Terzo Workshop sull'Astronomia Millimetrica in Italia
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ALMA/JVLA observations of the dust properties across the CO snowline in HD 163296

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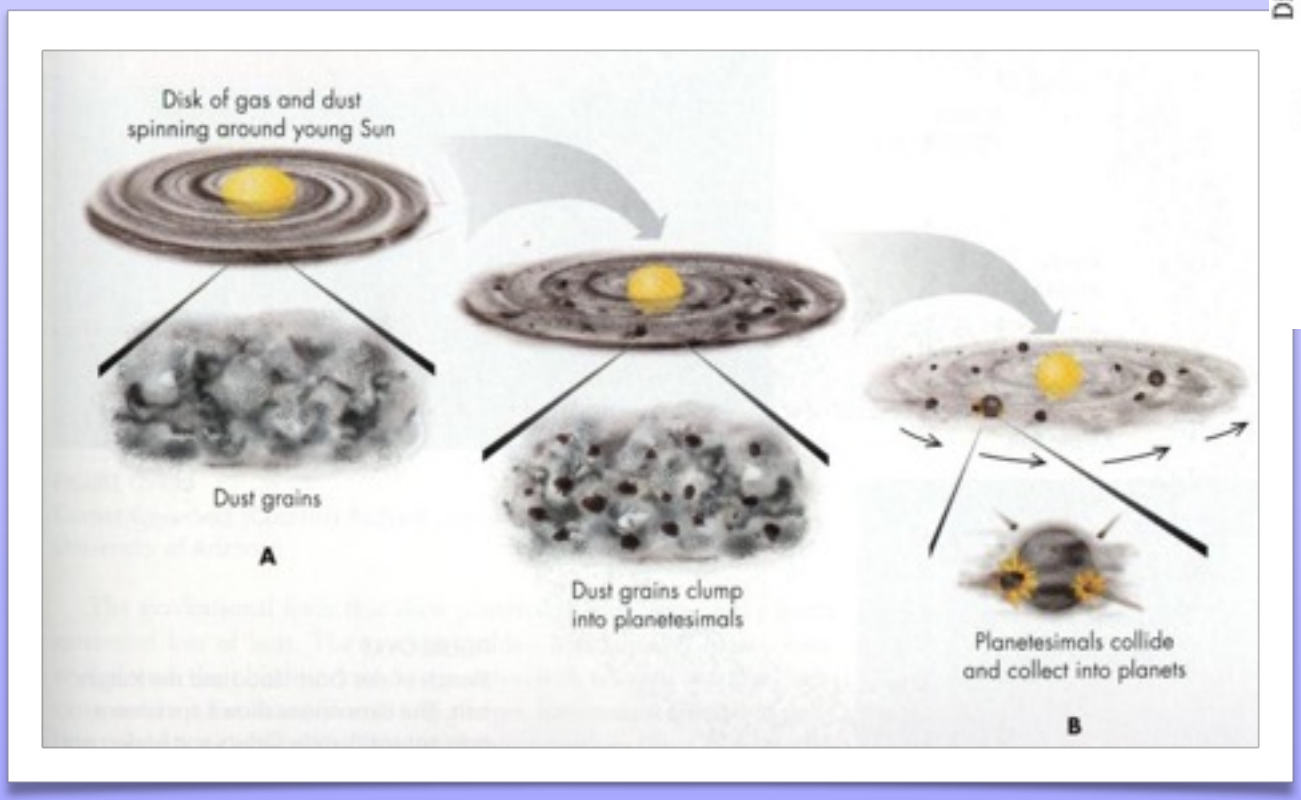
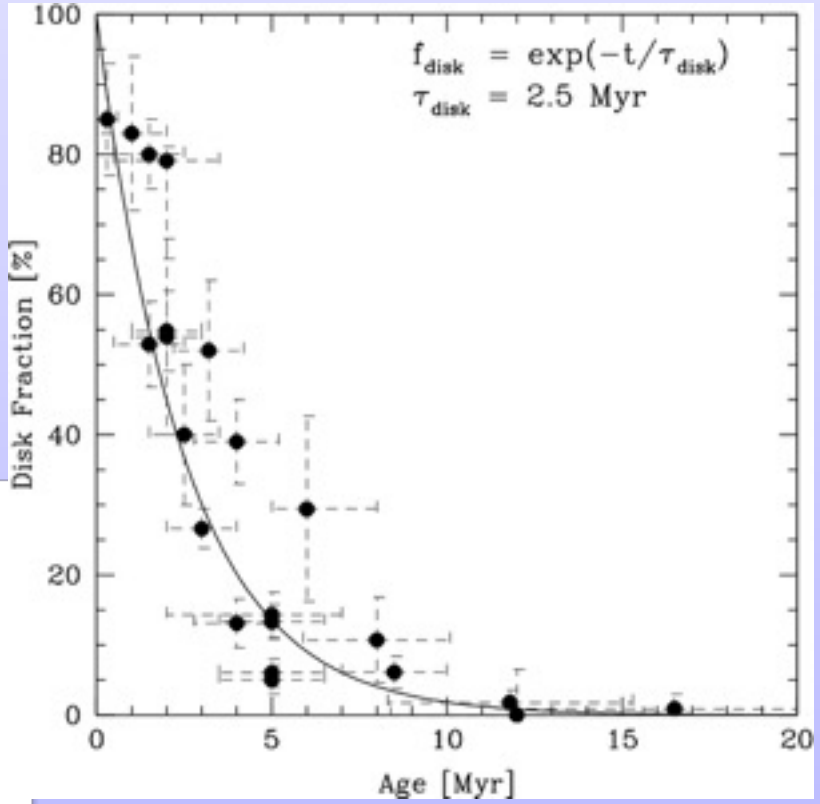
FROM DUST TO PLANETS

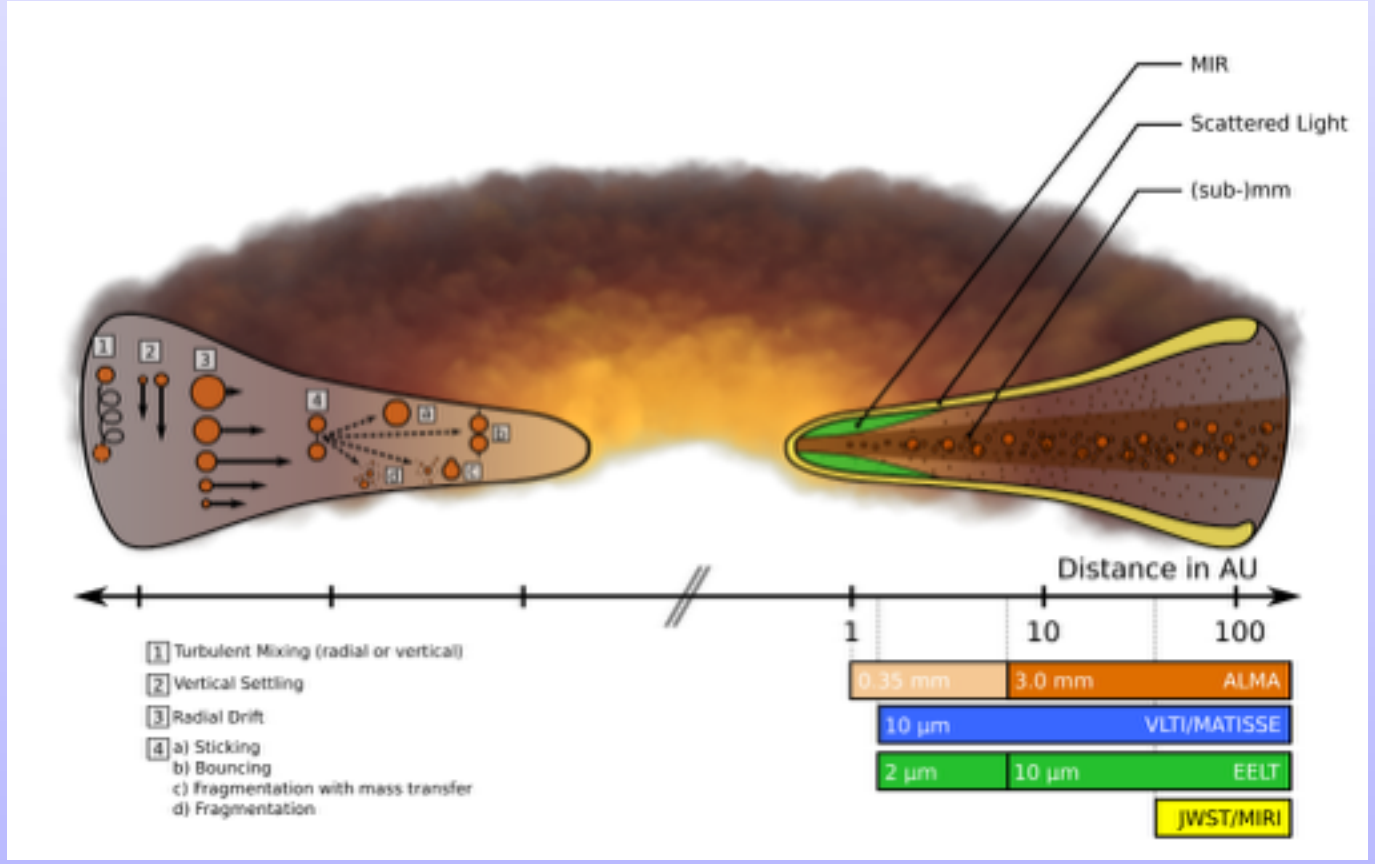
Circumstellar disks: the first step towards planet formation





[Mamajek 2009]

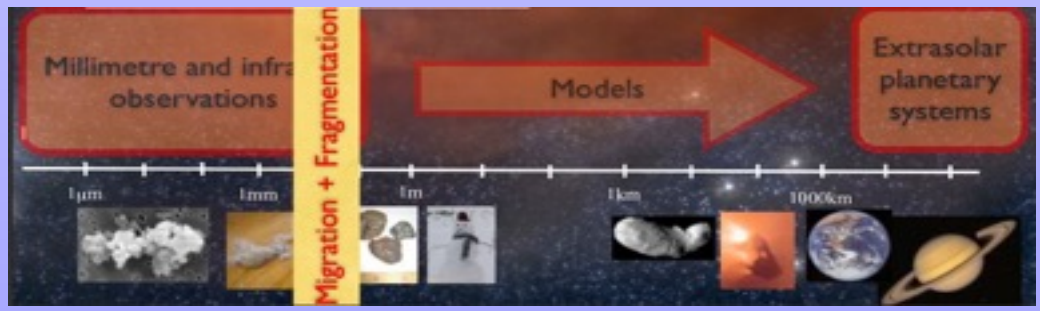
HOW DO WE DETECT DUST IN PROTOPLANETARY DISKS?



[Testi et al. 2014]

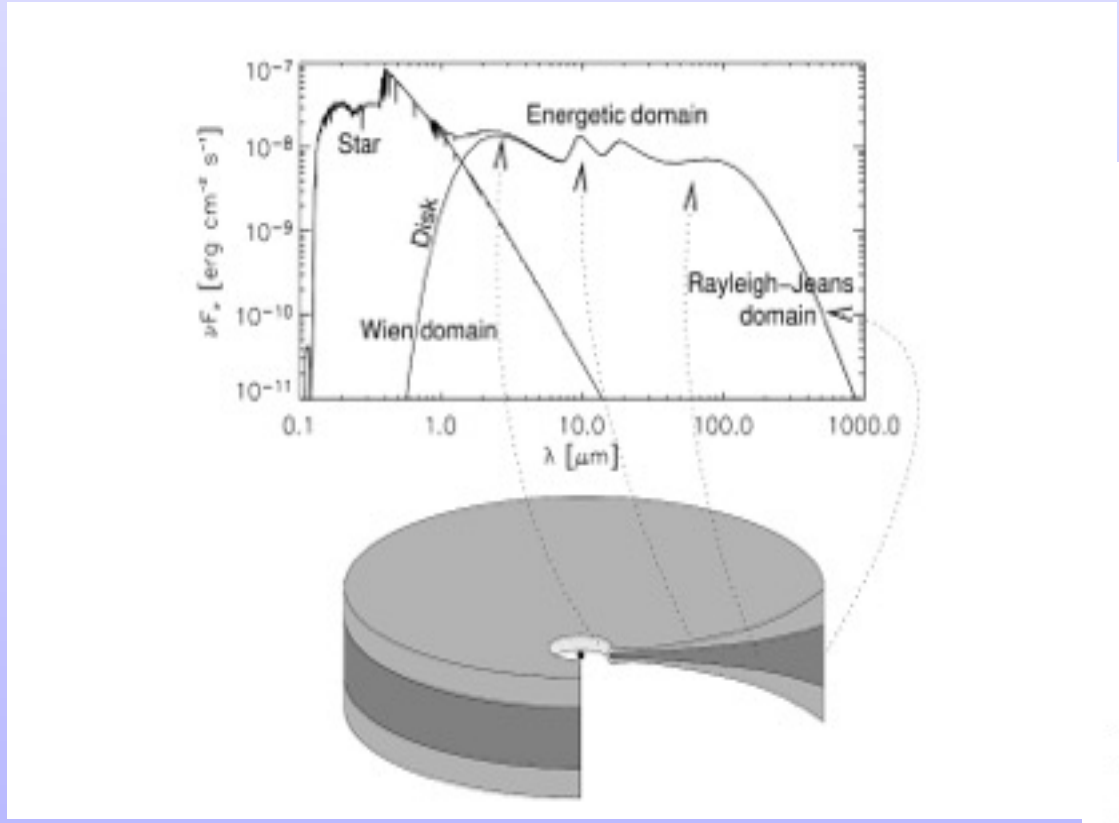
How big? → mm-cm MAX

Where? → infrared/
sub-millimeter/millimeter



OBSERVATION OF GRAIN GROWTH

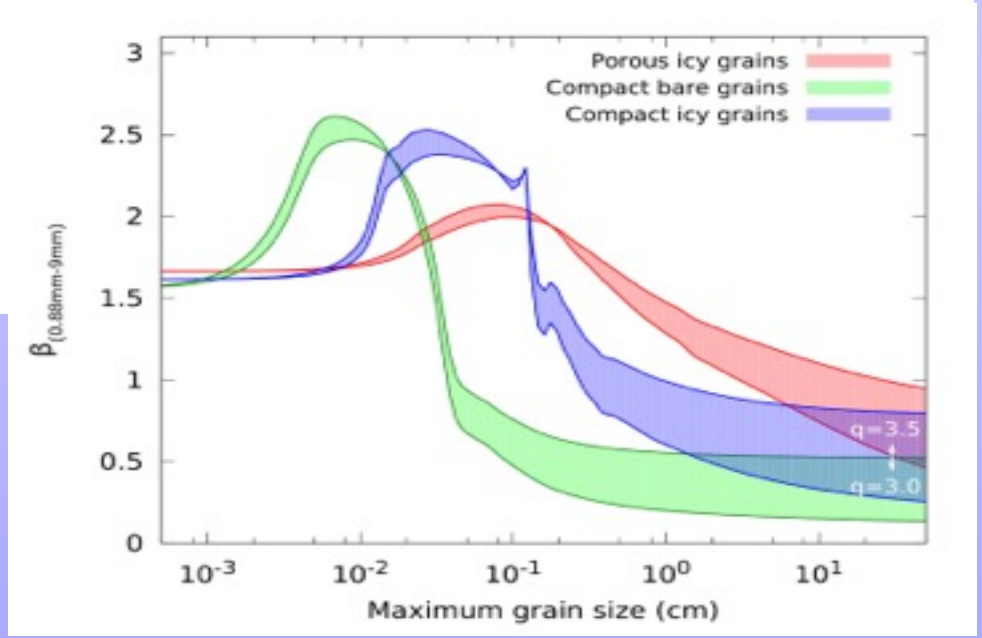
- Optically thin emission ($\tau << 1$)
- Rayleigh-Jeans regime ($h\nu << kT$)



[Dullemond et al. 2007]

$$F_\nu^i \propto M T_i \kappa_\nu^i \nu^2$$

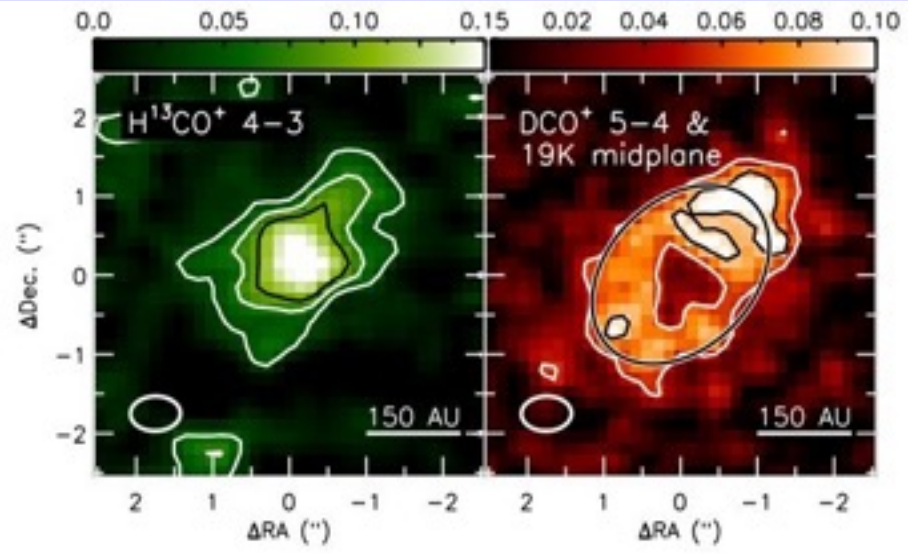
$$\kappa_\nu^i \sim \nu^\beta \Rightarrow F_\nu^i \propto \nu^{\beta+2}$$



[Testi et al. 2014]

HD 163296

CO snowline resolved with ALMA!



[Mathews et al, 2013]

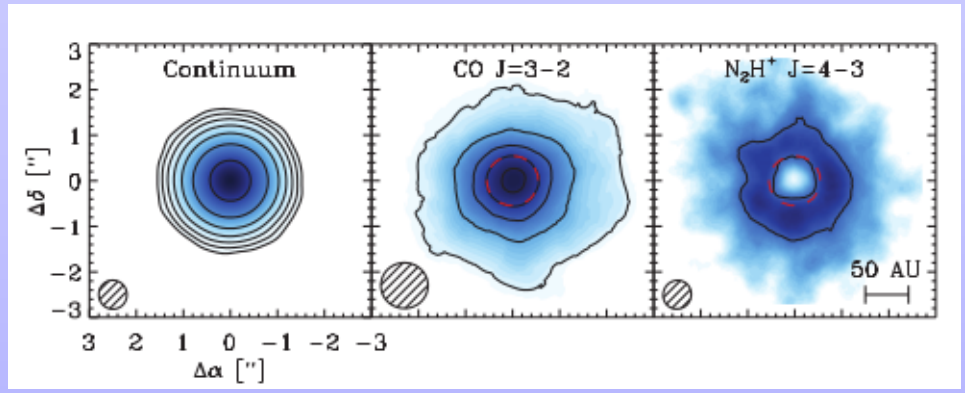
$H_3^+ + HD \Leftrightarrow H_2D^+ + H_2 + \Delta E$

$H_2D^+ + CO \rightarrow DCO^+$

Emission ring of DCO^+ : 95-195 AU

CO condensation temperature:
19 K → 155 AU ~1,3”

Herbig Ae star
Age ~ 5 Myr
$M_* = 2,3\ M_\odot$
$T_* = 9500$ K
$L = 36\ L_\odot$
d=122 pc
$M_{disk} \sim 0,09\text{-}0,17\ M_*$



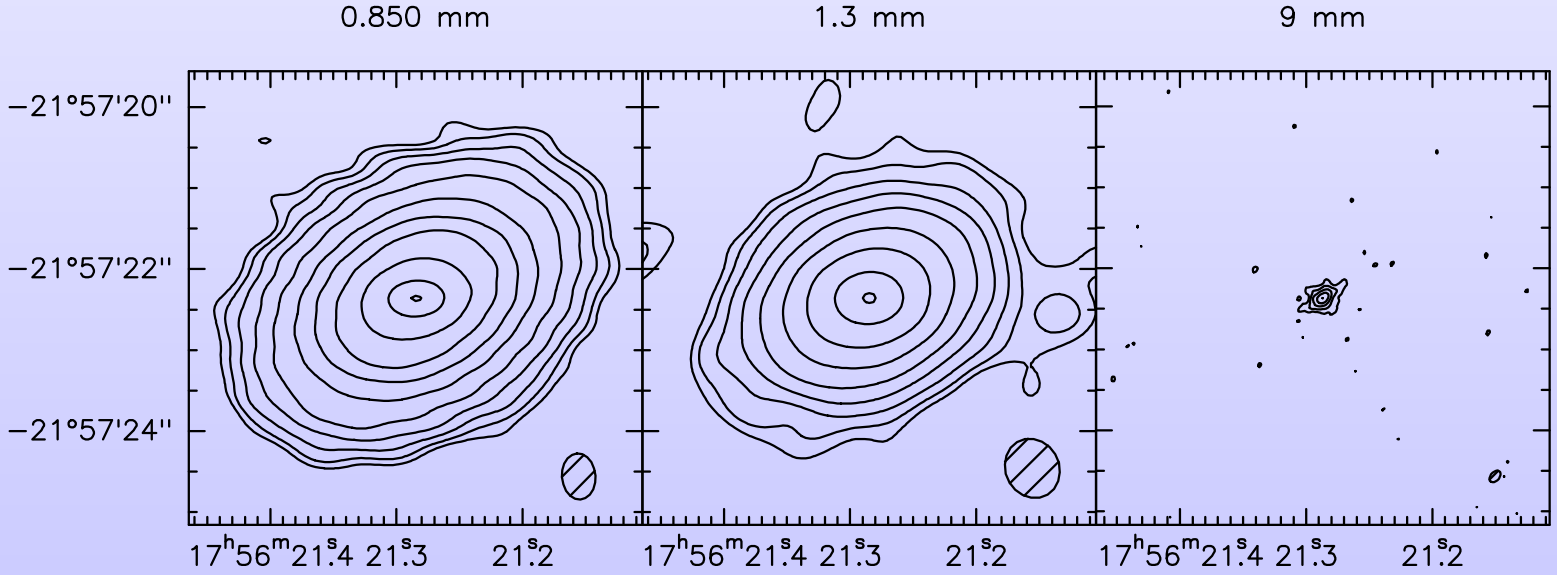
[Qi et al. 2013]

But DCO^+ not the better tracer:
N_2H^+ gives a CO snowline at

100 AU → 0.8”

[Qi 2015 in preparation]

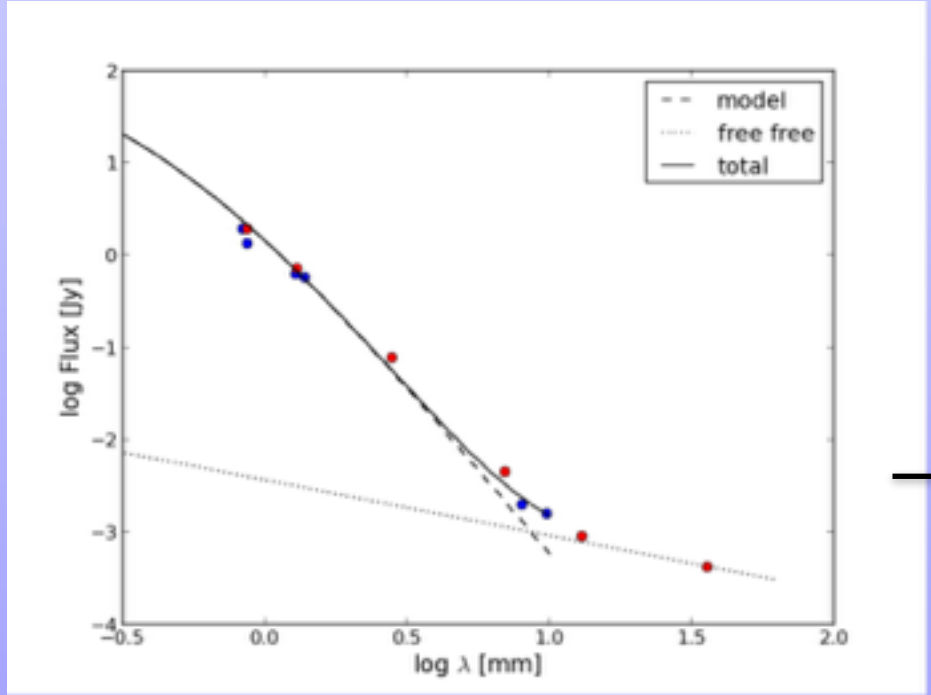
OBSERVATIONS



Beam 0.57x0.37''
~ 60AU

Beam 0.74x0.60''
~ 85AU

Beam 0.13x0.08''
~ 15AU

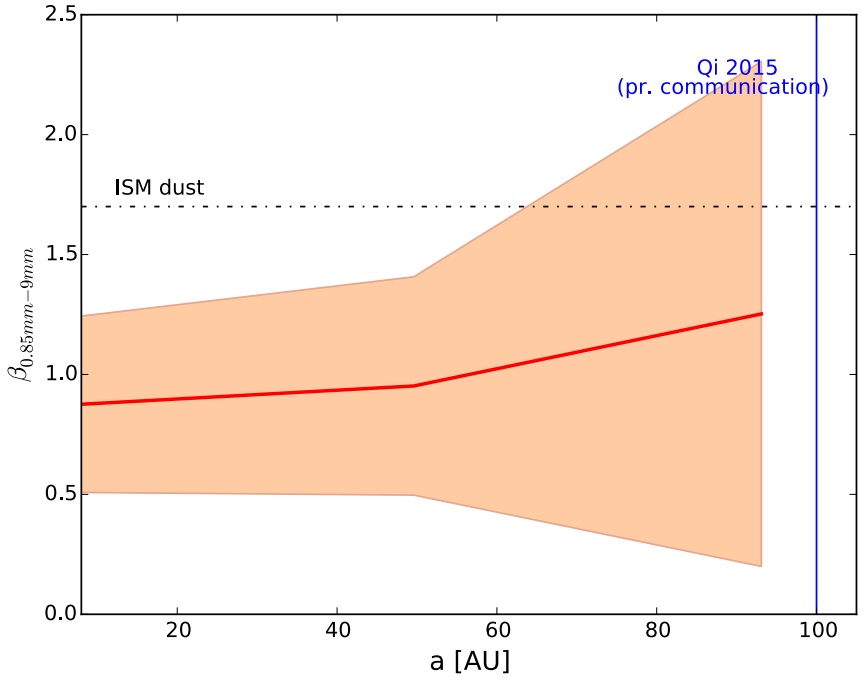


- ALMA B6/B7 Science Verification Cycle0-Cycle1 2012
- EVLA Ka Band - Disks@EVLA Project (PI C.Chandler) 2011

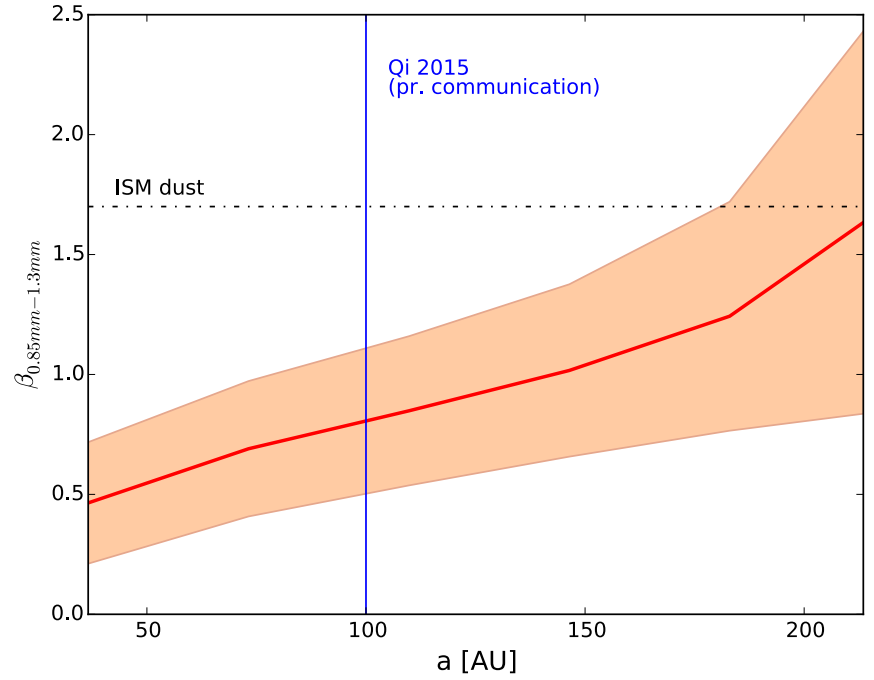
Free-free electron emission becomes a non-negligible contribution at millimeter wavelengths

RADIAL PROFILES OF SPECTRAL INDEX

850 μm - 9 mm

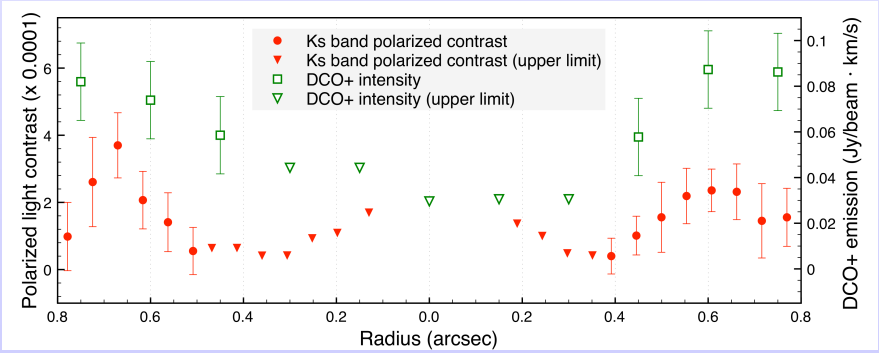


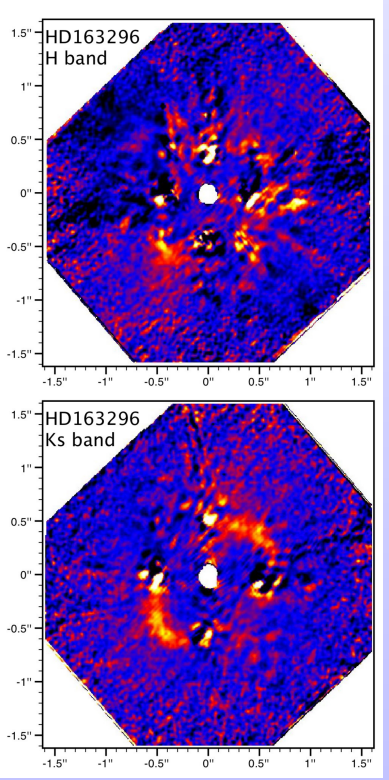
850 μm - 1.3 mm



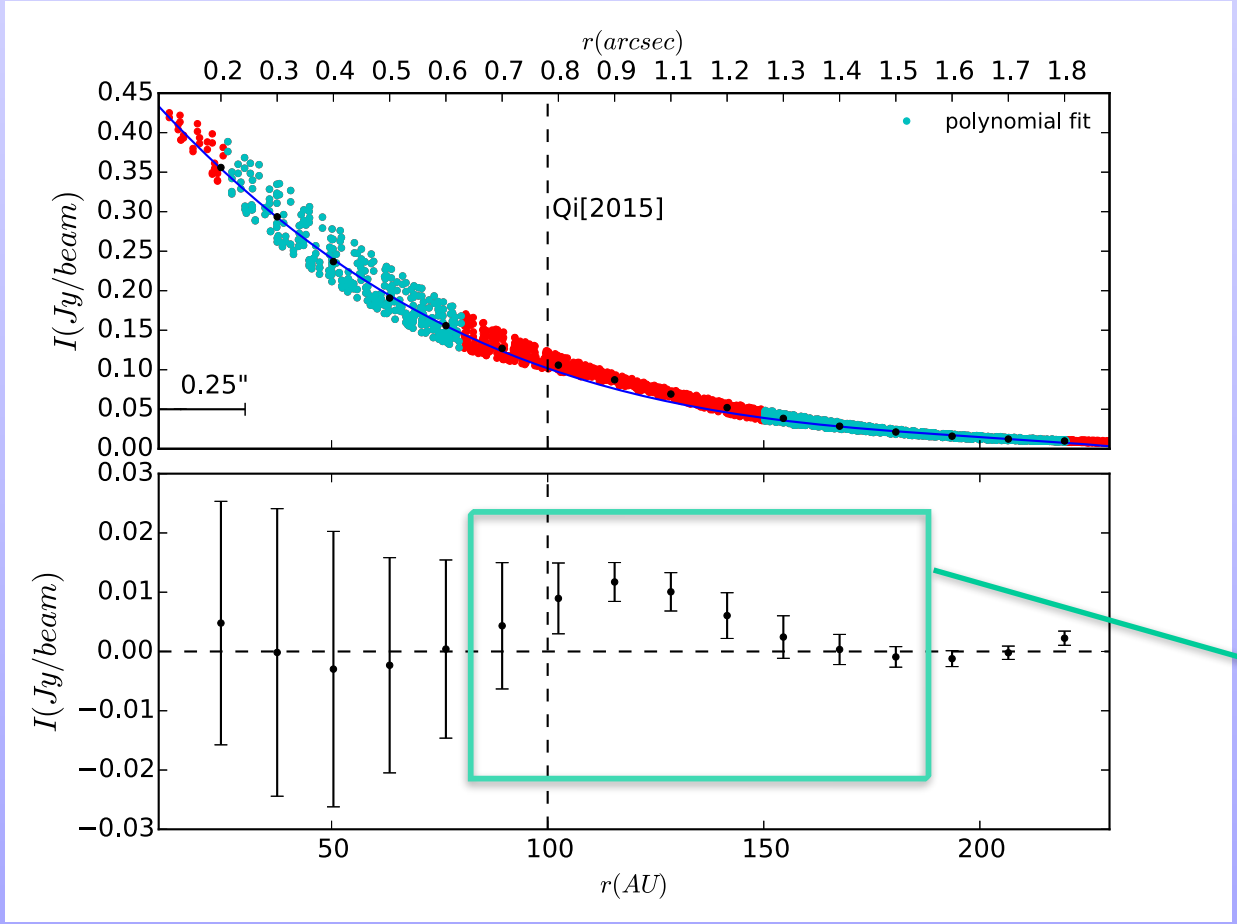
DUST EMISSION REVEALS NON-HOMOGENEOUS FEATURES IN THE DISK

[Garufi et al. 2014]





[Garufi et al. 2014]
Polarized light shows a ring structure at ~0.6” -1”(70-120 AU)



Polynomial fits leave an excess emission near the CO snowline

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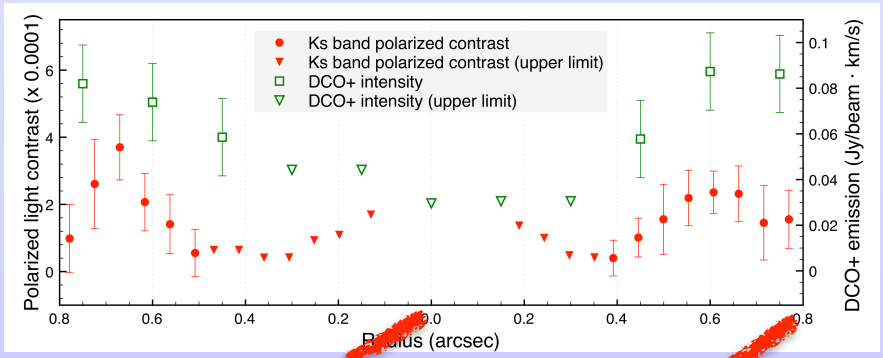

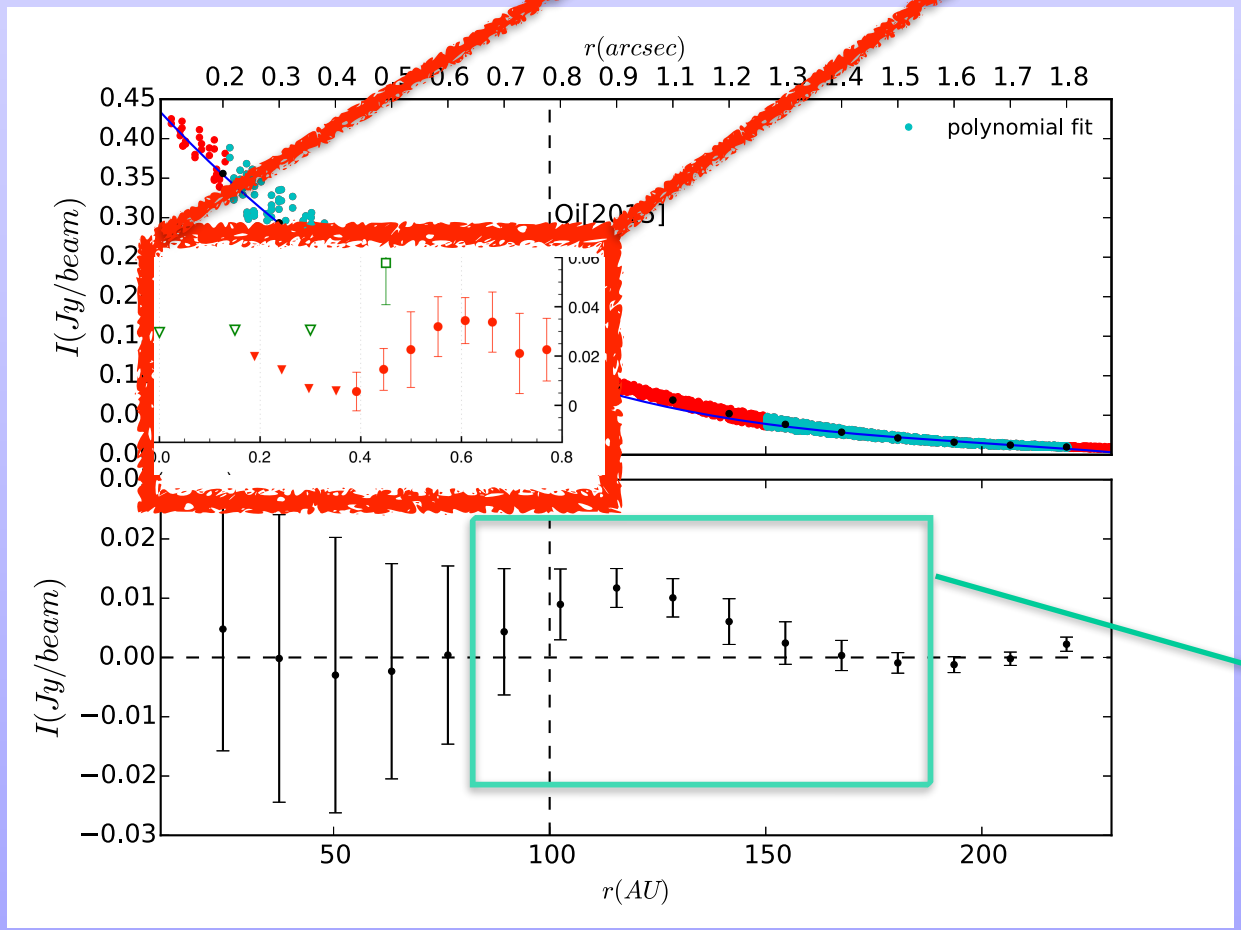

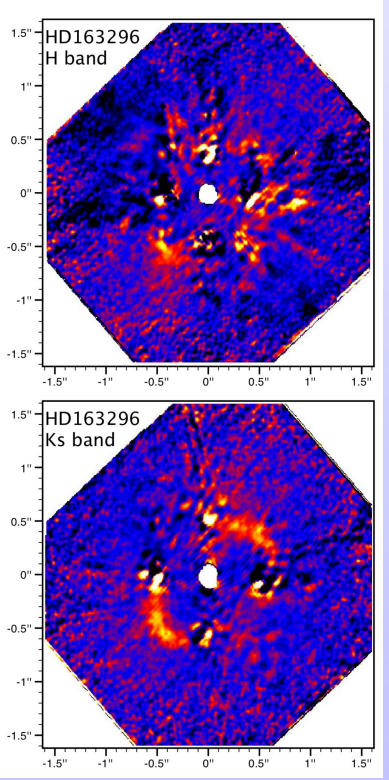

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Polynomial fits leave an excess emission near the CO snowline

MARCOV CHAIN MONTE CARLO FIT

[code developed by M. Tazzari@ESO]

$$X(\gamma, \Sigma_t, R_t, a_{0,max}, b_{max})$$

$$a_{max} = a_{0,max}\left(\frac{R}{R_0}\right)^{b_{max}}$$

$$\Sigma_g(R,T) = \Sigma_t\left(\frac{R_t}{R}\right)^{\gamma} exp\left\{-\frac{1}{2(2-\gamma)}\left[\left(\frac{R}{R_t}\right)^{(2-\gamma)} - 1\right]\right\}$$

6 wavelengths (0.835 mm, 0.866 mm, 1.29 mm, 1.38 mm, 8.00 mm, 9.83 mm)

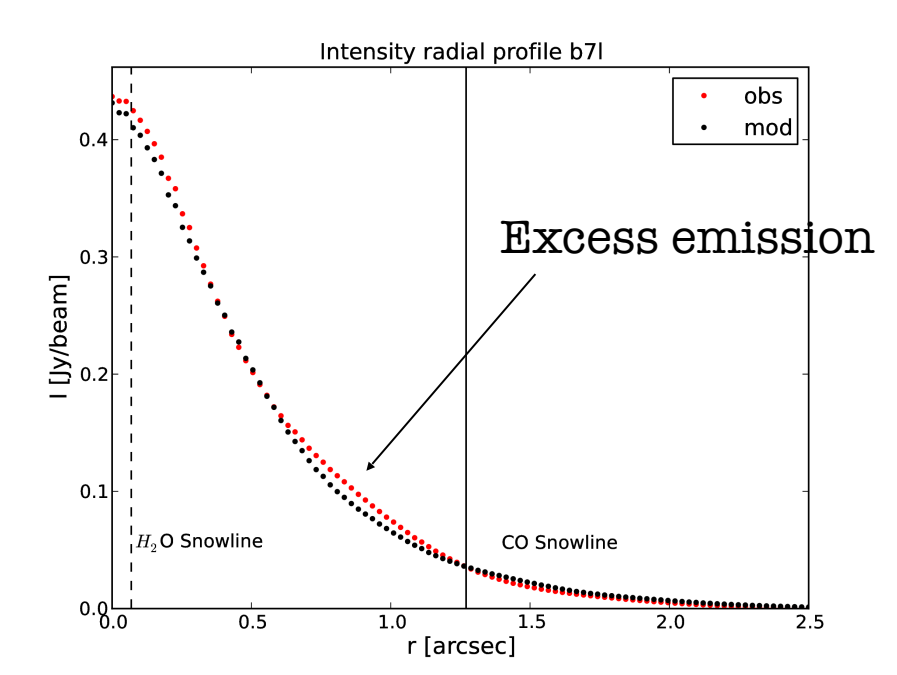
- For each λ, for each set of parameters → theoretical image
- Fourier transform (FFT) → calculate the visibilities
- Calculate the χ^2 between observations and model:

$$\chi^2 = \sum[(Re_o^2 - Re_t^2) + (Im_o^2 - Im_t^2)] \cdot w$$

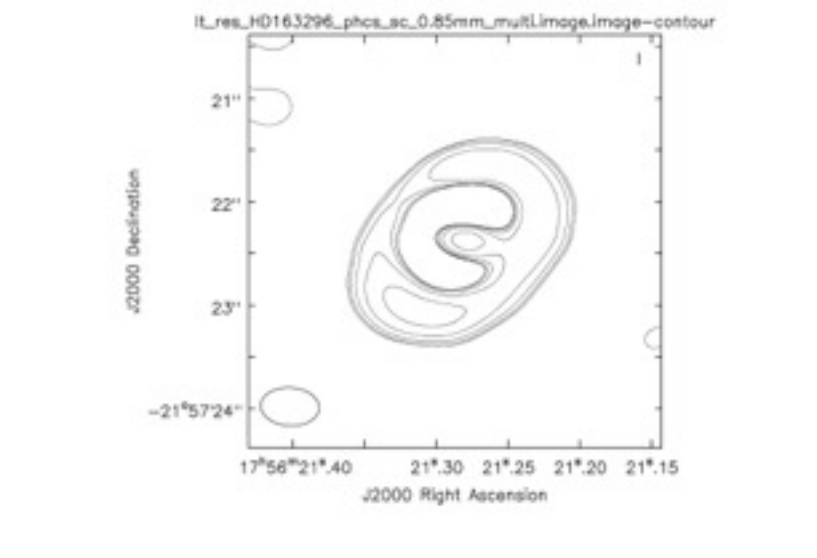
- Derive the probability distribution of the model parameters

MCMC FIT PRELIMINARY RESULTS

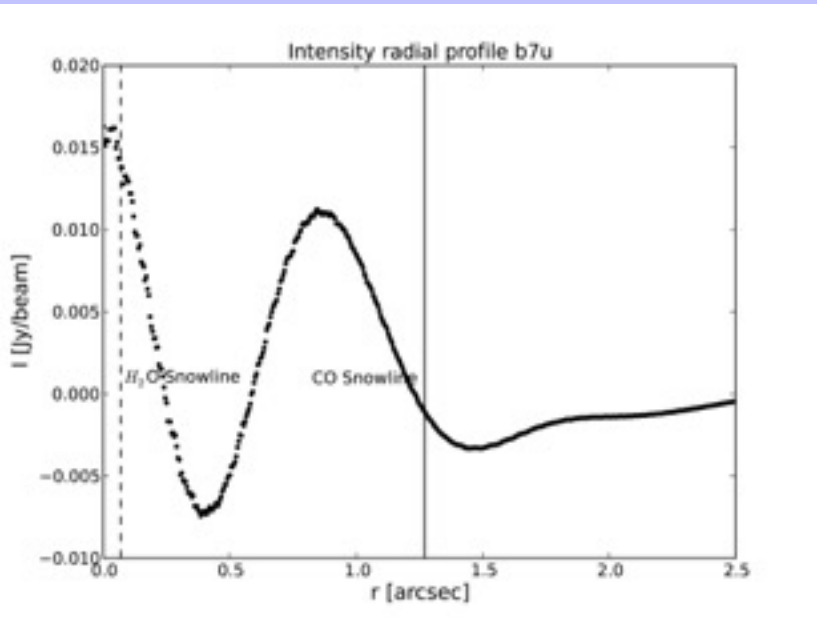
General overestimate of the central fluxes



Residual image 0,835 mm+ 0,866 mm



Residual radial profile 0,835 mm+ 0,866 mm



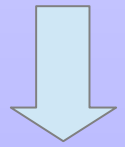
0,851 mm → residuals on a ring-like structure with a peak at r ≈ 0,85" = 100 AU

CONCLUSIONS AND OUTLOOK

- Radial profiles of the spectral index ß from our matched images show a ß < 1 inside ~ 150 AU and ß > 1 outside. This suggests the presence of large grains (at least mm sized) in the inner region and small grains in the outer regions

- A simple polynomial interpolation highlights an excess emission in a region centered at ~ 110 AU

- MCMC fit show a general underestimation of the central flux, and a ring excess emission in 0.850 mm at ~ 100 AU



- Model with a more detailed description of the disk properties (i.e.surface density) in the central regions.

- Observation with an higher sensitivity at longer wavelengths: EVLA 8-9.8 mm with higher signal-to-noise or ALMA Band 3 at 3 mm (high sensitivity and resolution ~ 60 mas in Cycle 3)