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MULTI-WAVELENGTH CHARACTERIZATION OF RING SUBSTRUCTURES IN HD 169142

DISK SUBSTRUCTURES IN THE PLANET FORMATION PARADIGM

- Disk substructures are mostly ubiquitous (e.g., talks by J. Huang, G. Herczeg, L. Pérez).

- Could be a key piece of the dust evolution process:

Dust radial drift + fragmentation → Maximum particle size of ~1 m

Solution: non-smooth gas distributions

i.e., pressure bumps to trap the dust.

ARE SUBSTRUCTURES THE SMOKING OF DUST TRAPS?

Substructures

- Dust trap
  - Planet-disk interaction (e.g., Zhu et al. 2014).
  - MHD effects (e.g., Flock et al. 2015)
- No pressure bump
  - Grain growth across snowlines (e.g., Pinilla et al. 2017)
  - Dust sintering (Okuzumi et al. 2016)

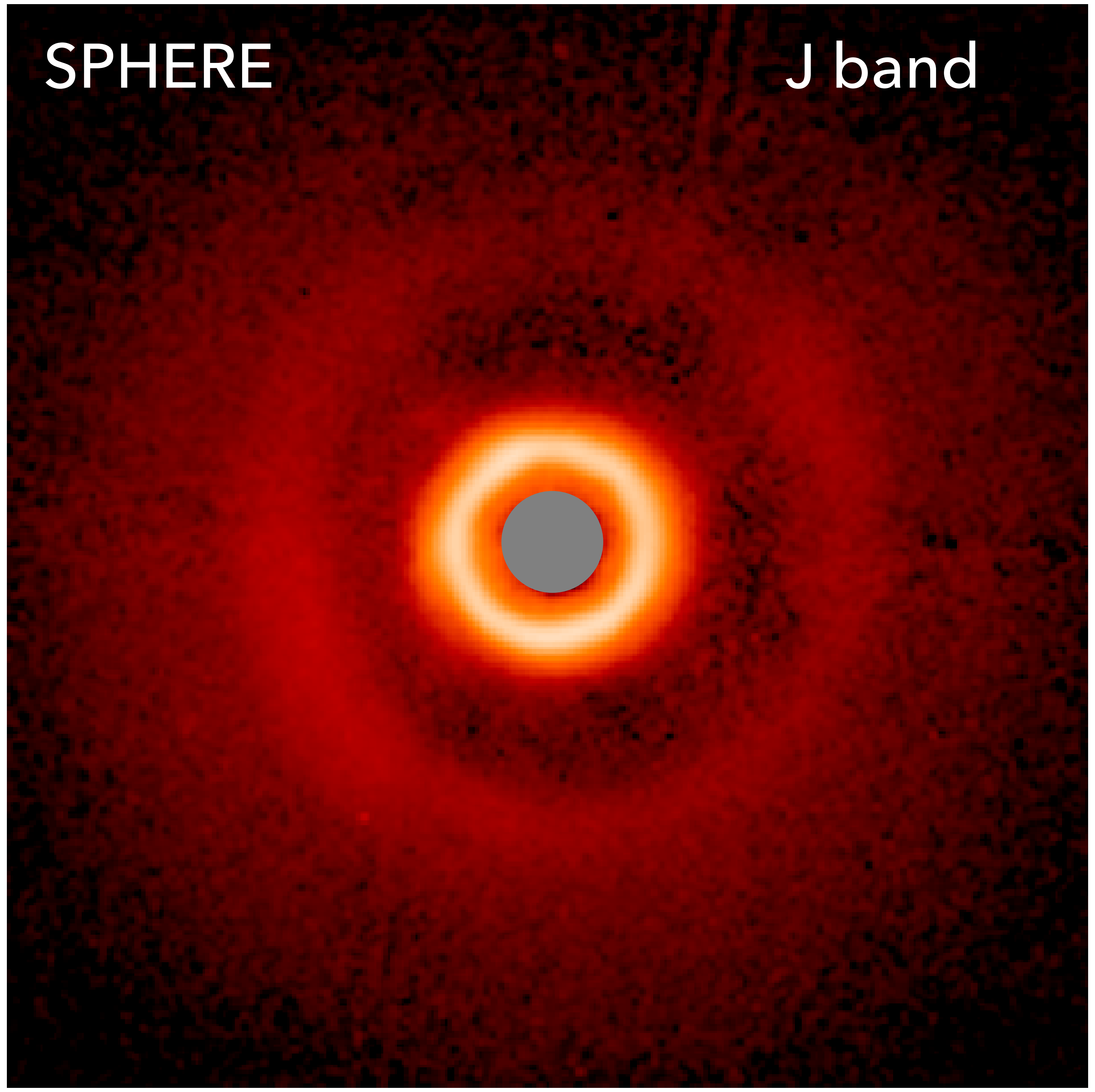
- Are disk substructures the smoking gun of dust traps?
- Are substructures enhancing the dust growth?

Characterizing dust content of substructures is key to understand their origin and role.

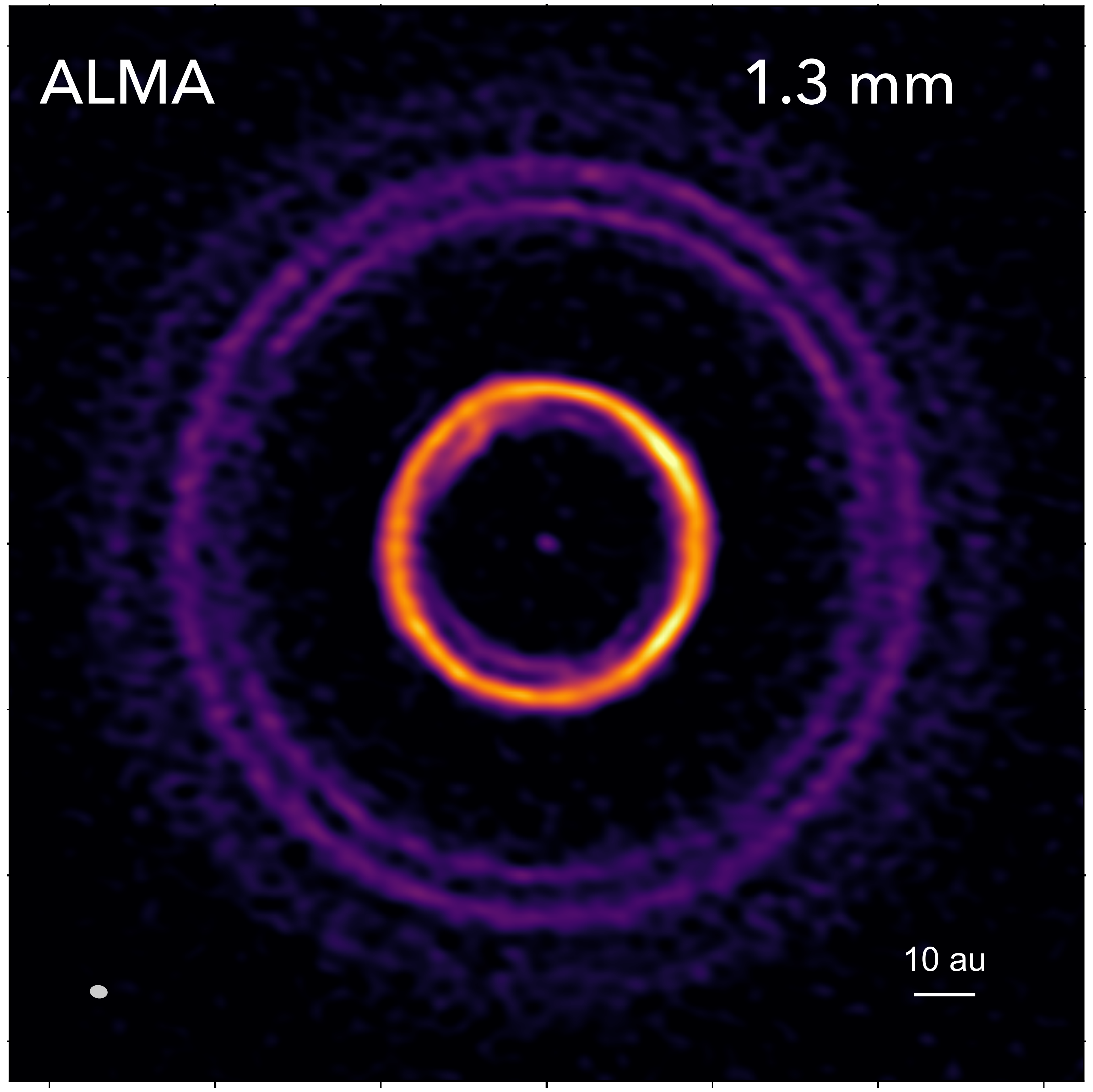
↓

Multi-wavelength observations in the (sub-)mm

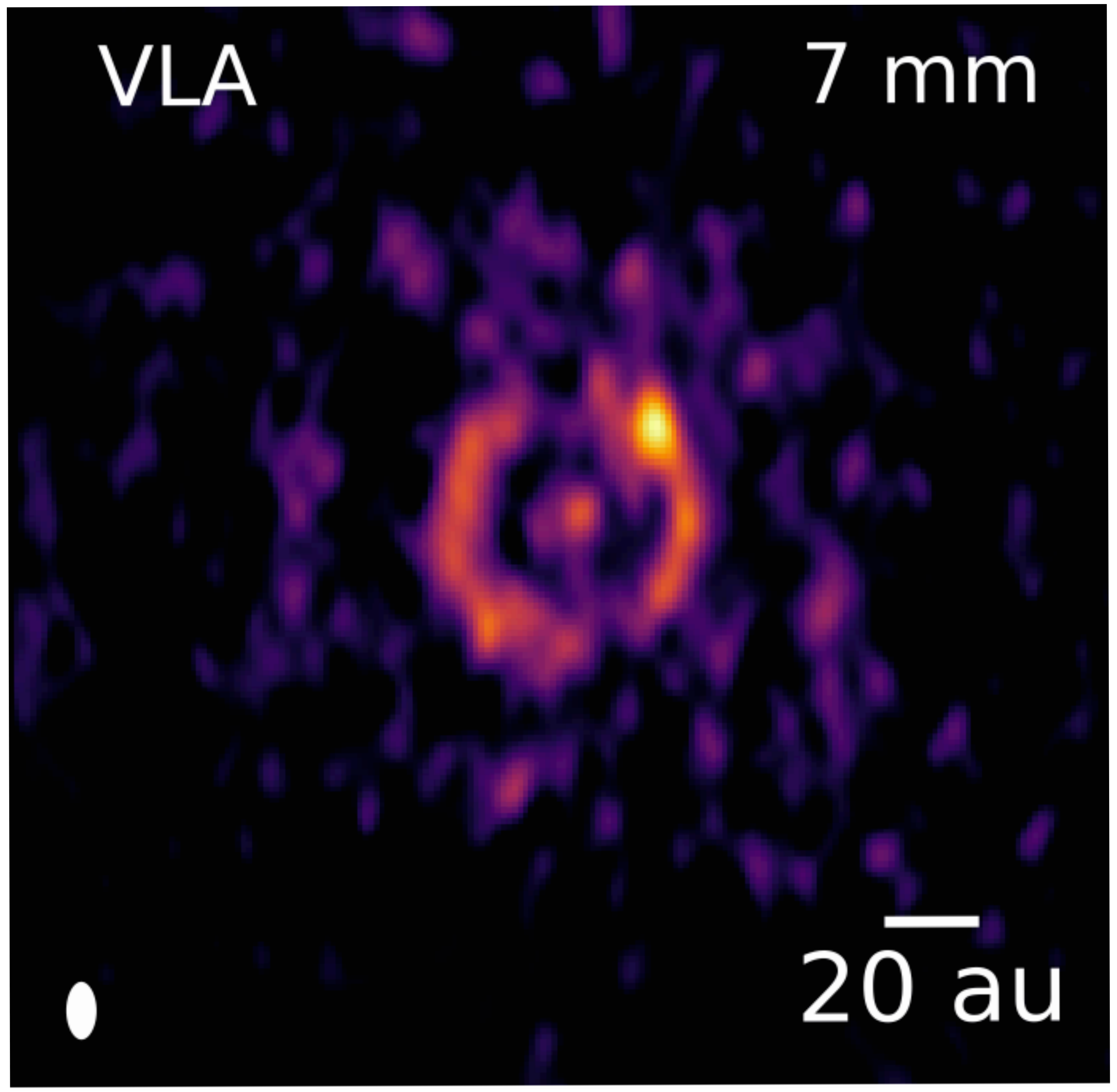
HD 169142



Pohl et al. (2017)



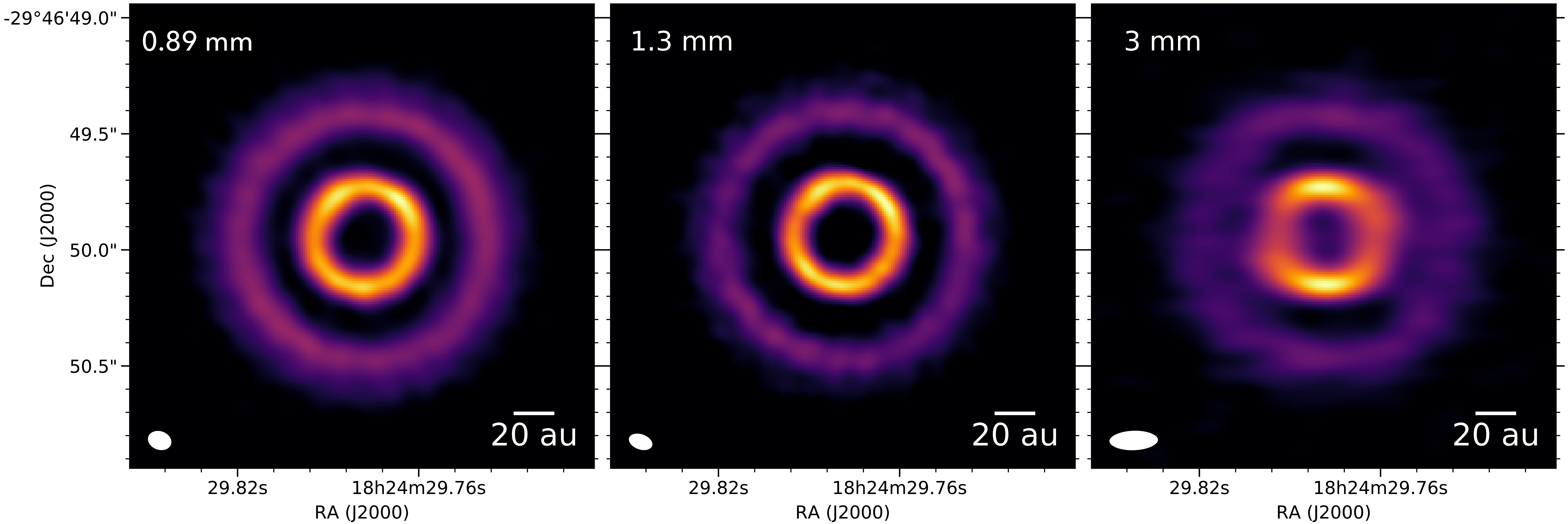
Talk by S. Pérez; Pérez et al. (2019)



Macias et al. (2017)

MULTI-WAVELENGTH ALMA OBSERVATIONS

- Archival band 7 (0.89 mm) and 6 (1.3 mm) data.
- New band 3 (3 mm) observations.
- Angular Resolution ~0.1 arcsec (~12 au)



-29°46'49.0"
49.5"
50.0"
50.5"
Dec (J2000)
0.89 mm
1.3 mm
3 mm
20 au
29.82s
18h24m29.76s
RA (J2000)
Average Intensity (mJy/beam)
Radius (arcsec)
B1
B2
B3
B4

MULTI-WAVELENGTH ANALYSIS

Spectral behavior of dust opacity depends on the dust particle size distribution.

Dust opacity:

$$\kappa_\nu \propto \nu^\beta$$

- $\beta \sim 1.6 - 1.8$ ISM-size
- $\beta \sim 0 - 1$ mm/cm

$$\tau_\nu[r] = \tau_0[r] \left(\frac{\nu}{\nu_0}\right)^{\beta[r]}$$

- Gray body:

$$I_\nu[r] = B_\nu(T_d[r]) \left(1 - e^{\tau_\nu[r]}\right)$$

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- Gray body:

$$I_\nu[r] = B_\nu(T_d[r]) \left(1 - e^{\tau_\nu[r]}\right)$$

$T_d[r]$ → Power law

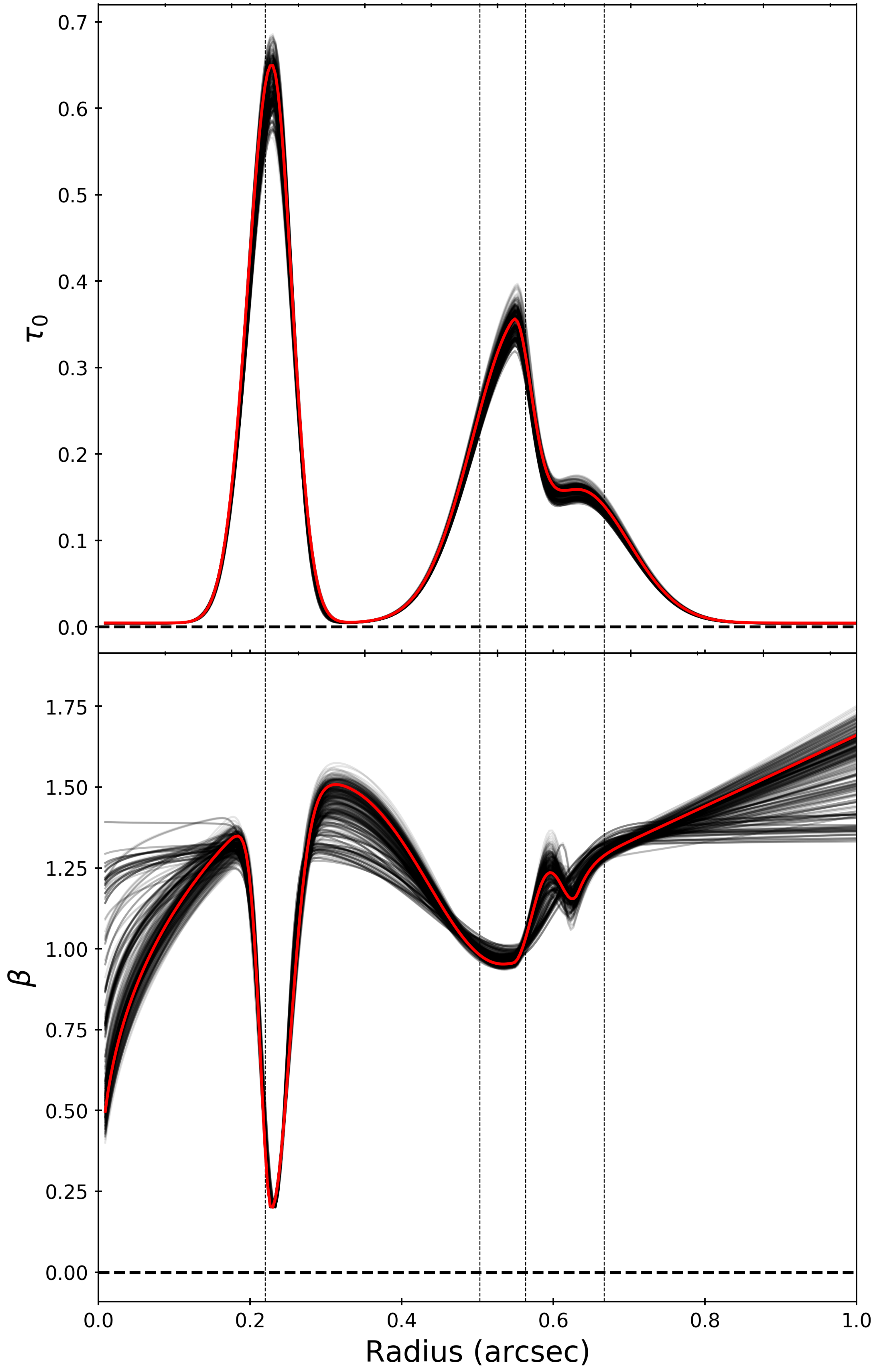
$\tau_0[r]$ $\beta[r]$ → Power law + 3 rings

+ inclination, PA, position offsets

MCMC

RINGS AS ACCUMULATIONS OF PEBBLES

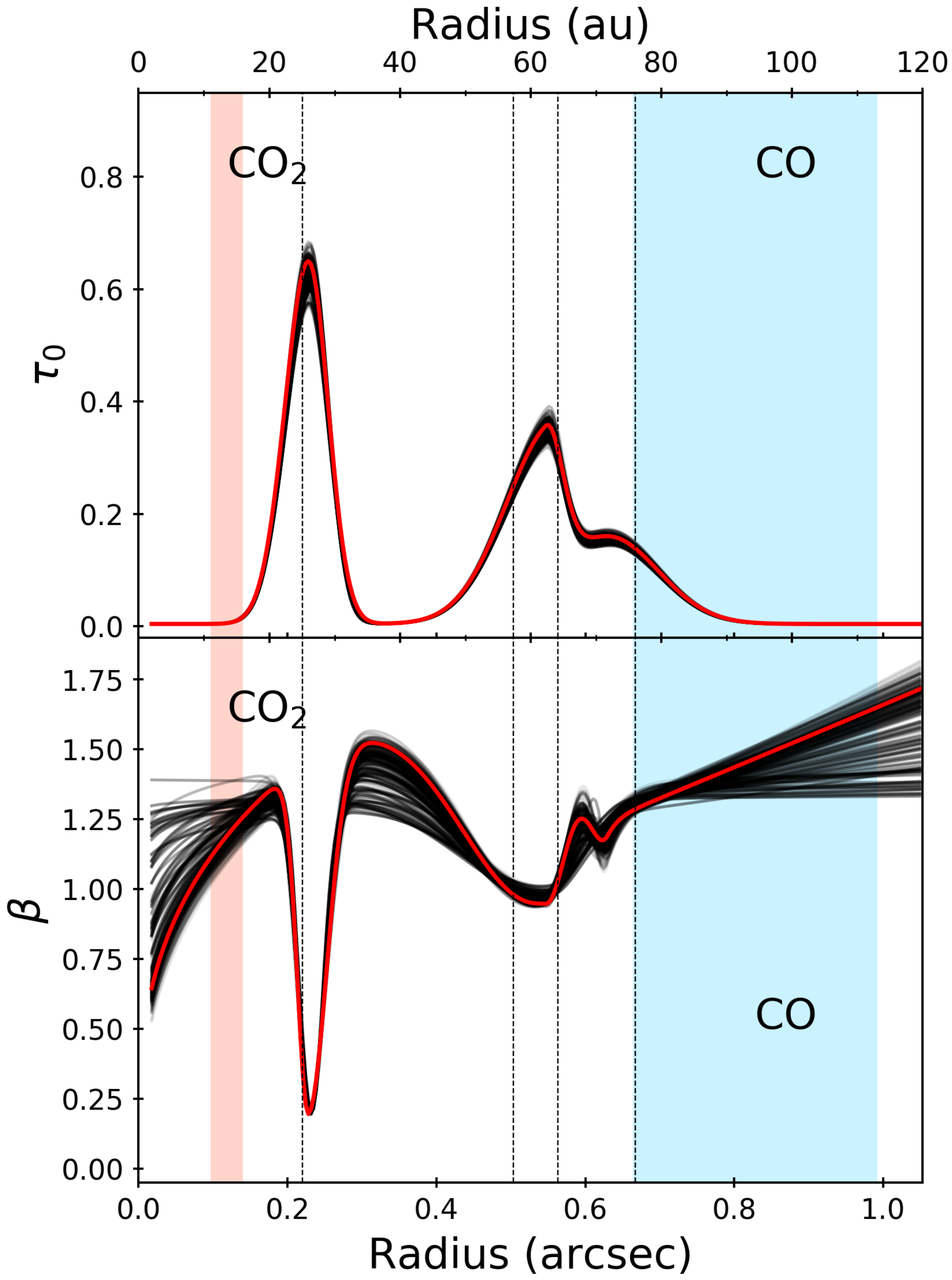
- The three rings are reproduced with increases in optical depth and decreases in beta → accumulations of large dust grains.



Macias et al. in press

RINGS AS ACCUMULATIONS OF PEBBLES

- The three rings are reproduced with increases in optical depth and decreases in beta → accumulations of large dust grains.
- We can discard snowlines as a main driver of substructures.
- Rings are likely associated with pressure bumps.
- Disk probably harbors multiple giant planets (Pohl et al. 2017; Bertrang et al. 2018).



Macias et al. in press

DUST PARTICLE SIZE DISTRIBUTION

- Dust opacities as in DSHARP (Birnstiel et al. 2018) and $n(a) \propto a^{-p}$

Max grain size: a_{max}

Size distribution slope: p

→ β, κ_0

Dust surface density: Σ_d →

κ_0, Σ_d → τ_0

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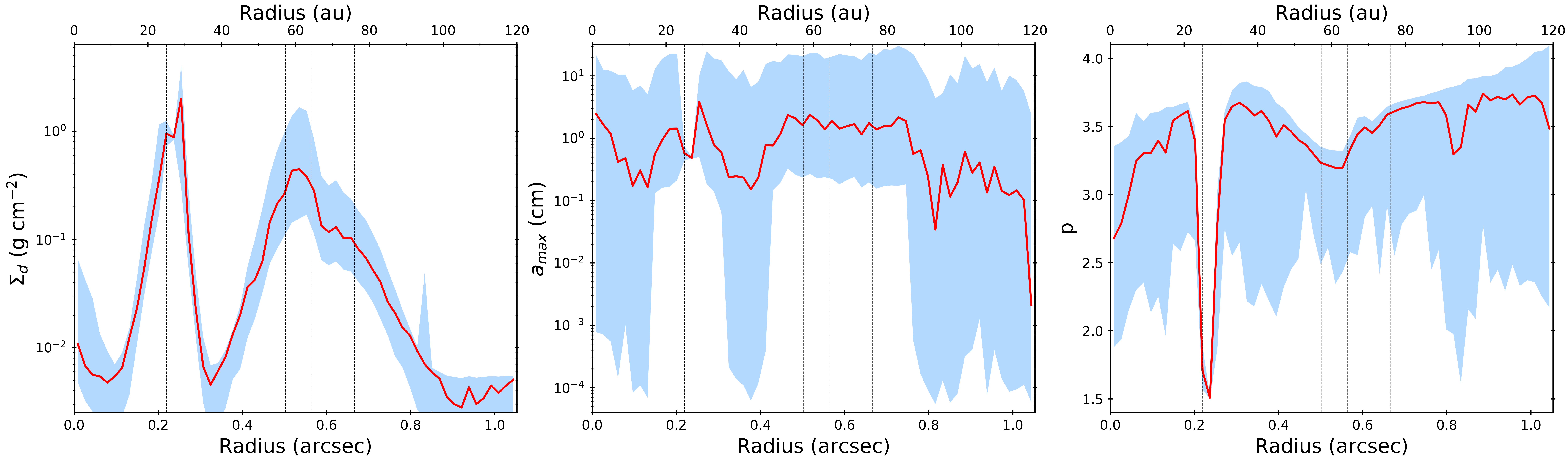
Size distribution slope: p

Dust surface density: Σ_d

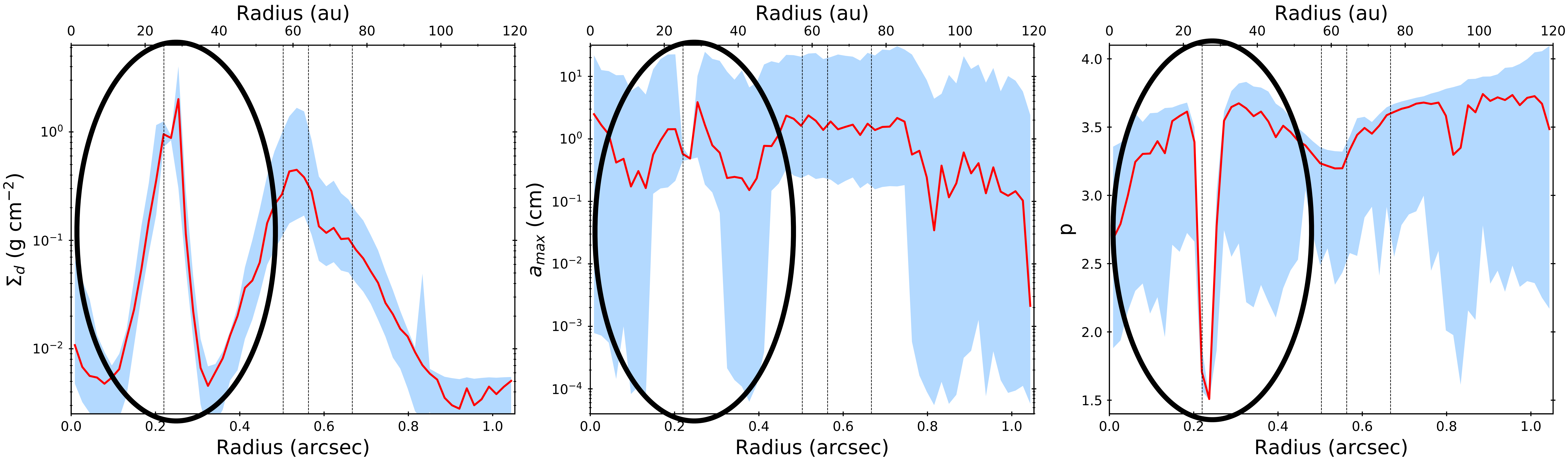
a_{max}, p → β, κ_0

κ_0, Σ_d → τ_0

- Dust mass = $160^{+250}_{-90}\ \mathrm{M}_{\oplus}$
- Maximum grain size: 2 mm - 20 cm
- p = 3.5 in gaps (ISM-like)



INNER RING HARBORS A STRONG BUILD-UP OF LARGE PARTICLES



- τ_0 ~ 0.7
- β ~ 0.25

- Max grain size ~1 cm
- Slope p~1.5
- dust-to-gas mass ratio ~ 1 (with Σ_g from Fedele et al. 2017).

→

- Streaming instability?
- Scattering?

Macias et al. in press

SUMMARY & CONCLUSIONS

- ALMA ~0.1″ (~12 au) data at 0.89 mm, 1.3 mm, and 3 mm of HD 169142.
- Discard: snowlines as the origin of main substructures in HD 169142.
- Confirm: substructures are associated with pressure bumps trapping large particles: potential sites for further planetesimal formation.
- Inner ring might contain appropriate conditions for streaming instability.
- Future prospects:
  - More targets.
  - More resolution: Cycle 6 ~0.05″ @ 3 mm (PI: Macias).
  - (More) scattering.
  - More wavelengths: VLA.

THANKS!