PACS observations of dust and gas in transition disks

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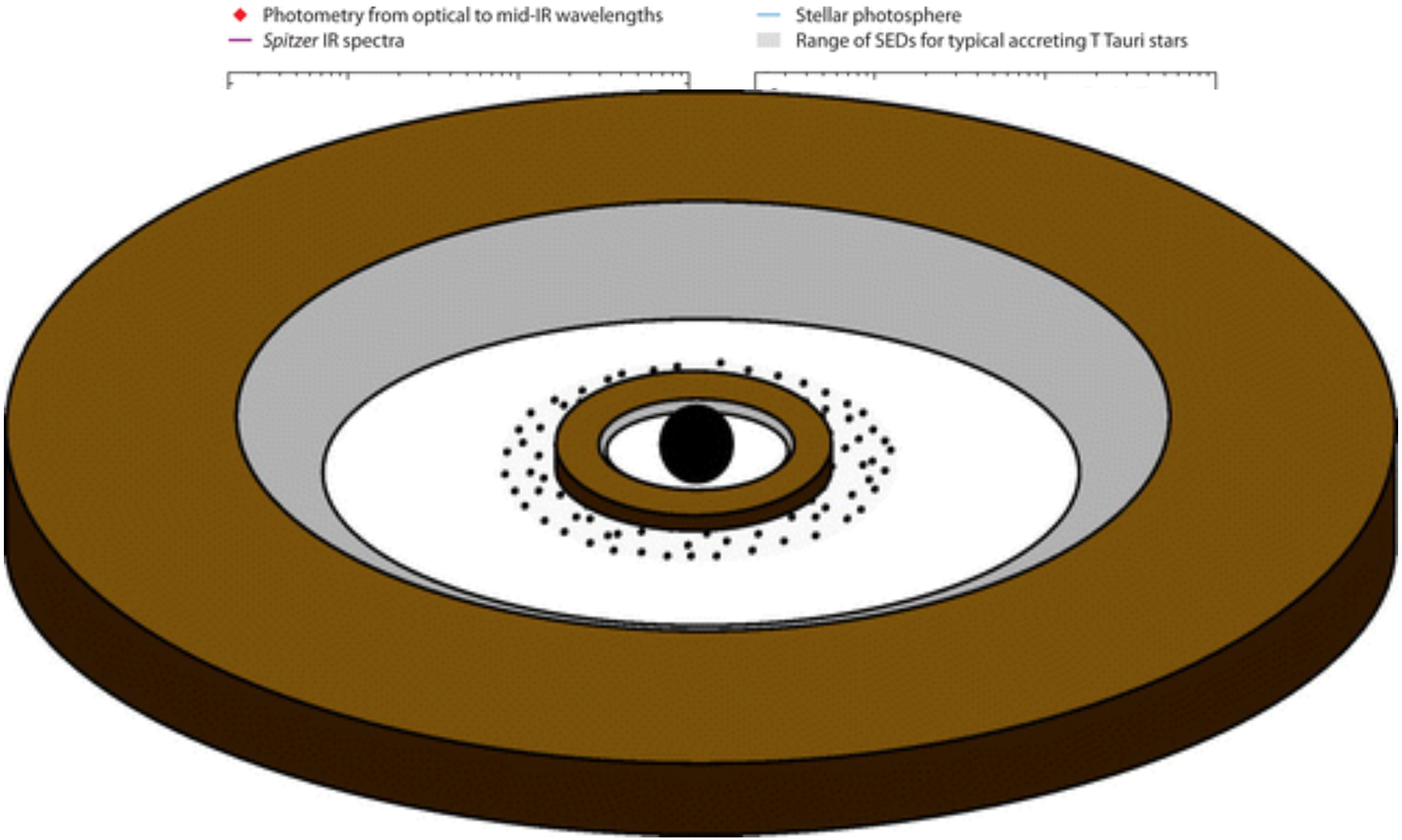
What are Transition Disks ?



Williams JP, Cieza LA. 2011.
Annu. Rev. Astron. Astrophys. 49:67–117

Sketch from C. Espaillat

The SAMPLE

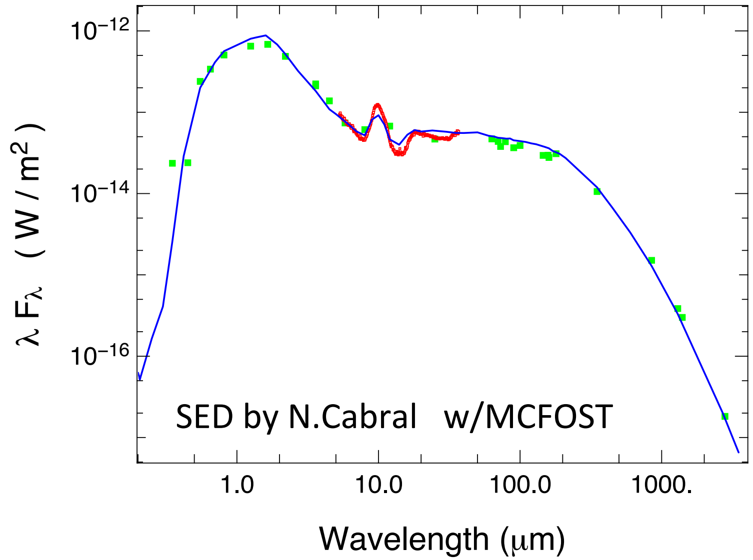
Lk Ca 15

$L_* = 0.74\ L_{sun}$

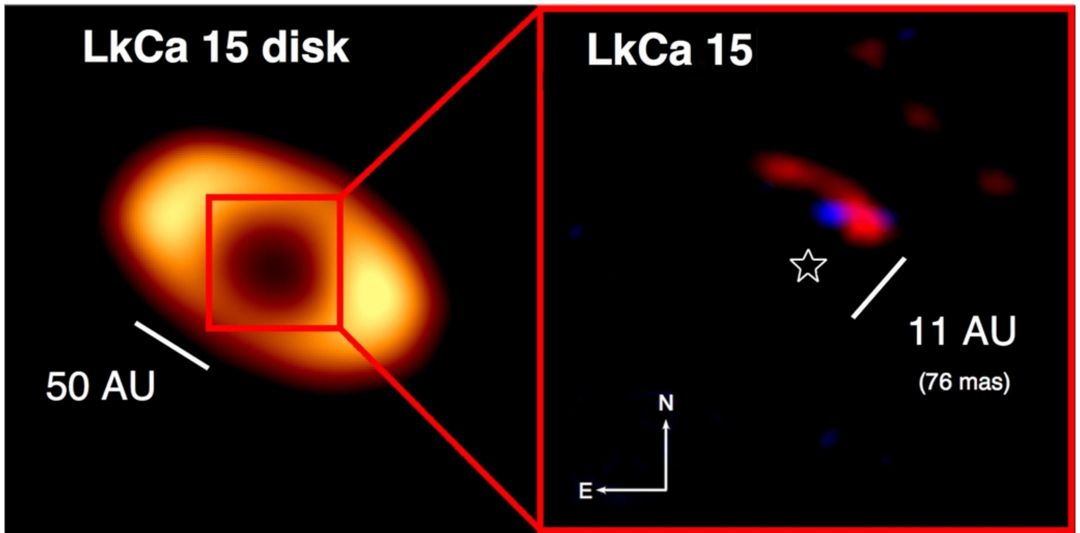
$T_* = 4400$ K (K5)

$M_{dust} = 0.001 Msun$

Large gap ~ 46AU



Kraus & Ireland 2012



The SAMPLE

GM AUR

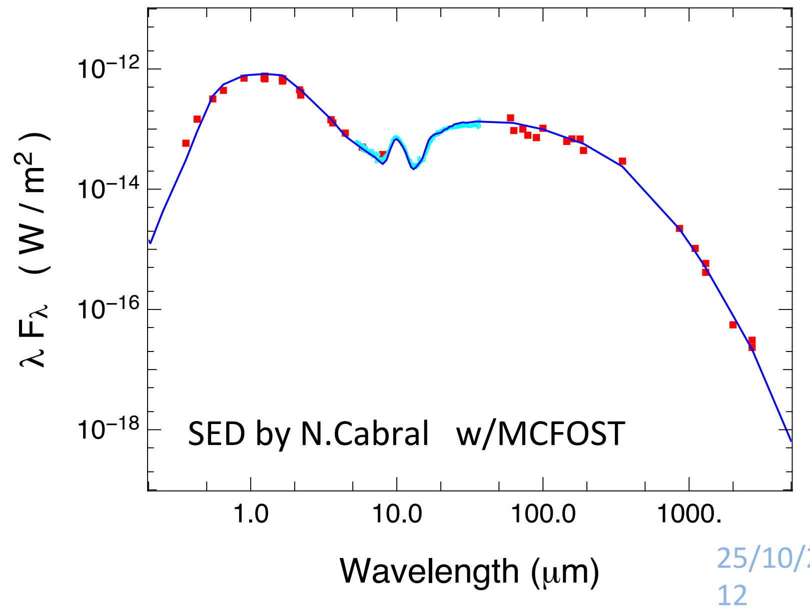
$L_* = 1.1\ L_{sun}$

$T_* = 4730$ K

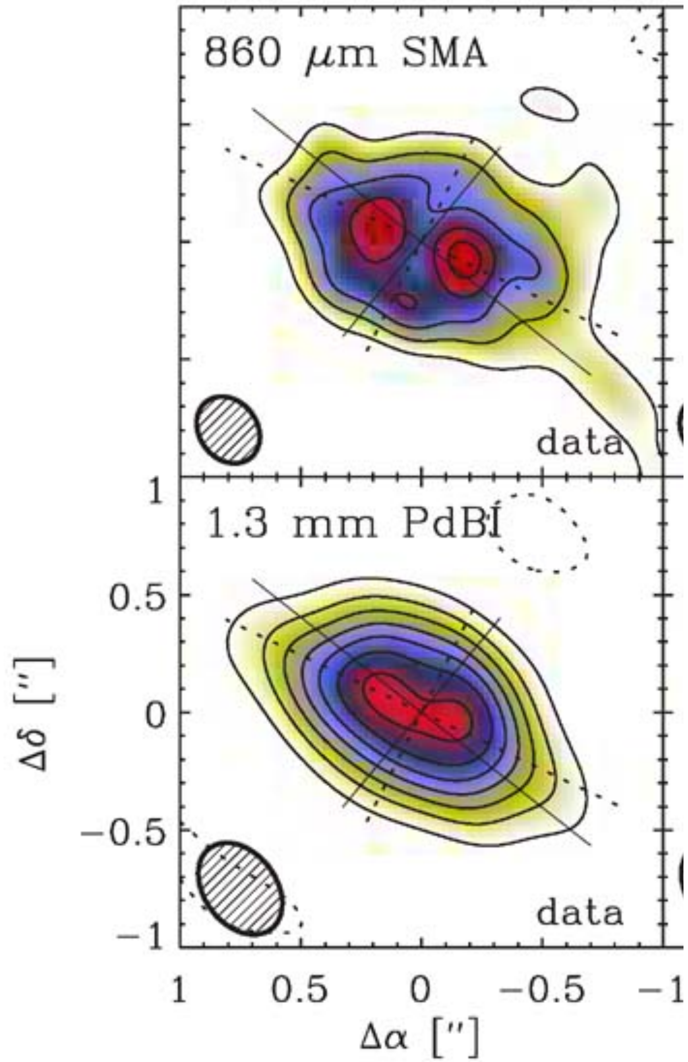
$M_{acc} = 8\ 10^{-9}\ M_{sun}/yr$

Mdust = 0.001 Msun

Large gap ~ 24AU



Hughes et al. 2009



The SAMPLE

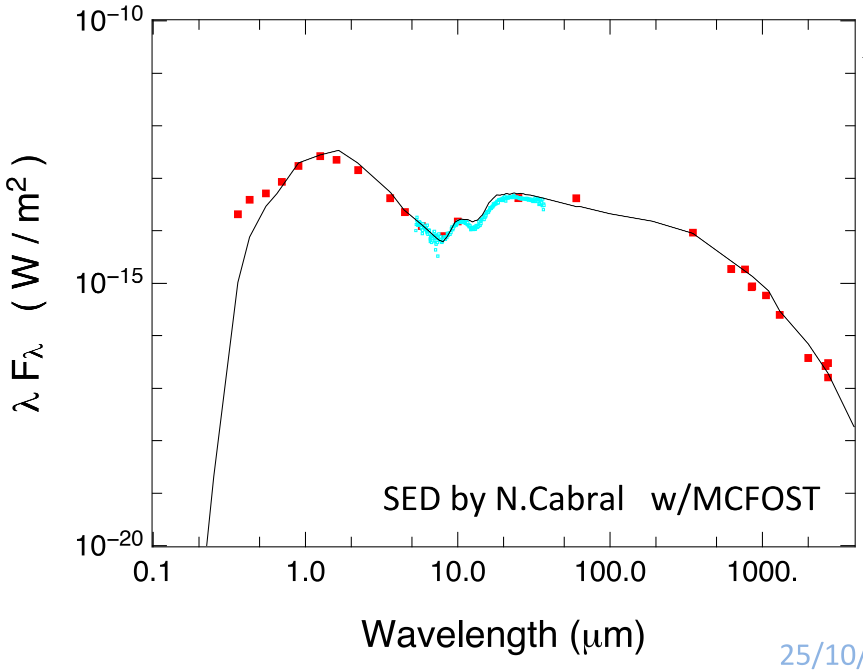
DM Tau

M1

$L_* = 0.25L_{sun}$

Small gap ~ 4AU

Mdust ~ 0.002 Msun

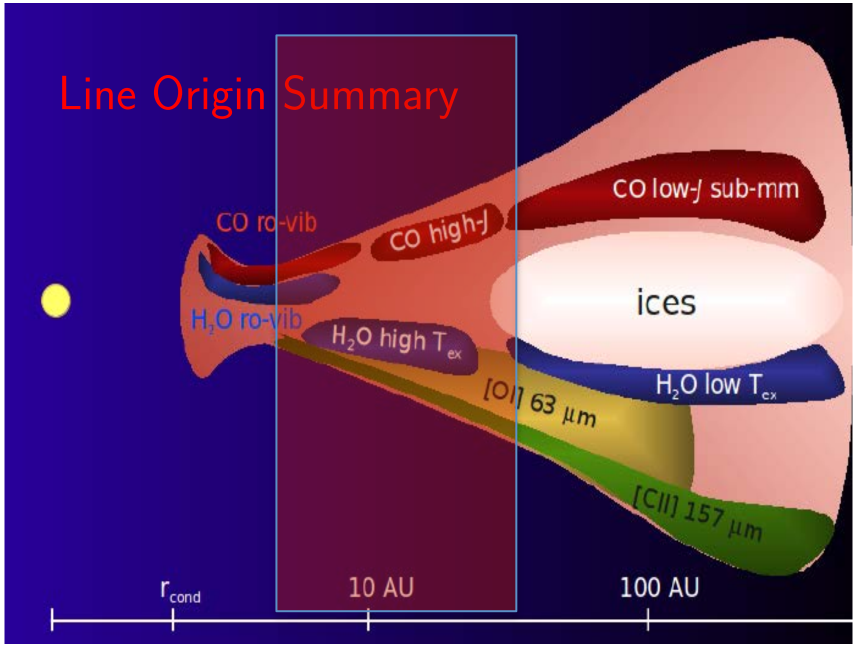


UX Tau A +CoKu Tau 4

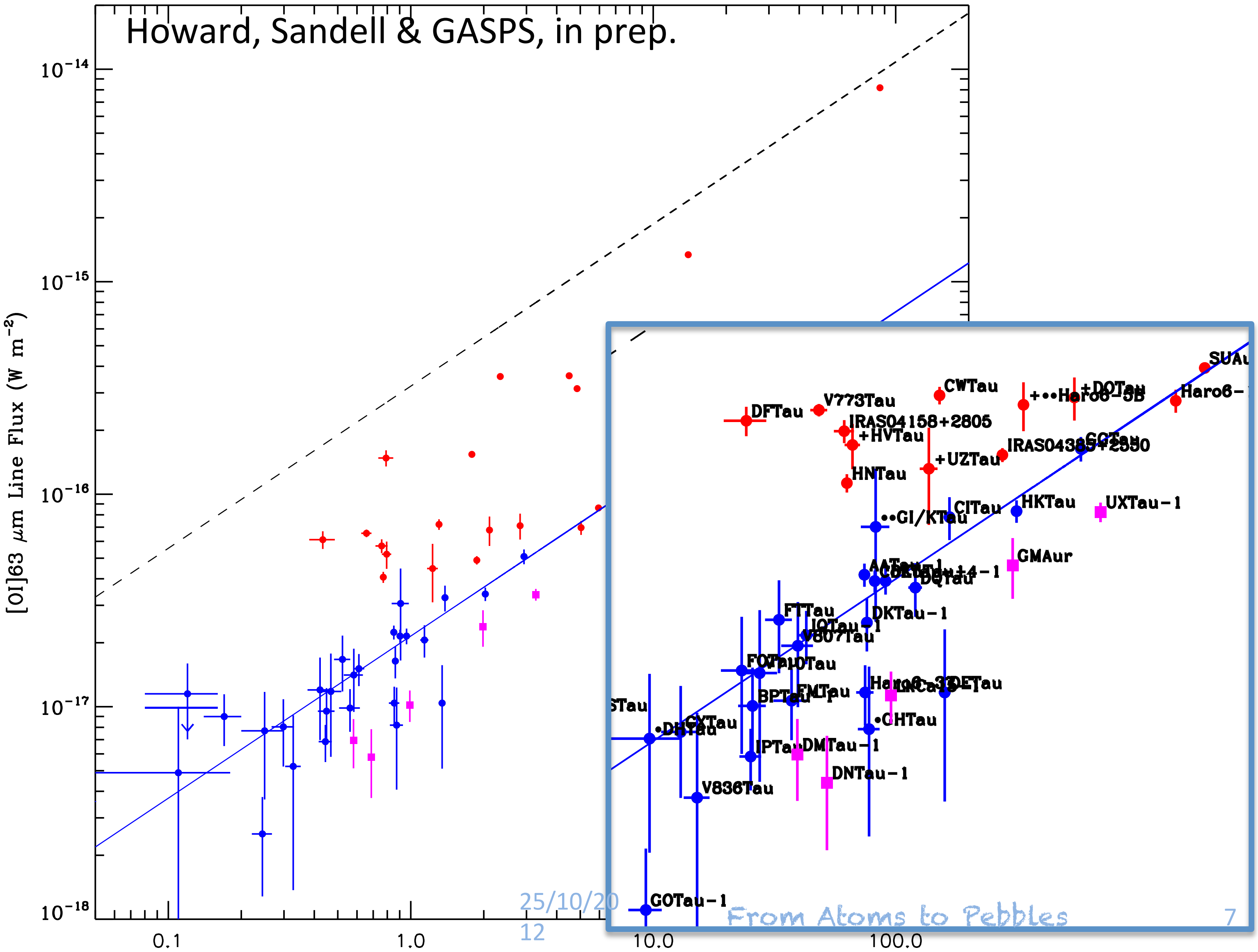
- UX Tau A: not as well documented.
- CoKu Tau 4: a binary
- Will not discuss these 2 but PACS data available, and showing same trend.

Herschel, GASPS and transition disks

- Low J 12CO lines are optically thick. They come from outer disk
- CO ro-vib , and Spitzer water lines come from inner disk
- Very few tracers probe the intermediate regions (in radius) of disks
  - OI 63 is bright, a (the) main coolant in disks, and a good tracer, but not possible from ground.



The PACS data for Taurus



Origin of the lower ratio of [OI]63 / continuum

- Modelling strategy

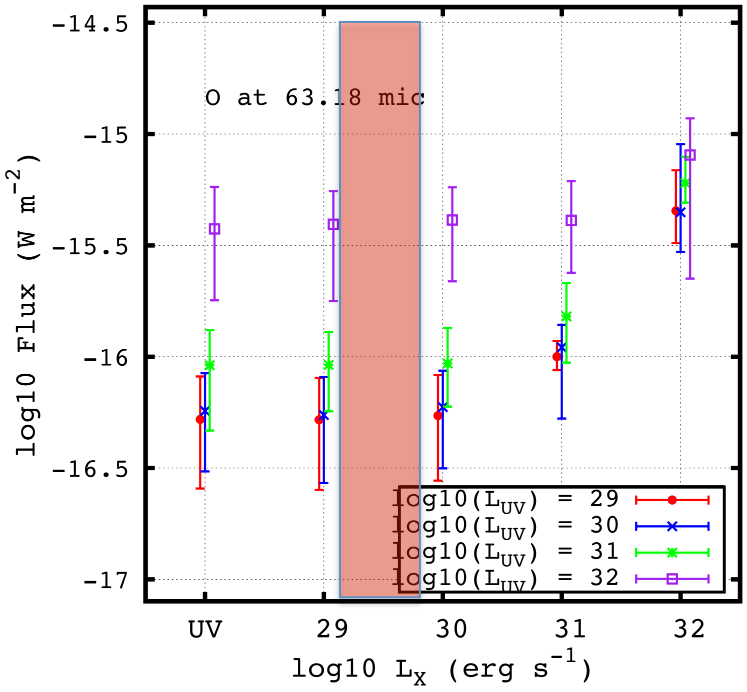
  AKA the DENT pipeline

  Woitke et al. (2010)

  Kamp et al. (2011)

  Menard et al. (in prep.)

  - Build SED model
    - Provides cont. model
      - Rho_dust
      - Tdust
      - J_nu
  - Inject into Gas model
    - set L_x, L_{UV}
      - Lx from XEST
        - Few 10^{29} erg/s
    - Set amount of VSG, PAH and G/D ratio
  - Radiative transfer



Aresu et al. 2011, & in prep.

Origin of the lower ratio of [OI]63 / continuum

- Modelling strategy
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  - Radiative transfer

- 3 steps
  1. Dust and rad. Field from SED + No UV, No X-Rays, G/D =100
     1. Tgas = Tdust
  2. Set Luv to match obs.
     1. Yang et al. (2012)
  3. Reduce amount of PAH and/or Gas-to-Dust ratio if needed

GM Aur, results

	Data (W/m^2)	Star	Star + L_{FUV} (PAH=10-5 ISM)	Star + $10L_{FUV}$	Star + L_{FUV} + G/D =50 (PAH = 10-5 ISM)
[OI] 63	**2 e-17**	**2.7 e-18**	1.6 e-17	**2 e-16**	1.3 e-17
[OI] 145	**<3 e-18**	4 e-20	4.7 e-19	3 e-18	3.1 e-19
CII	**<3 e-18**	3.5 e-19	8.1 e-19	7 **e-18**	7.3 e-19
CO (3-2)	**3.4 e-19**	3.8 e-19	4.1 e-19		3.6 e-19
CO (2-1)	**1.5 e-19**	1.4 e-19	1.3 e-19		1.2 e-19
12CO(3-2) / 13CO(3-2)	**3.4**	2.7	2.6		3.8

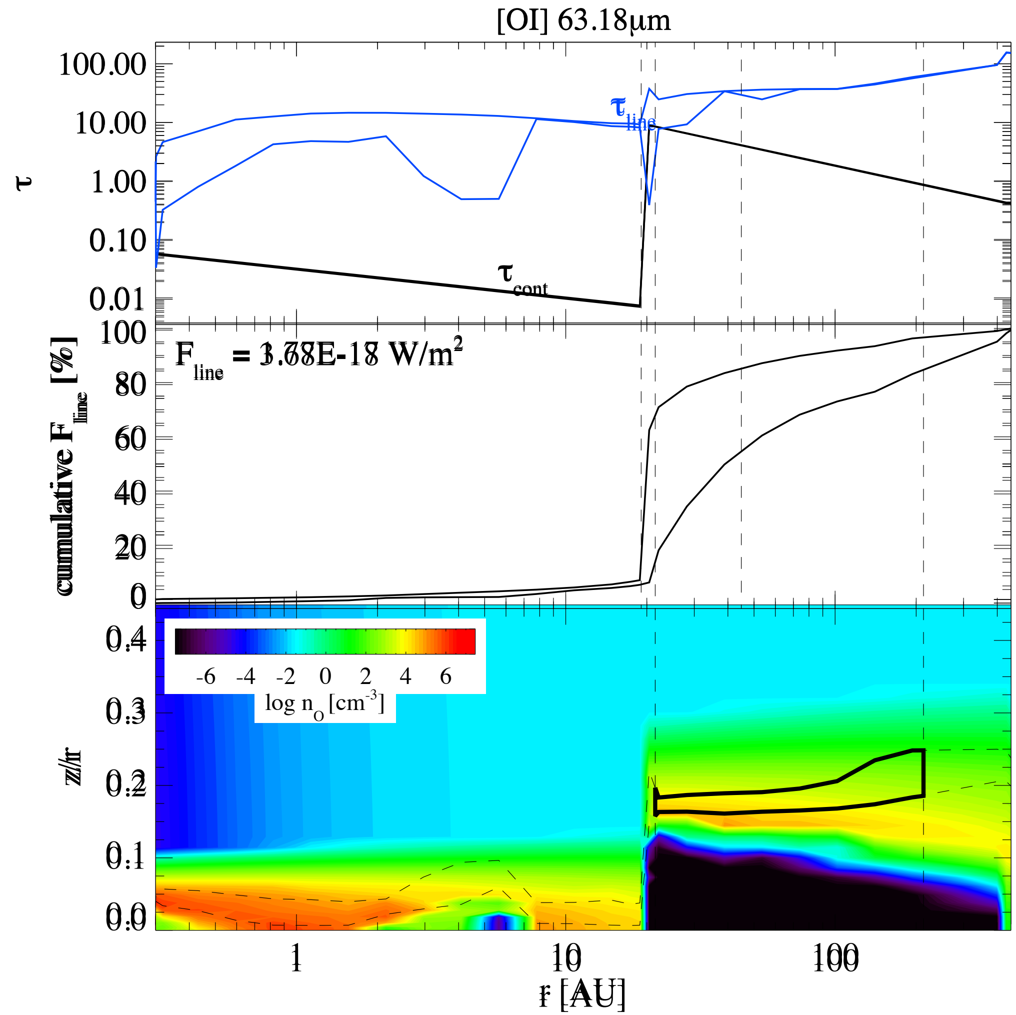
LkCa15, TW Hya , …

- Similar in spirit!
- Exact numbers vary
  - TW Hya -> G/D lower

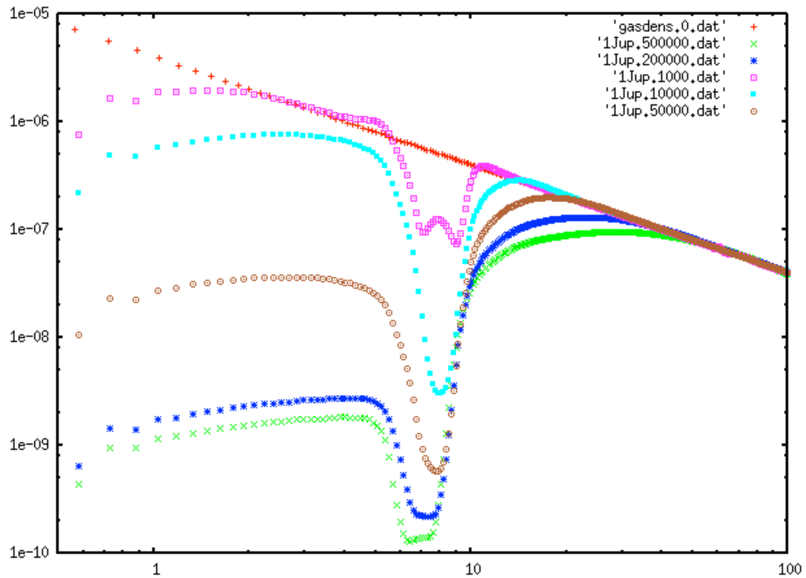
Note: see also poster by Garufi on FT Tau

G/D ~ 100

Location, impact of geometry



Witnessing disk evolution and dispersal?



Credit, P. Varniere w/FARGO
See Tatulli et al. (2011)

- Assume transition disks DO trace evolution and are linked to the presence of planet(s)
- The pressure max. outside of gap may trap dust particles
  - Gas flows in
  - Small dust flows in
  - Large dust piles-up
    - See poster by Pinilla
- If outside reservoir is shut off… density will decrease, gas may go away faster than (large) dust.

GM Aur in the UV, small dust inside

HST – PSF subtracted

F1450LP (1450-2000 A) F1650LP (1650-2000 A).

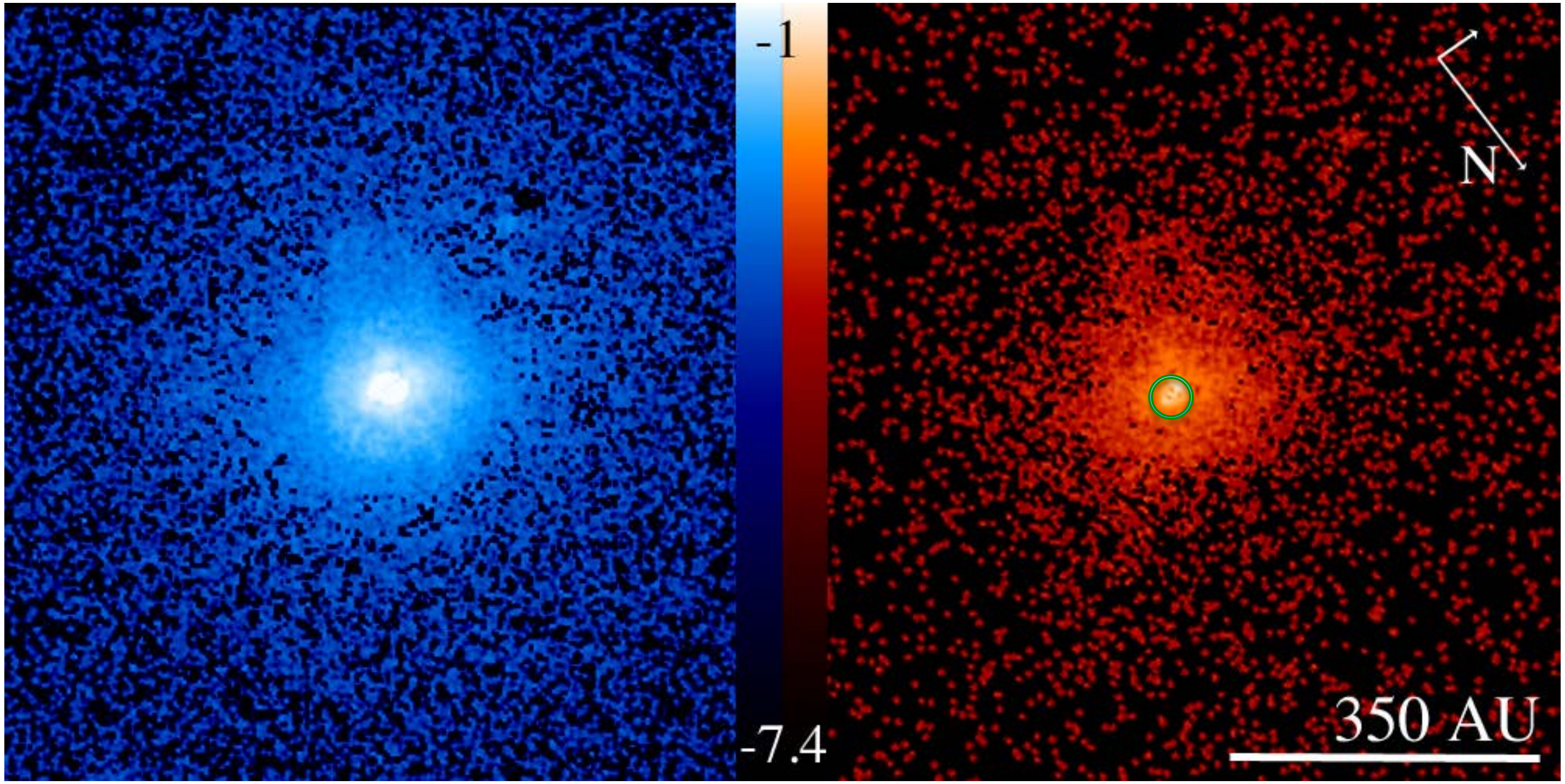


Image credit: Jeremy HORNBECK

Final Remarks… looking ahead

Regarding GASPS:

- The goals were to find how much gas was available to form Gas giant planets…

  … and track how it evolved with time.
- Herschel has provided the data. GASPS' is moving along in the analysis.

Regarding the disks themselves:

- We are witnessing dramatic changes in the disk structure and content at a stage (TD) when the disks evolve rapidly, likely because of planets formation…
  - The Evolution of the disk is intimately linked to formation of the planet(s).
  - and vice-versa.