictions of line intensities

BDs have jets : spectroastrometry in forbidden optical lines

Object	Spectral Type	Estimated Mass (M_{jup})	Li
ISO-Cha1 217	M6.2	80[1]	[S 6
2MASS1207-3932	M8	24[2]	[
ρ-Oph 102	M6*	60[3]	[O
o-Oph 32	M8	40[3]	[O
LS-RCrA 1	M6.5	35-72[4]	H



Phan-Bao et al. 2008

FIG. 1.— An overlay of the J-band (1.25 μm) near-infrared Two Micron All Sky Survey (2MASS) image and the integrated intensity in the carbon monoxide (CO $J = 2-1$) line emission from 3.8 to 7.7 km s^{-1} line-of-sight velocities. The blue and red contours represent the blue-shifted (integrated over 3.8 and 5.9 km s^{-1}) and red-shifted (integrated over 5.9 and 7.7 km s^{-1}) emissions, respectively. The contours are 3,6,9,...times the rms of 0.15 Jy $beam^{-1}$ km s^{-1}. The brown dwarf is visible in the J-band image. The position angle of the outflow is about 3°. The peaks of the blue- and red-shifted components are symmetric to the center of the brown dwarf with an offset of 10″. The synthesized beam is shown in the bottom left corner.

Mwind ~ Macc

Poster #51 (Whelan)

Very similar to TTS jets

Mass Accretion and Mass Loss

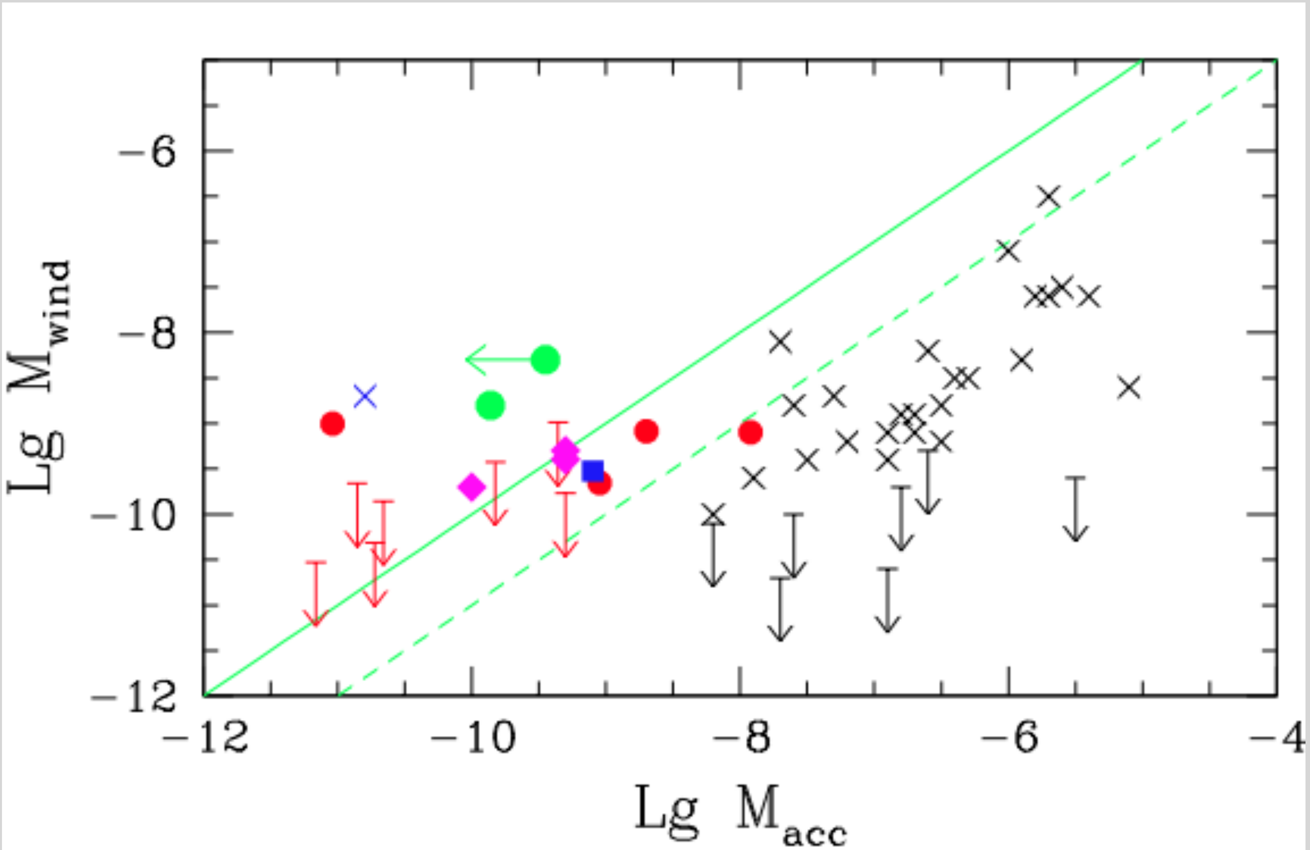
×Hartigan et al. 1995 (TTS in Taurus)

●Herczeg & Hillenbrand 2008 (0.035-0.17 Msun)

◆Whelan et al. (0.035-0.08 Msun)

×■Bacciotti et al. 2011 (0.5, 0.13 Msun)

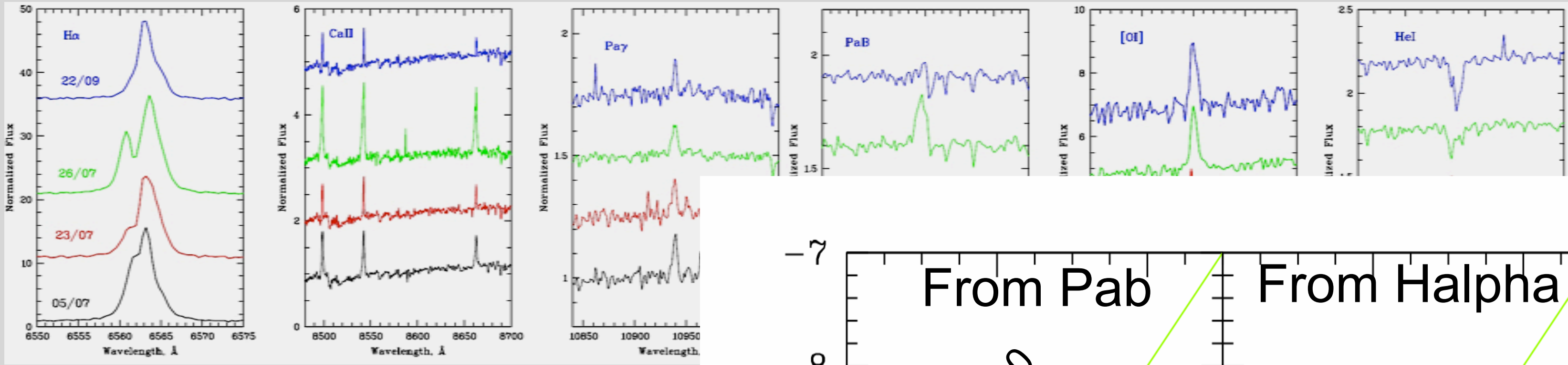
●Rigliaco et al. in prep (0.16,0.2Msun)

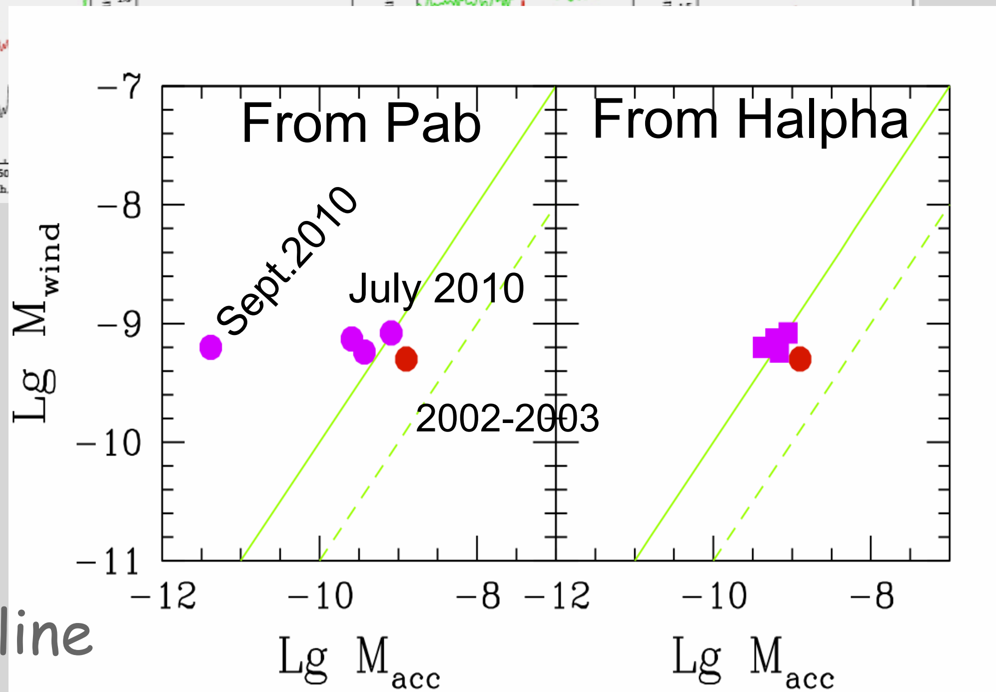


There are monsters, more at low Macc (?)

X-Shooter provides simultaneously accretion and outflow measurements

ρ-Oph102: ~60 M_J





Testi, Costigan, et al., in prep

- ✓Stable in time
- ✓Strong wind
- ✓Dangerous to rely on a single line

Summary

- ✓ Formation process(es)
  - BDs have disks, accrete and eject matter
  - So far, BDs behave like TTS
  - There are trends with the mass of the central object, but no discontinuities
  - It is possible that we have not reached the "critical" mass
- ✓ Disk physics and evolution:
  - BD disks have very low mass (no Jupiters)
  - If BD disks have mm-size grains, this will set strong constraints on grain evolution: maybe easier than we think to form planetesimals in all disks
  - Mass ejections in BDs: several objects with low Macc have strong mass-loss