Dust grain growth from (sub-)mm interferometry in the Taurus-Auriga and ρ-Oph protoplanetary disks

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Dust grain growth from sub-mm/mm λ

Method: 1) sub-mm/mm SED ➡ α ($F_\lambda \sim \lambda^{-\alpha}$)

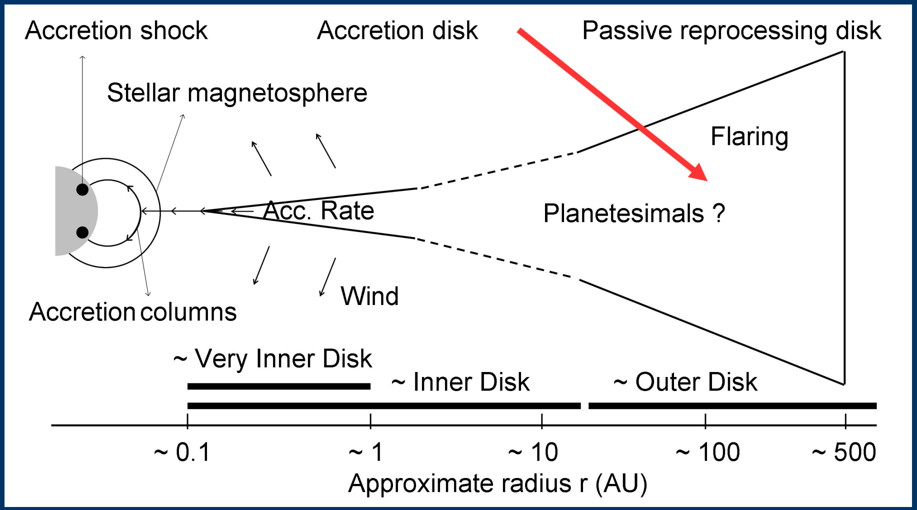
2) info on the disk structure (hi-res interferometry)

➡ estimate for β ($\kappa_\lambda \sim \lambda^{-\beta}$)

IF $\beta < \beta_{ISM} \sim 1.7$ ➡ DUST GRAIN GROWTH

Diagnostic of grain growth:

- up to ~mm/cm-sized grains ($a_{max} \sim \lambda$)
- in the disk midplane (low optical depth)
- in the disk outer regions (R > 50 AU)



Dutrey 2008

Goals and Sample

Extend β-estimates to

- longer λ (λ>1mm, to minimize emission from opt. thick inner regions)
- "fainter" disks (F_{1mm} < 100 mJy, more representative of the whole disk pop.)
- increase the statistics (investigate trends over a homogeneous sample)
- different SFRs (dependence on environment)

New data @3mm:
PdBI: 17 YSOs in Taurus-Auriga (rms ~ 0.3 mJy)
ATCA: 25 YSOs in ρ-Oph (rms ~ 0.4 mJy)

PdBI (French Alps)

ATCA (Narrabri, AUS)

Sample selection criteria:
- class II YSOs (no or very little envelope)
- literature (sub-)mm data + 3mm
- isolated disks (no gravitational tidal effects)

⇨ 43 disks (21 Taurus, 22 ρ-Oph)

From α to β

For a completely optically thin disk, in RJ regime:

$$\beta = \alpha - 2$$

With optically thick inner regions:

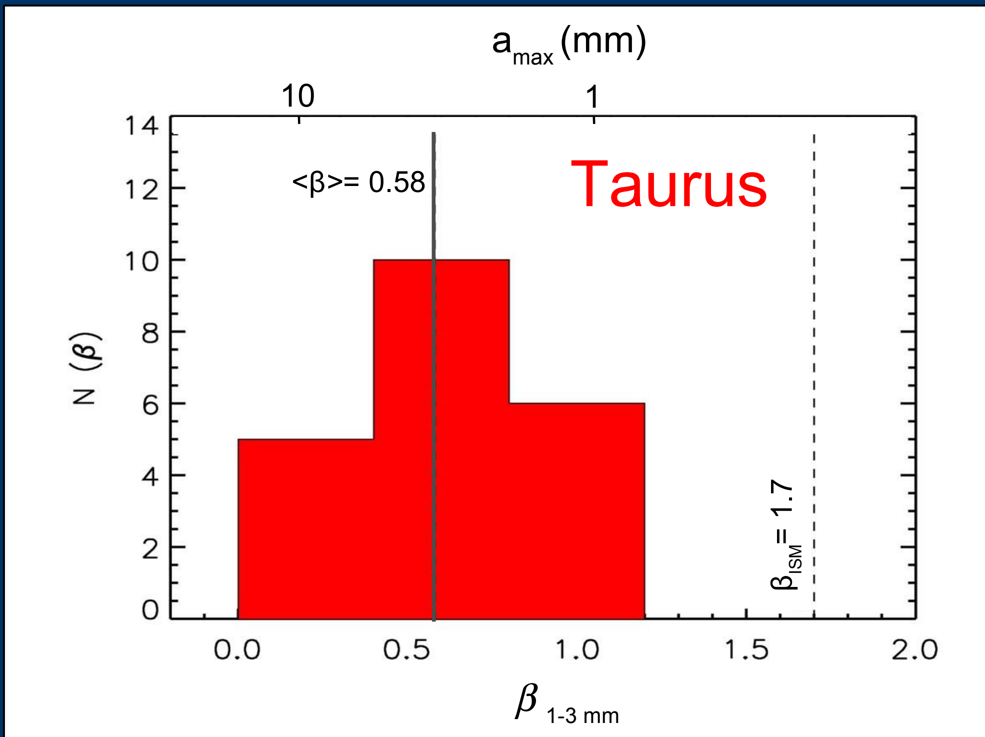
$$\beta > \alpha - 2$$

⬇

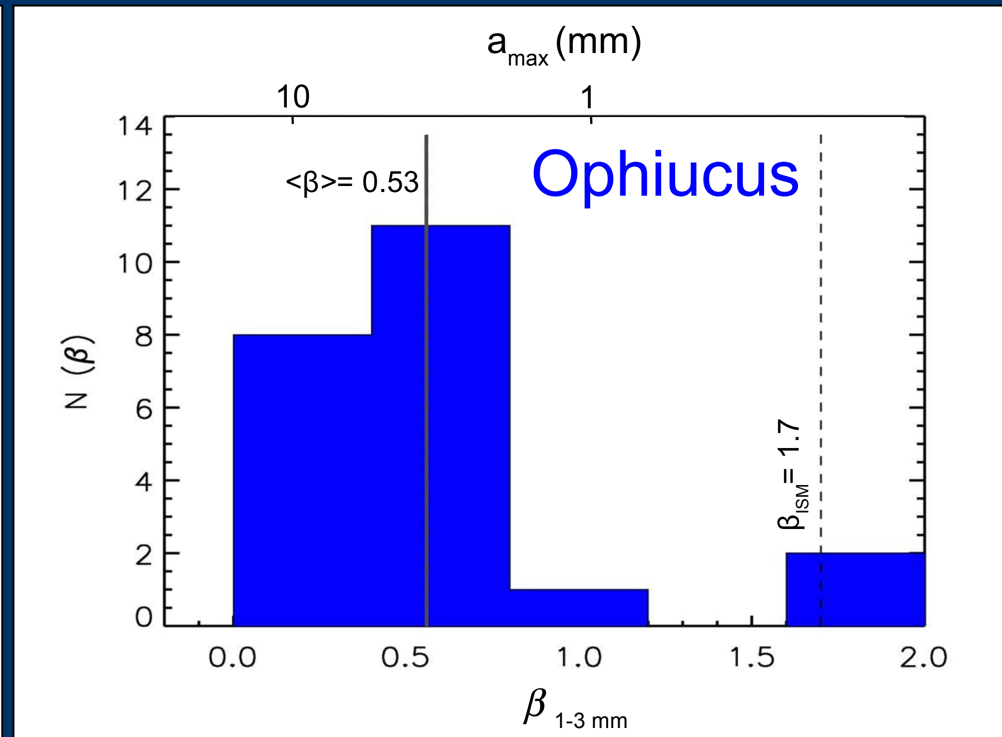
two-layer (surface+midplane) flared passively irradiated disks (Dullemond et al. 2001)

disk outer radii constrained with hi-res interferometric data (e.g. Andrews & Williams 2007, Isella et al. 2009) when available: 55% in our sample, for the others similar outer radii assumed

β-distribution



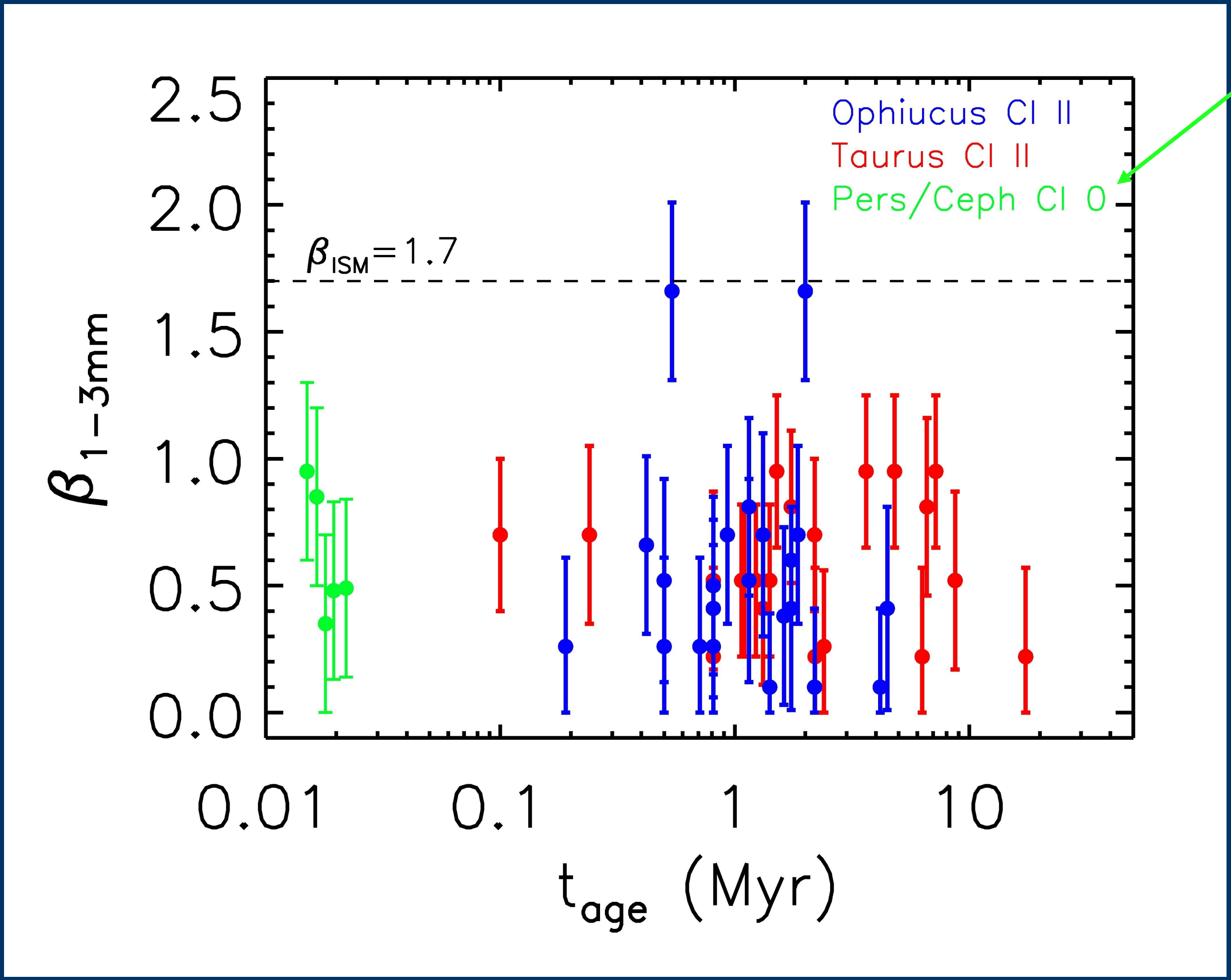
Ricci et al. 2009, submitted to A&A



Ricci et al. 2010, in prep.

- only for 2/43 disks ISM-like dust grains are consistent with the data; a_{max} > 1mm for nearly all the disks
- $<\beta>_{Tau} \approx <\beta>_{Oph}$, but the two distributions are not equal (KS test: 60% that distributions are intrinsically different: disks in Ophiucus statistically with larger grains?)

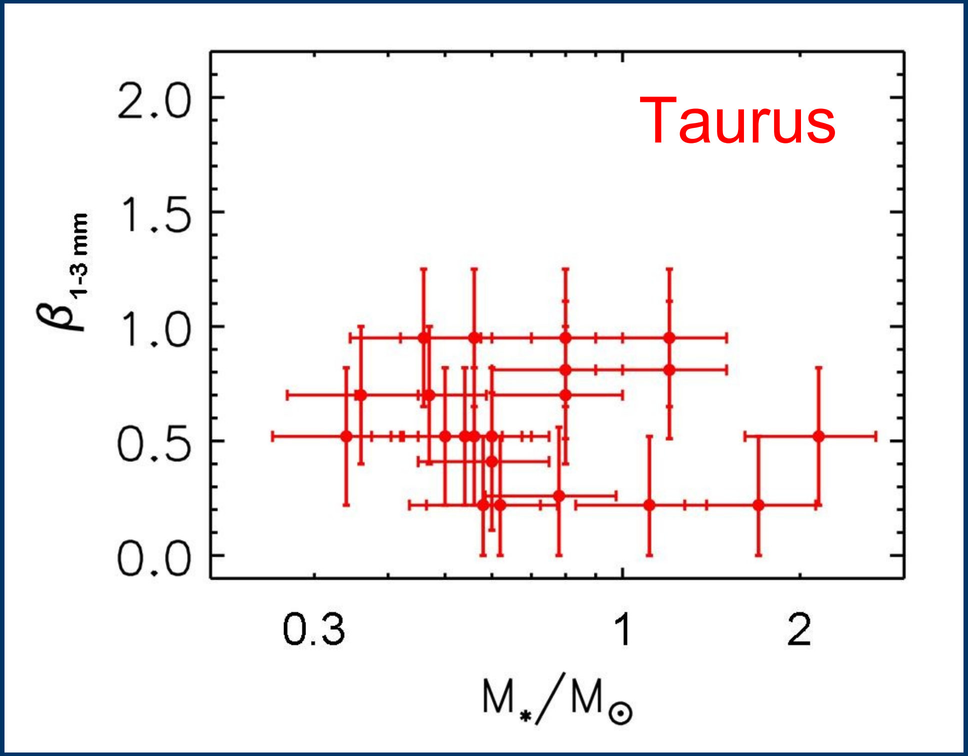
β vs age

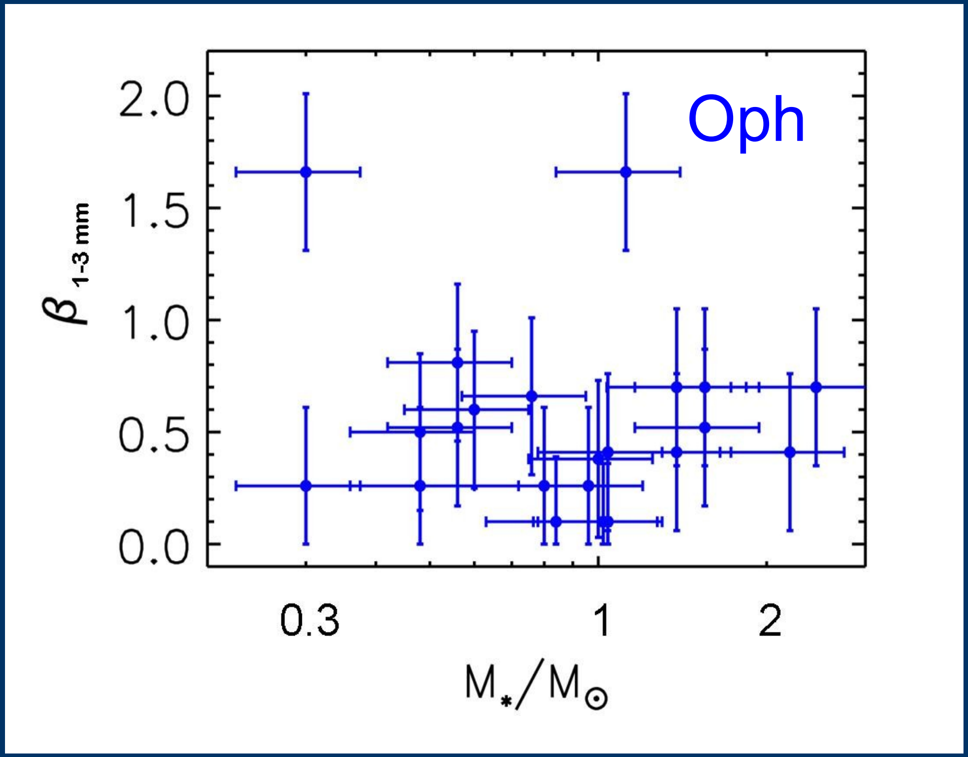


Kwon et al. 2009

- grains grown to ~mm sizes very early on
- presence of large grains stationary (vs short timescale of inward radial drift)

β vs stellar properties





no significant trends between β and stellar properties (e.g. M_{Star}, L_{Star}, $\dot{M}$) for $0.3 < M_{Star} < 2\ M_{Sun}$

Summary

Investigation of the mm dust opacity spectral index β over a homogeneous sample of 43 isolated Class II T-Tauri disks in Taurus-Auriga and ρ-Ophiucus

- for 41/43 disks the derived $\beta_{1\text{-}3mm}$ are consistent with the presence of ~mm-size dust grains in the disk outer regions (Rodmann et al. 2006)
- large dust grains appear to form early on in the star formation history and their presence is stationary throughout all the Class II evolutionary stage
- $\beta_{1\text{-}3mm}$ does not correlate with stellar properties
- are the β-distributions in Taurus and ρ-Oph intrinsically different?

⇨ Need for more data (ALMA, EVLA, CARMA, PdBI, ATCA)