Brown dwarf disks

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Ricci et al. 2012, ApJ 761, L20

Ricci et al. 2014, ApJ 791, 20

Testi et al. 2016, A&A in press, arXiv: 1606.06448

What are Brown Dwarfs?

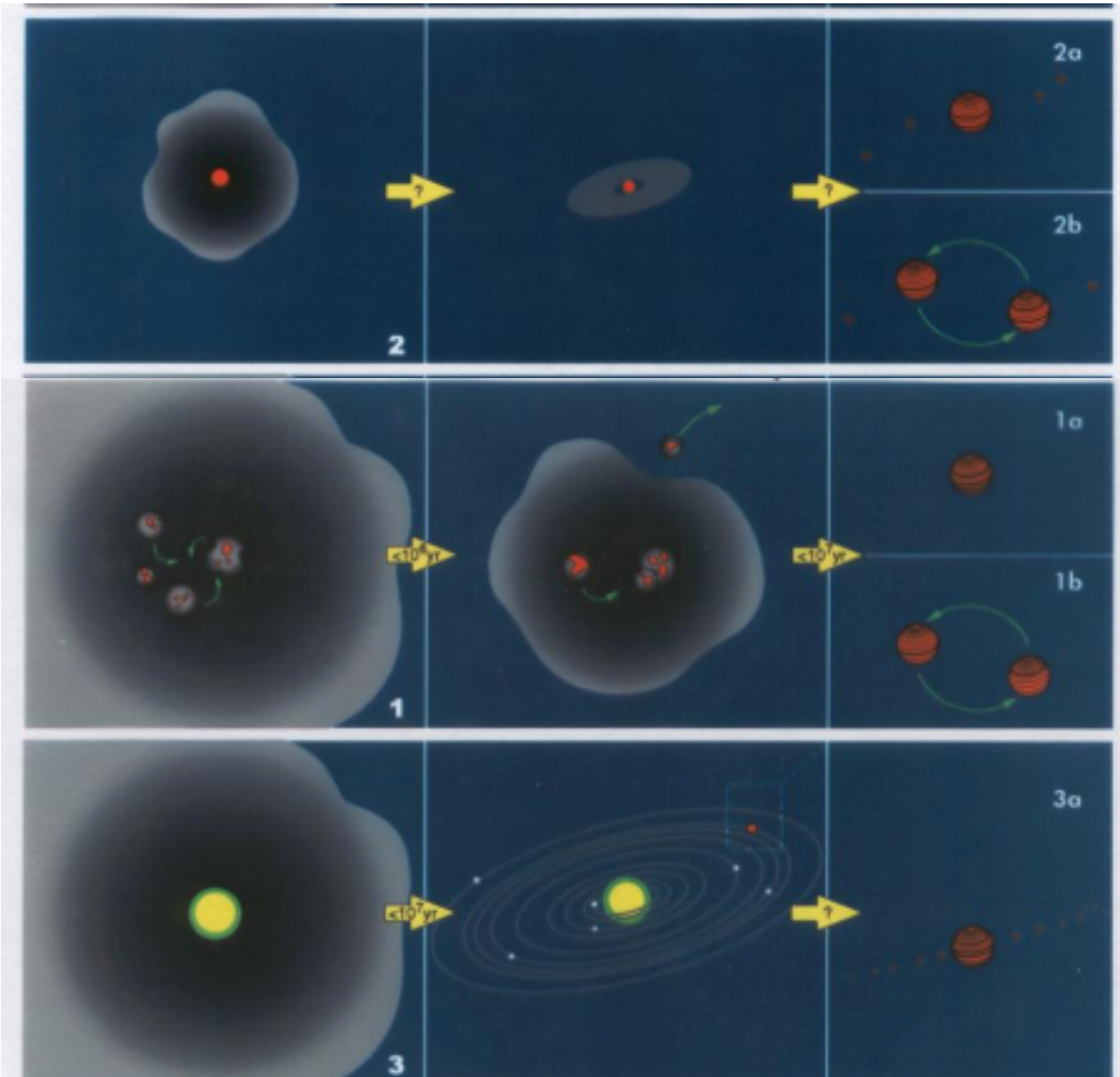
- Failed stars
  - they will never burn hydrogen but will keep contracting and cooling down

Mass <0.08 Msun ~80 $M_{Jupiter}$

- Field BDs are very cold and faint
- Young BDs are warmer and much more luminous

- The mass threshold for hydrogen burning is not critical when studying very young stars and their formation
  - “BD” is every object with mass ≤0.1Msun

Formation of BDs



"Standard" core collapse

[Shu, Adams and Lizano, ARAA 1987]
[Padoan & Nordlund 2004]

Ejection of embrios

[Reipurth and Clarke 2001]

Disk Fragmentation

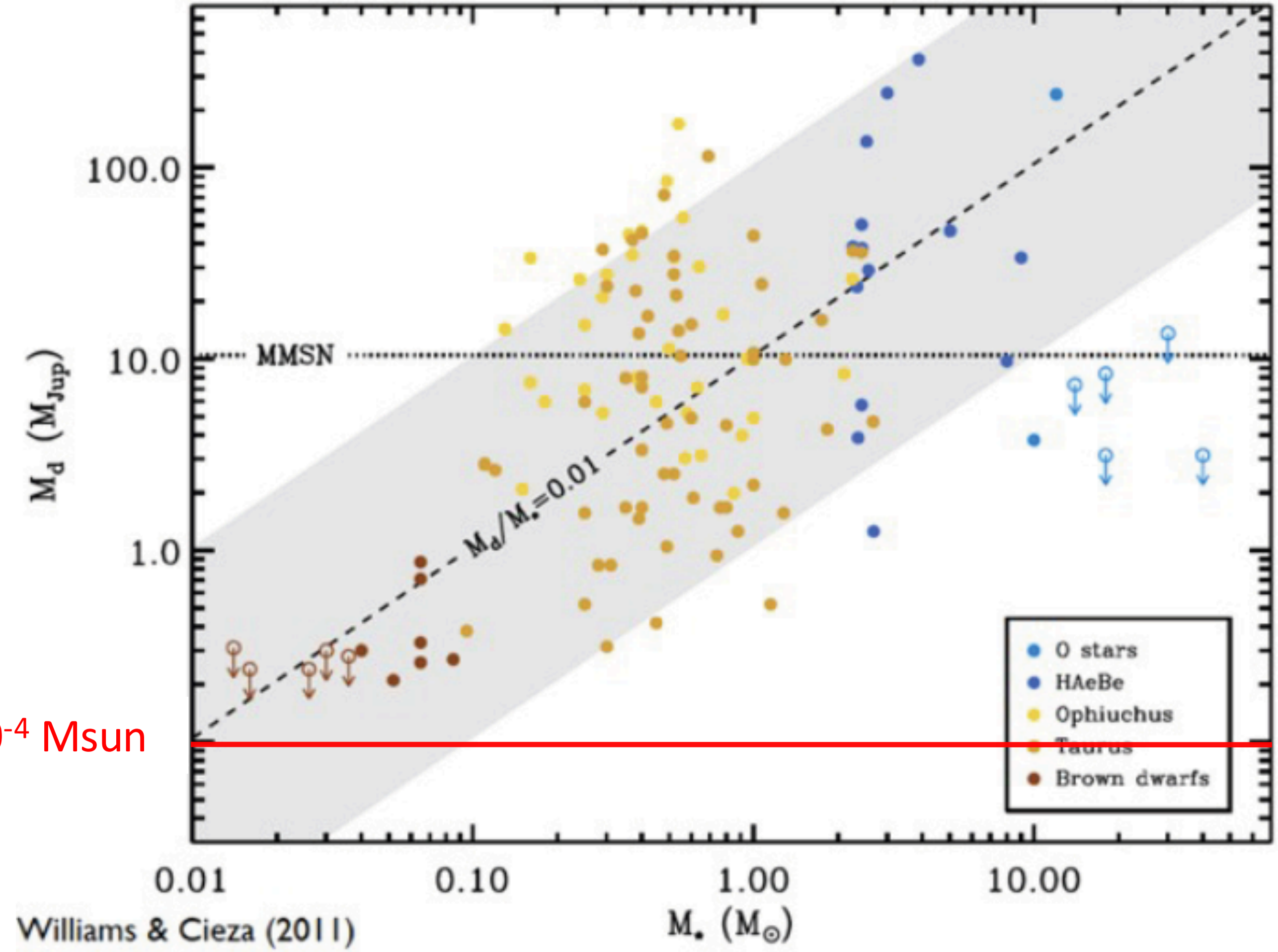
[Boss 1998;
Stamatellos & Withworth 2009]

Why are BDs interesting?

- BDs provide an extreme regime for star and planet formation
  - Relevance for star formation mechanism
  - And for disk physics (large leverage)
  - Can BD disks form planets ?

- Interesting physics (atmosphere, dust condensation, weather, etc.)

Disk masses (dust) from sub-mm fluxes



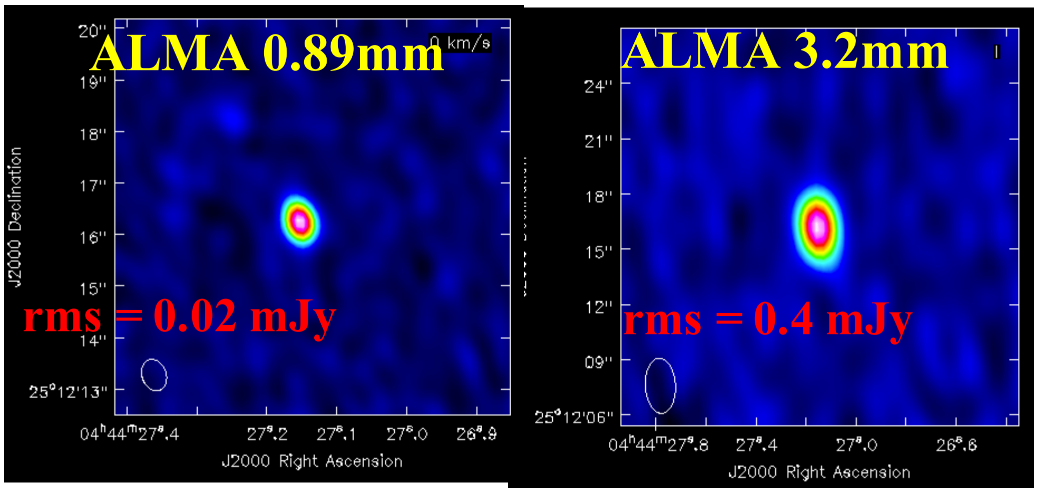
10^{-4} Msun

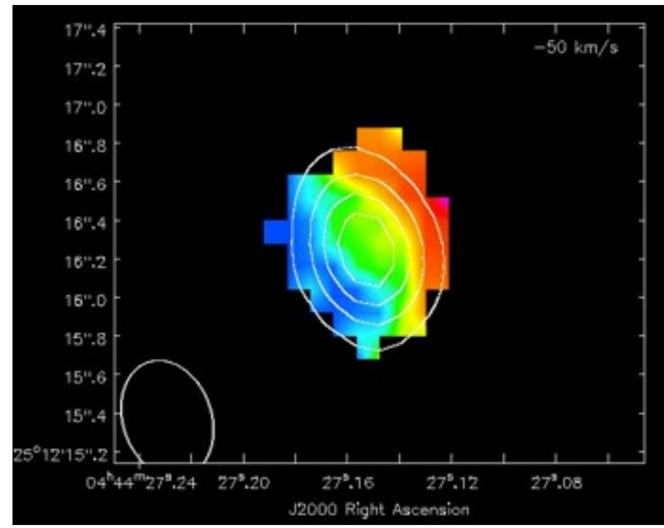
Scholz et al. 2006; Mohanty et al. 2012; Andrews et al. 2012

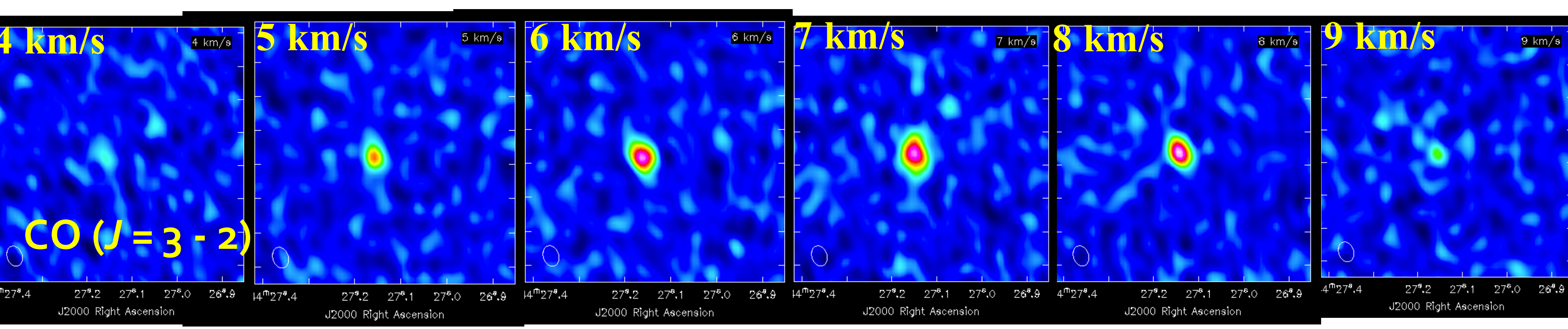
BD 2M0444

$M_\star$ ~0.05 $M_\odot$
M_{disk}~2x10-3 $M_\odot$
Rout ~150AU

Alma

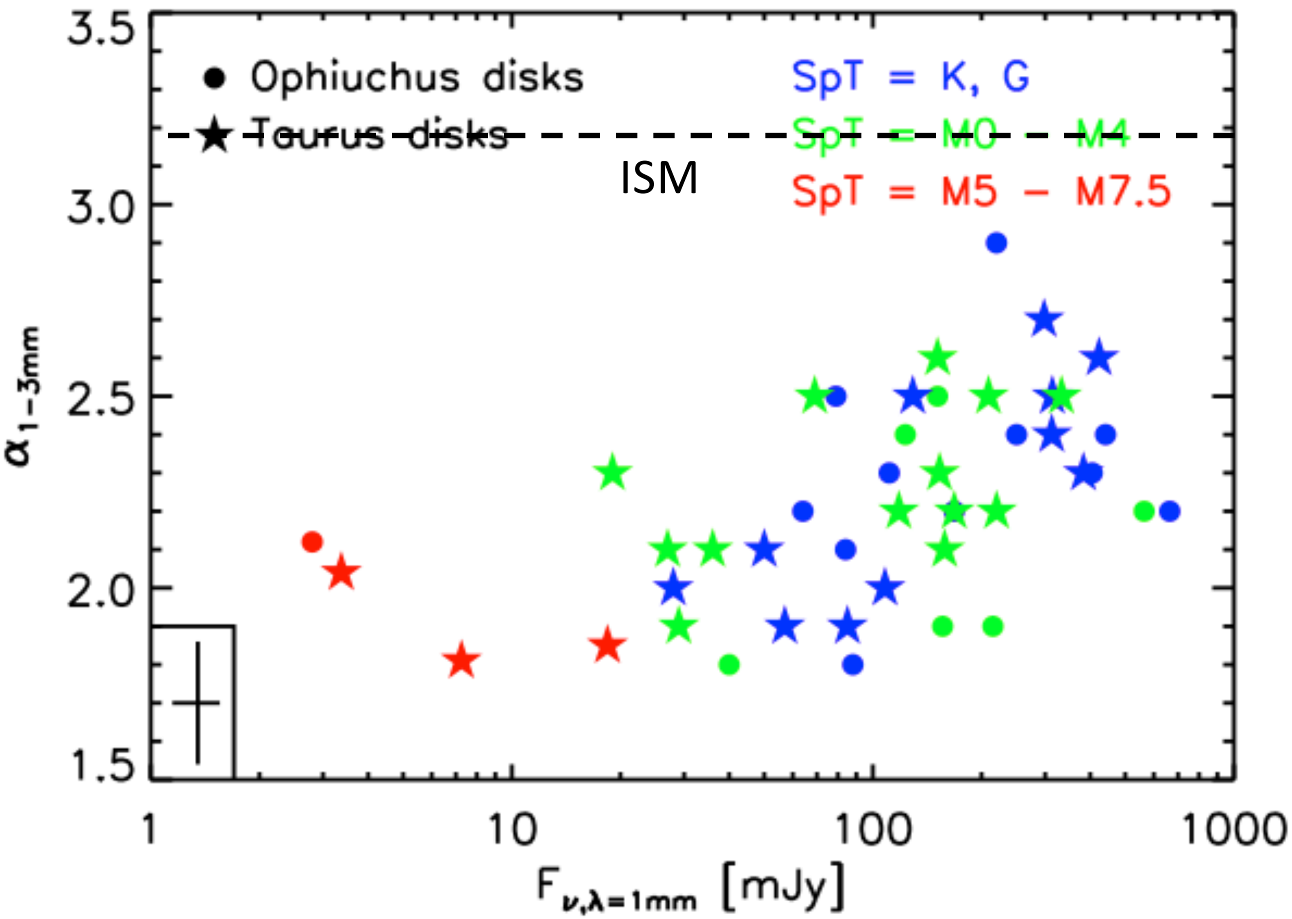






Ricci et al. 2014

Disks in Taurus and Ophiuchus

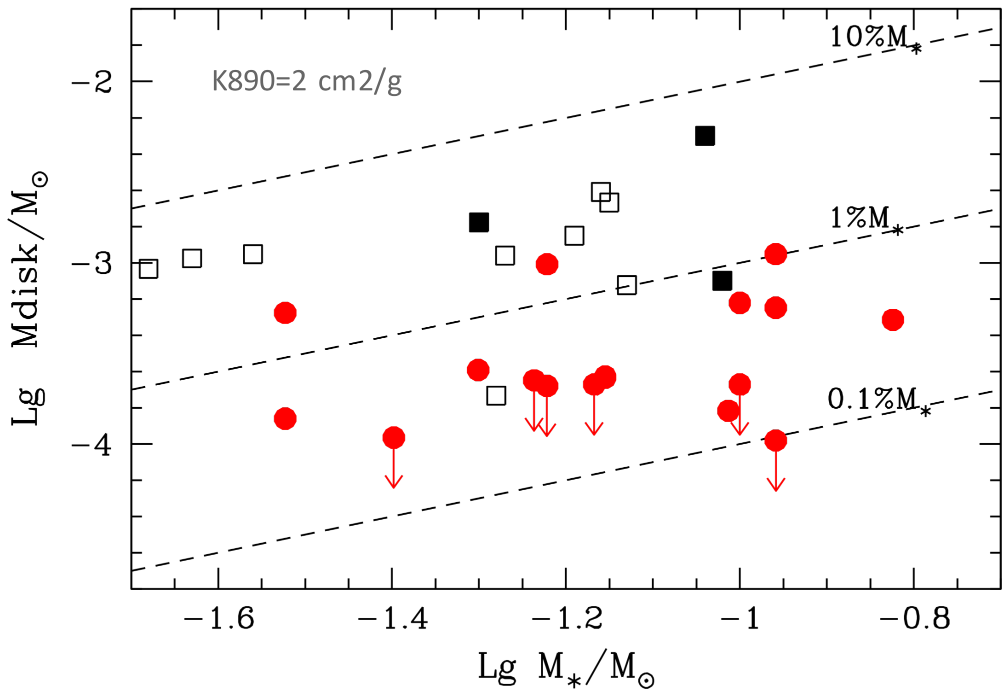


- ✓ All TTS and BDs have very small β (large grains) in their outer disk
- ✓ These grains contain a very large solid mass

Ricci et al. 2010ab, 2011, 2013, 2014

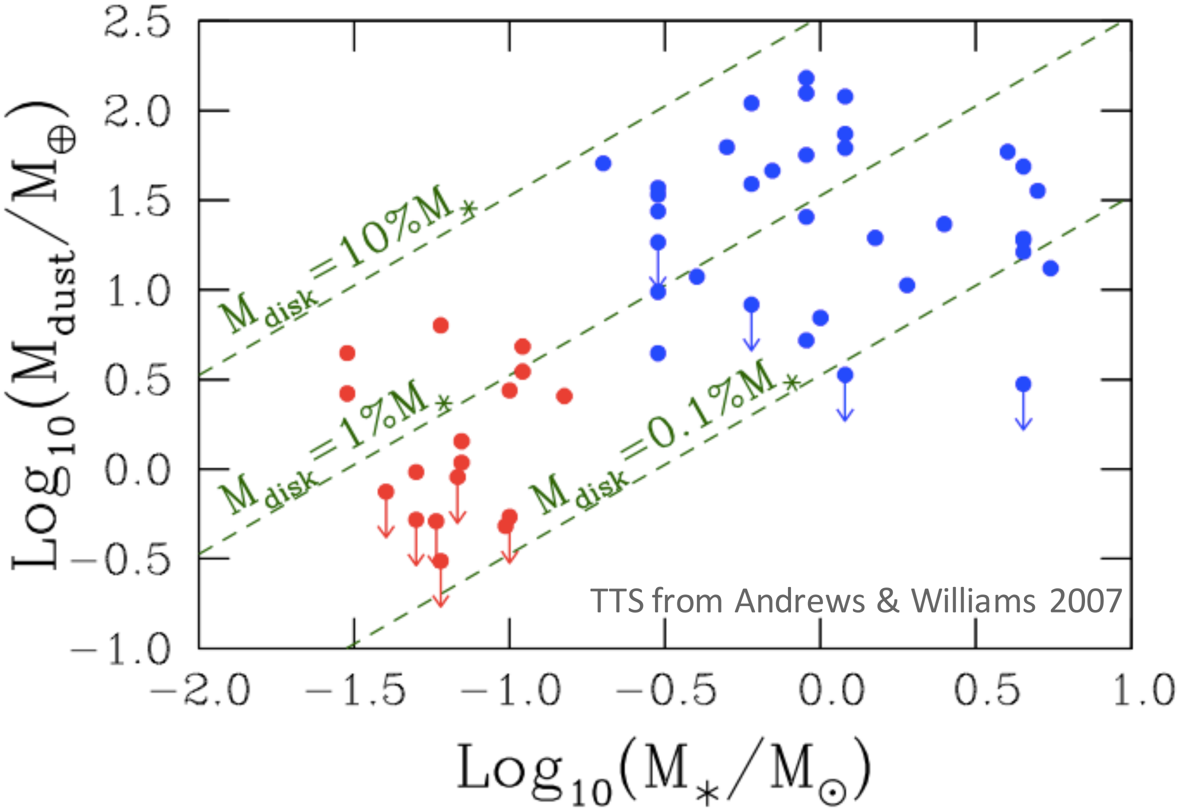
Alma BDs

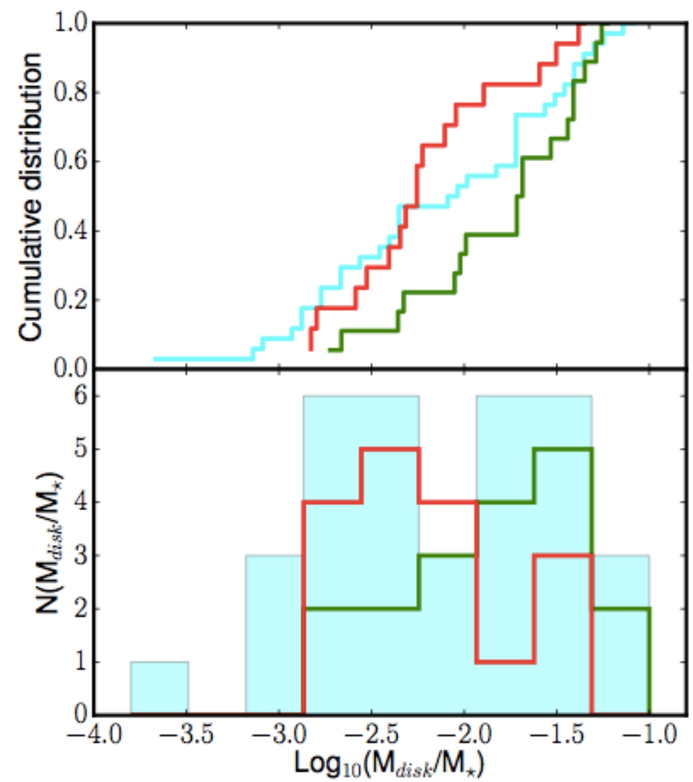
- **Rho-Oph**: 17 spectroscopically confirmed Class II BDs (all at the time of the proposal, ~30 are known now); Testi et al. in prep.
- **Taurus**: 3 BDs (already mm-detected); Ricci et al. 2014



Mdisk < 1 M_J; Mdisk/Mstar <1%

The ρ-Oph BDs





- All the spectroscopically confirmed BDs in ρ–Oph at the time of the proposal (17)
  - 11 detected at 890 mic
  - 2 resolved

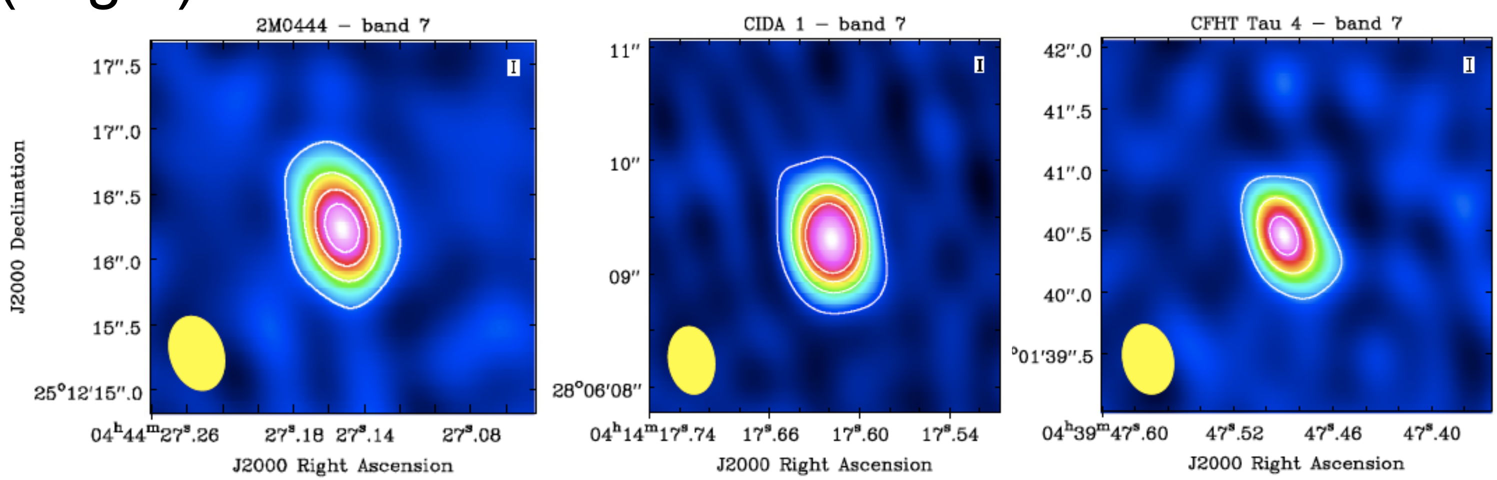
Are BD disks less massive than scaled TTS disks?

✓Opacity

✓Temperature (worse at shorter wavelengths)

Disk sizes

- Taurus BDs : Continuum and CO(3-2) –> **R~40-140 AU** (large!)



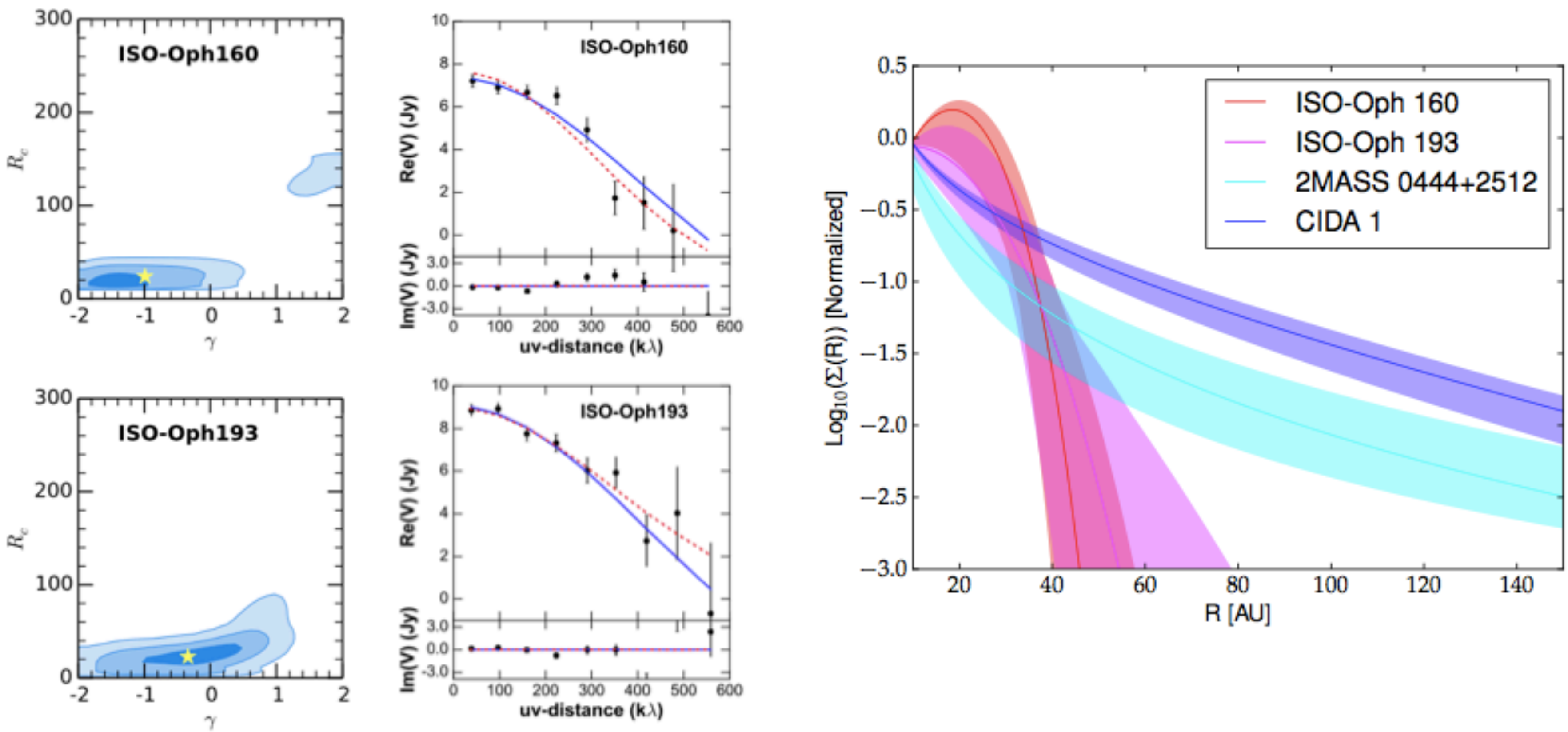
Dusty Disks

- **Taurus:**
- CIDA 1 M5.5 α~2.1 Rout>30-50AU
- CFHT Tau 4 M7 α~1.9 Rout >30-50AU
- 2M0444+2512 M7.25 α~2.1 Rout~150AU

- **Rho-Oph:**
- 2/11 clearly resolved

Disk truncation in Oph?

- Taurus BDs : Continuum and CO(3-2) –> **R~40-140 AU**
- Oph BDs : Continuum–> **R<~30 AU**



Summary

- BDs have disks!
  - Grains show evidence for growth (small samples)
- Most of them are relatively low mass
  - Not easy to form planets!
- Possible evidence for truncation?
  - The two resolved Oph disks seems to be truncated
  - Is this an imprint of formation? Dust evolution? Or are these two just two odd balls?