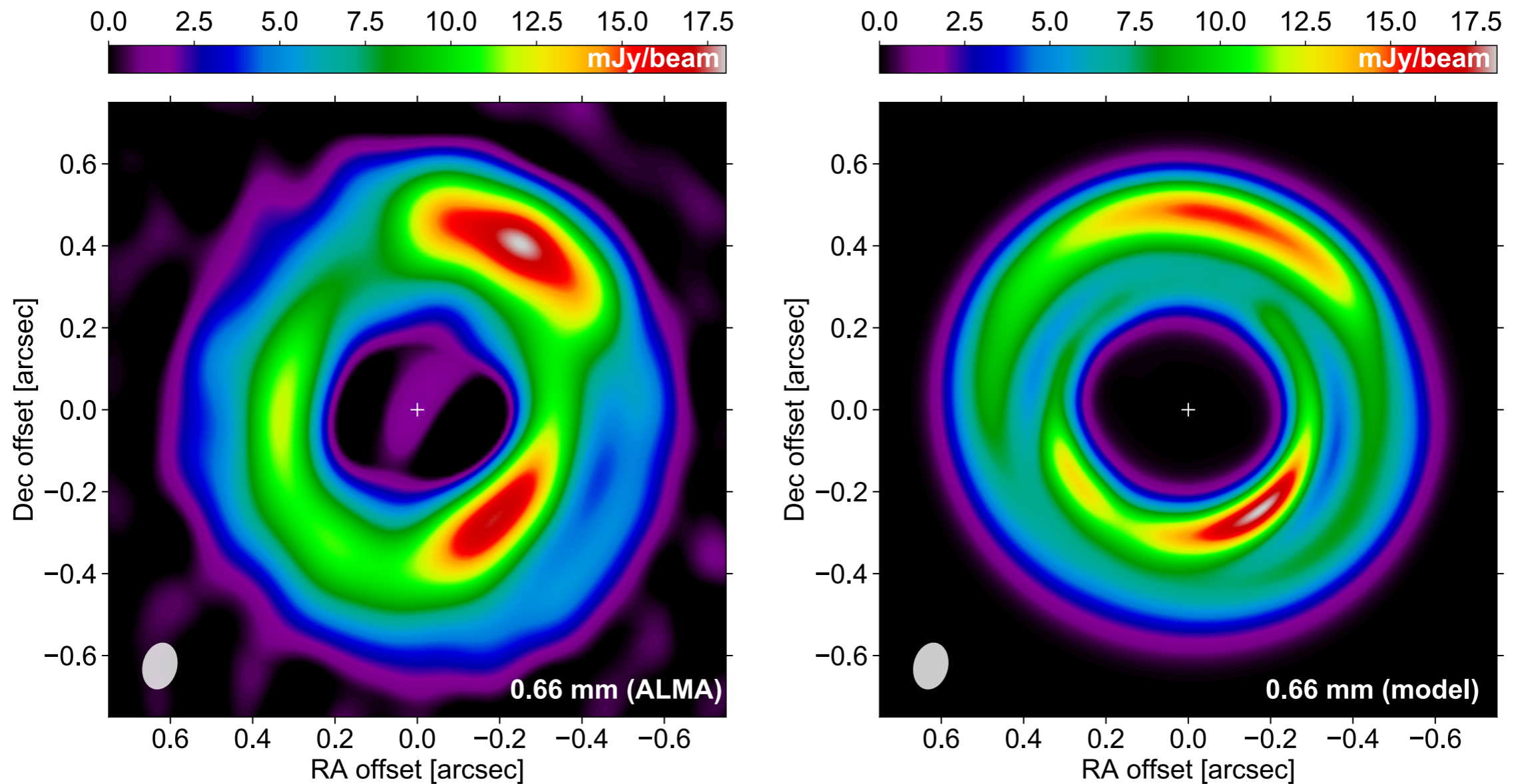


Observational predictions of the presence of giant planets in the dust's radio emission of protoplanetary discs

Clément Baruteau (CNRS/IRAP, Toulouse)



Observed and synthetic images of the continuum emission in the **MWC 758 disc** at $\lambda \sim 0.6$ mm

Observational predictions of the presence of giant planets in the dust's radio emission of protoplanetary discs

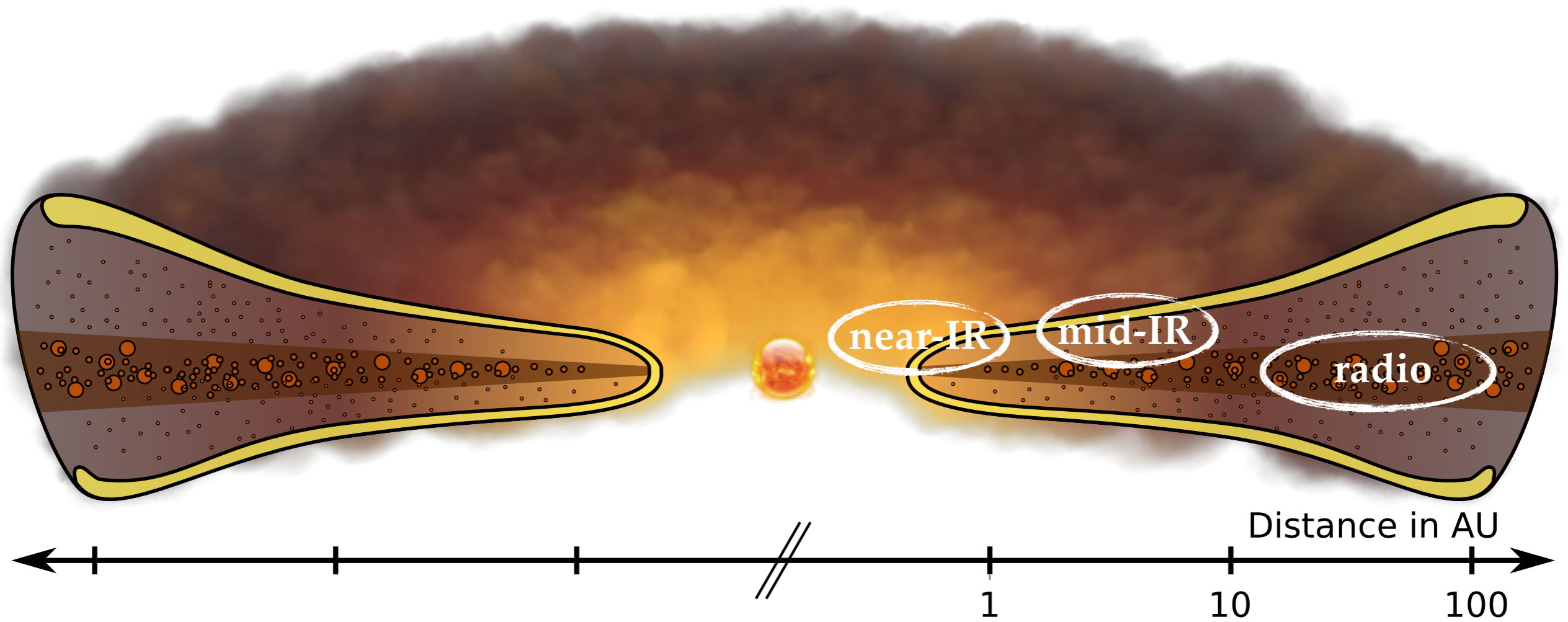
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- Structures in protoplanetary discs
- MWC 758: an archetypal transition disc?
 - ✦ observational constraints
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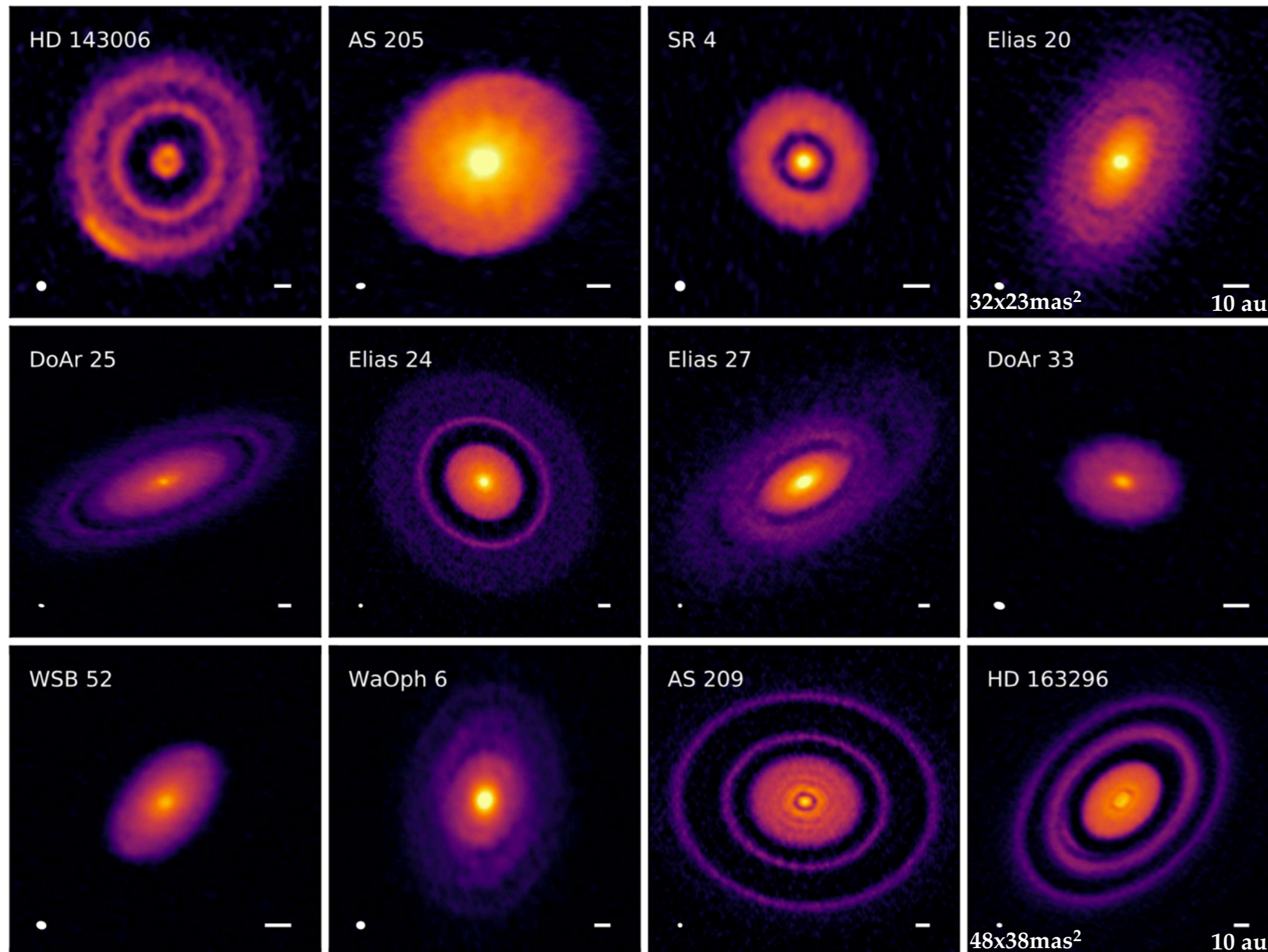
T. Birnstiel

Structures in protoplanetary discs

- Spatially resolved observations indicate that **radial discontinuities** and (large-scale) **asymmetries** may be **common** features of the continuum **emission** of protoplanetary discs

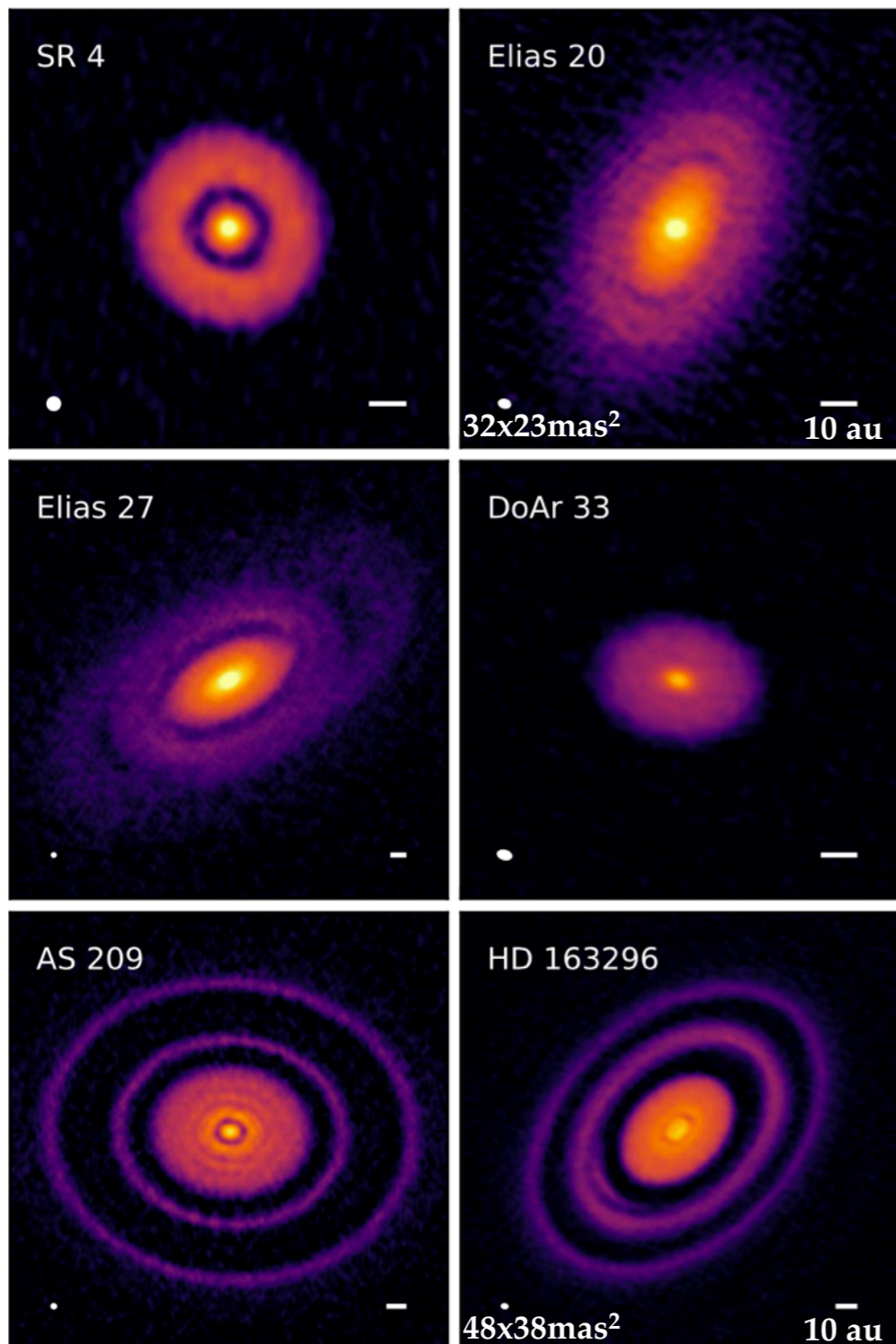
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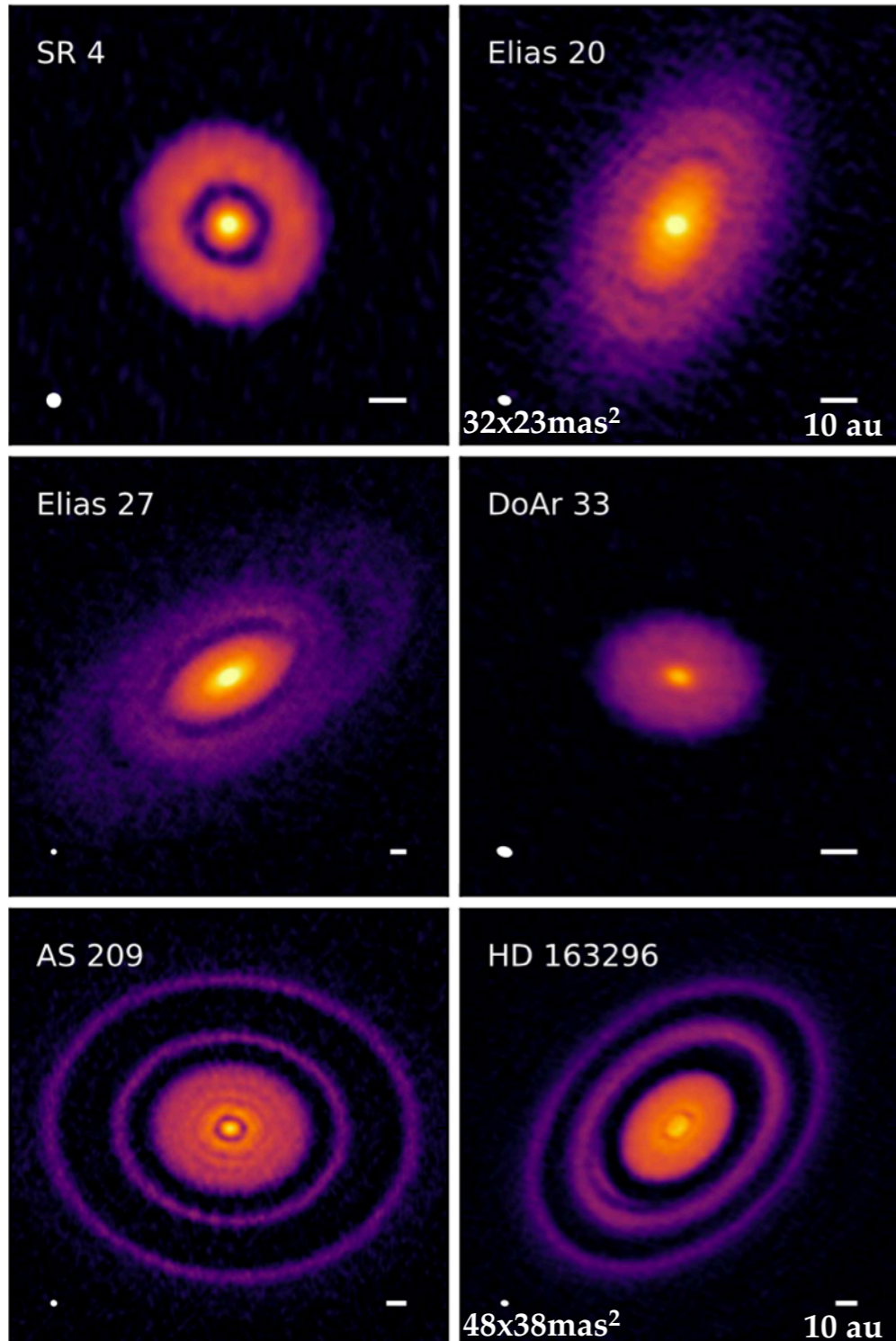
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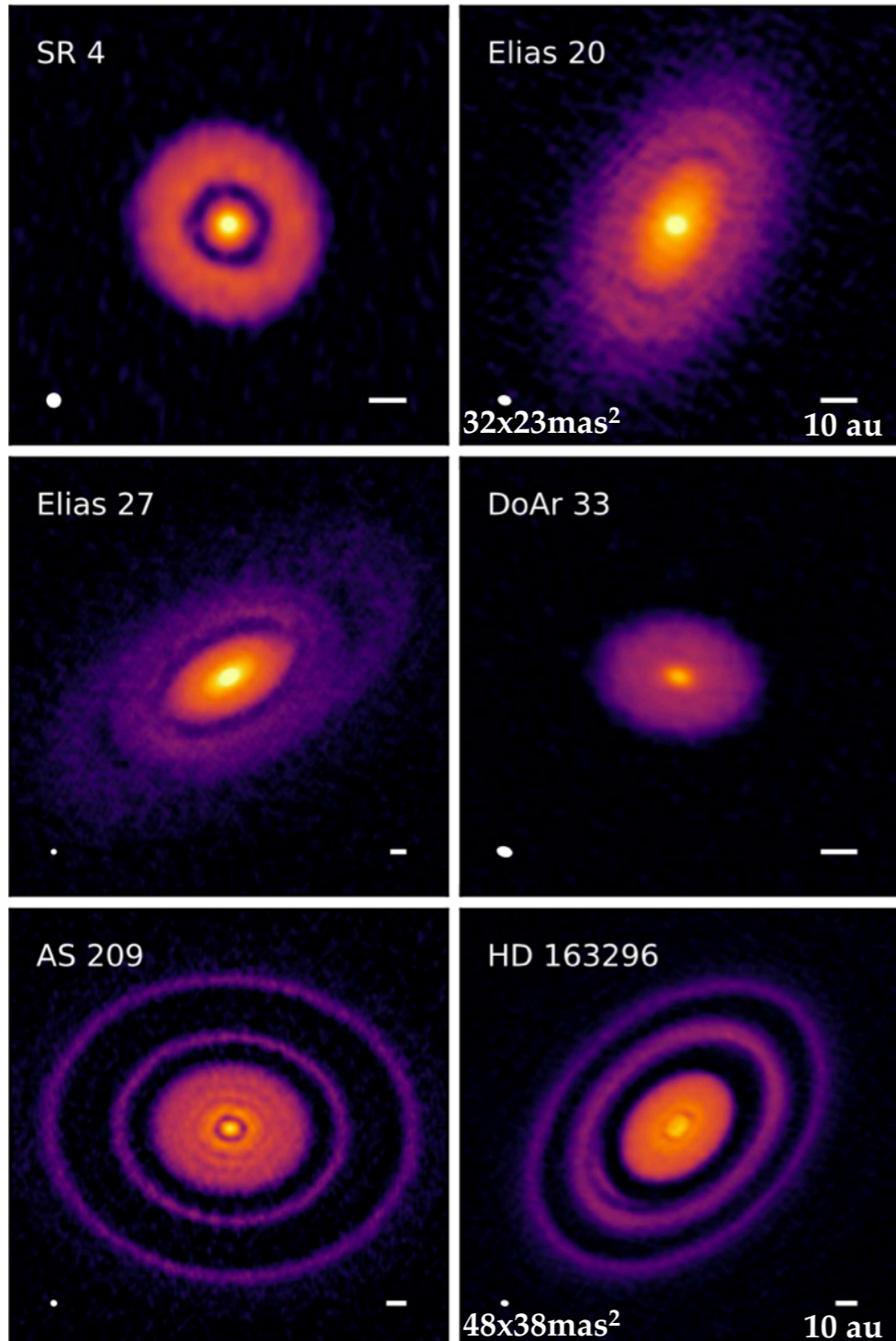


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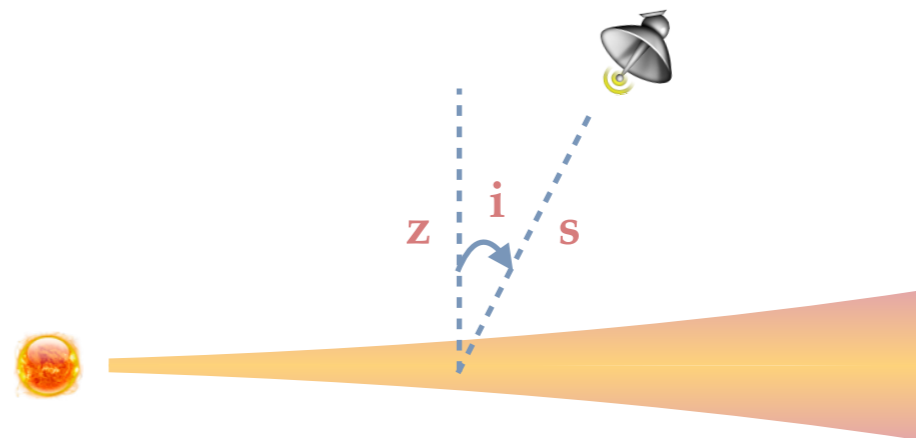


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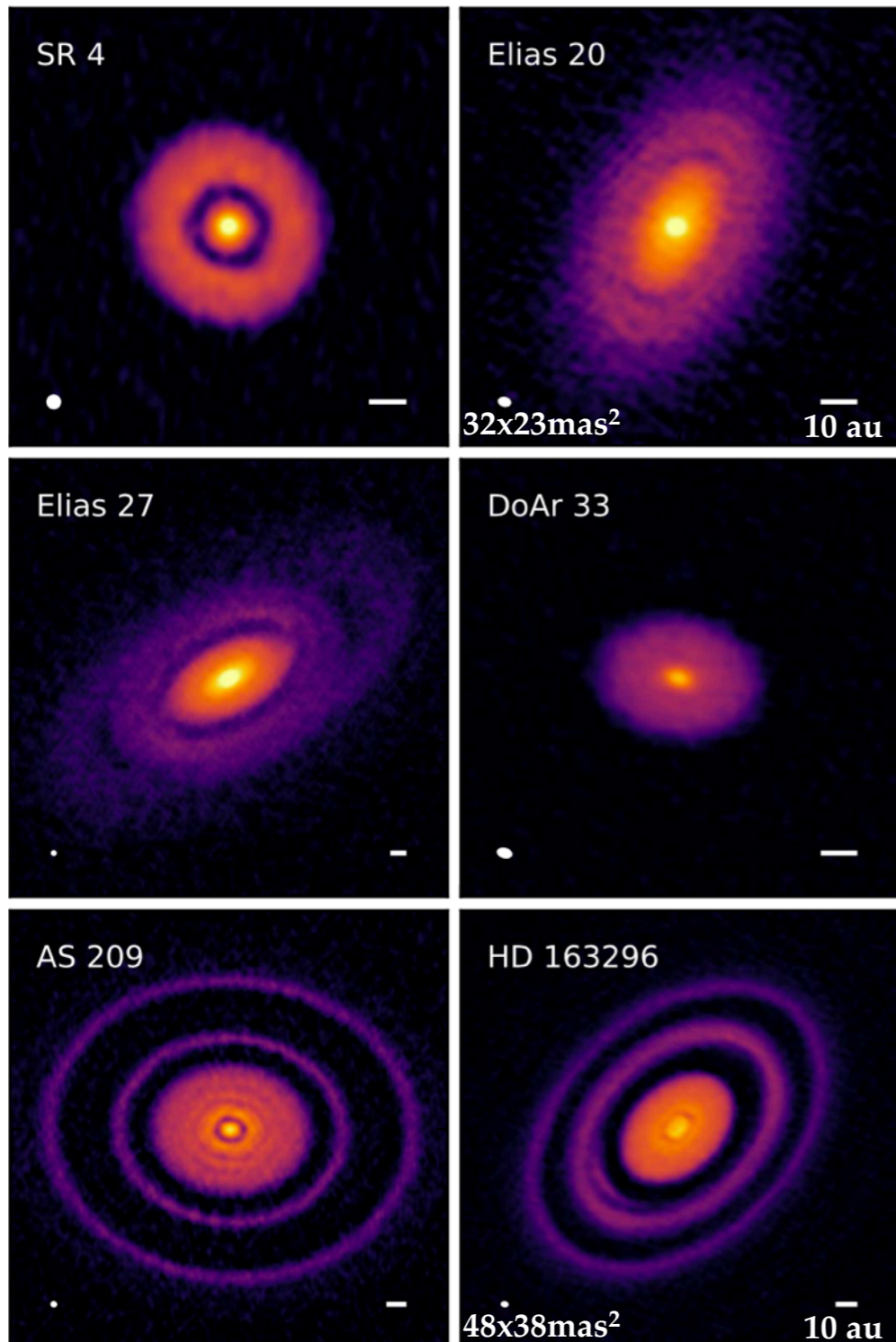
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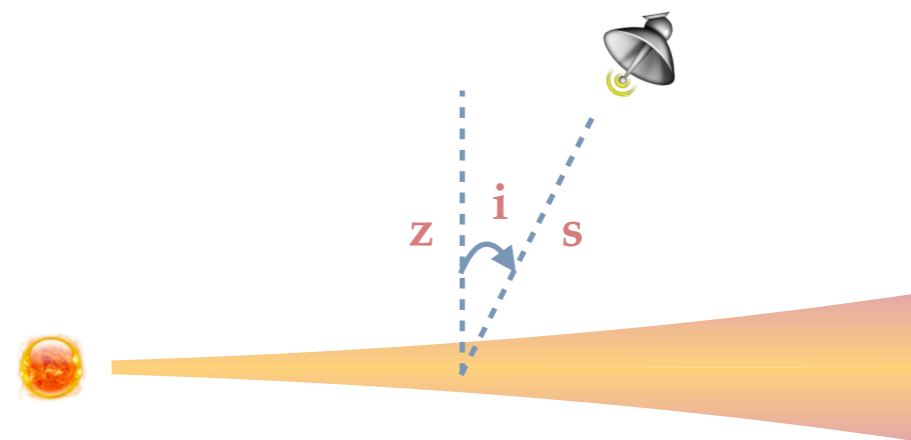


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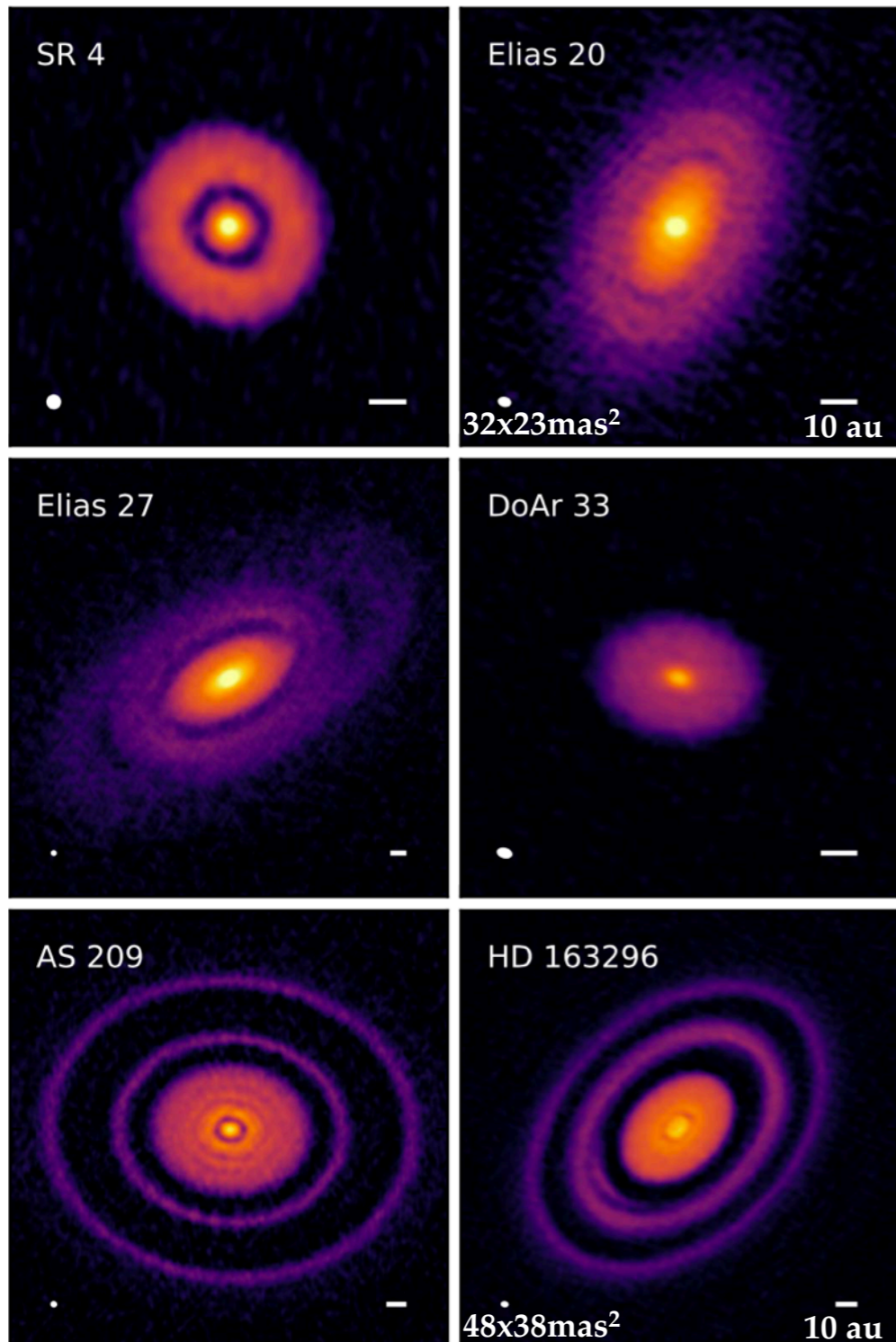
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\uparrow \uparrow
 $= dz / \cos(i)$ dust's surface density



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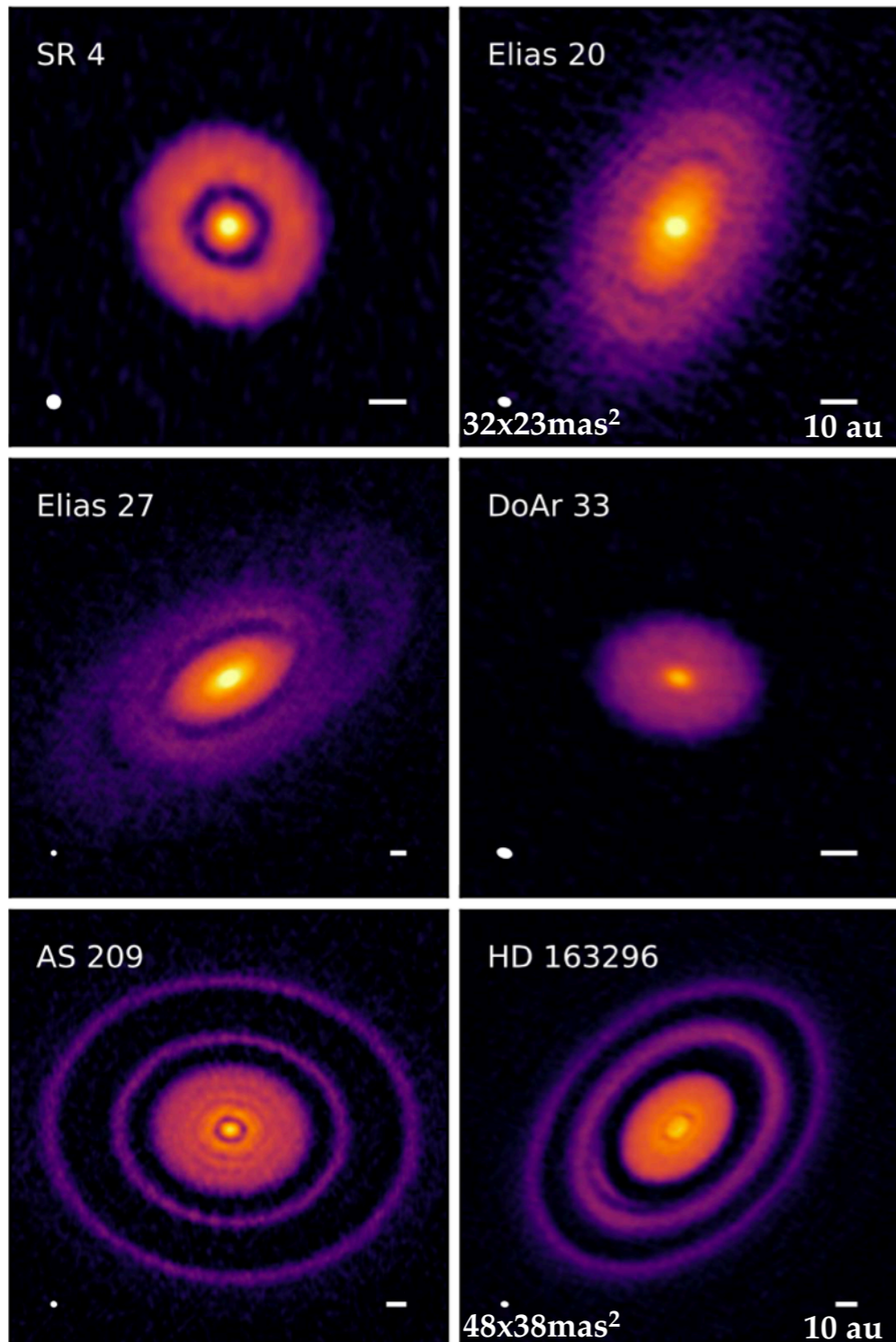
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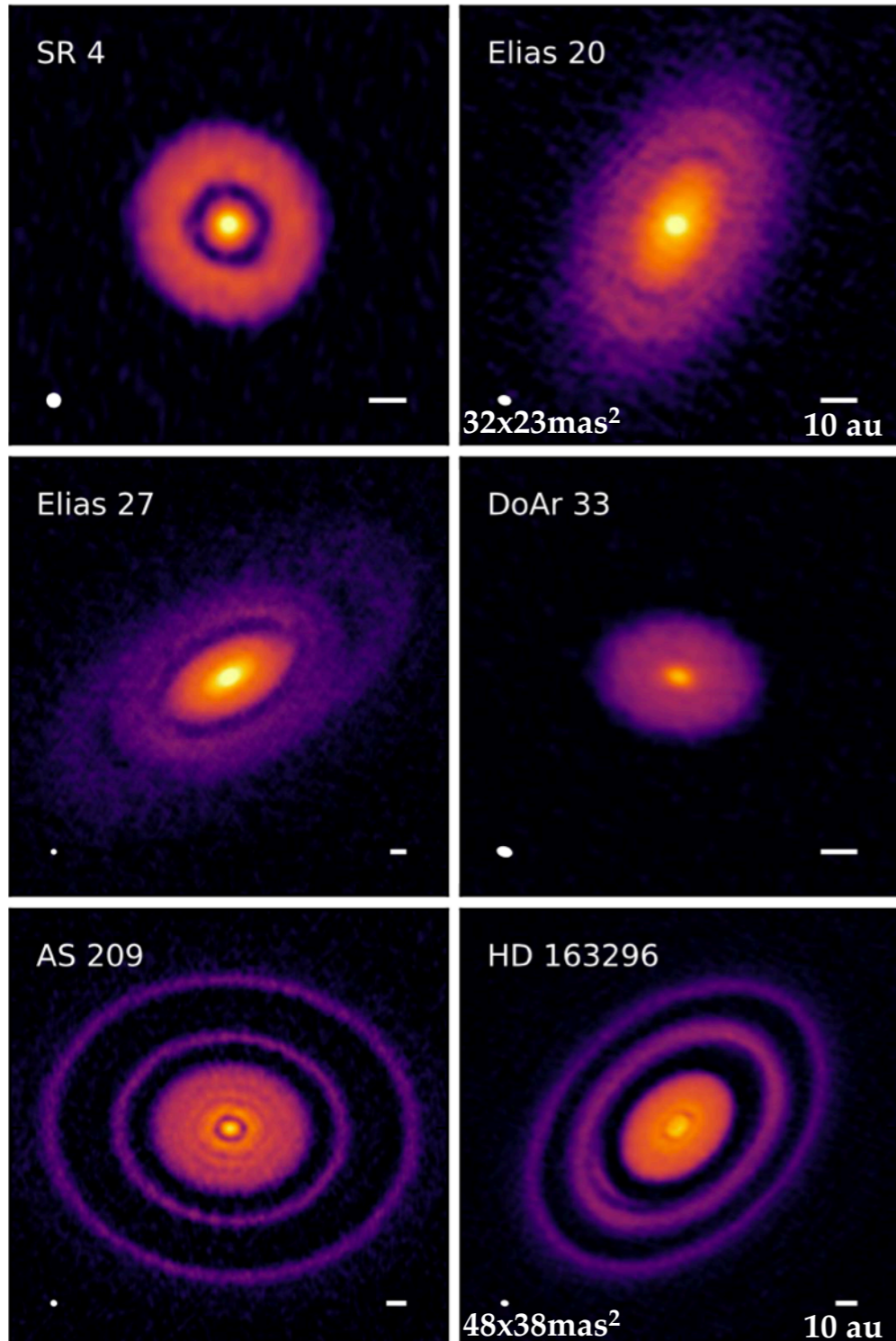
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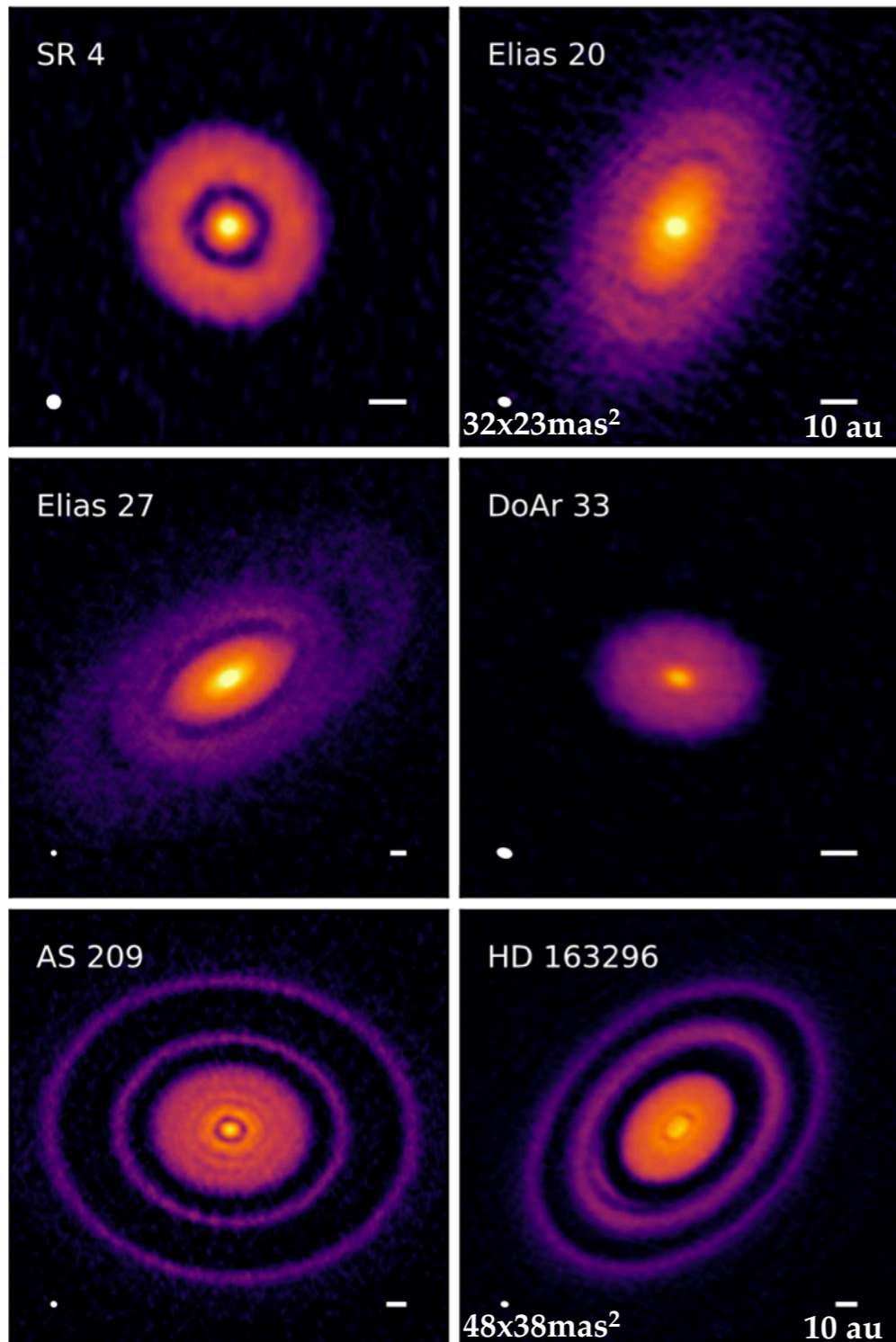
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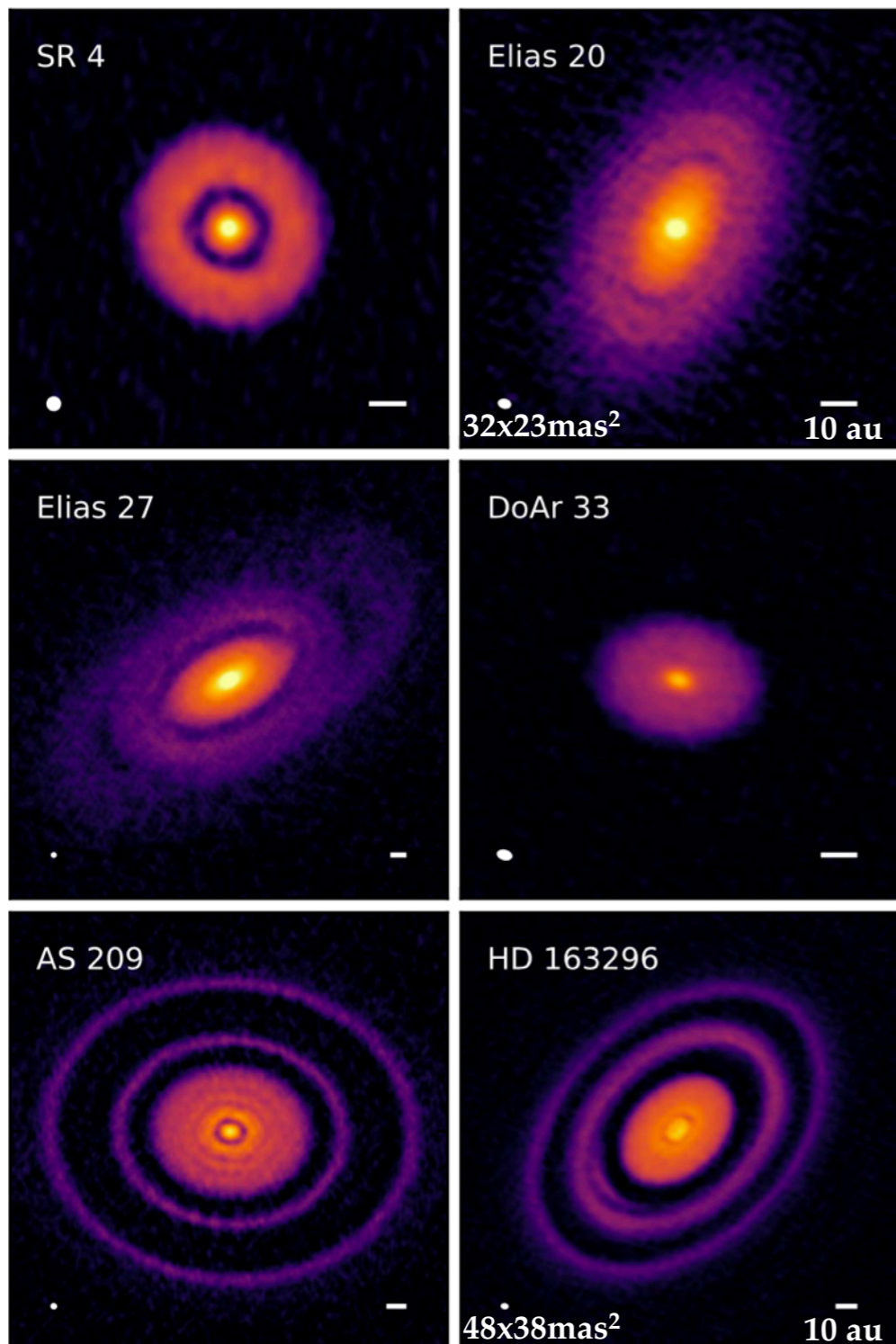
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- ! dust and gas may have **different** spatial distributions and temperatures

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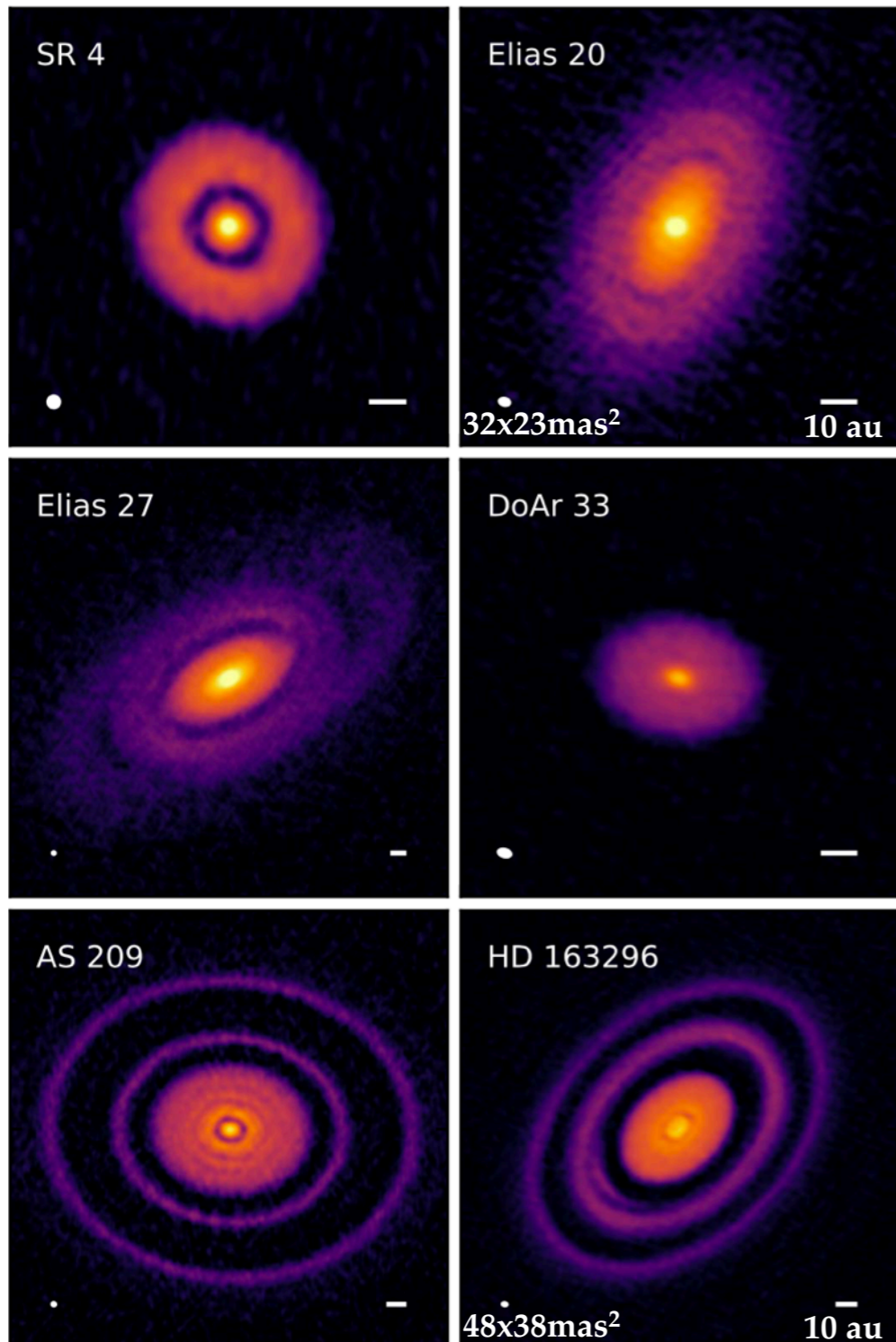
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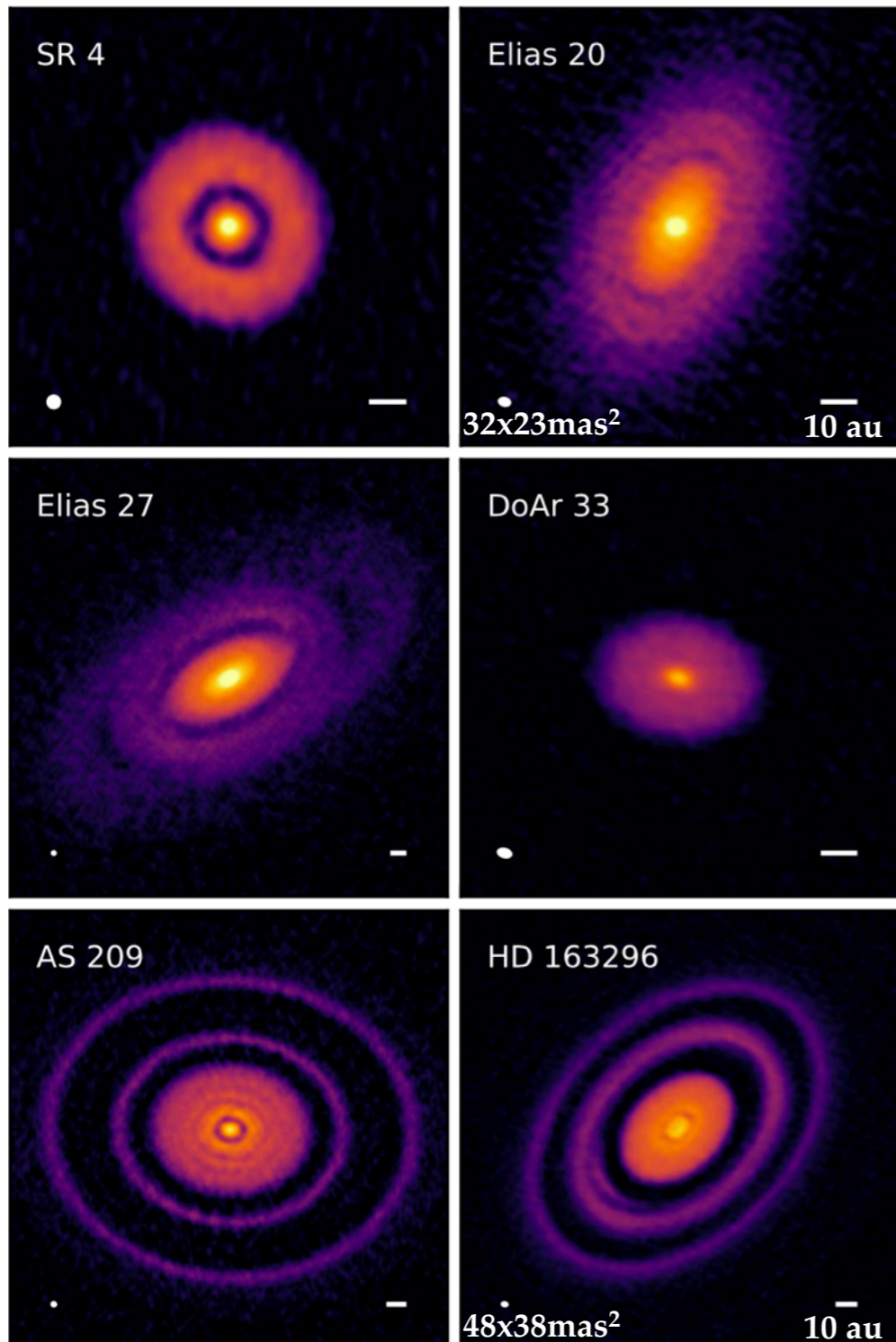
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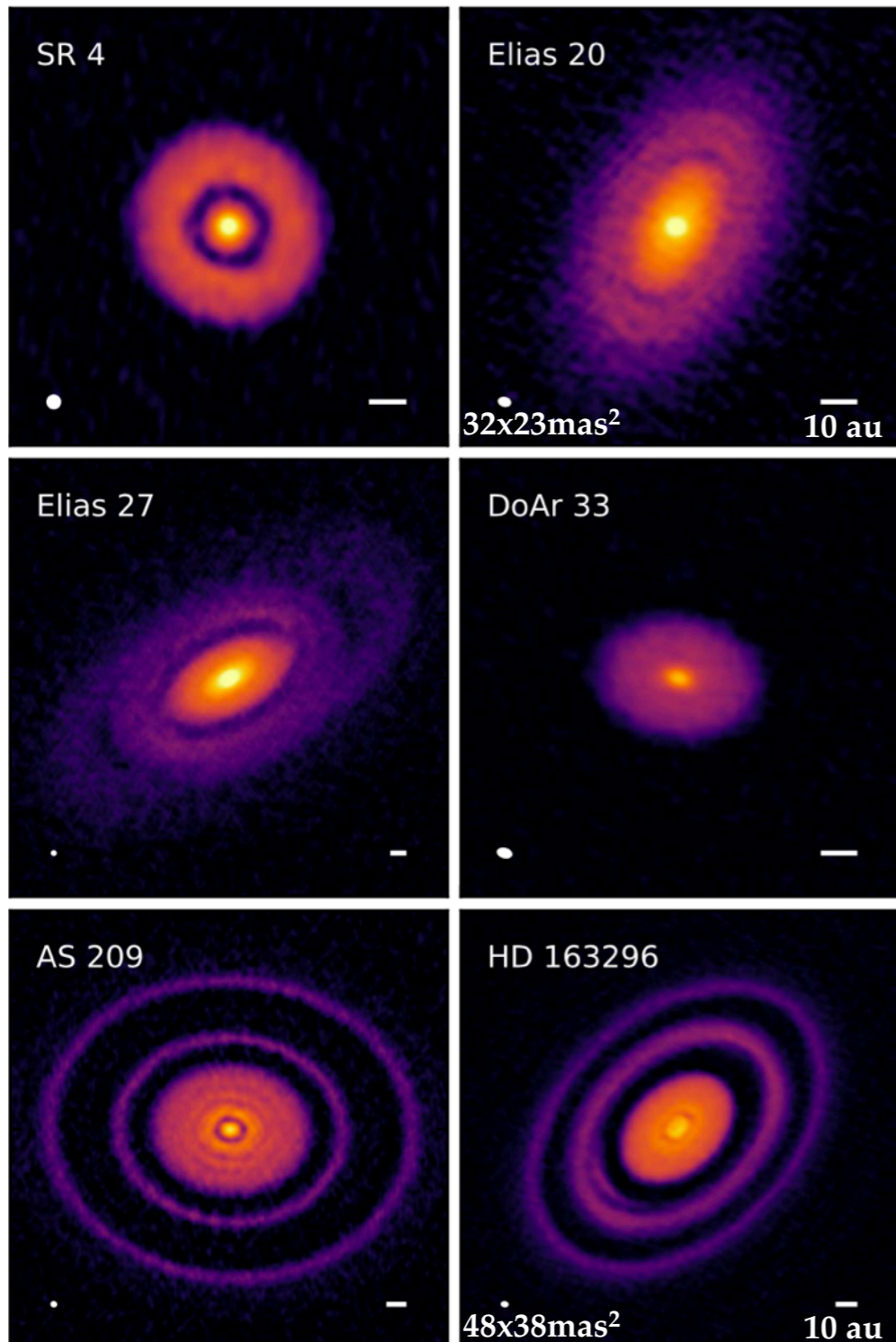
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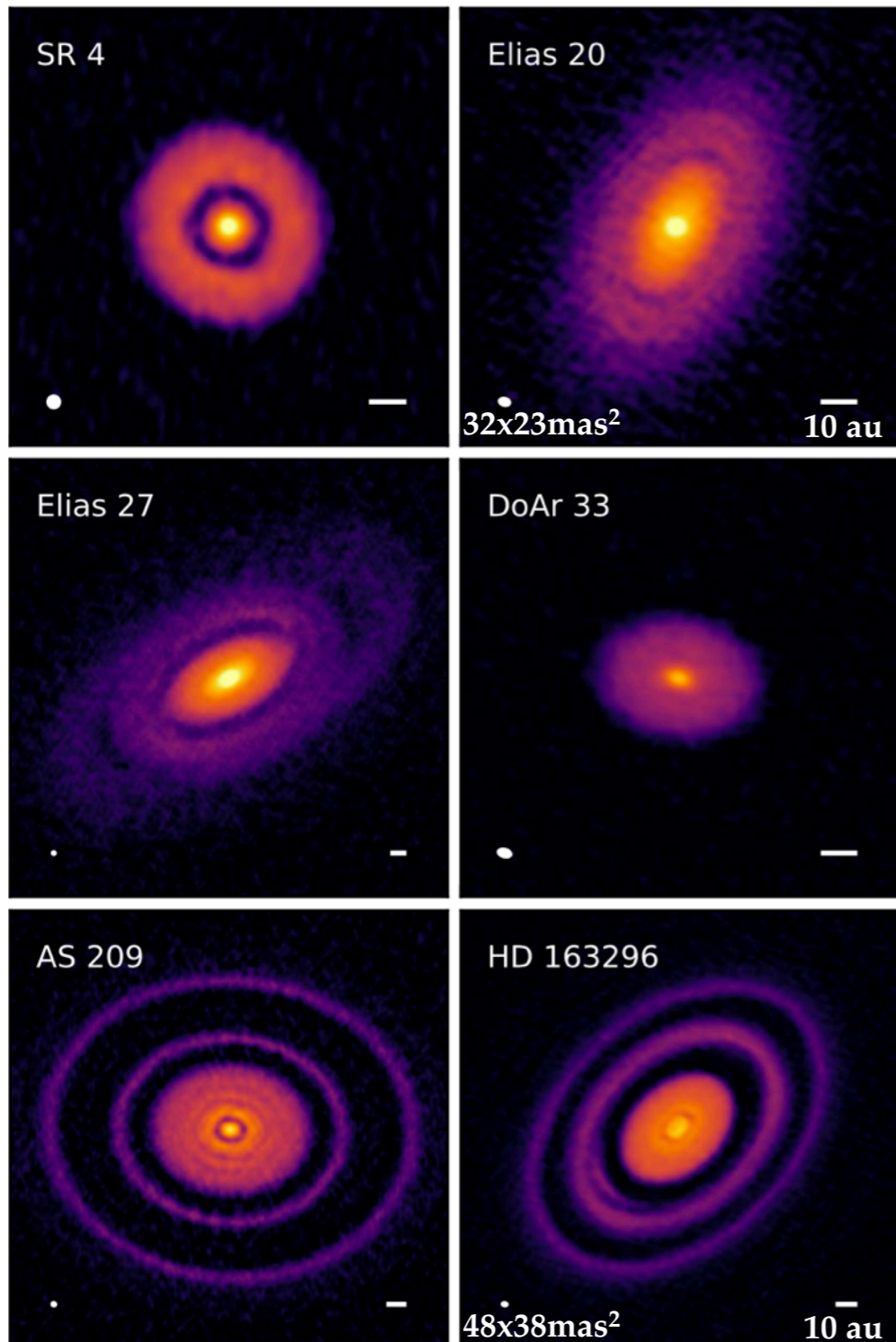
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 - ❖ need for **multi-wavelength** observations to constrain these structures and disentangle the various scenarios

Observational predictions of the presence of giant planets in the dust's radio emission of protoplanetary discs

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MWC 758: an archetypal transition disc?

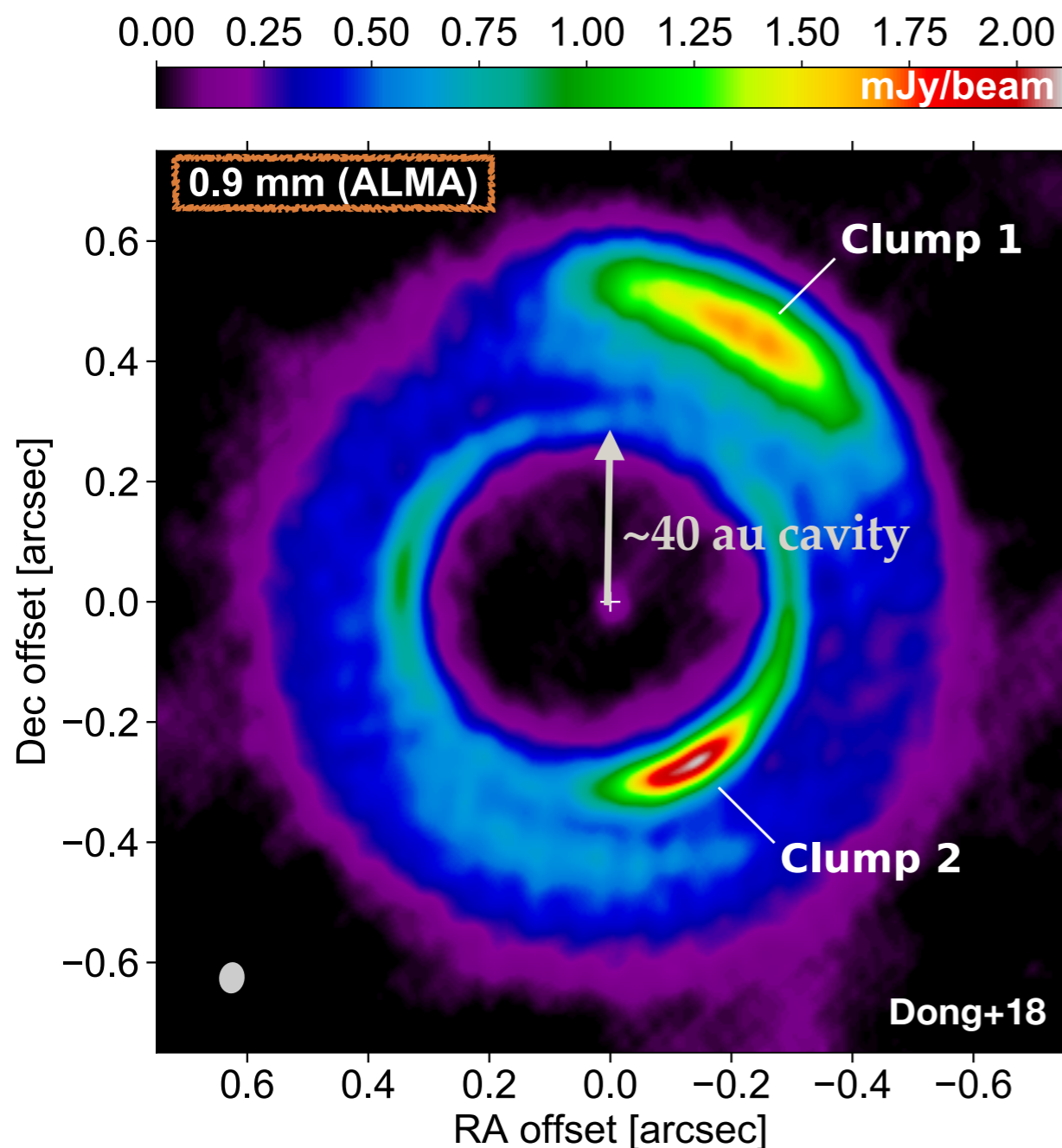
- The disc around **MWC 758** nicely illustrates that discs may look very different when observed at different wavelengths

star: Herbig A5, **mass:** $1.5 \pm 0.2 M_{\odot}$ (1σ), **age:** 3.5 ± 2.0 Myr (1σ), **dist.:** 160 ± 2 pc (1σ), $\dot{M}_{\star} \sim 10^{-8} M_{\odot} \text{ yr}^{-1}$

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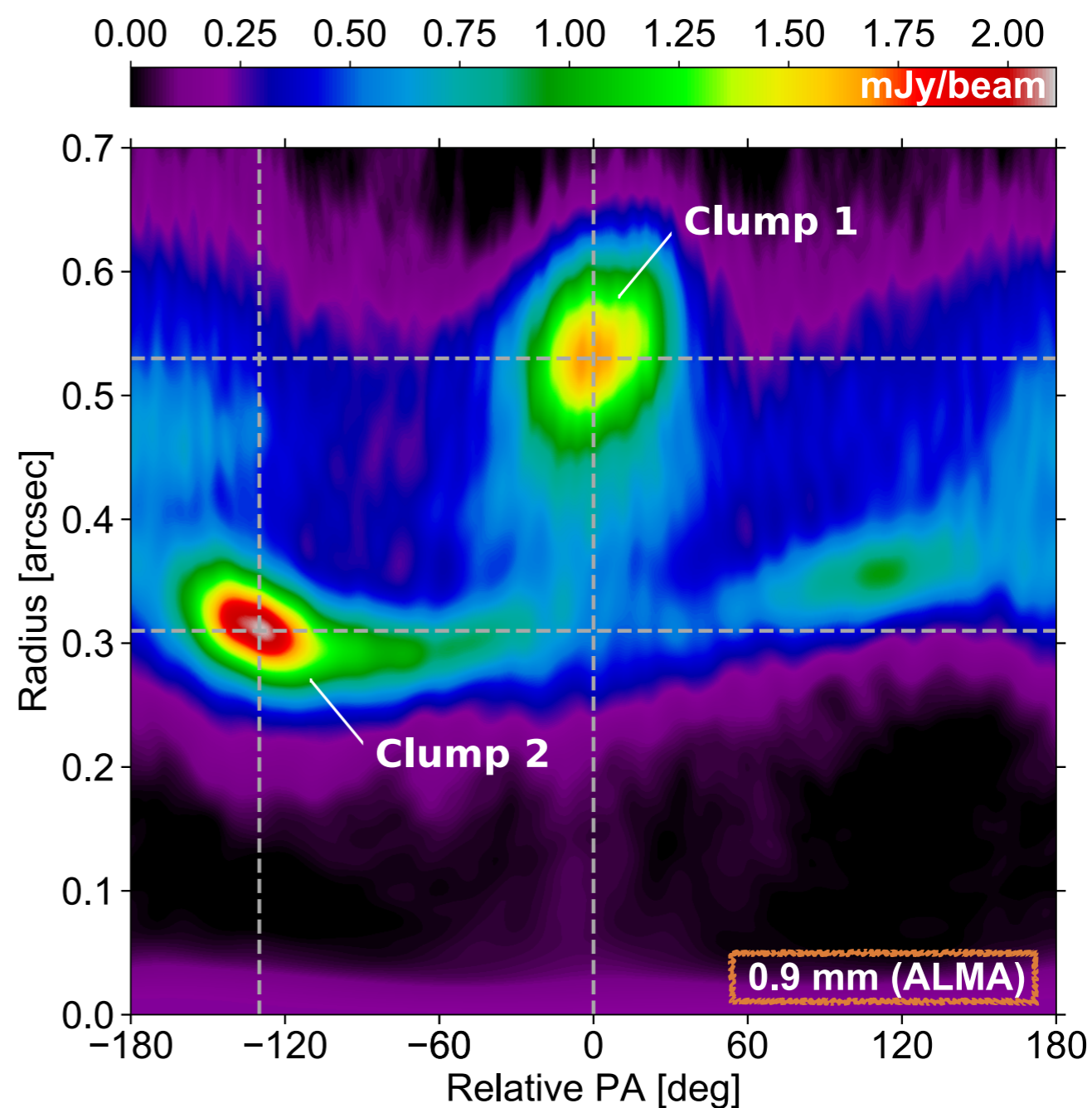
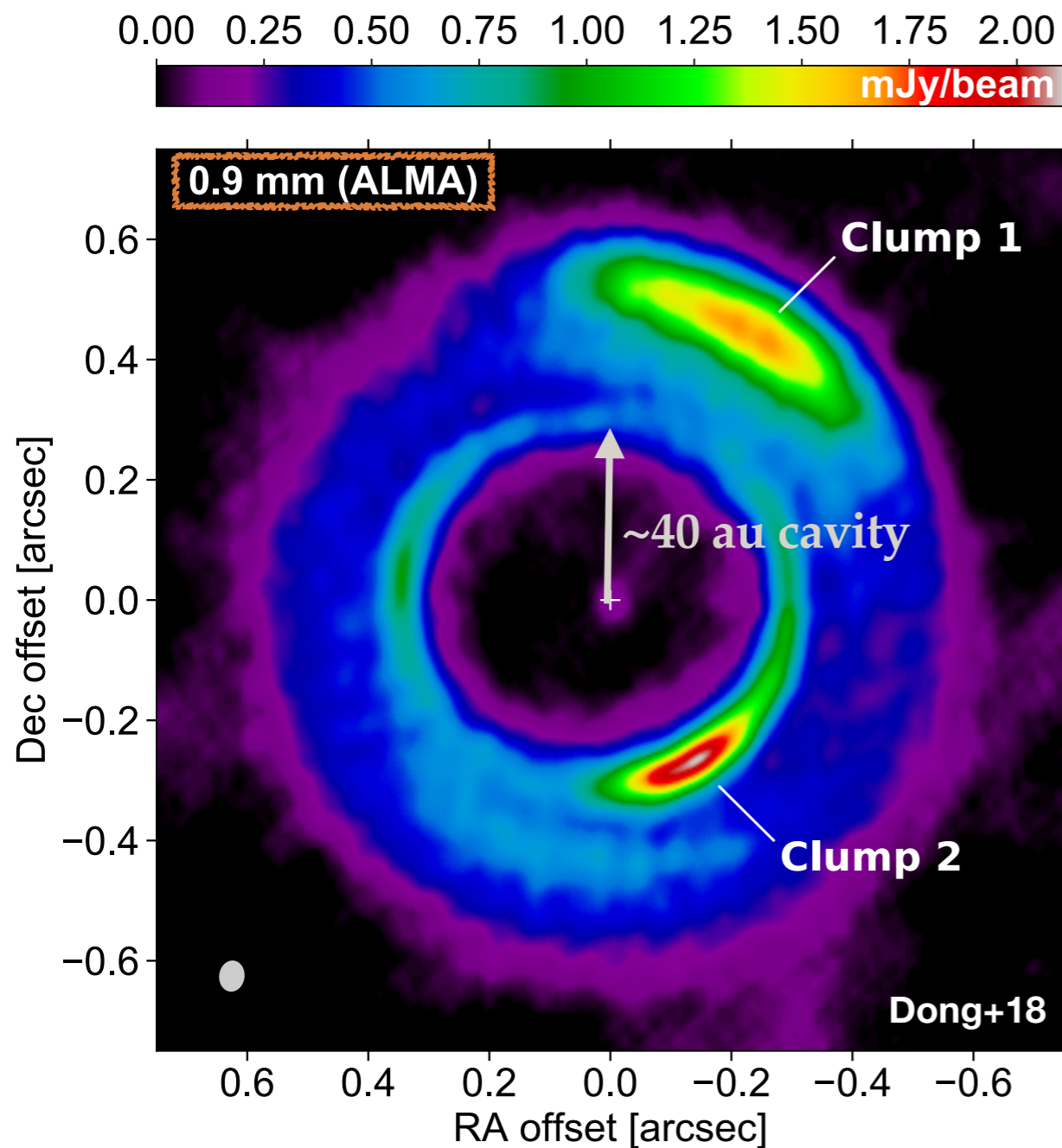


- (large-scale) central cavity in the radio + absence of near-IR excess emission in the SED classify MWC 758 as a *transition disc*
- 2 asymmetric and mildly eccentric rings of emission (passing by clumps 1 and 2) on top of a fainter ring of background emission

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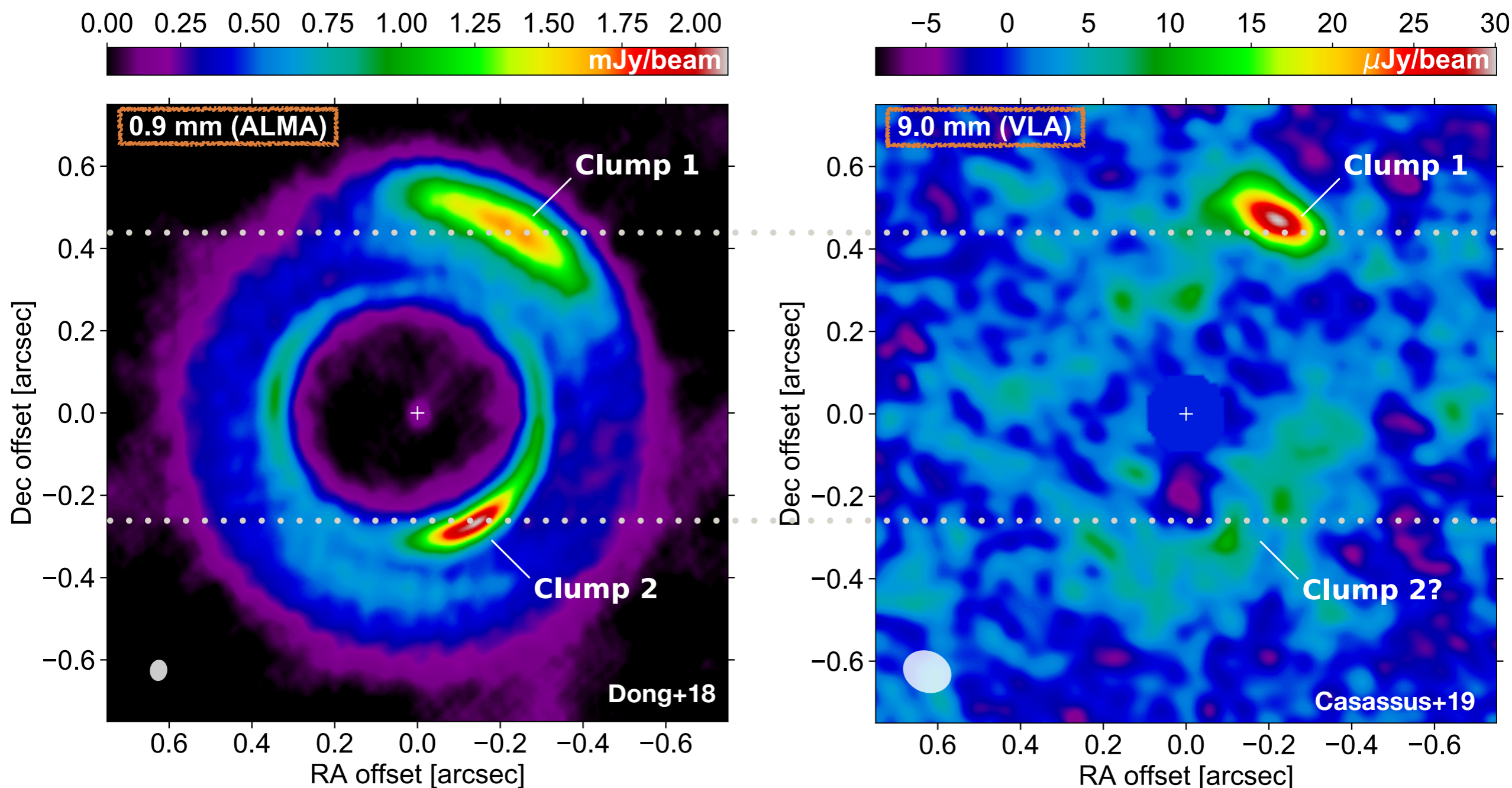


deprojected map ($i \sim 21^\circ$, PA $\sim 65^\circ$)

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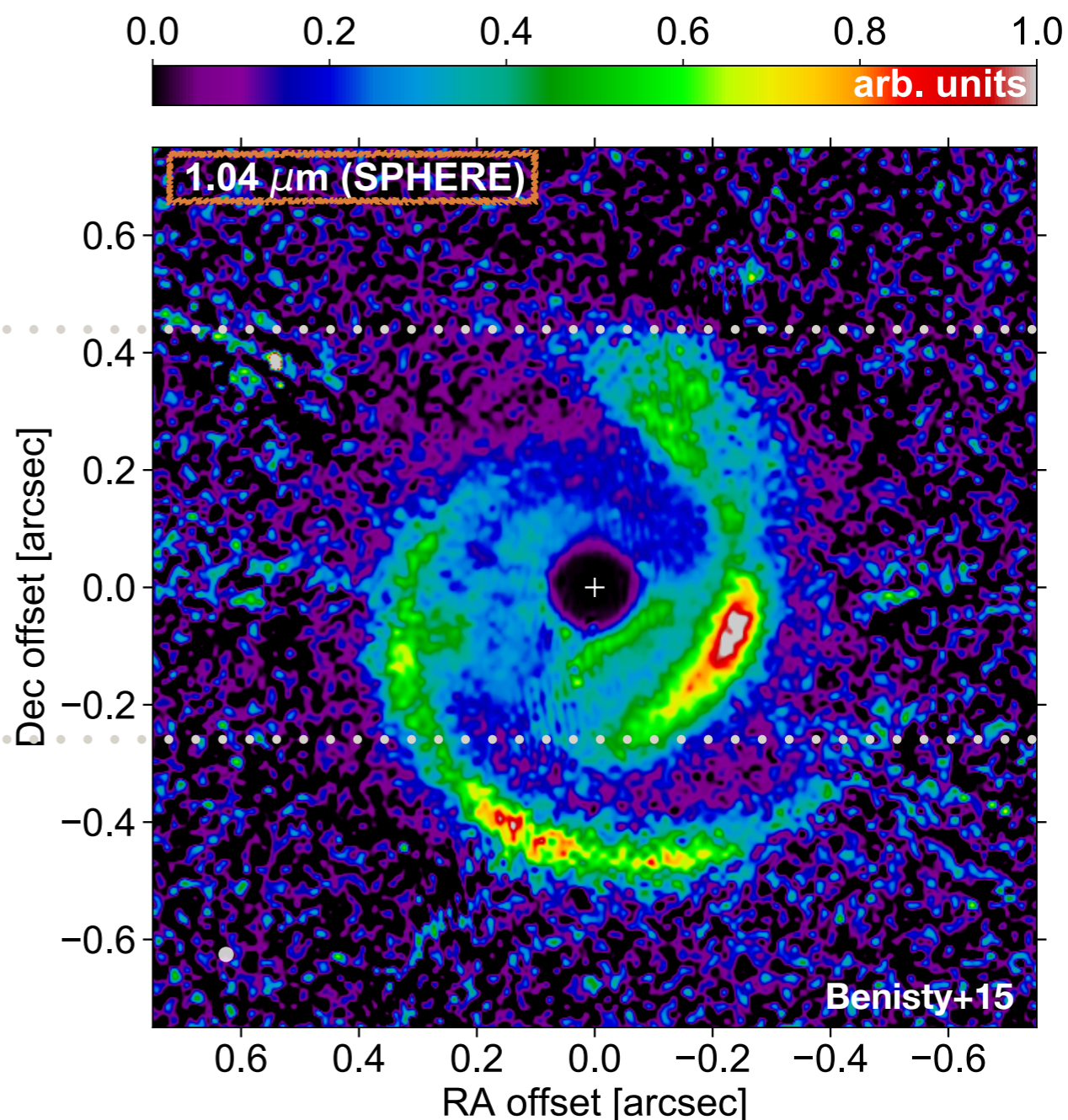
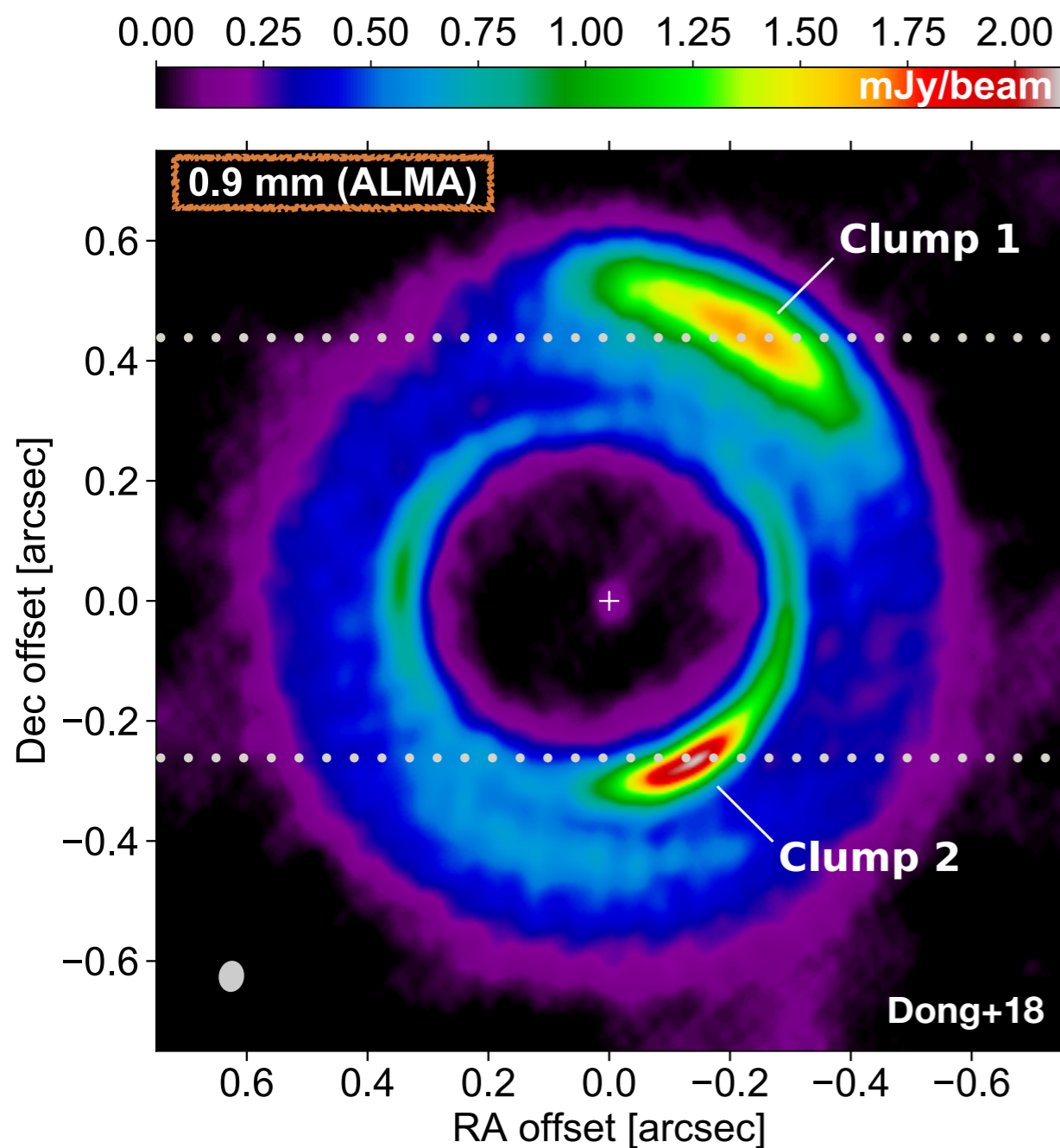


→ clump 1 is narrower at 9 mm: signature of dust's azimuthal trapping?

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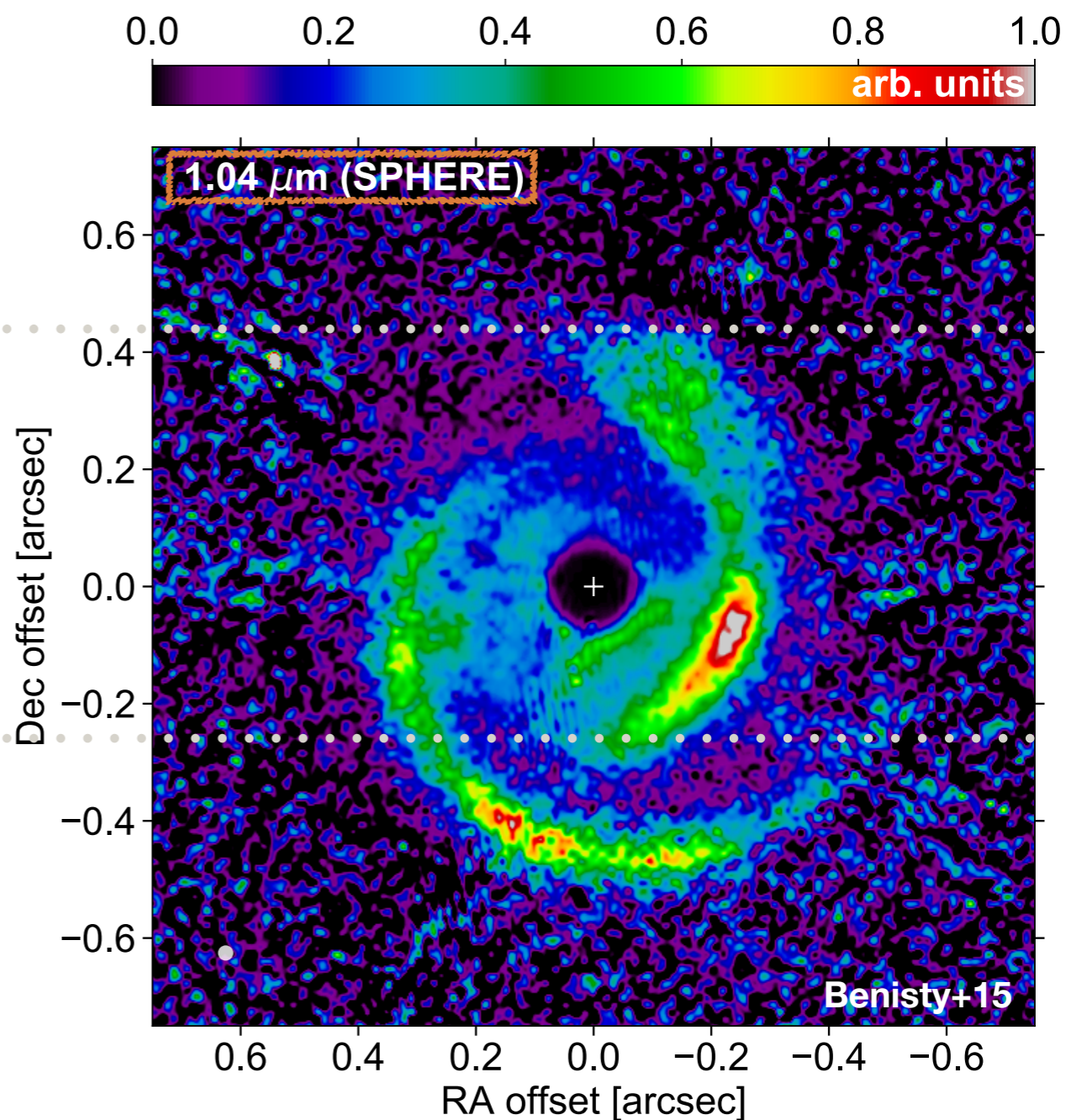
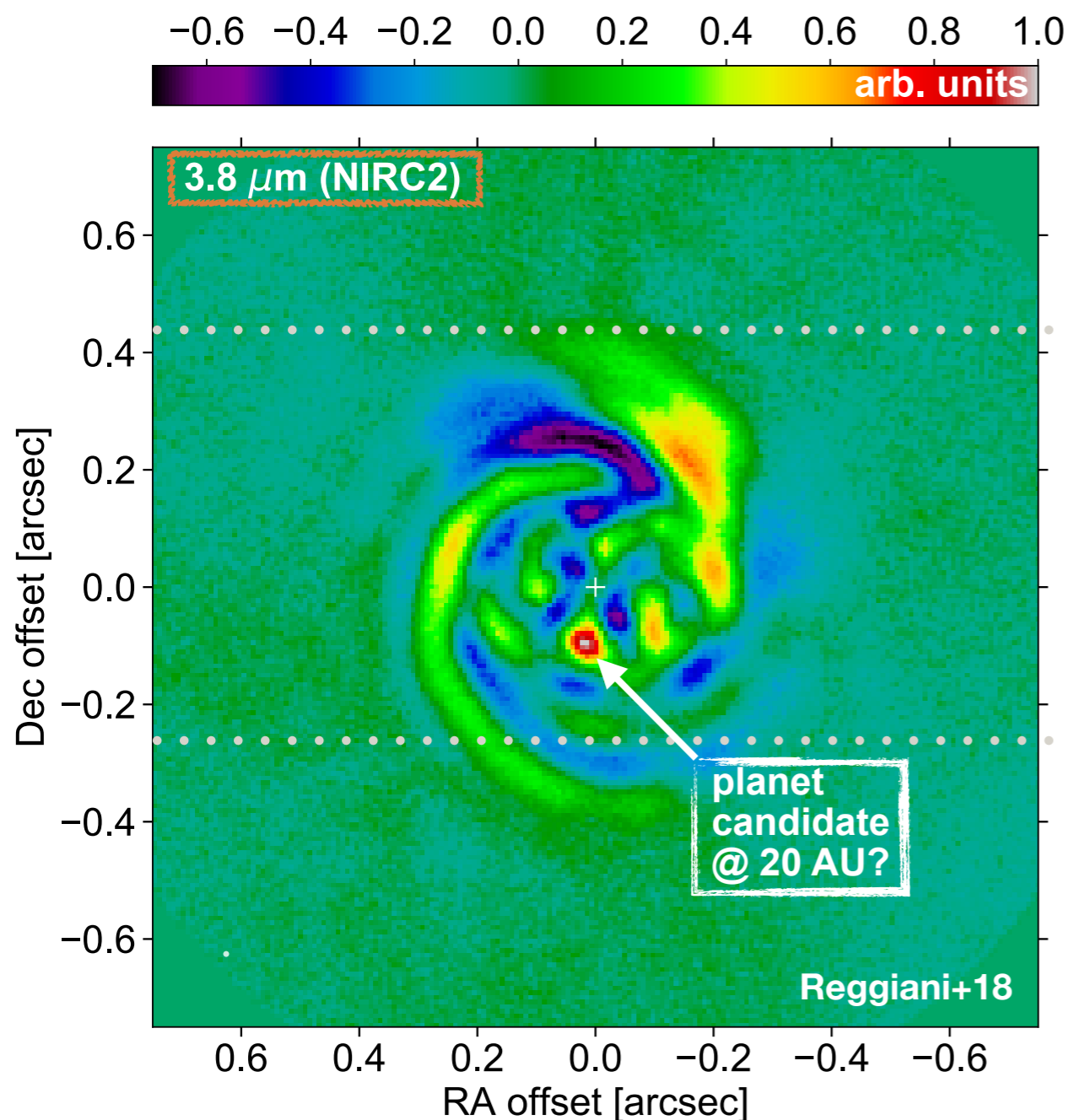
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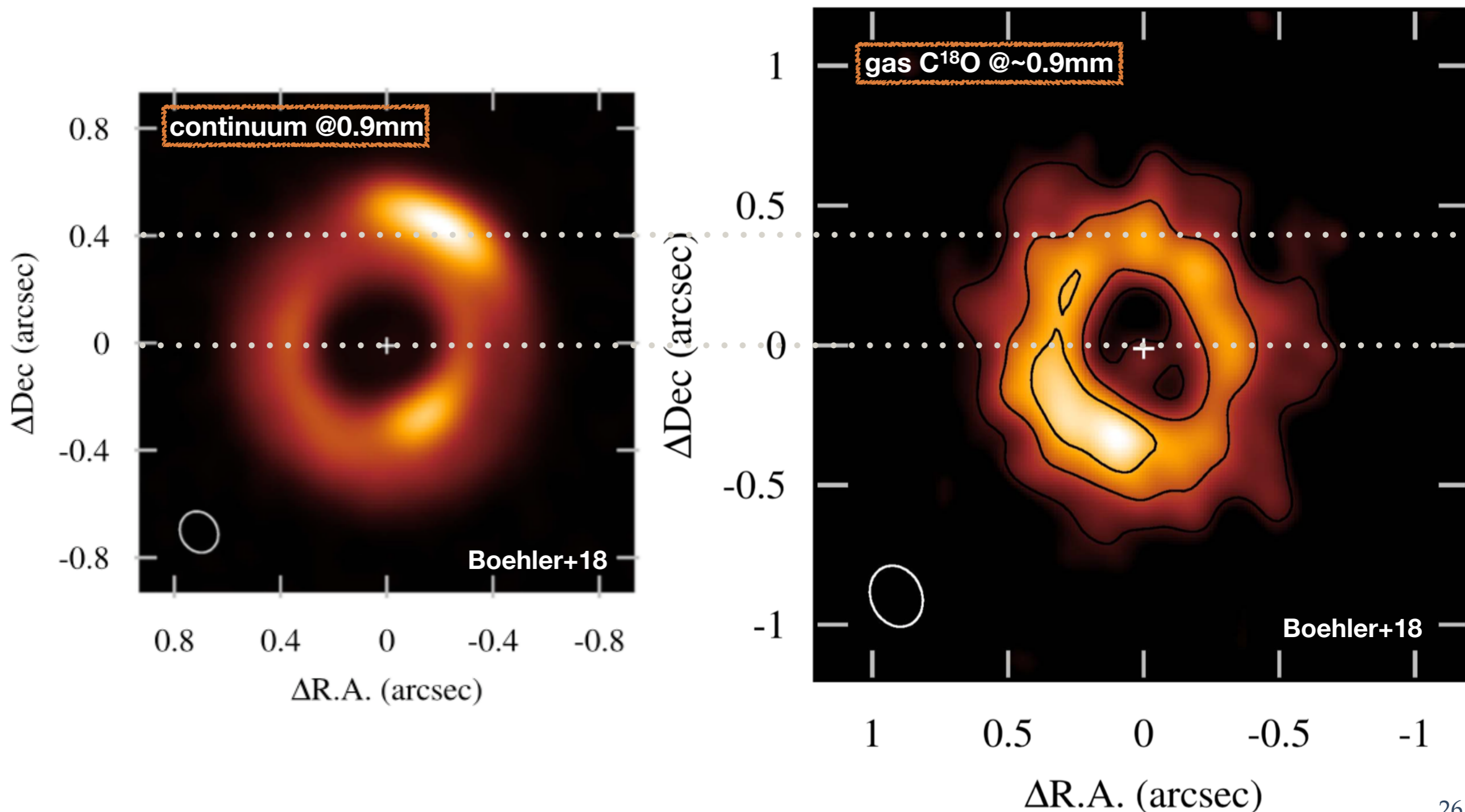
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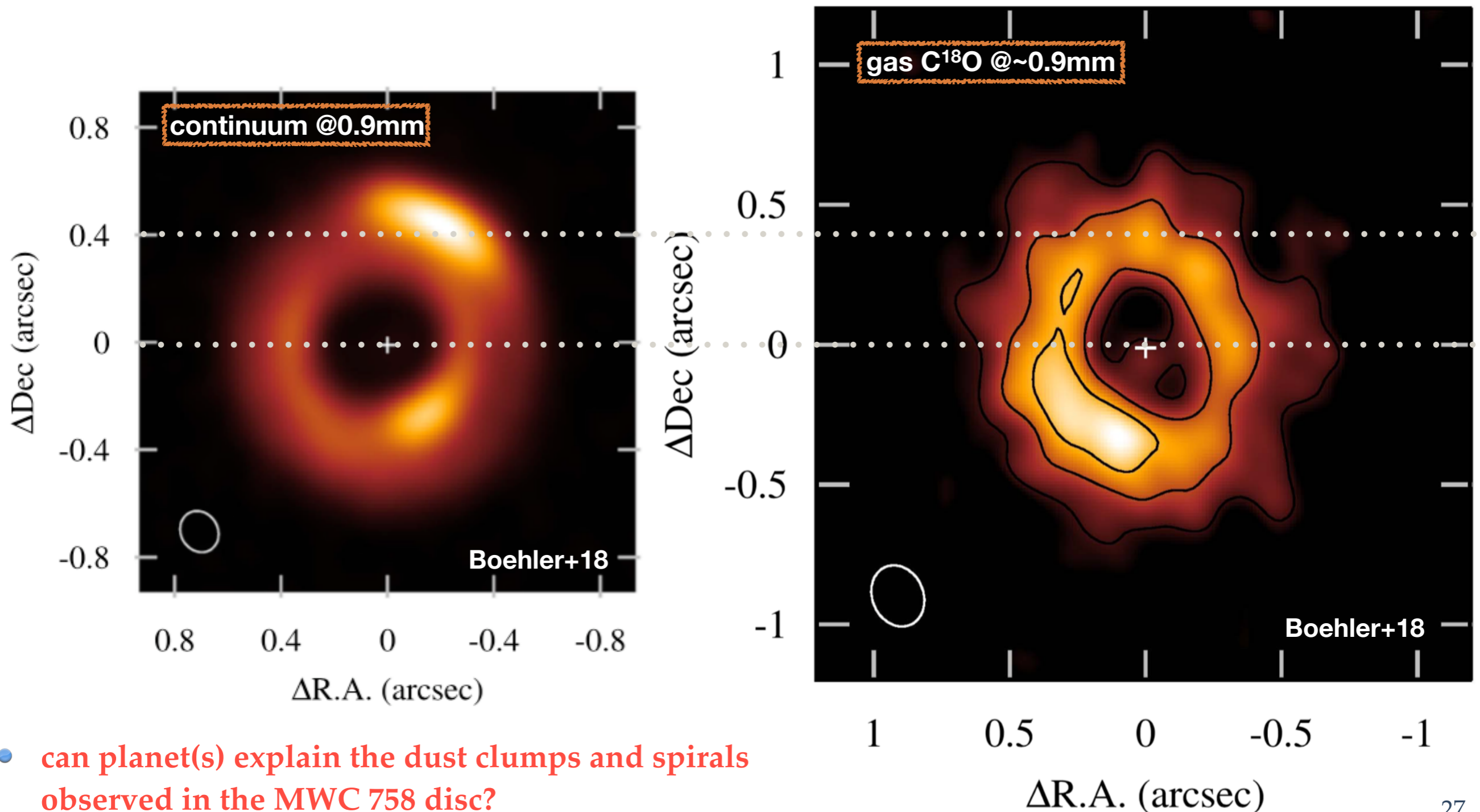
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MWC 758 disc: physical model and numerical methods

2D gas+dust simulations post-processed with dust radiative transfer calculations

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Gas model

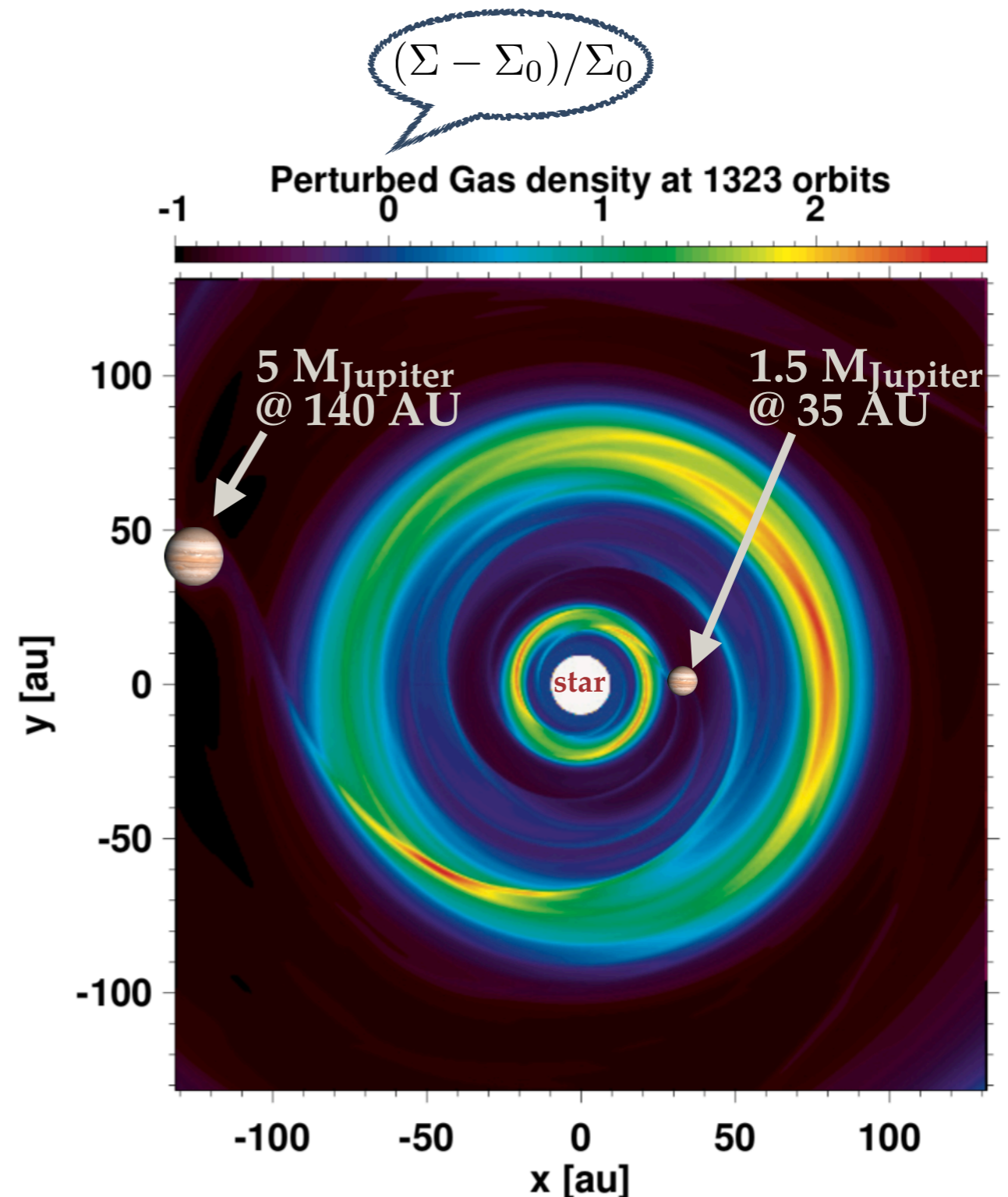
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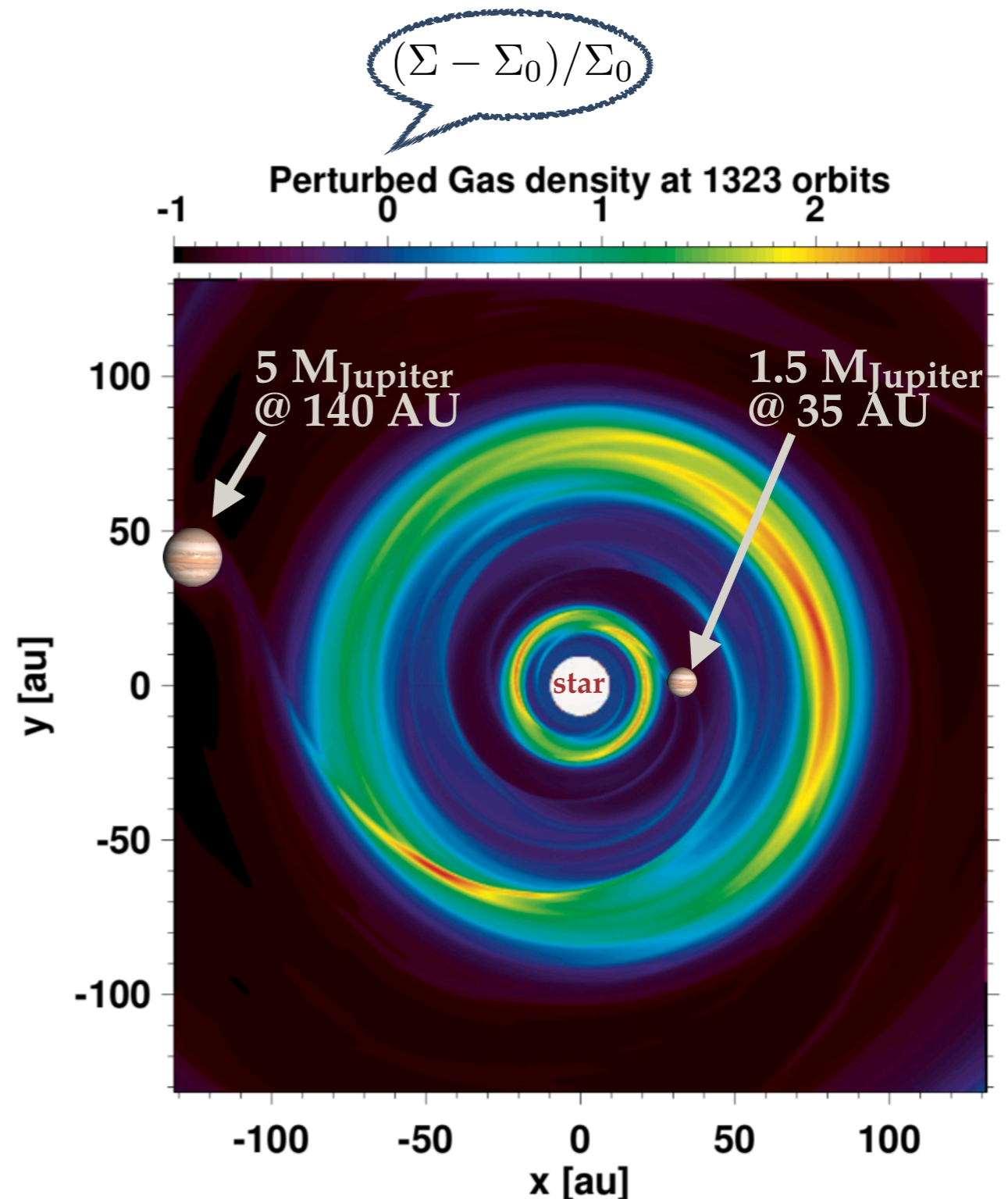


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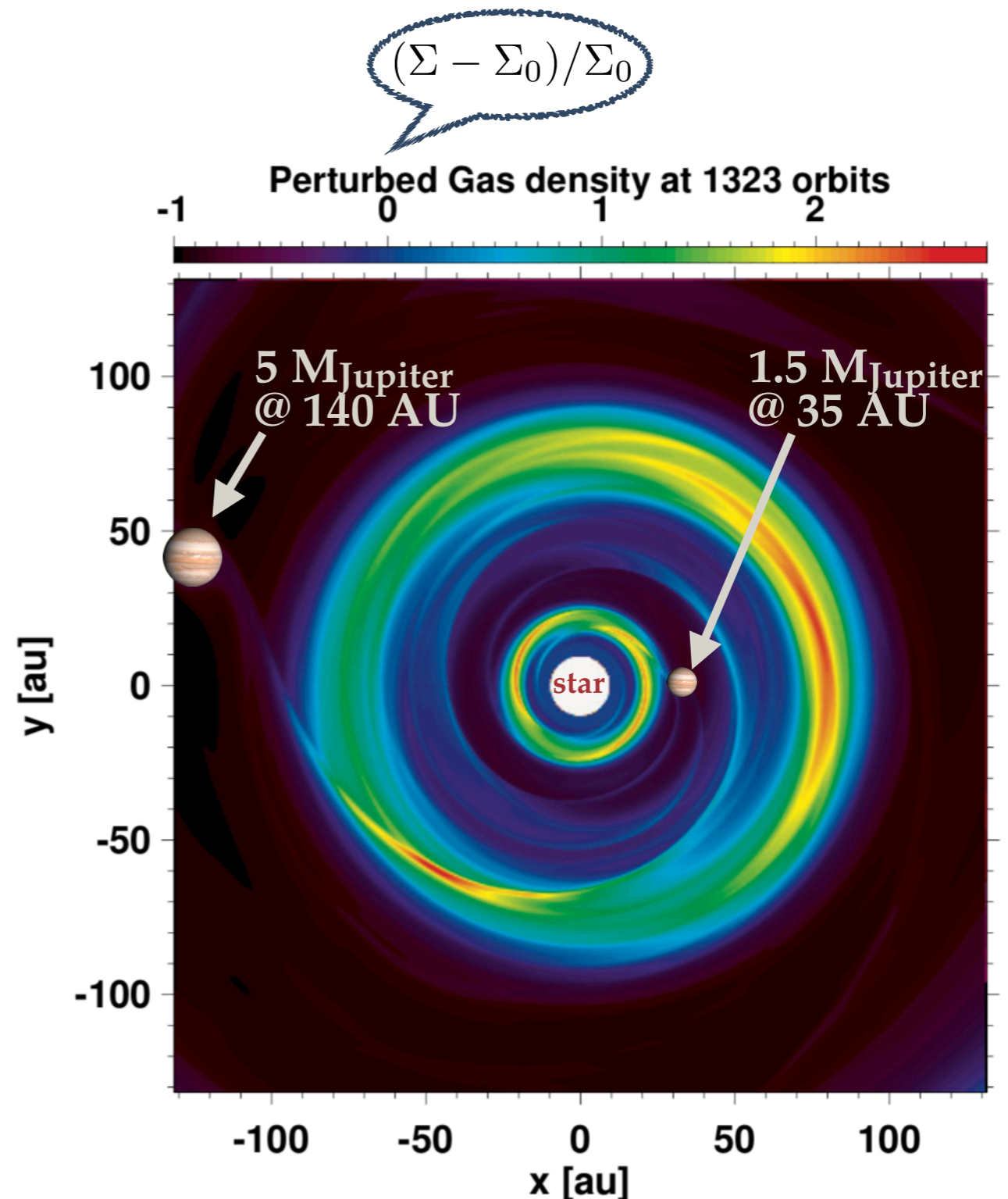


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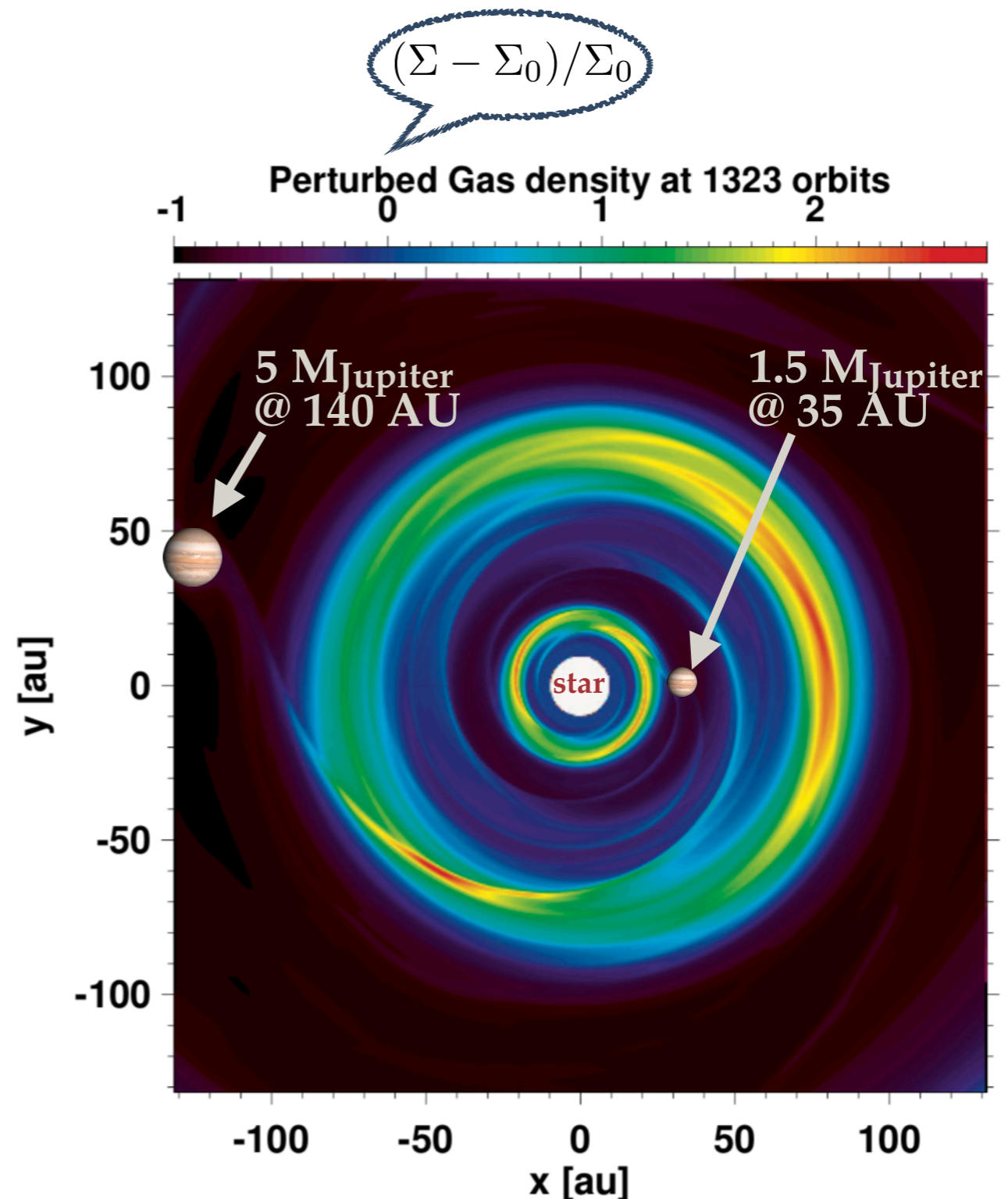


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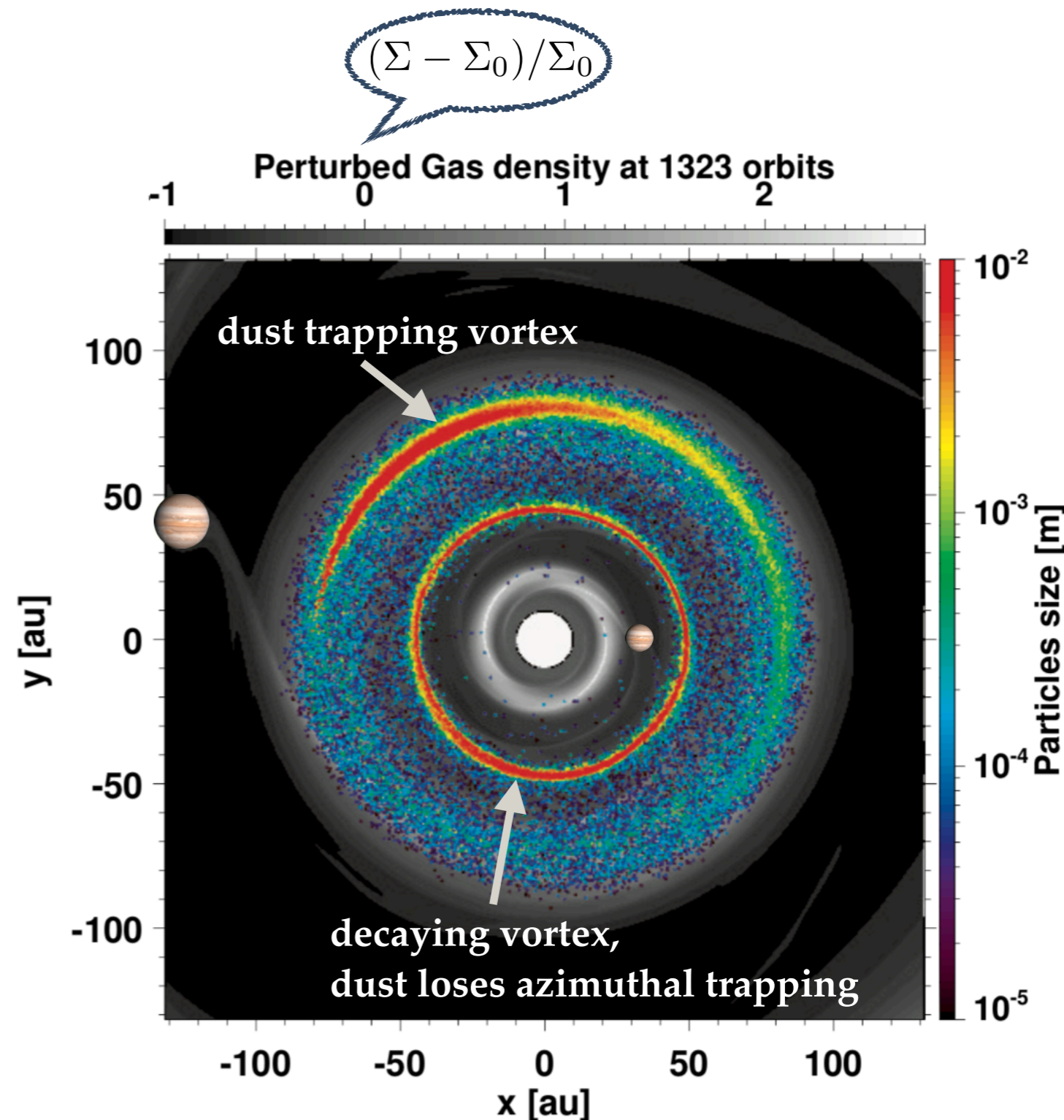


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- Lagrangian particles that feel:
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 - gas turbulent viscosity

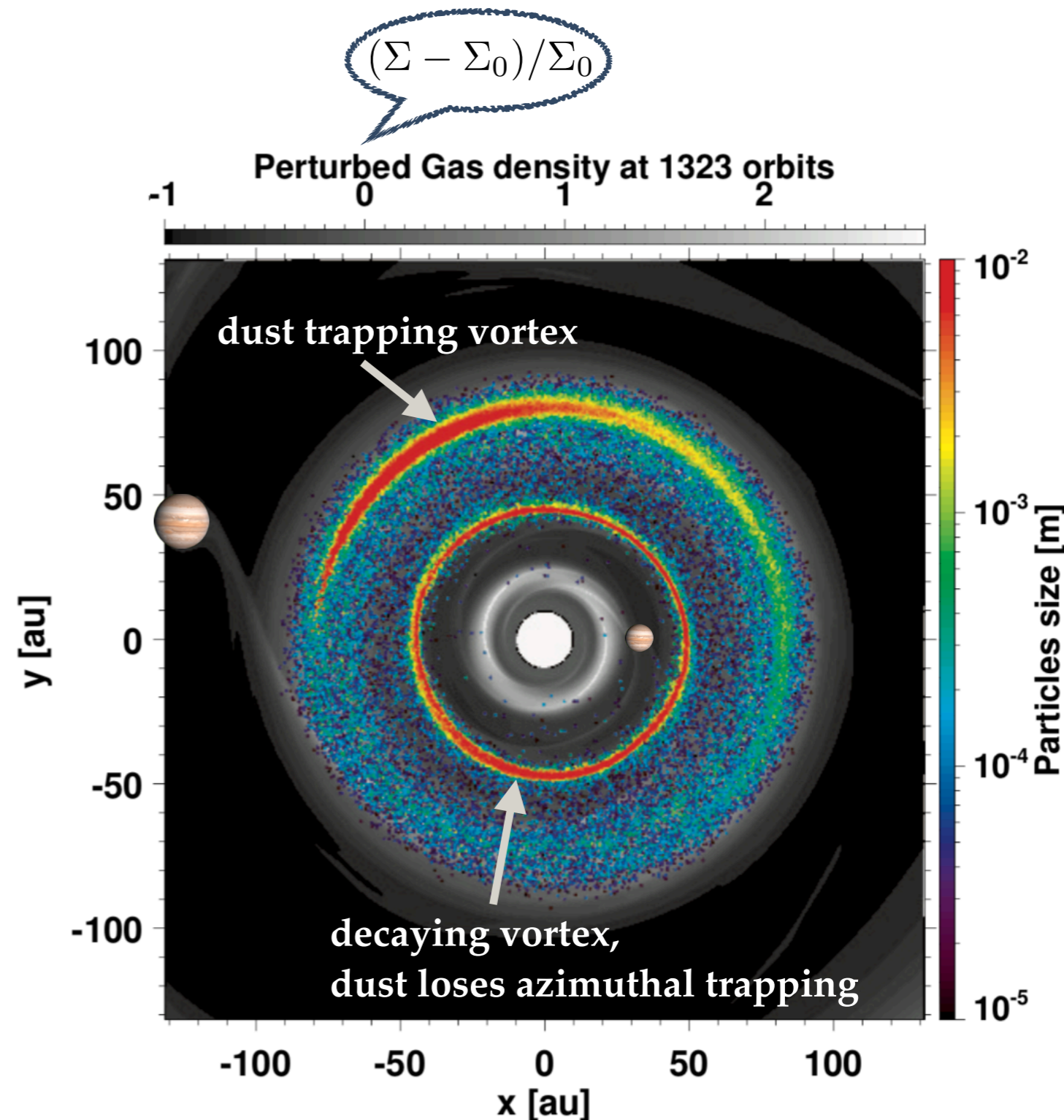


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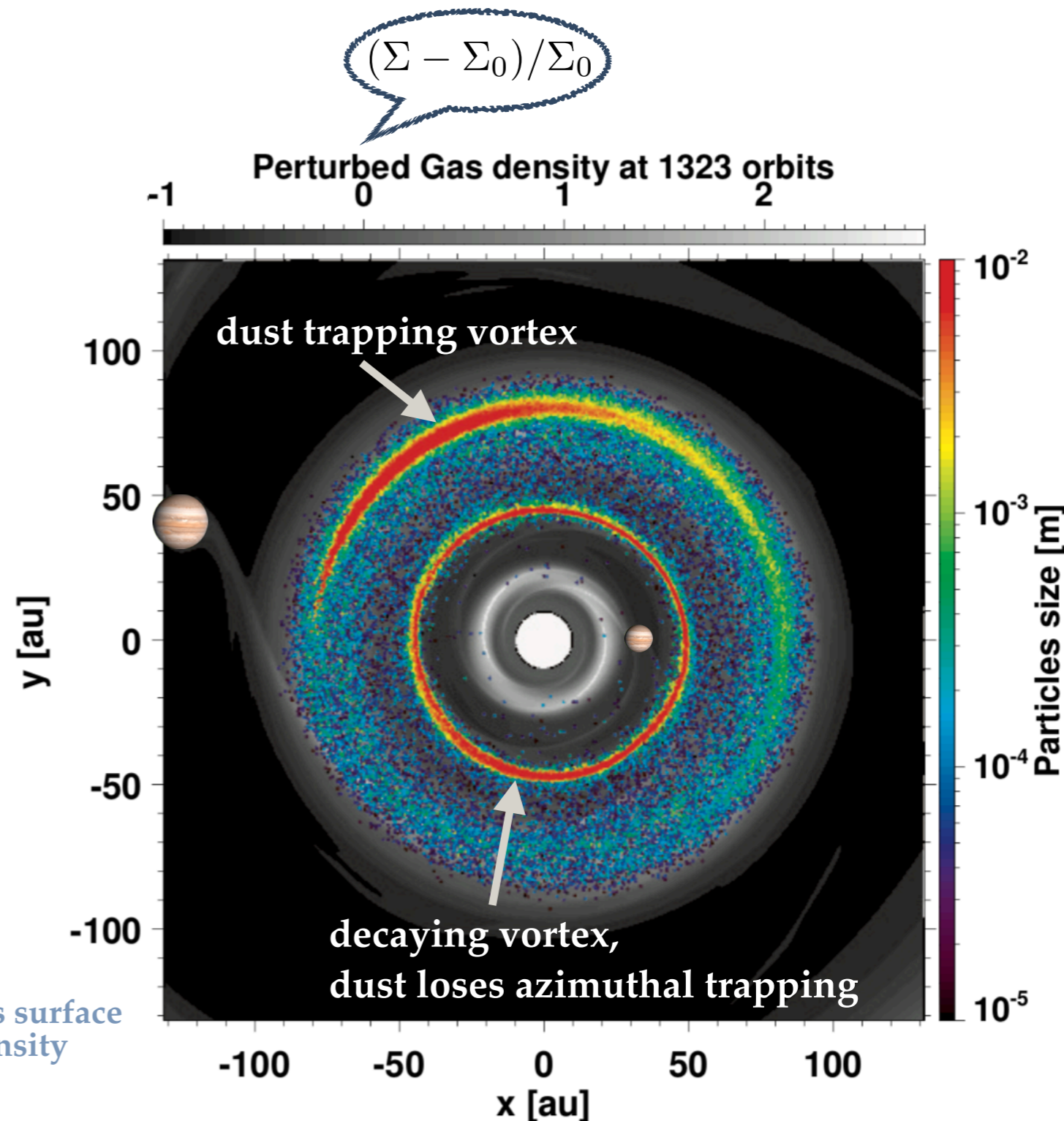
gas turbulent viscosity

dust size

dust's internal density

gas surface density

→ strong degeneracy!

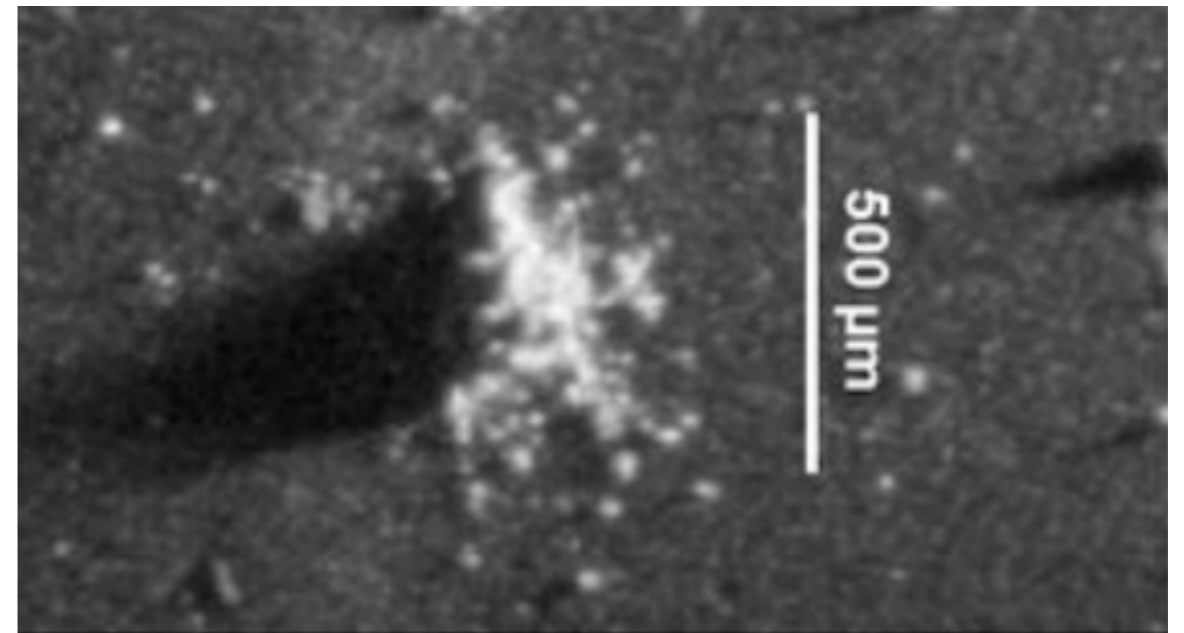


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- Dust particles between $10\mu\text{m}$ and 1cm with a size distribution $n(s) \propto s^{-1}$, an internal density of 0.1 g cm^{-3} , and initial location between the planets



dust grains from comet 67P collected by Rosetta
Schultz+ 2015

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we solve RT equation in 3D with RADMC3D code

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- vertical expansion

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MWC 758 disc: physical model and numerical methods

2D gas+dust simulations post-processed with dust radiative transfer calculations

Radiative transfer (RT)

we solve RT equation in 3D with RADMC3D code

dust's spatial distribution (simulation)

- dust's size distribution (e.g. $n(s) \propto s^{-3.5}$)
- dust's total mass

dust's surface density

- vertical expansion

dust's volume density

①

- star
- opacities

T_{dust}

! dust is a **mixture** of a silicate matrix, water ices and a vacuum inclusion

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- opacities
- disc geometry

- star
- opacities

specific intensity

ray tracing (RADMC3D)

T_{dust}

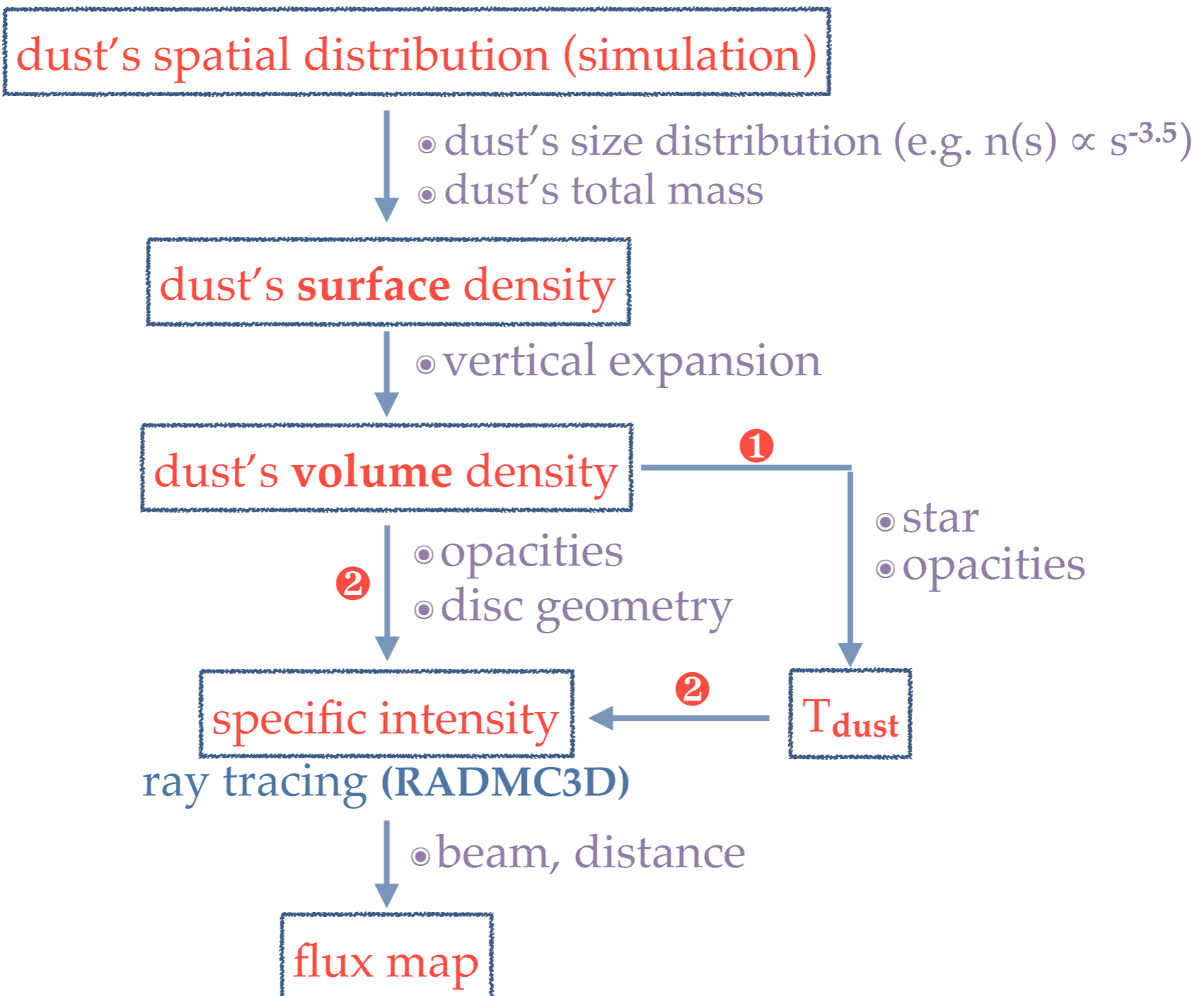
(thermal absorption + anisotropic scattering)

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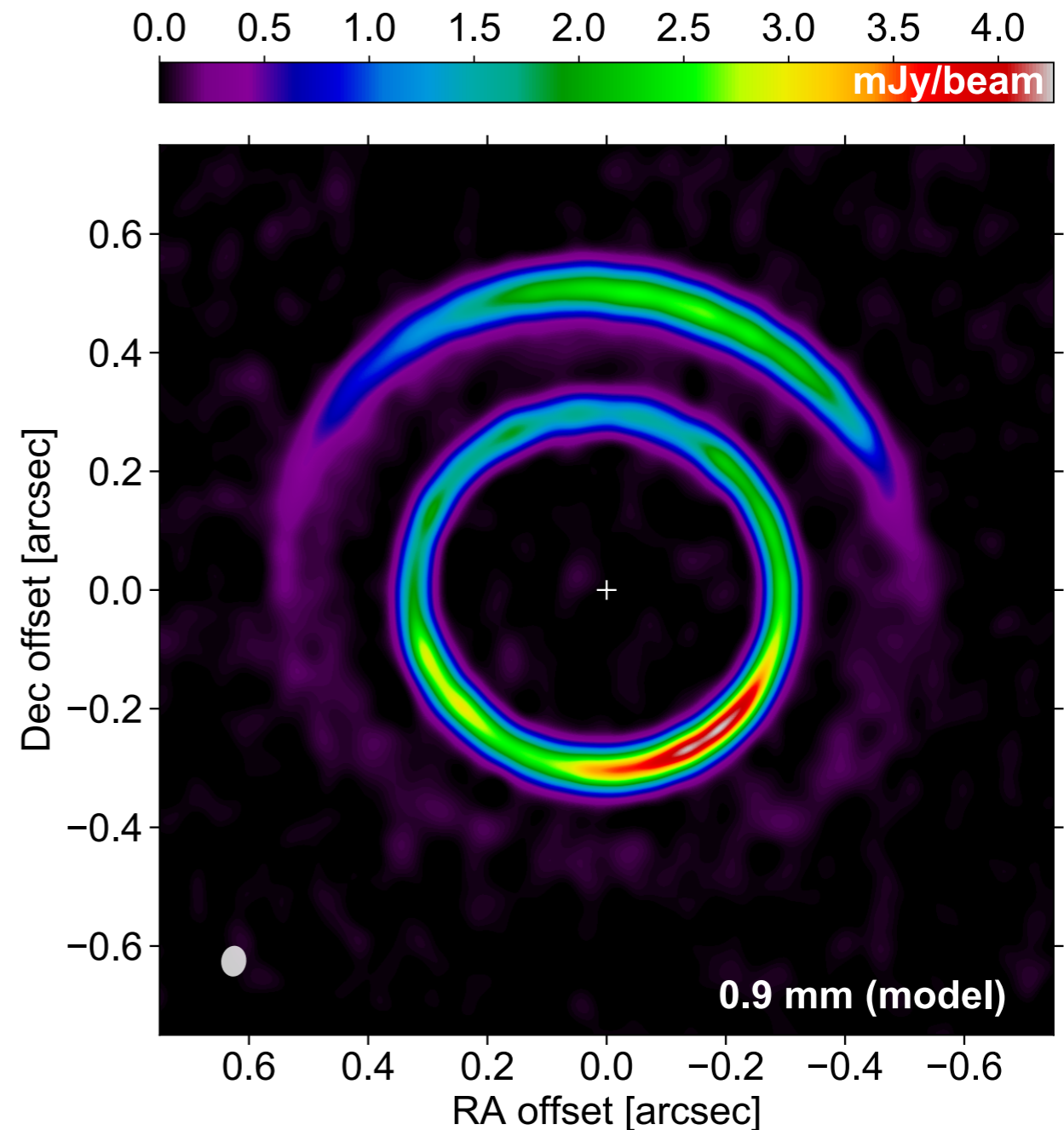
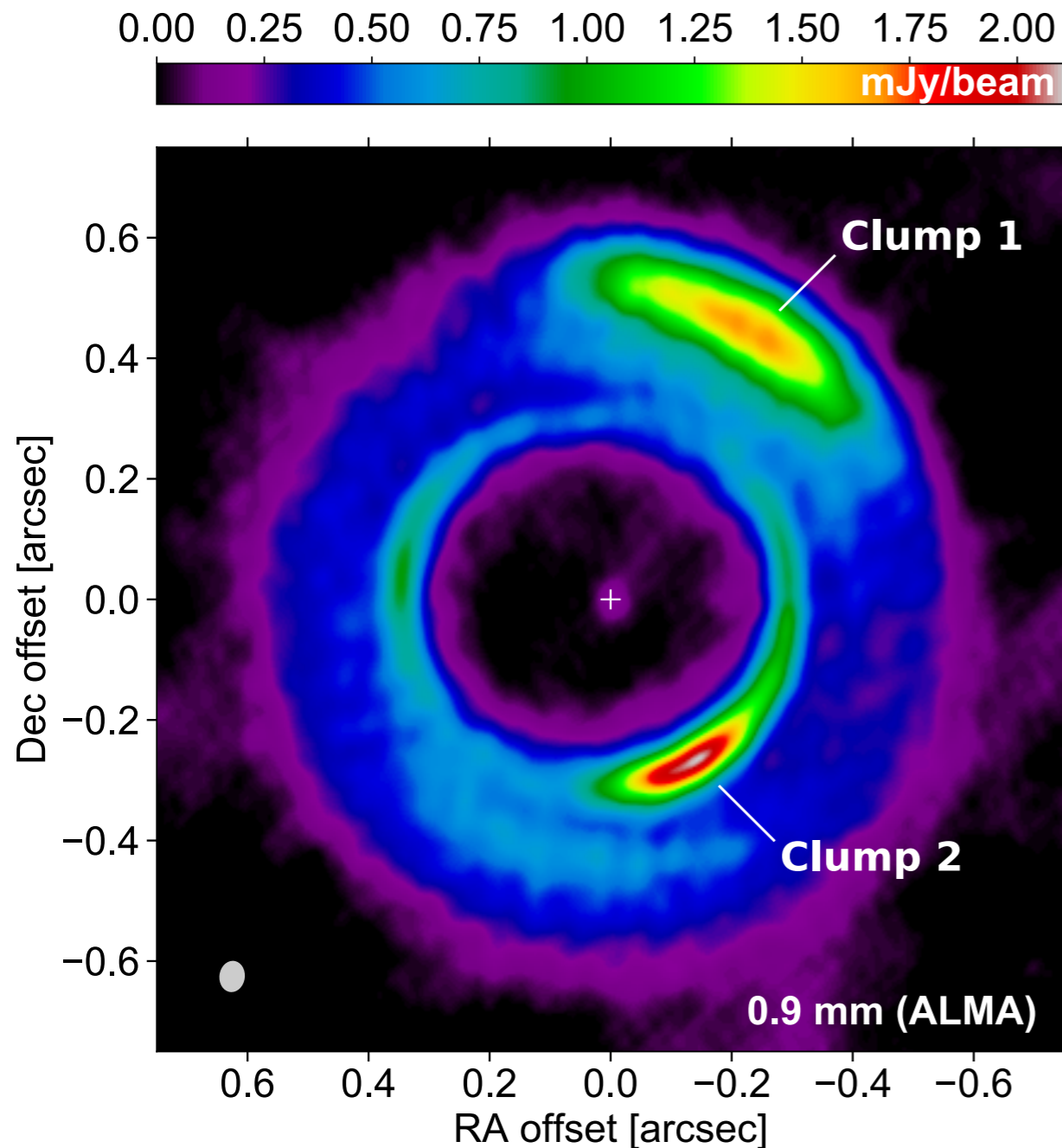
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Two giant planets sculpting the MWC 758 disc?

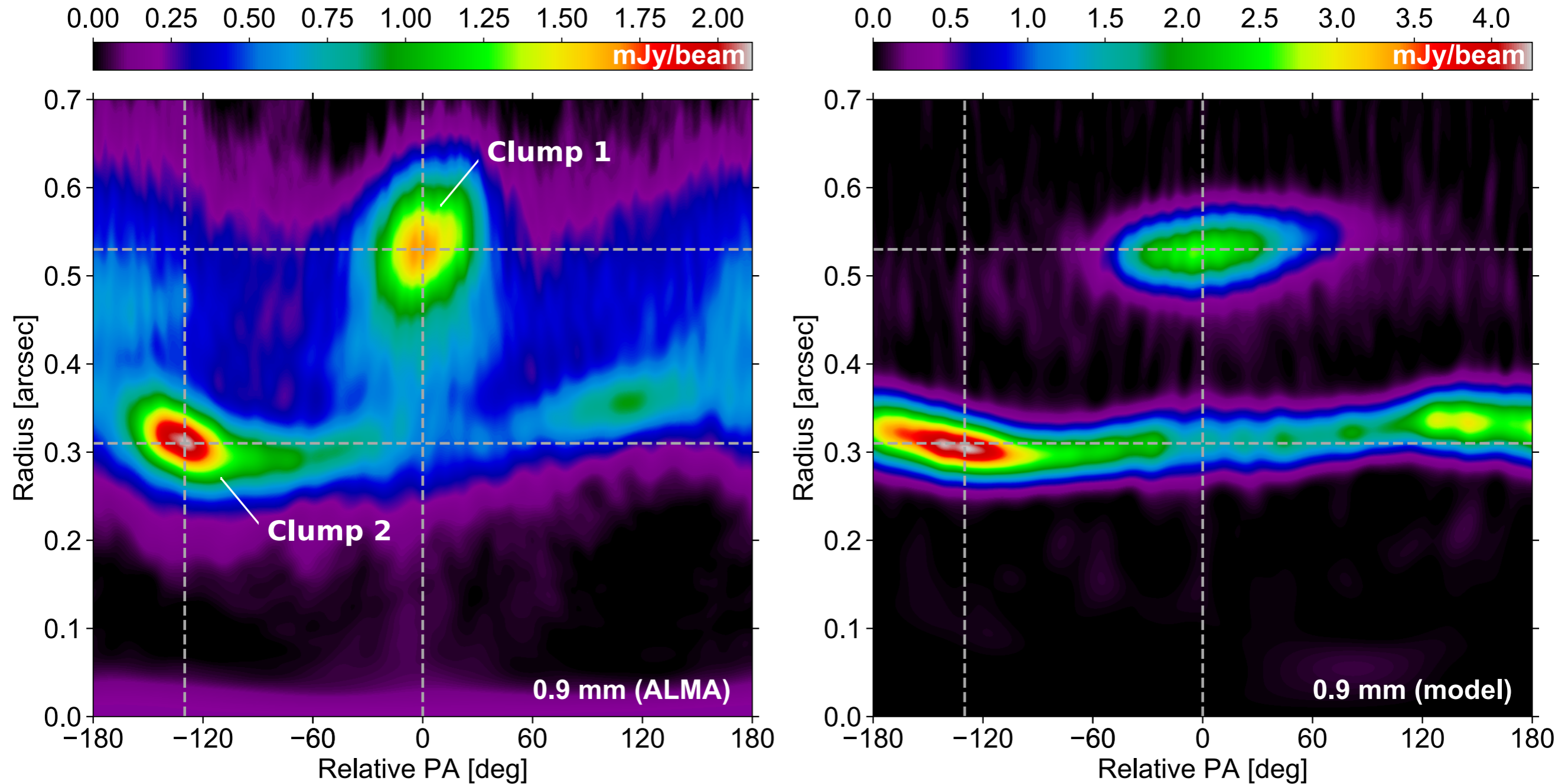
Baruteau+ 19



- dust size distribution $n(s) \propto s^{-3}$ for s in $[10\mu\text{m} - 1\text{cm}]$, $M_{\text{dust}} \sim 120 M_{\text{Earth}}$
- dust is a mixture of a silicate matrix, water ices and a vacuum inclusion

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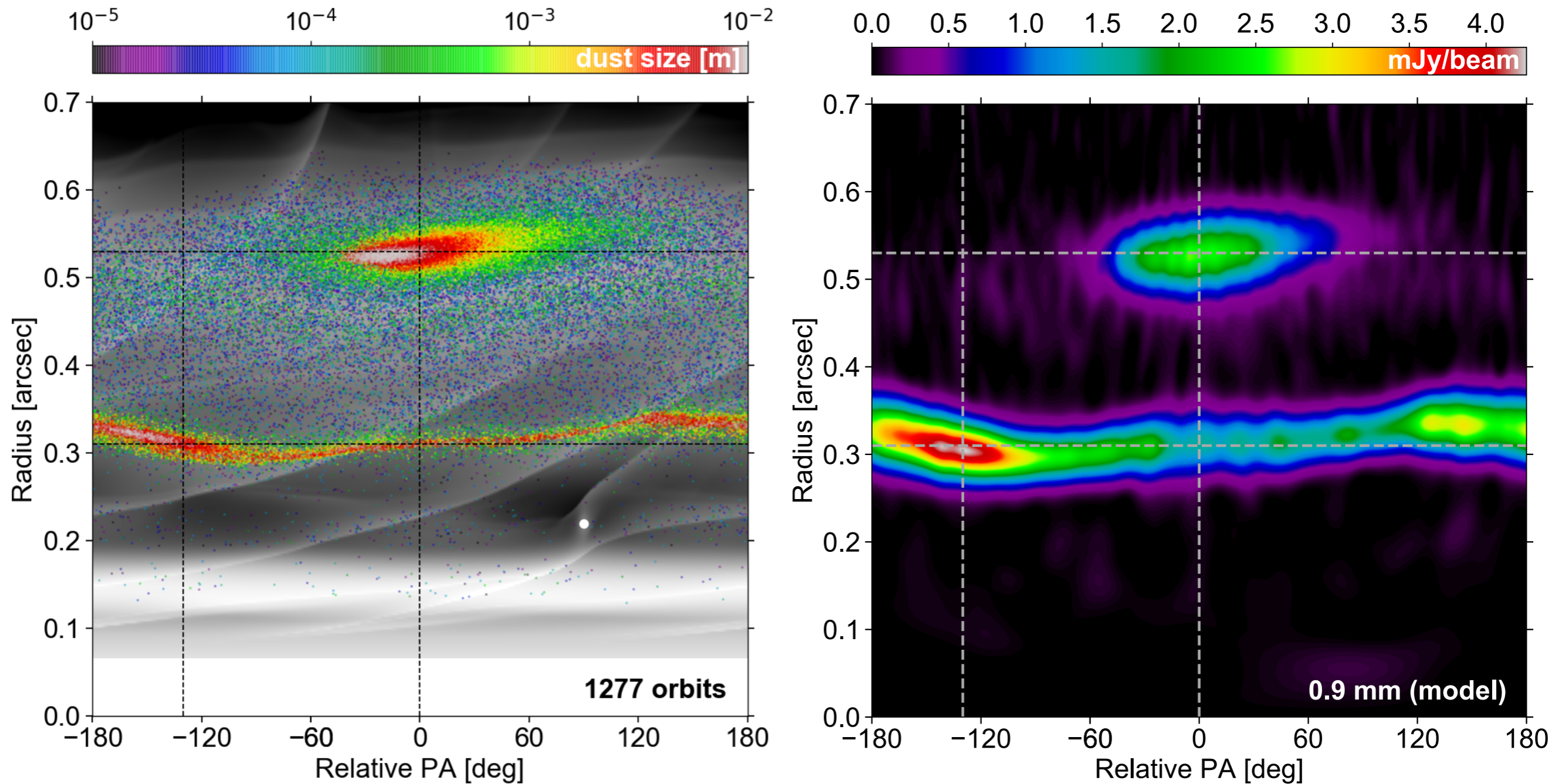
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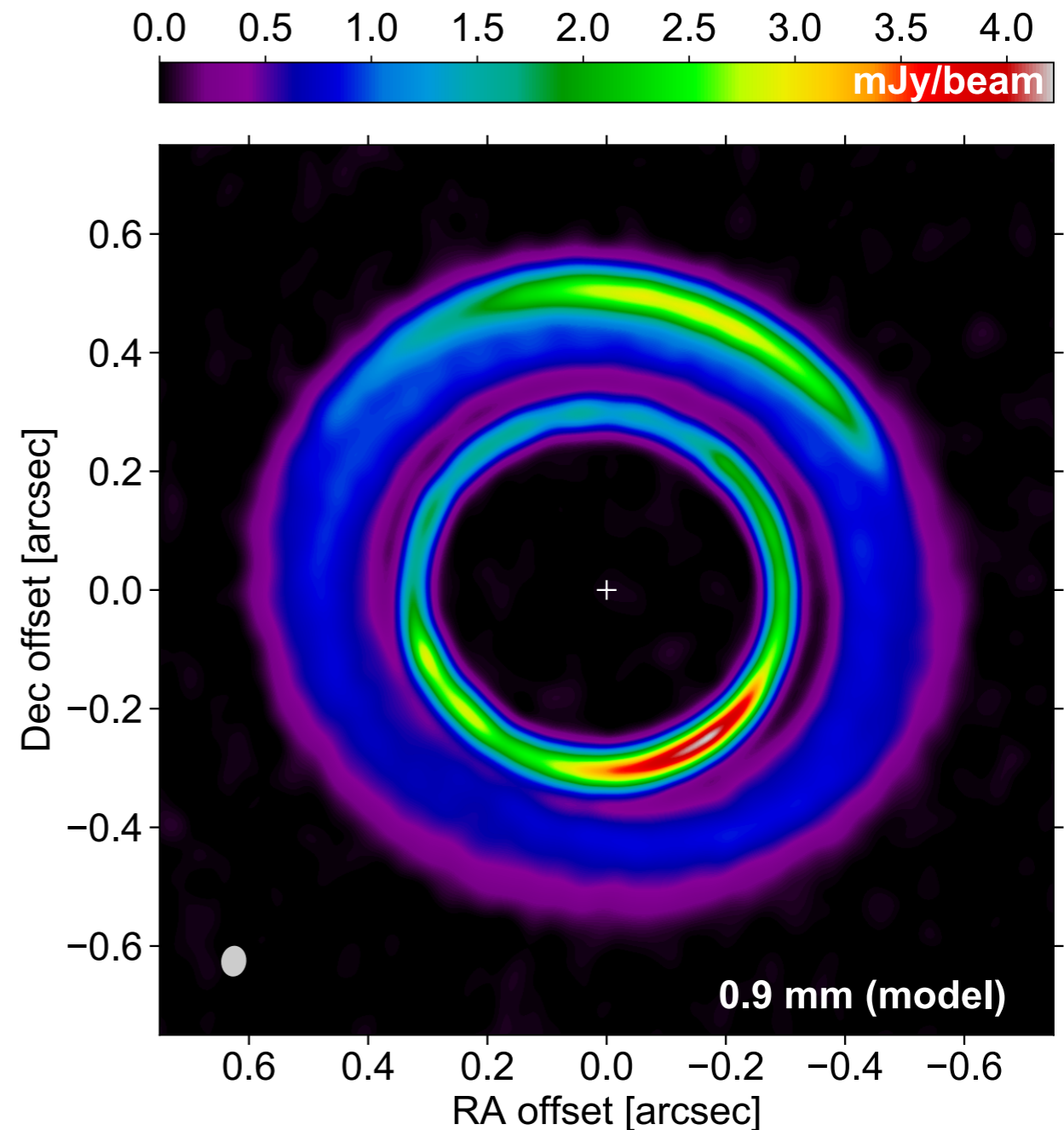
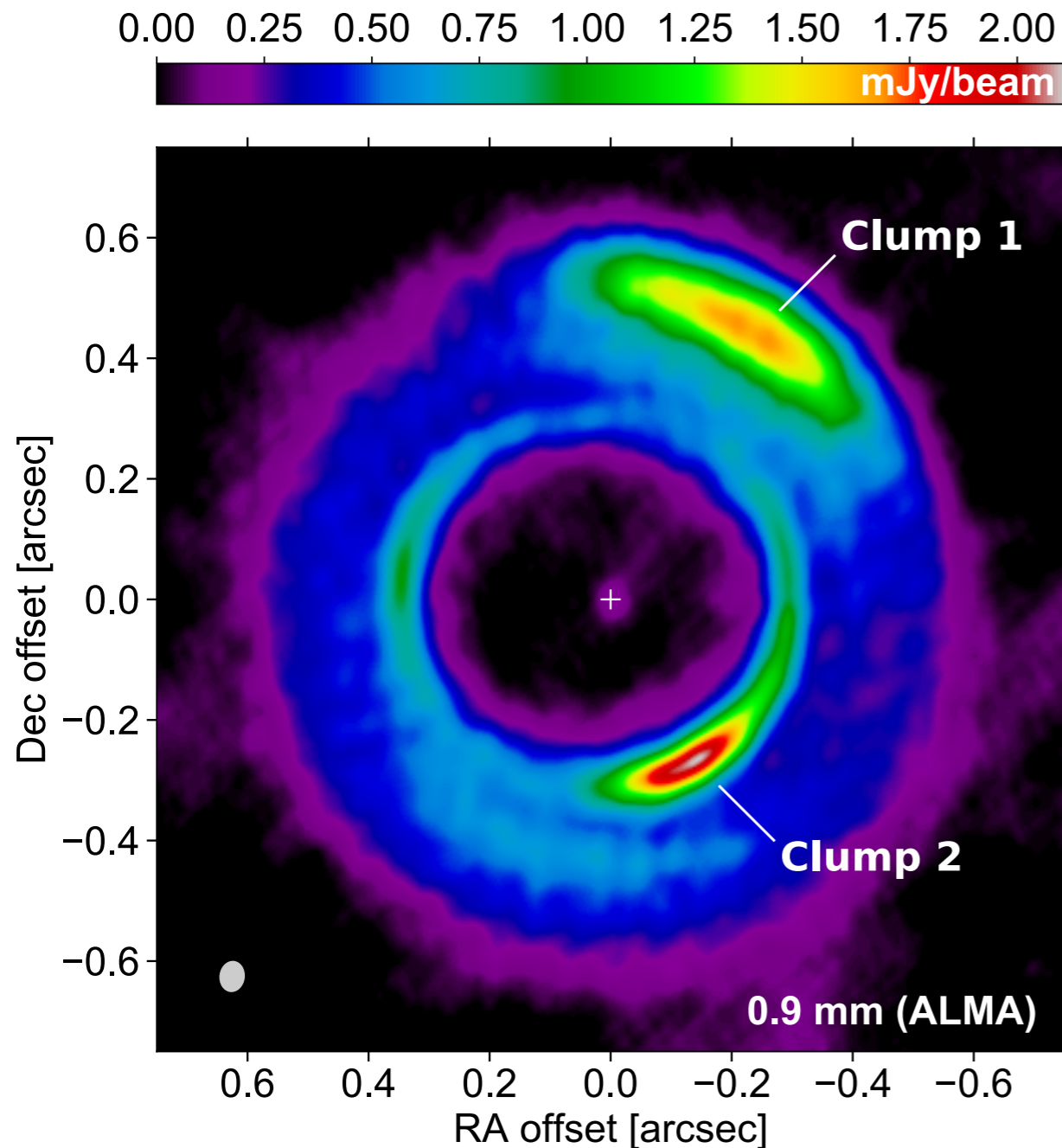
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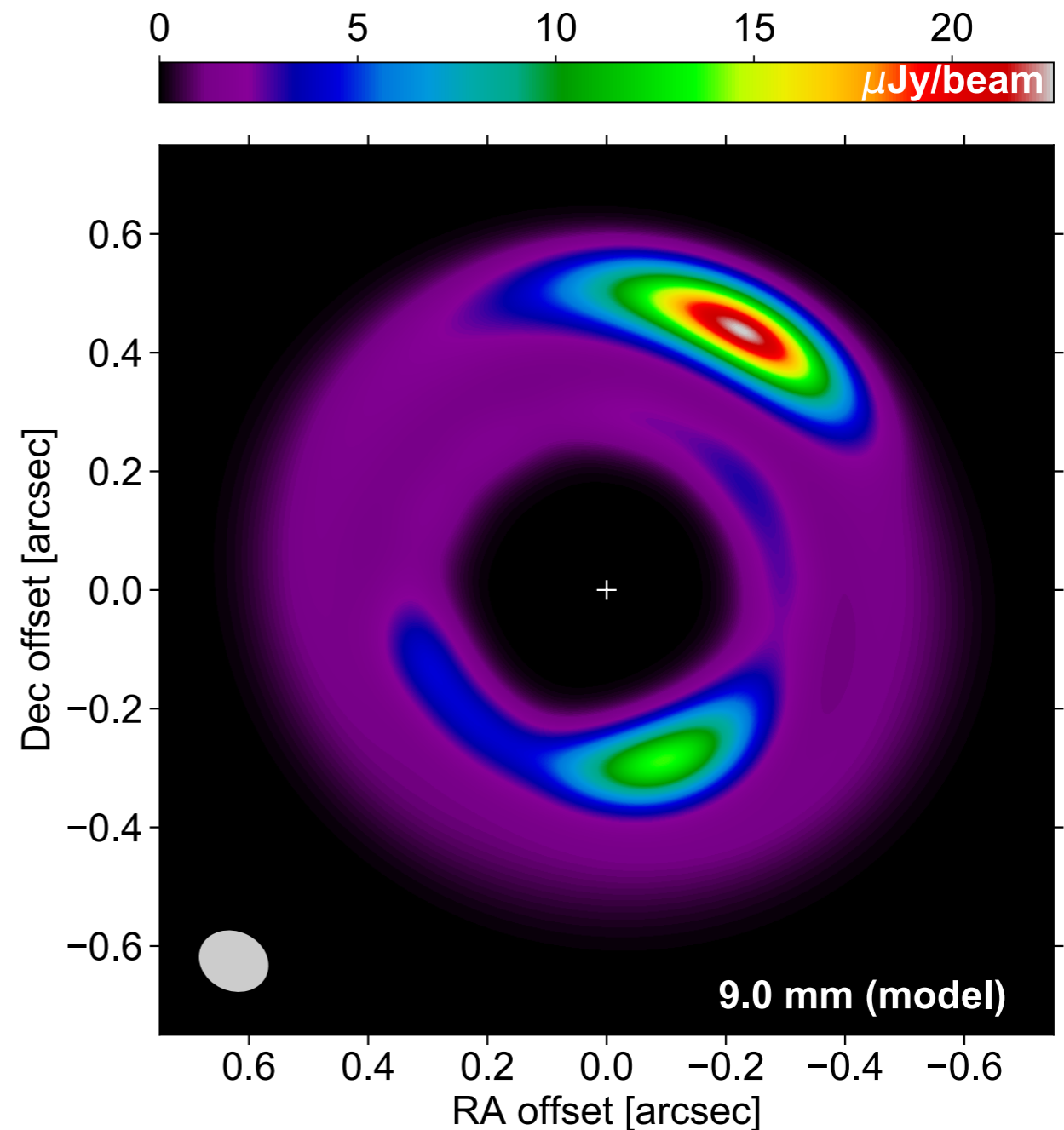
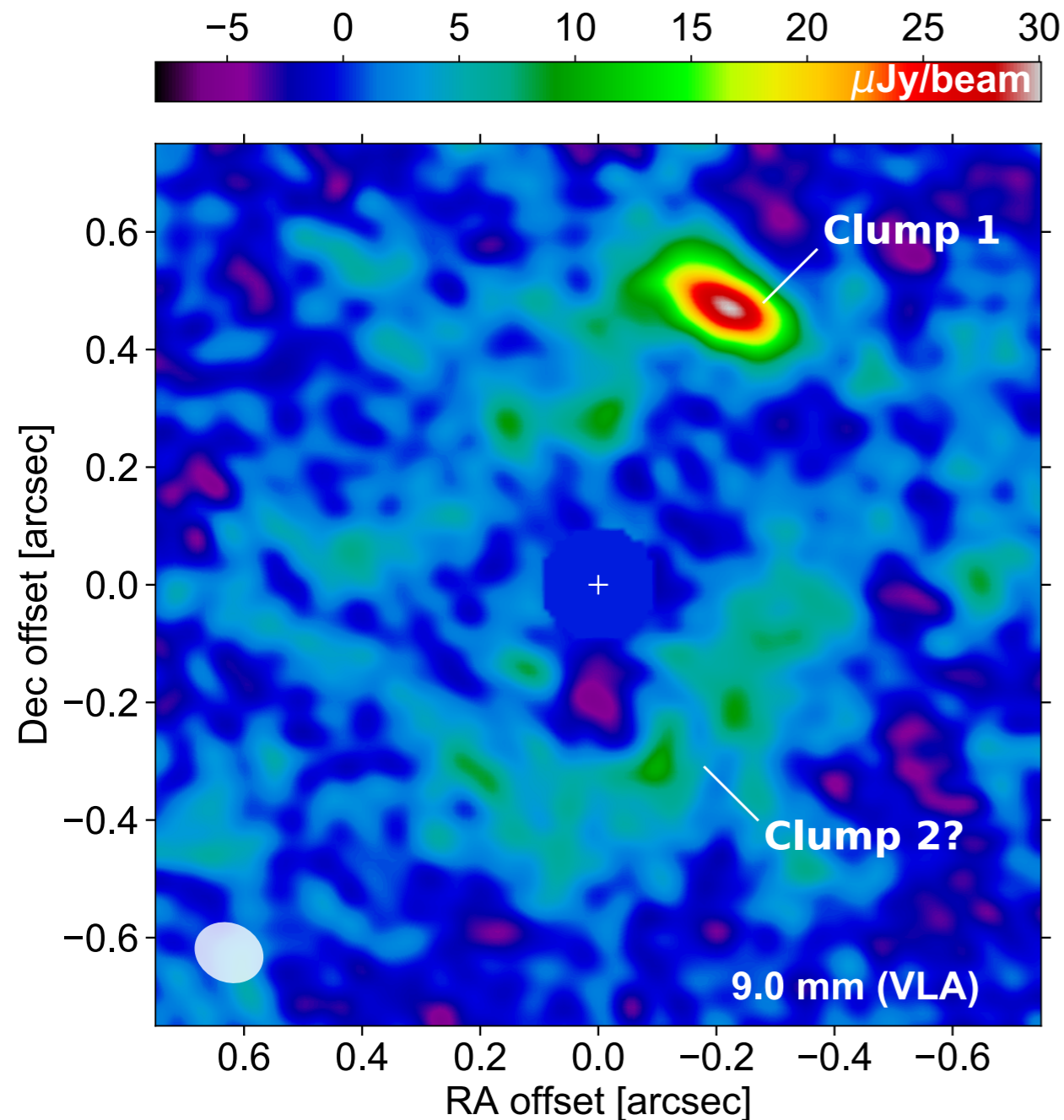
Baruteau+ 19



- dust size distribution $n(s) \propto s^{-3}$ for s in $[10\mu\text{m} - 1\text{cm}]$, $M_{\text{dust}} \sim 120 M_{\text{Earth}} + 24 M_{\text{Earth}}$ of *small dust* well coupled to the gas between the two rings
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Two giant planets sculpting the MWC 758 disc?

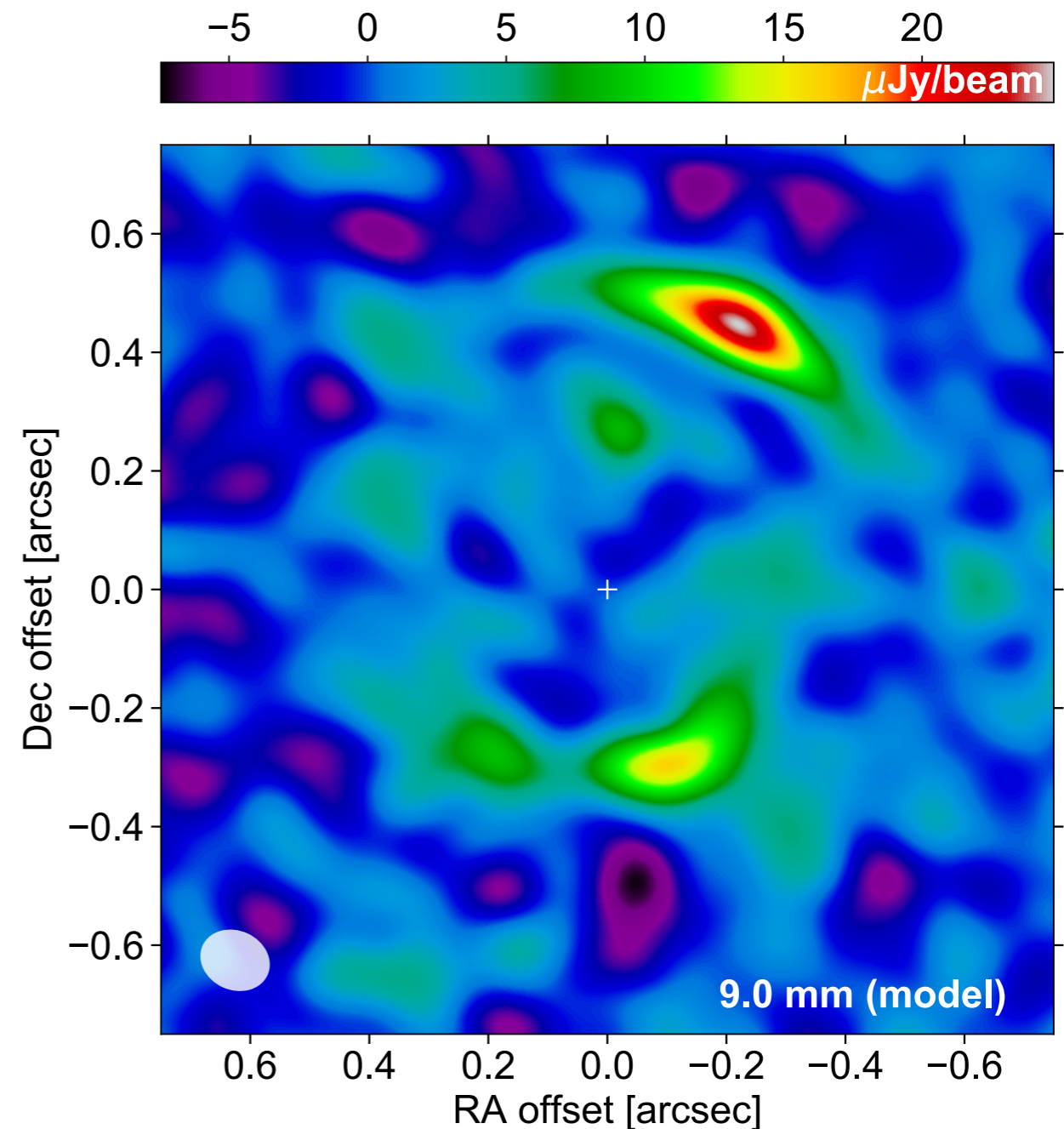
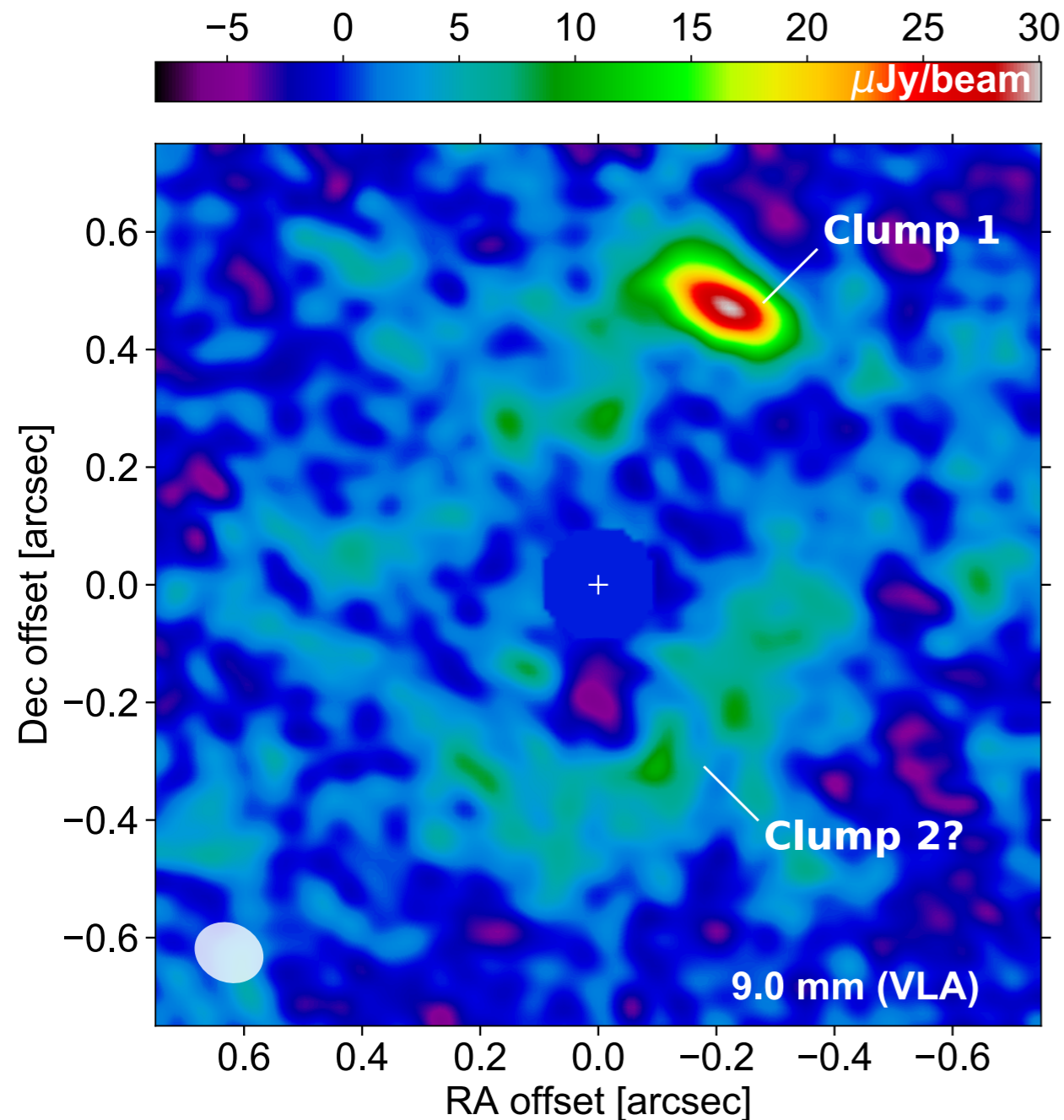
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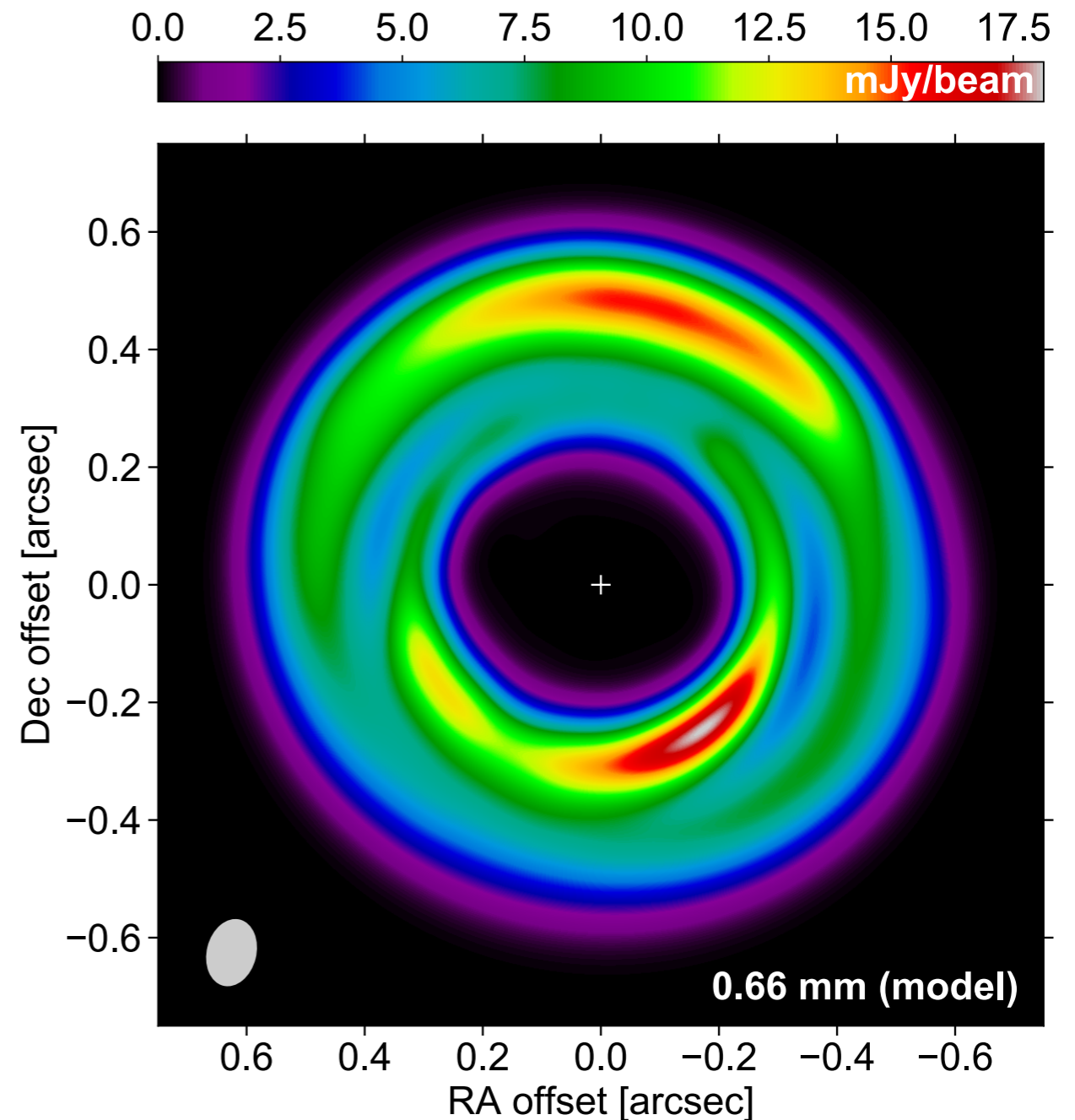
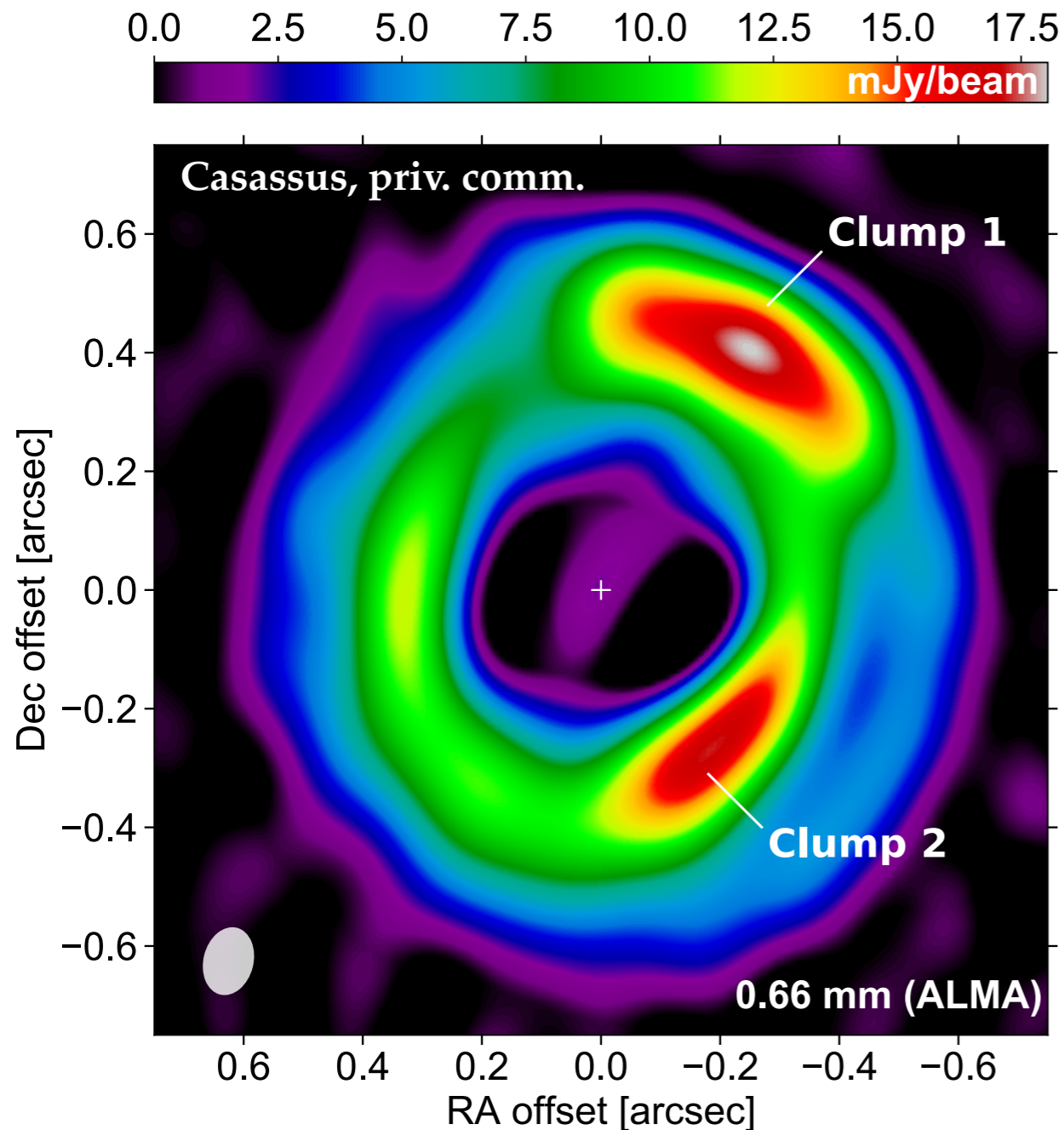
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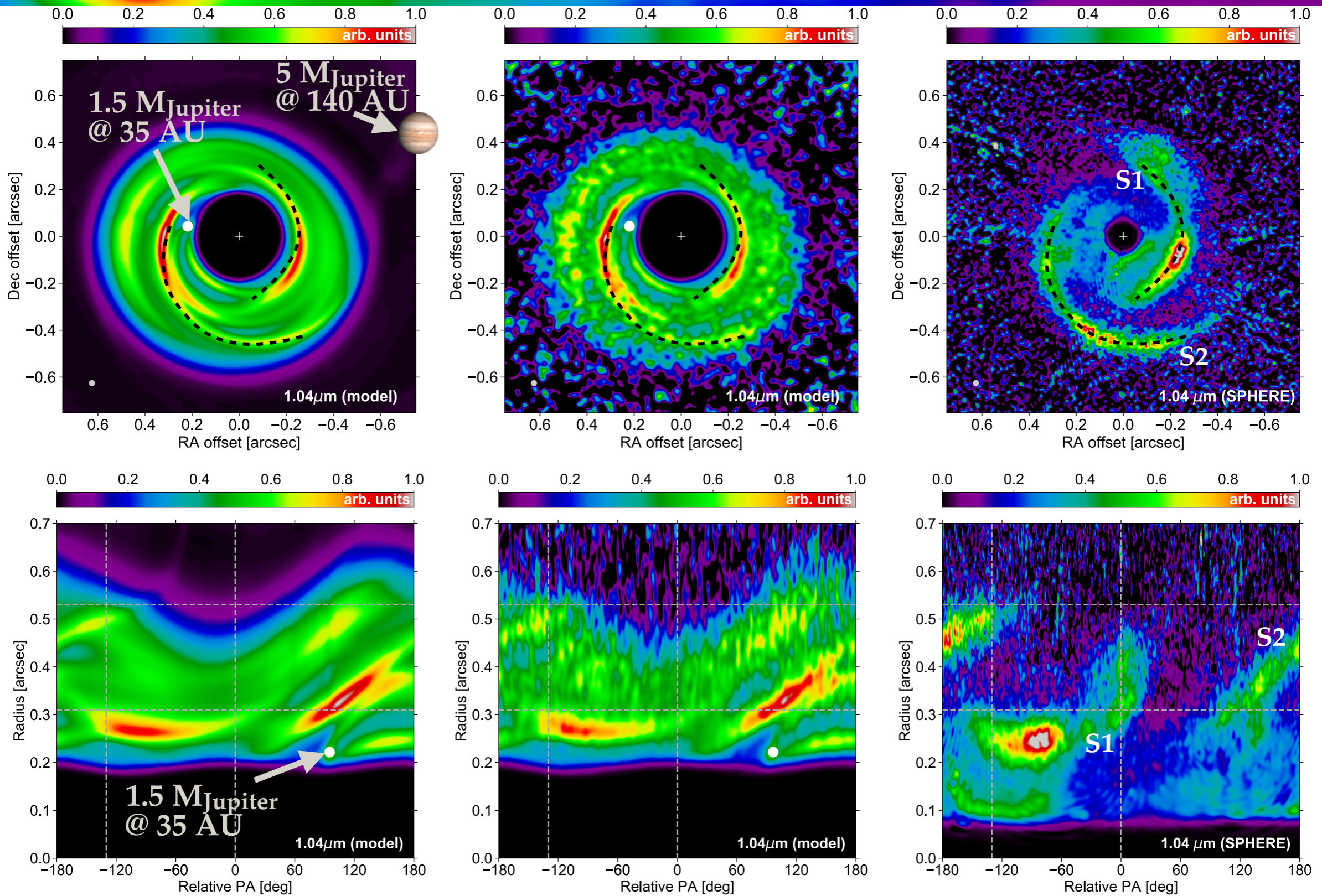
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Two giant planets sculpting the MWC 758 disc?

Baruteau+ 19



- dust size distribution $n(s) \propto s^{-3.5}$ for s in $[0.01 \mu\text{m} - 0.3 \mu\text{m}]$, $M_{\text{dust}} \sim 8 M_{\text{Earth}}$
- dust is well coupled to the gas, compact, made of silicates and amorphous carbons

Observational predictions of the presence of giant planets in the dust's radio emission of protoplanetary discs

Clément Baruteau (CNRS/IRAP, Toulouse)

Outline

- Structures in protoplanetary discs
- MWC 758: an archetypal transition disc?
 - ❖ observational constraints
 - ❖ two giant planets in the MWC 758 disc?
- **A migrating mini-Neptune planet in the HD 169142 disc?**
- Intermittent planet migration and the formation of multiple rings in protoplanetary discs

A migrating mini-Neptune in the HD 169142 disc?

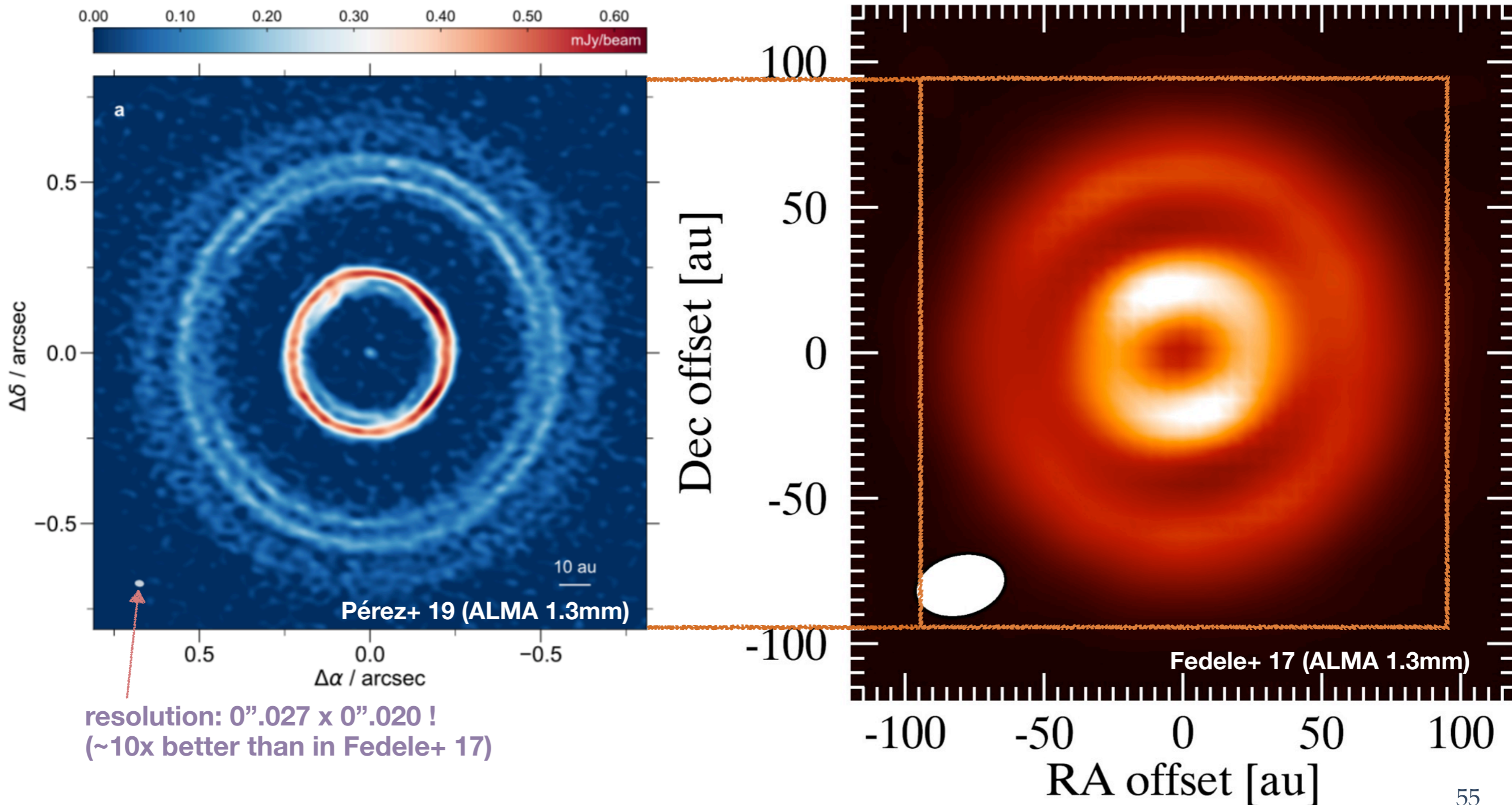
Pérez, Casassus, Baruteau+ 19

- **star:** Herbig Ae, **mass:** $1.7 \pm 0.2 M_{\odot}$ (1σ), **age:** 6^{+6}_{-3} Myr (1σ), **dist.:** 114 ± 1 pc (1σ), $\dot{M}_{\star} \sim 2 \times 10^{-9} M_{\odot} \text{yr}^{-1}$

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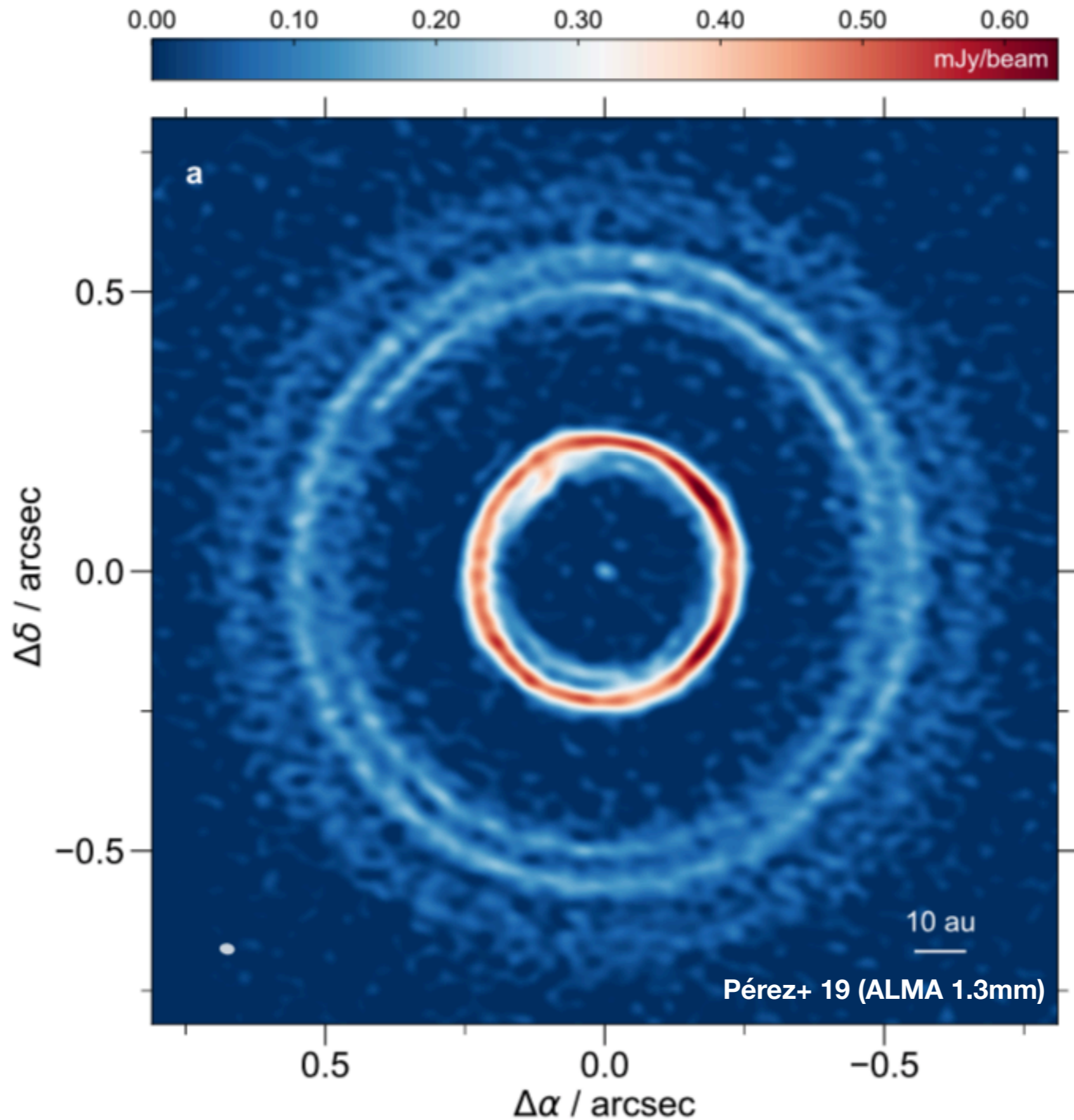
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- **disc:** rings and gaps seen in near-IR scattered light, and in the radio at several wavelengths



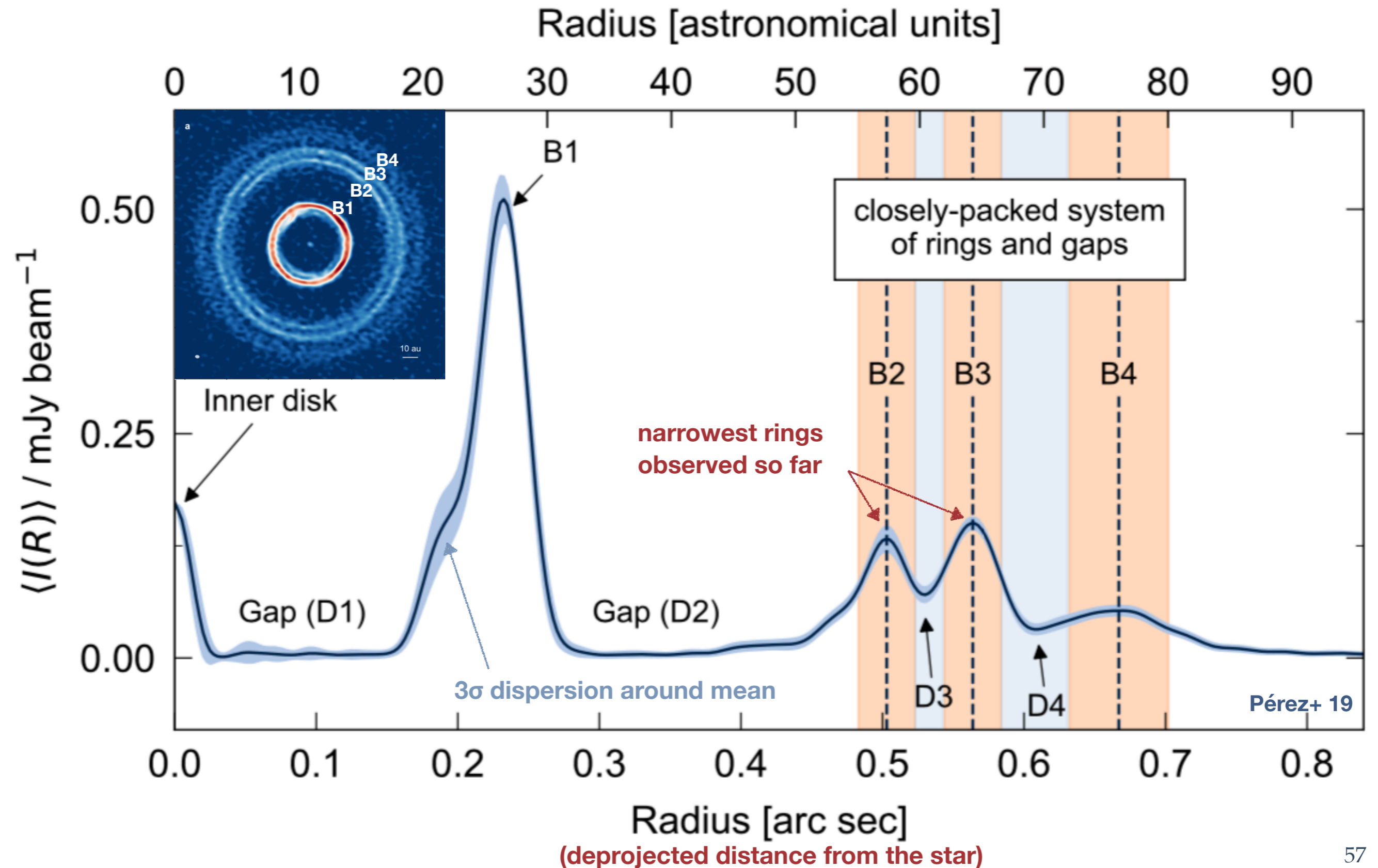
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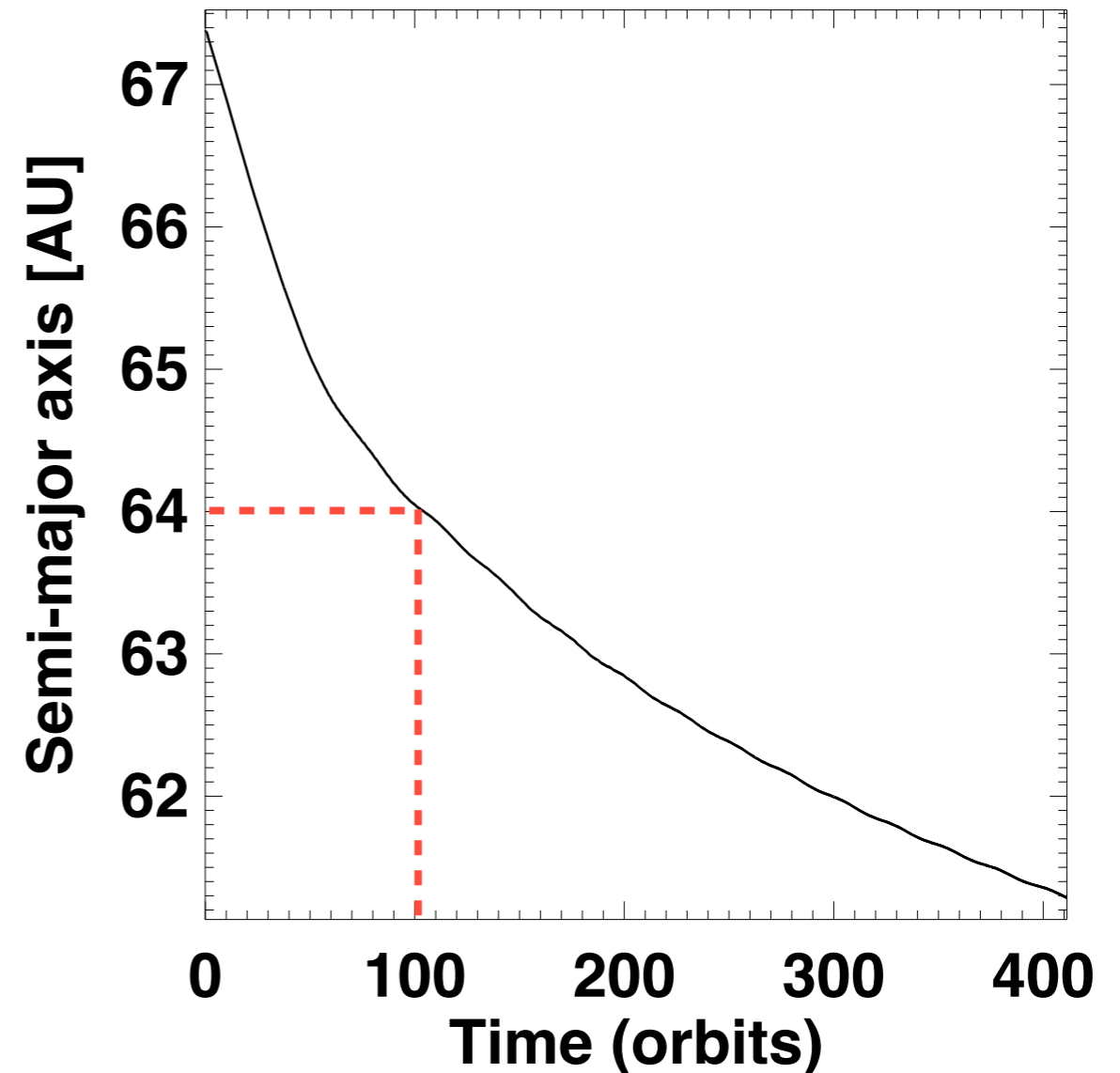
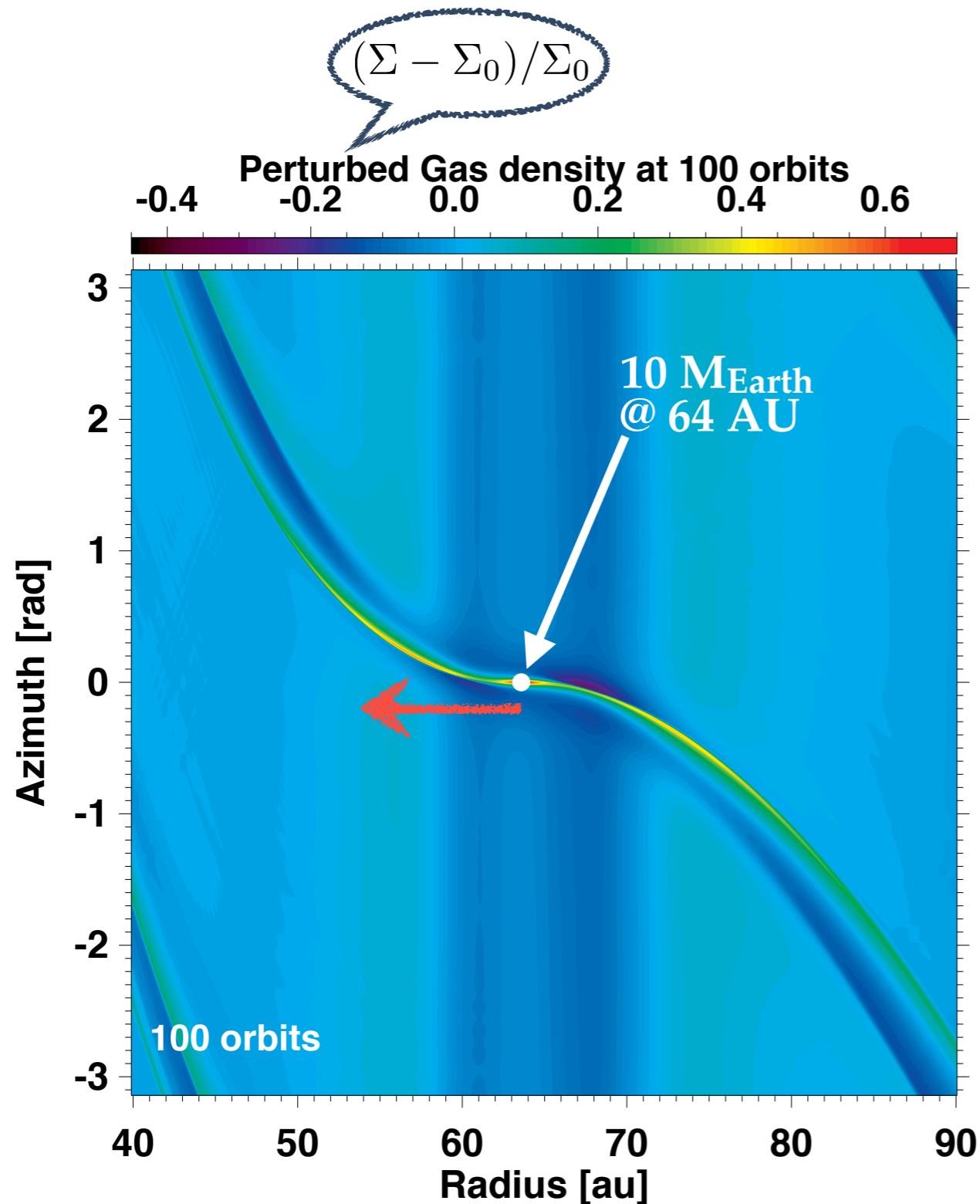
Pérez, Casassus, Baruteau+ 19



The three narrow rings spot a forming planet

Pérez, Casassus, Baruteau+ 19

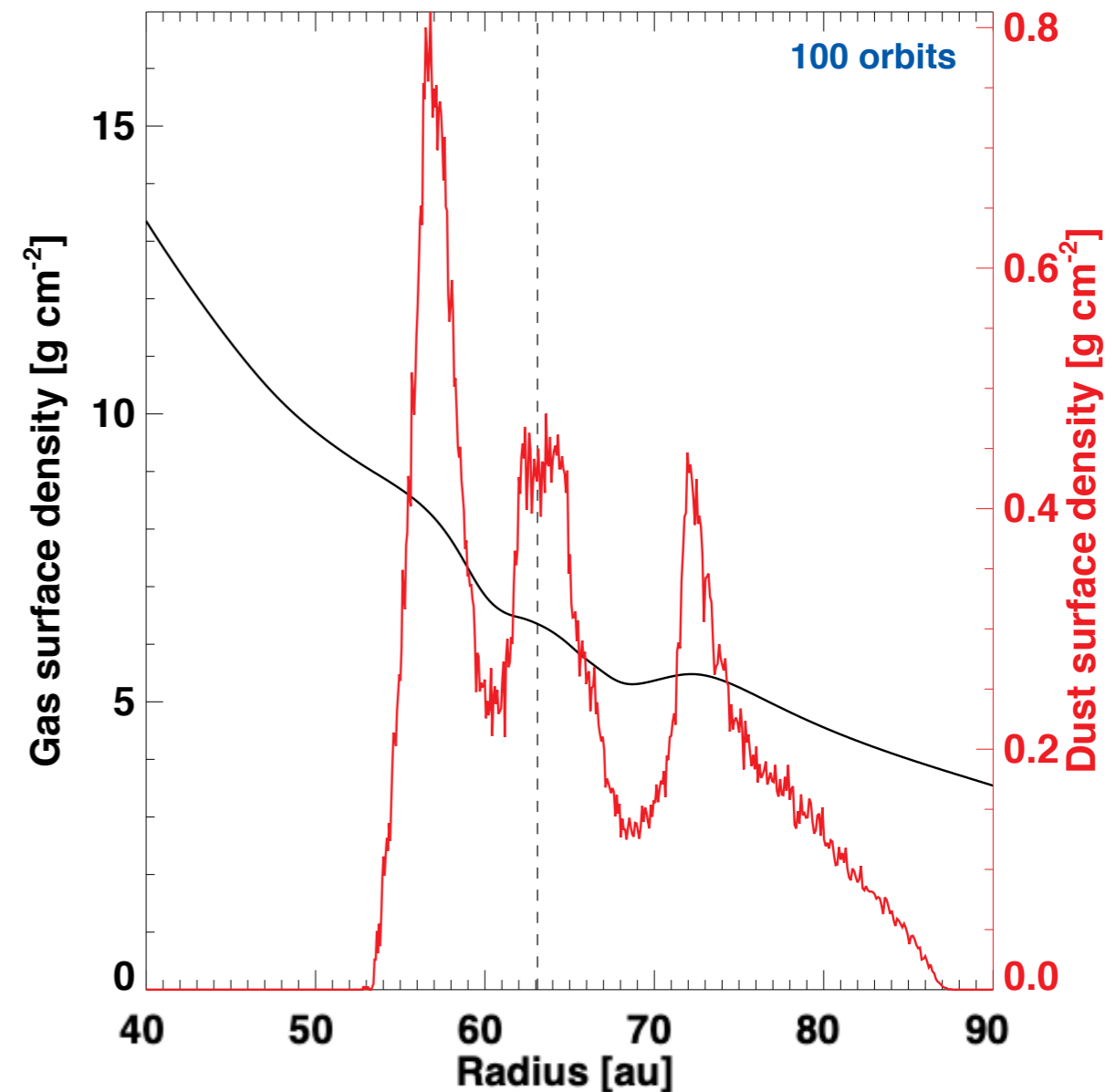
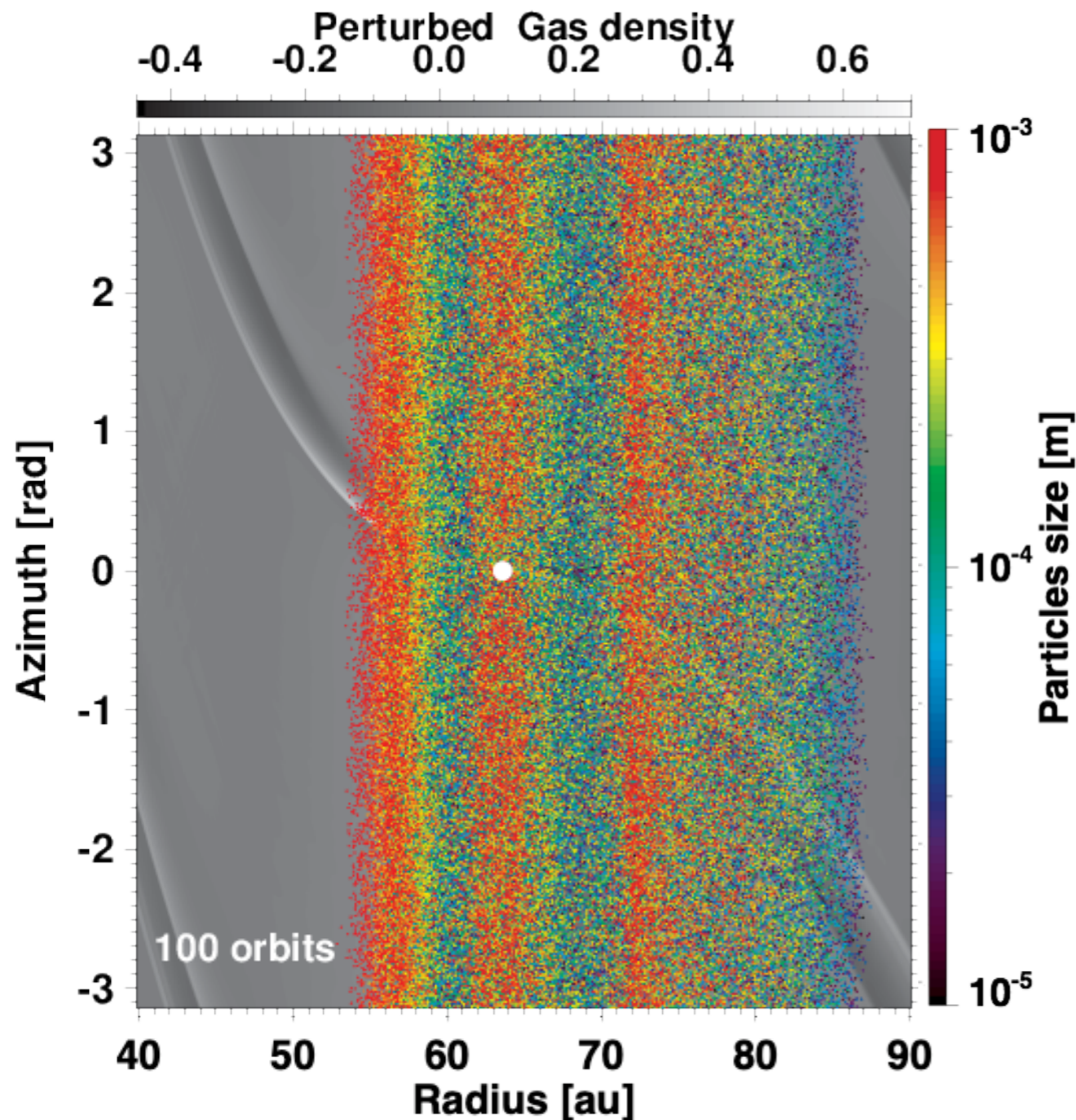
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Pérez, Casassus, Baruteau+ 19

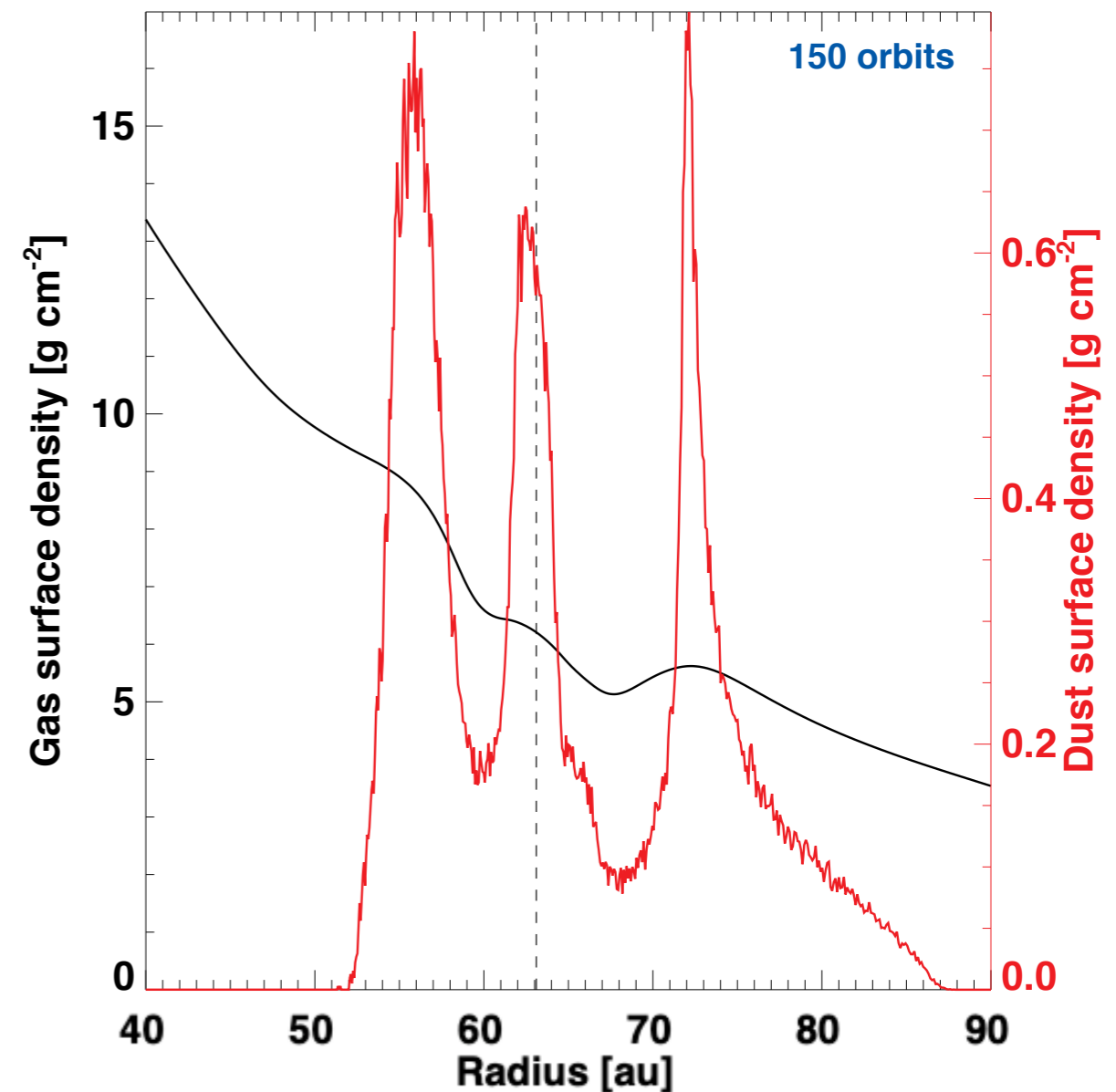
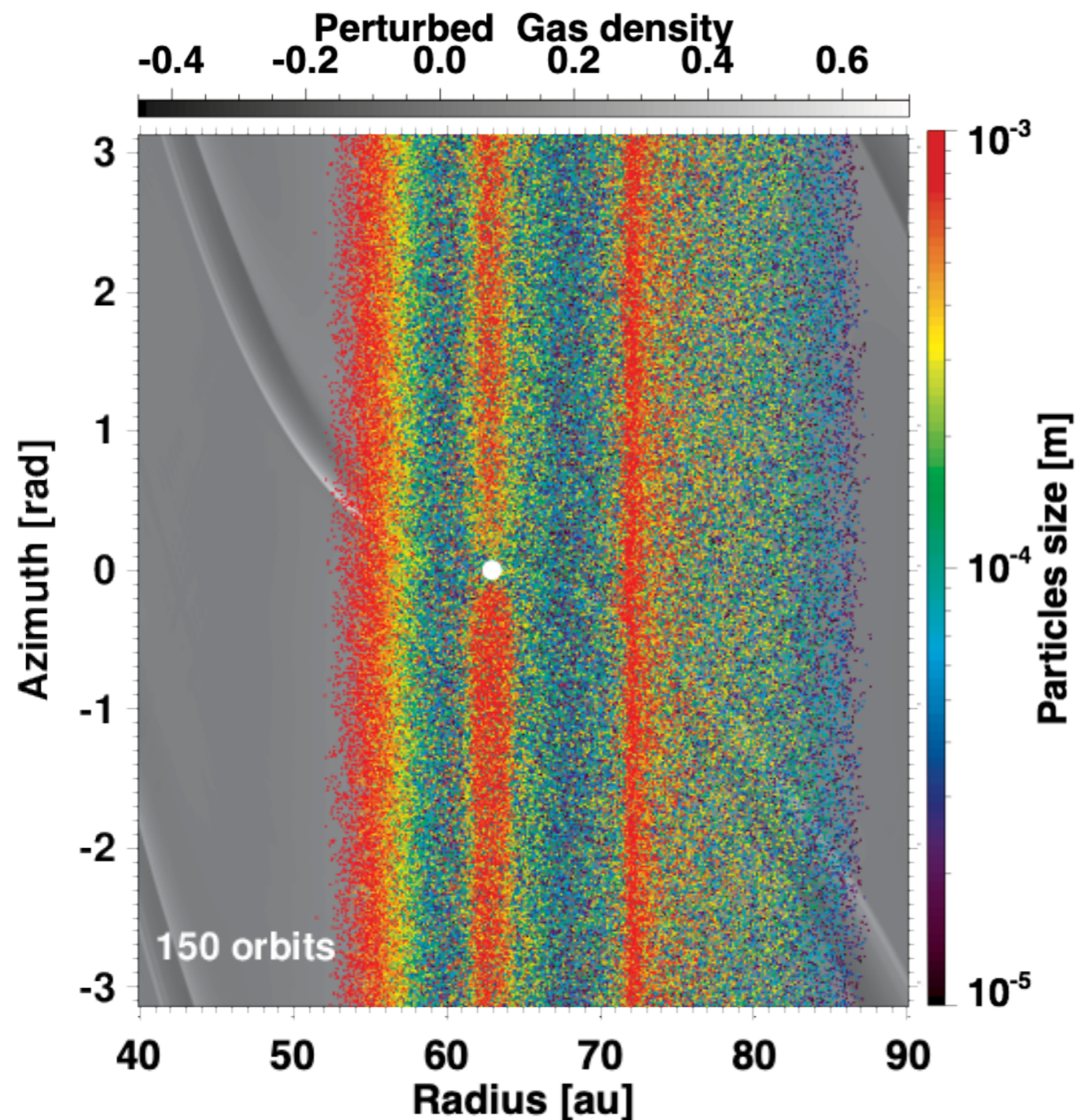
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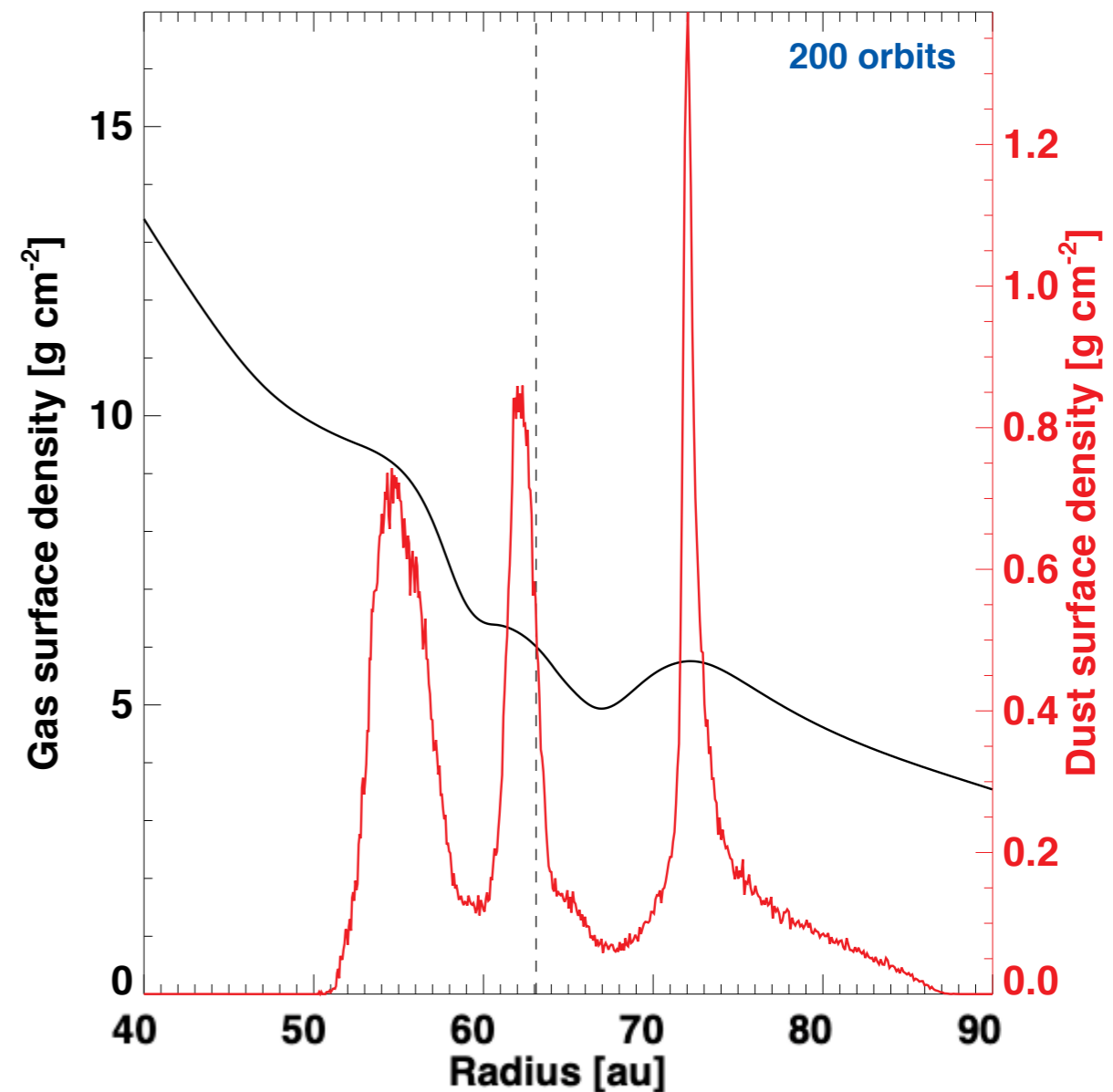
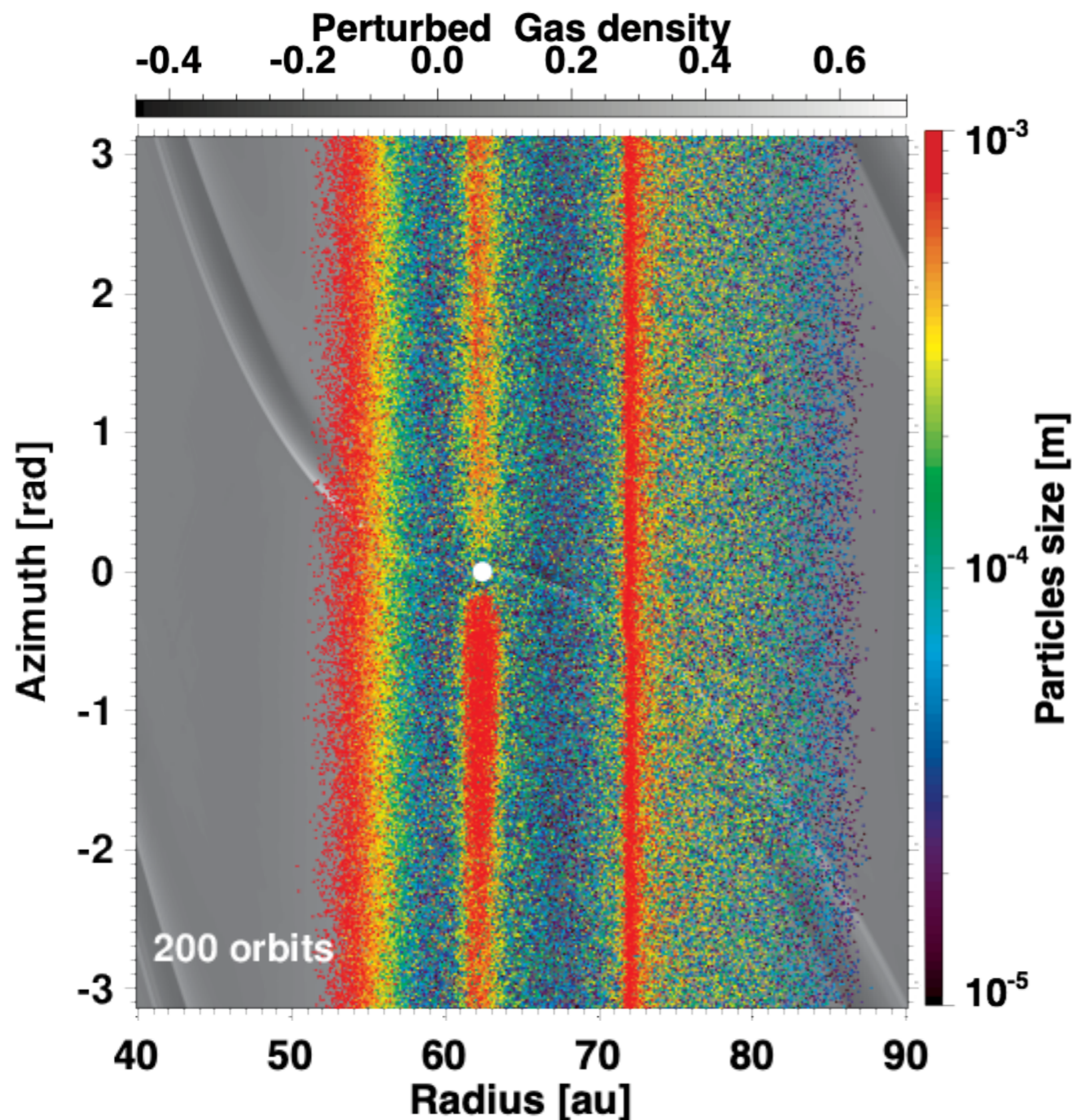
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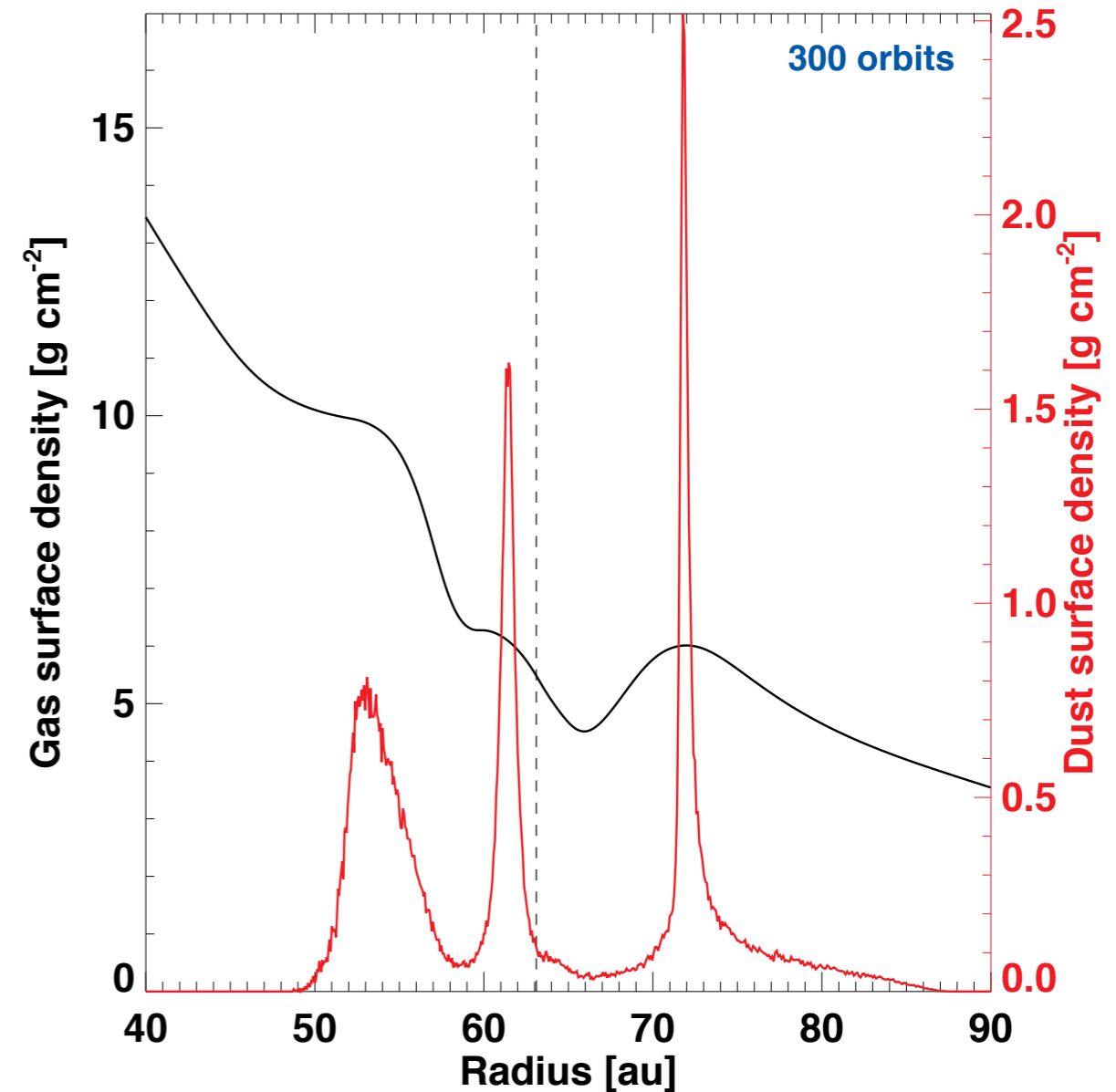
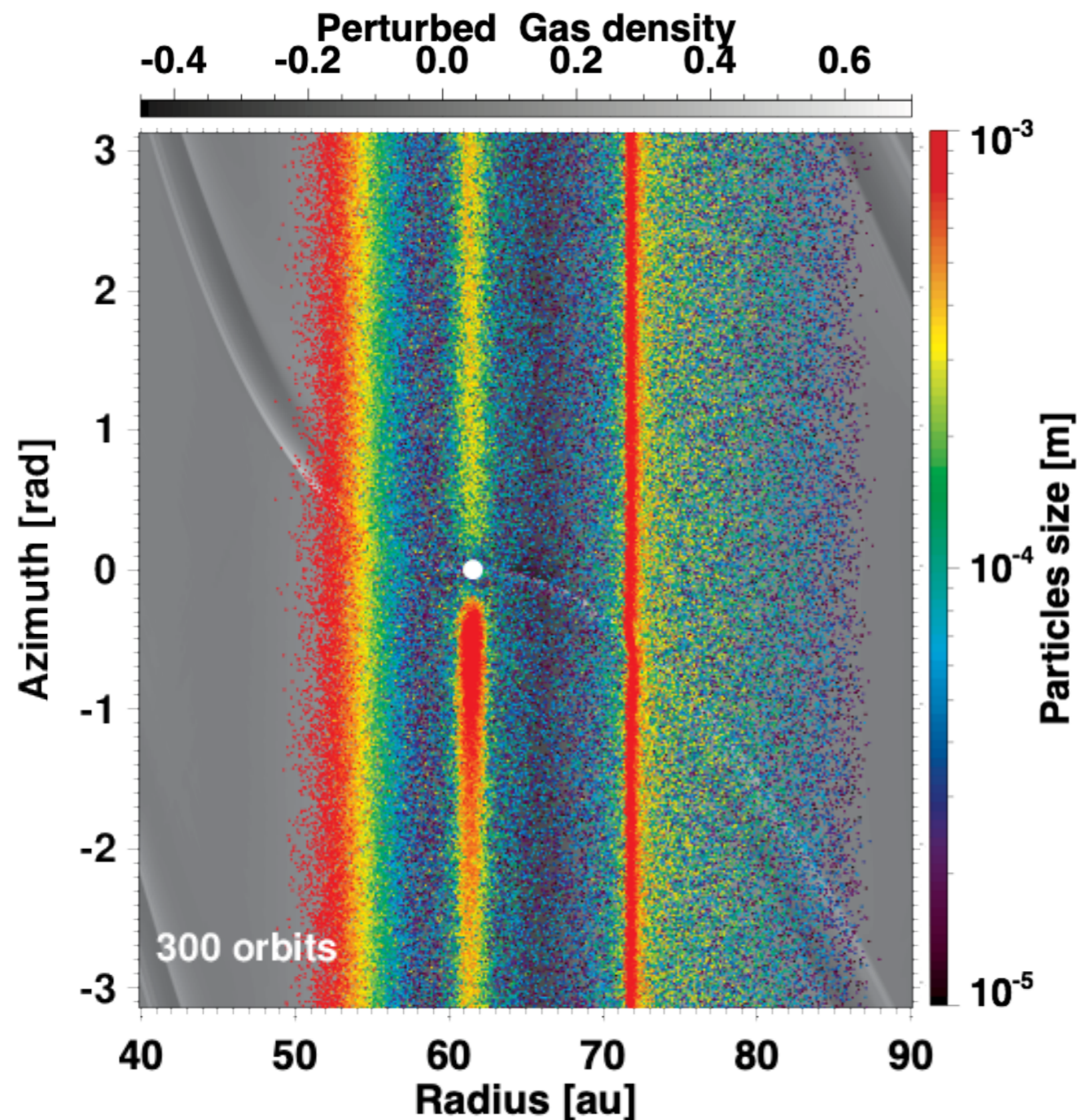
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Pérez, Casassus, Baruteau+ 19

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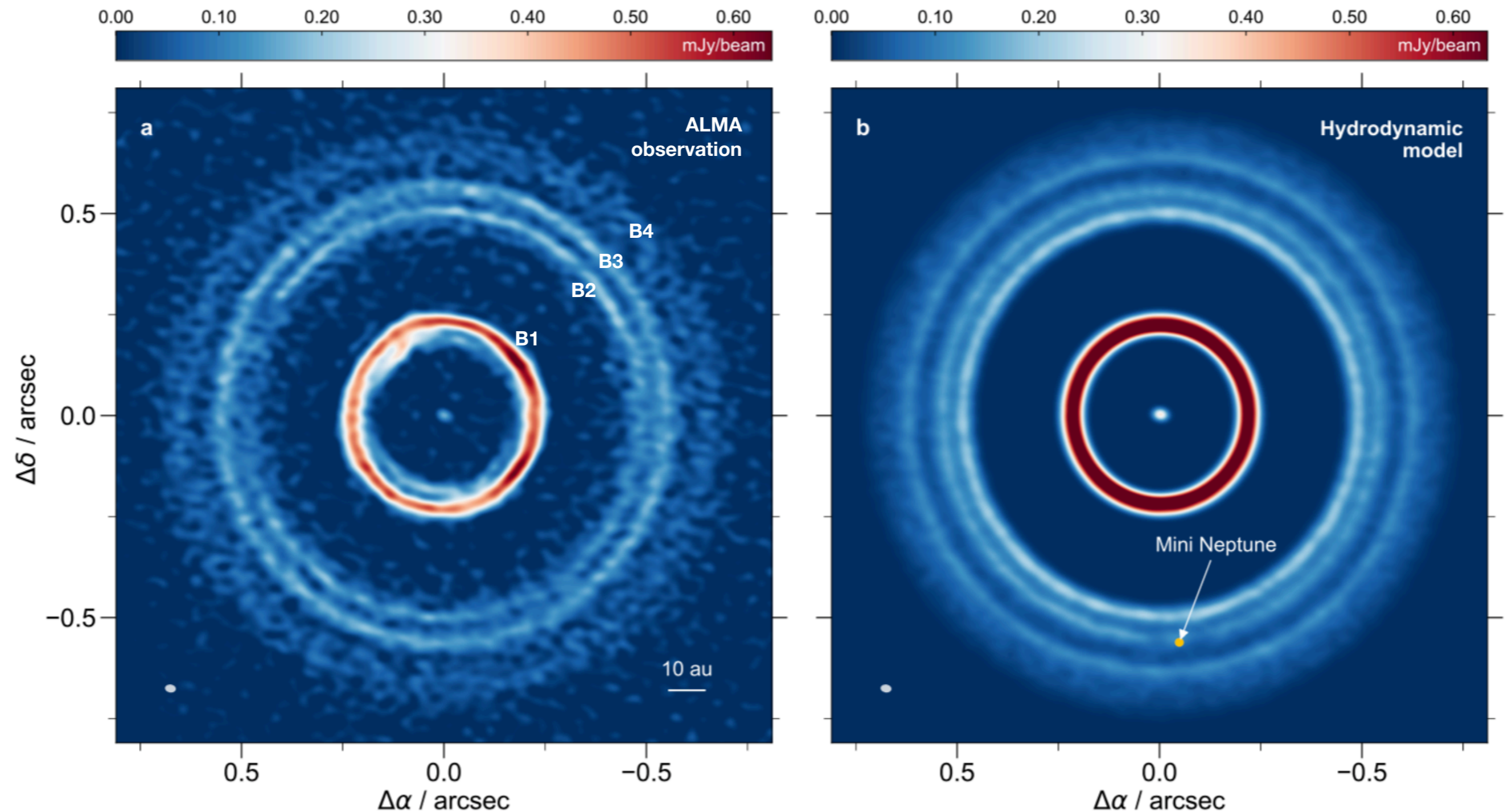


→ radial asymmetry of the dust rings is a natural outcome of the planet's inward migration!

The three narrow rings spot a forming planet

Pérez, Casassus, Baruteau+ 19

- 2D gas+dust simulations post-processed with dust radiative transfer calculations
- RT calculation: dust size distribution $n(s) \propto s^{-3.5}$ for s in $[10\mu\text{m} - 1\text{mm}]$, $M_{\text{dust}} \sim 100 M_{\text{Earth}}$



inner parts of the disc (including B1 ring)
artificially added

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How does planet migration shape the dust in discs?

Wafflard-Fernandez & Baruteau, in prep.

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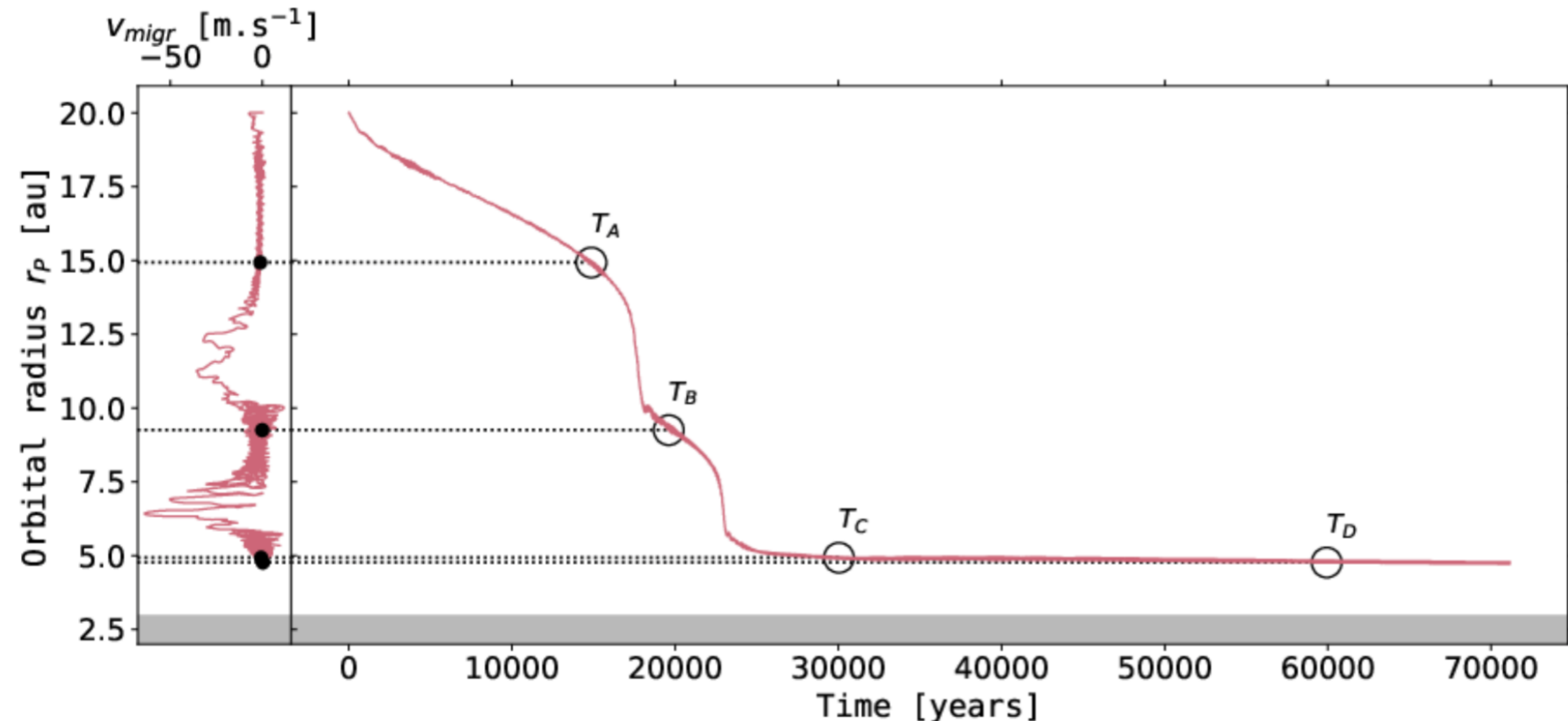
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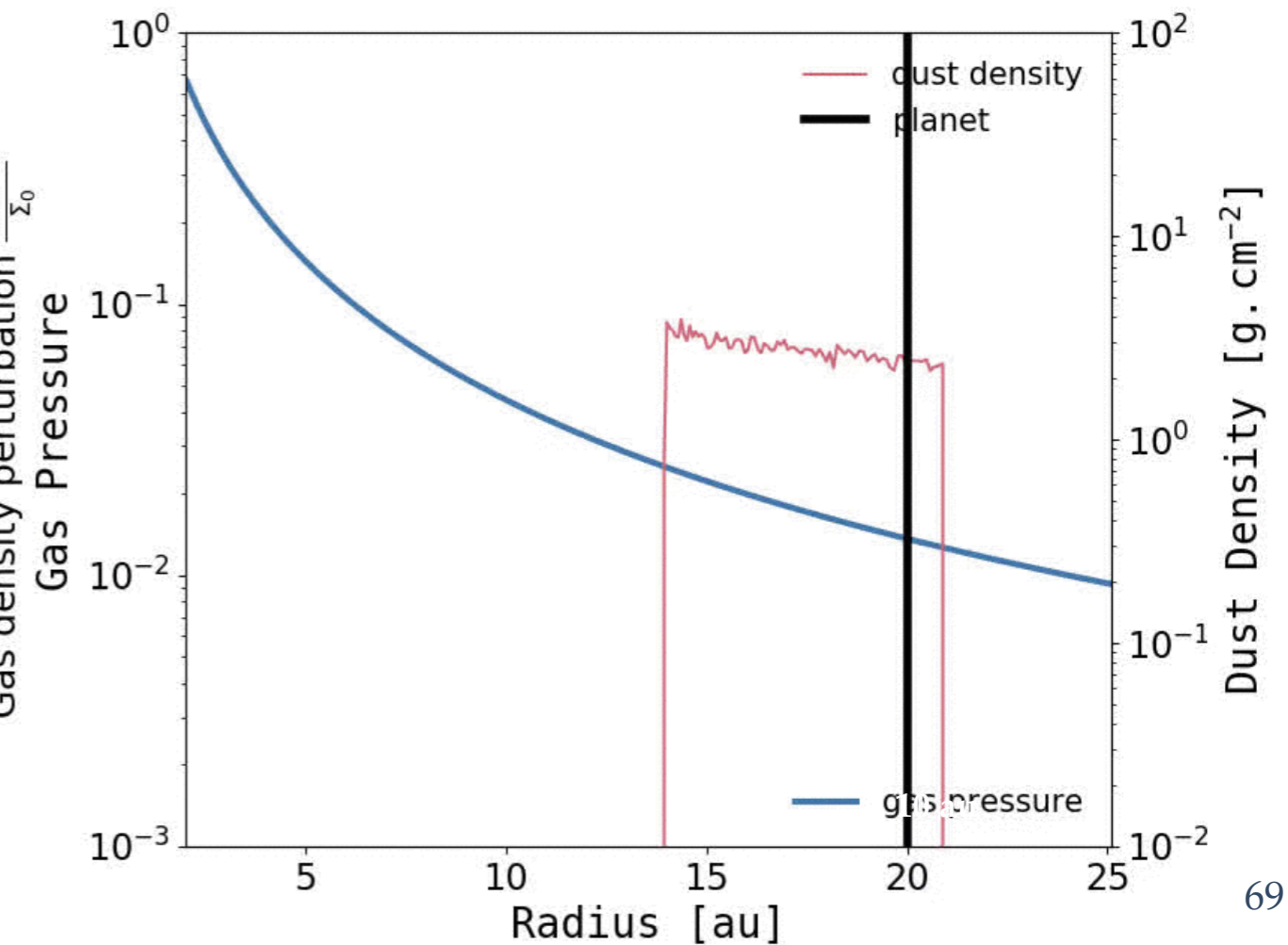
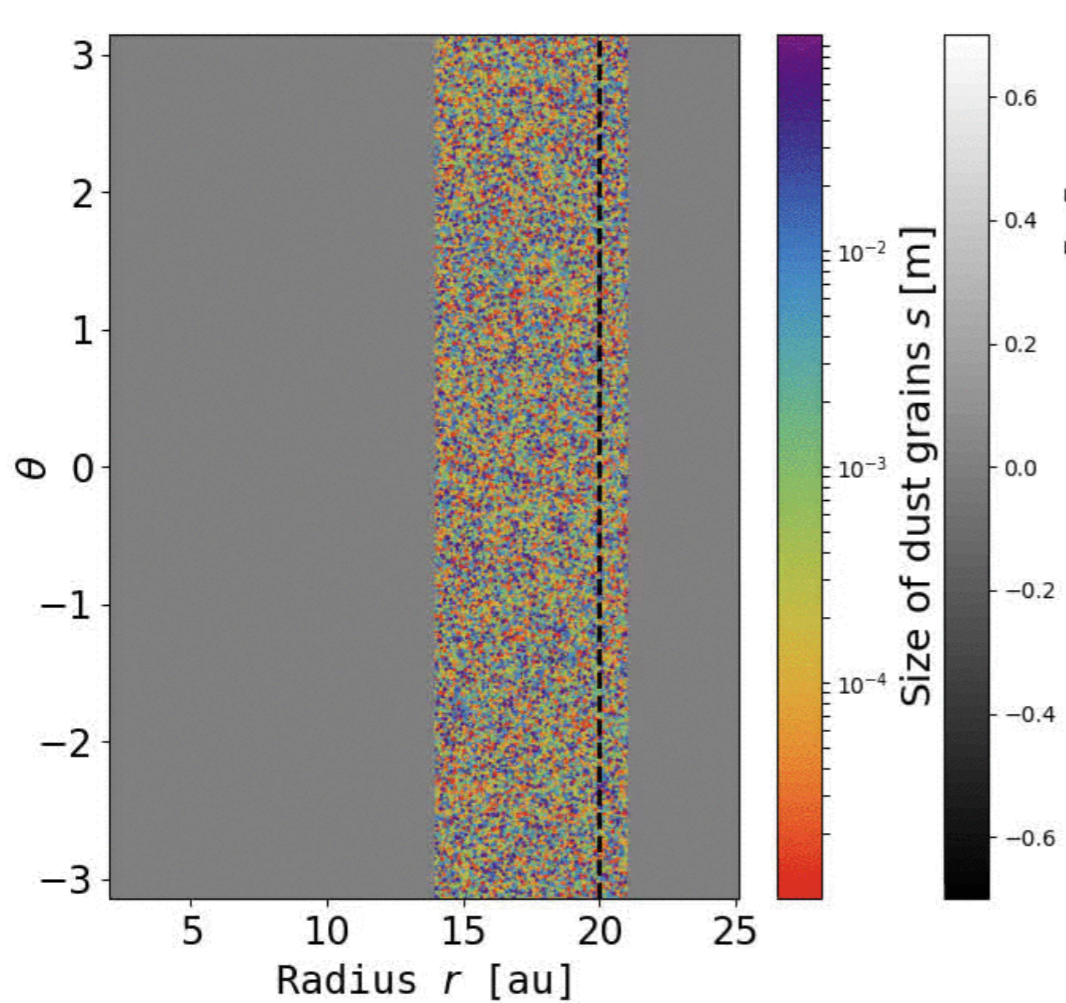
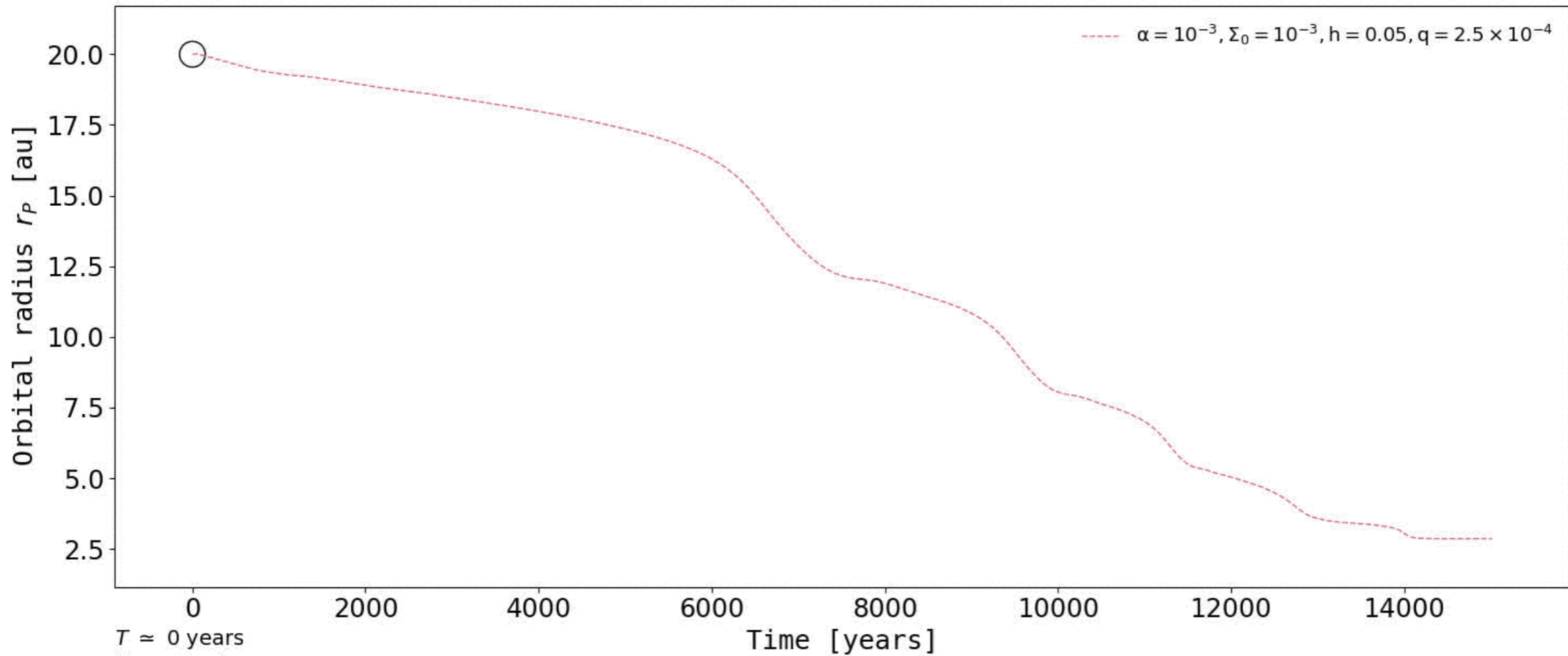
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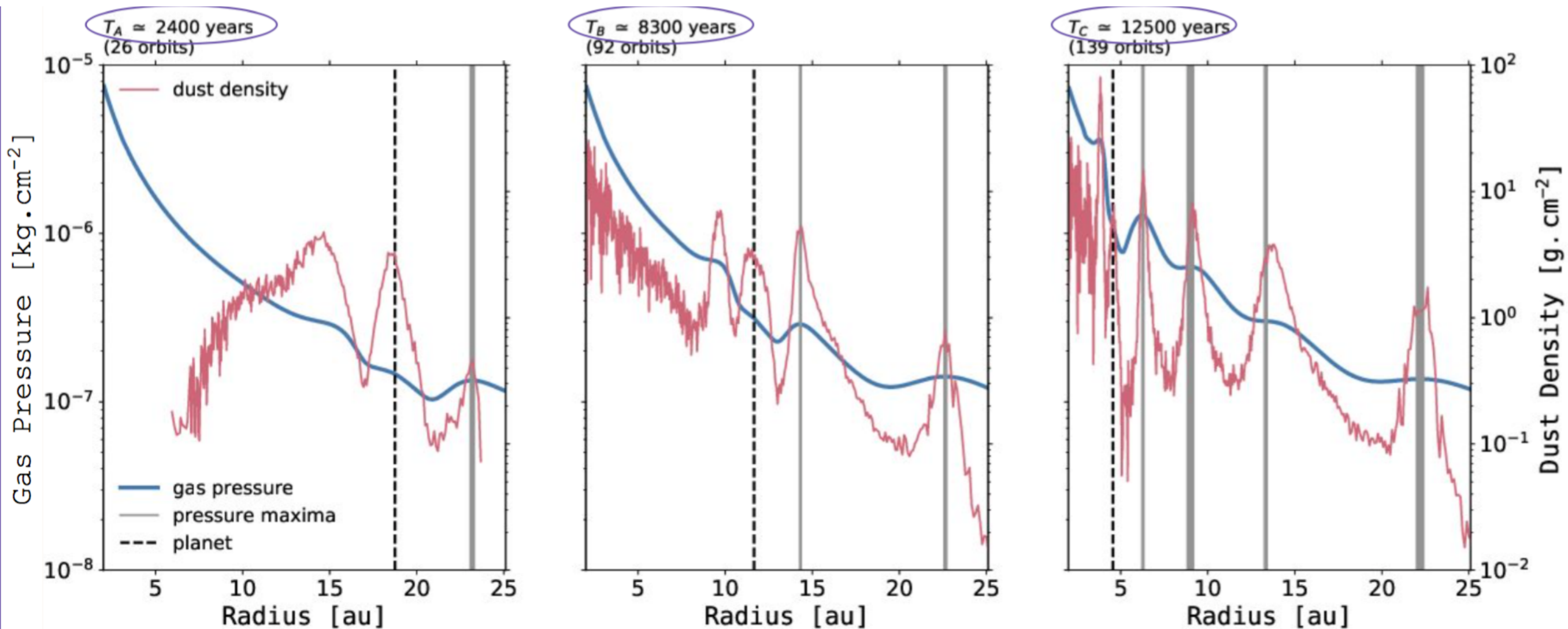




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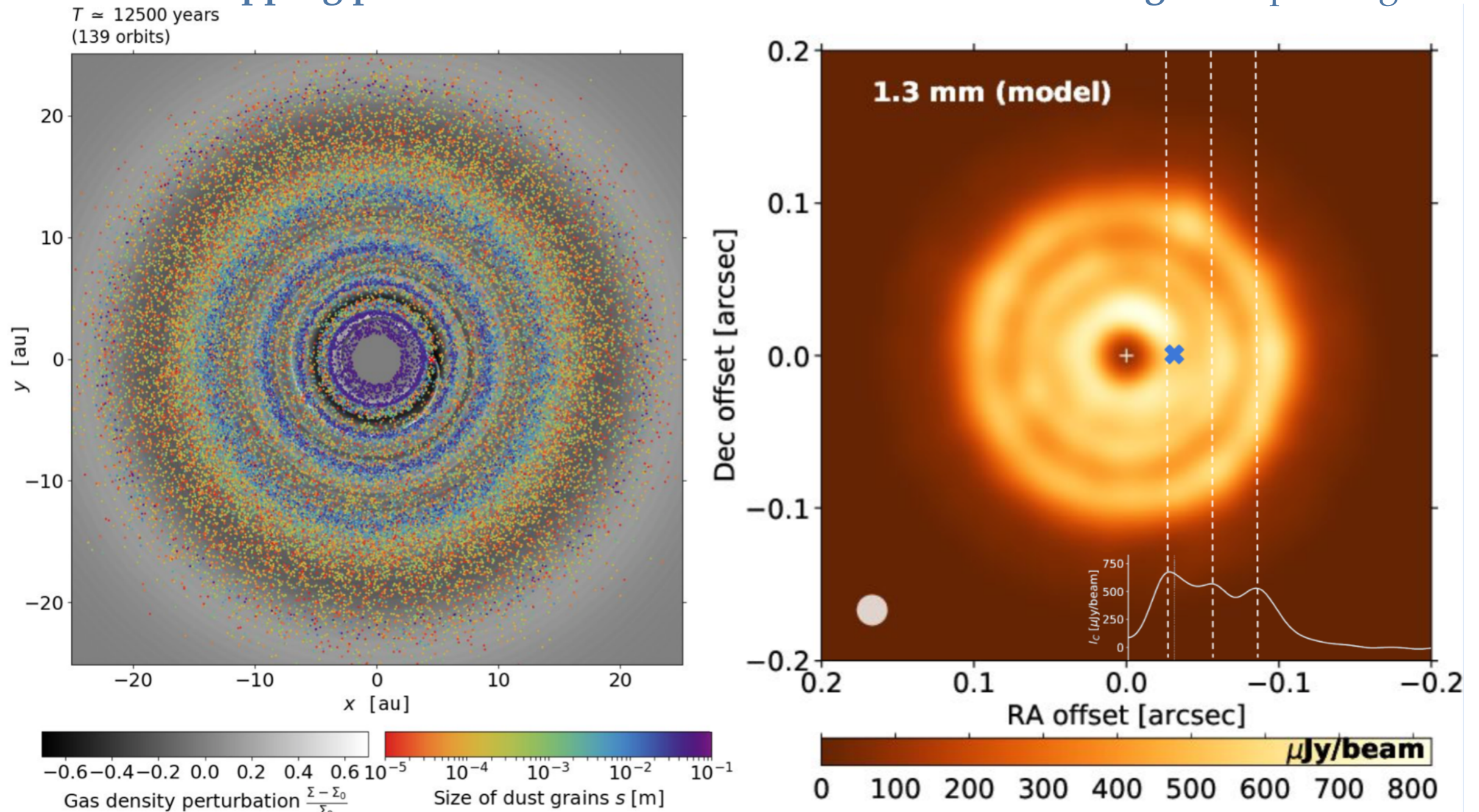
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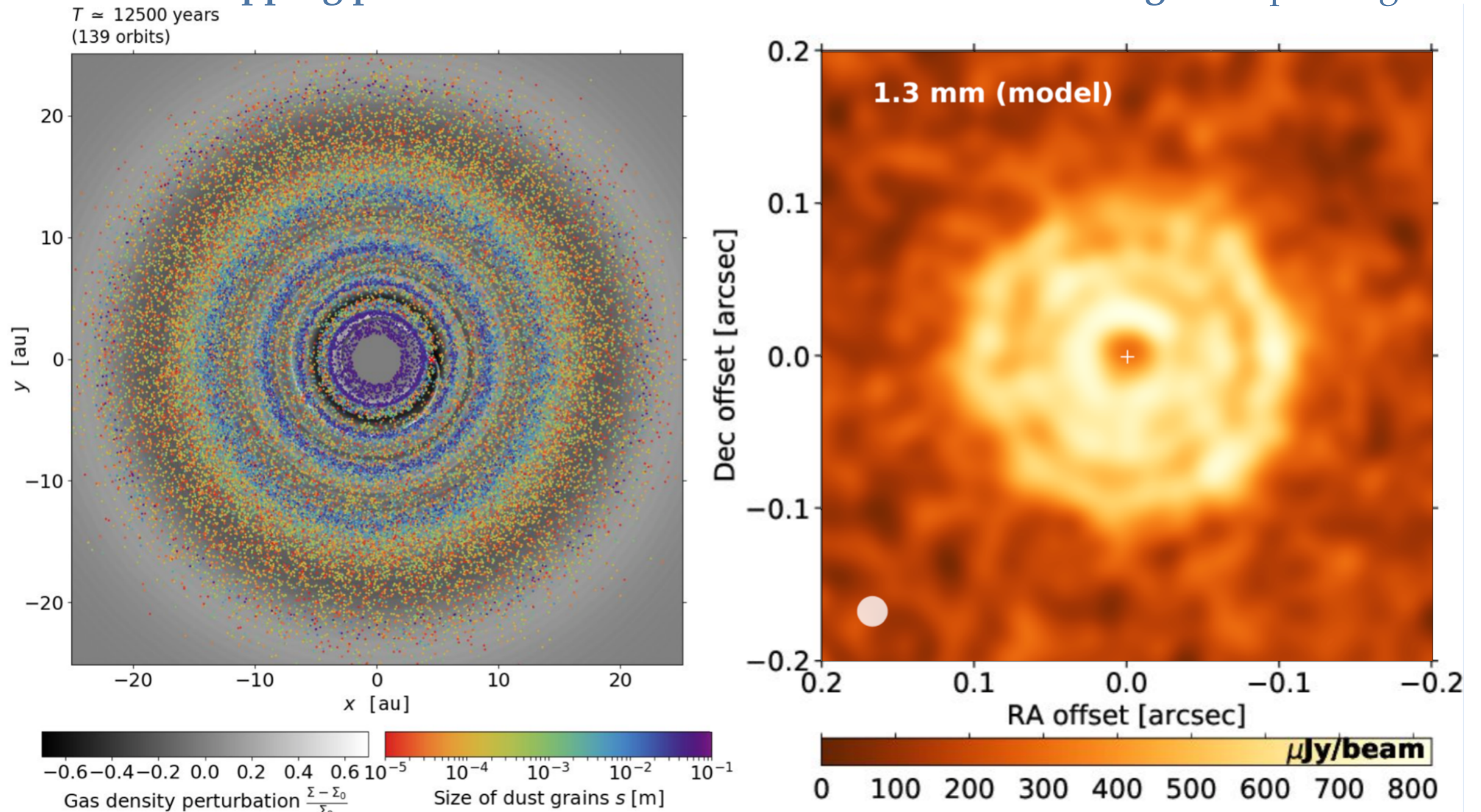
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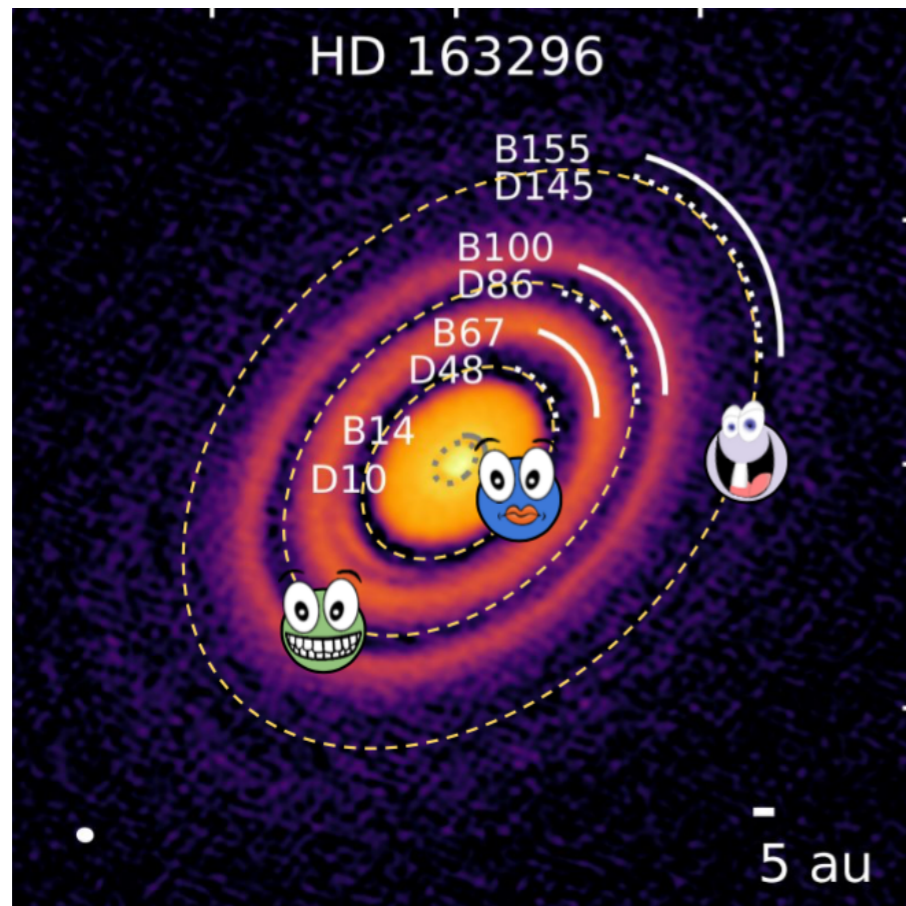
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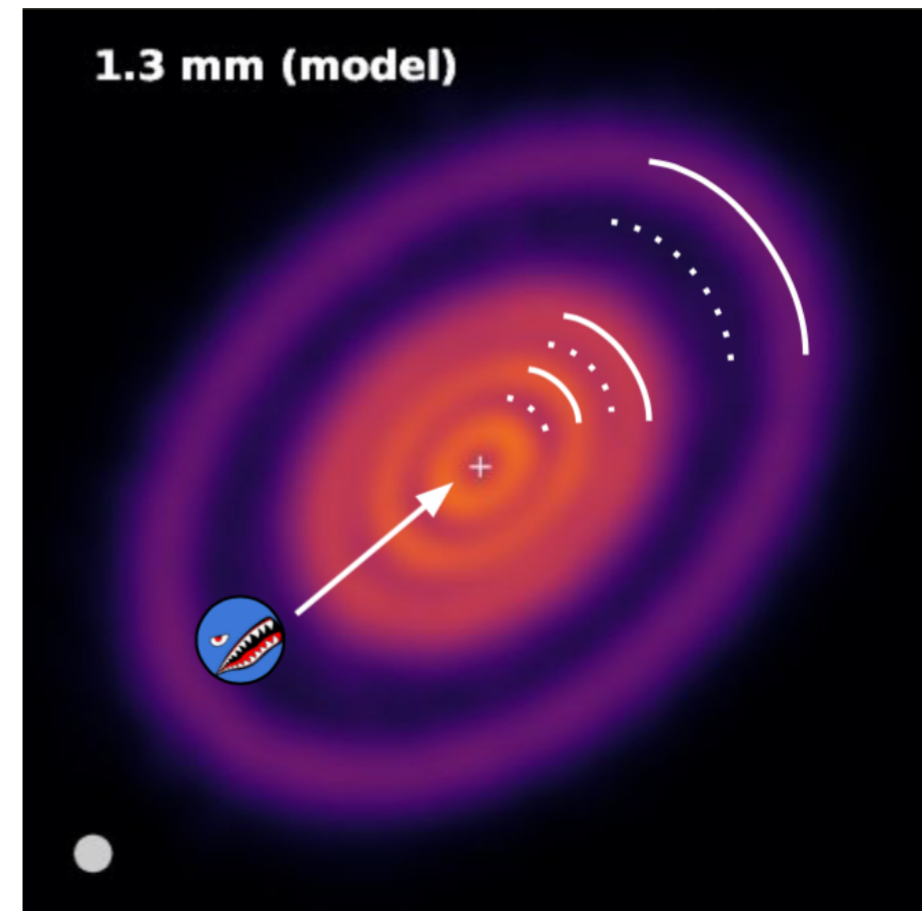
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current understanding

N dark rings = N fixed planets

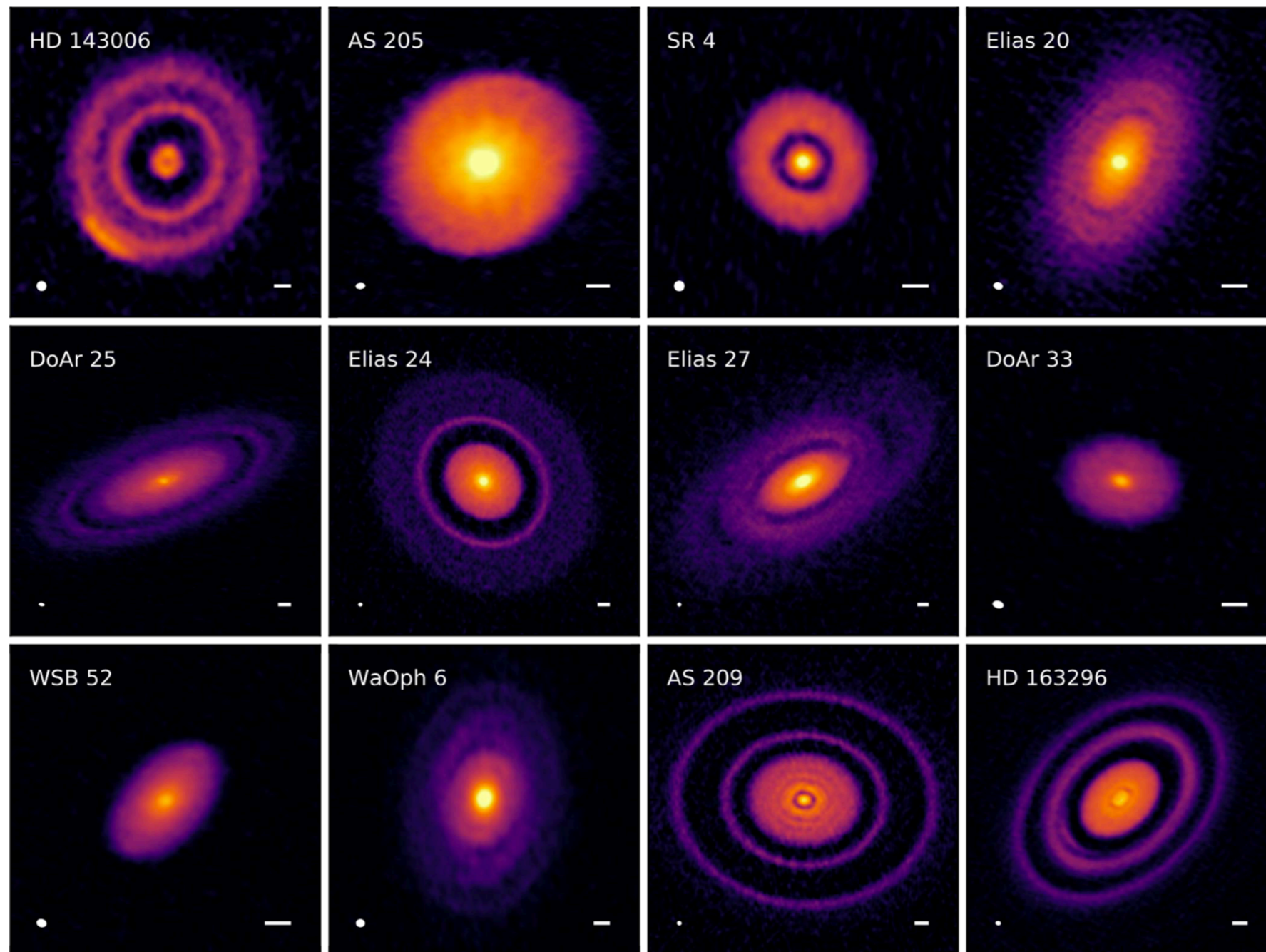


new scenario

a **single** migrating planet can form **multiple** dark and bright rings

Some open questions

thanks for your attention!



Andrews+ 18, DSHARP collaboration (ALMA@1.3mm)

- What structures are **indirect** signatures of planets?
- If planets, why don't we see them **directly**? Would observed structures rather **constrain** planet formation or migration?

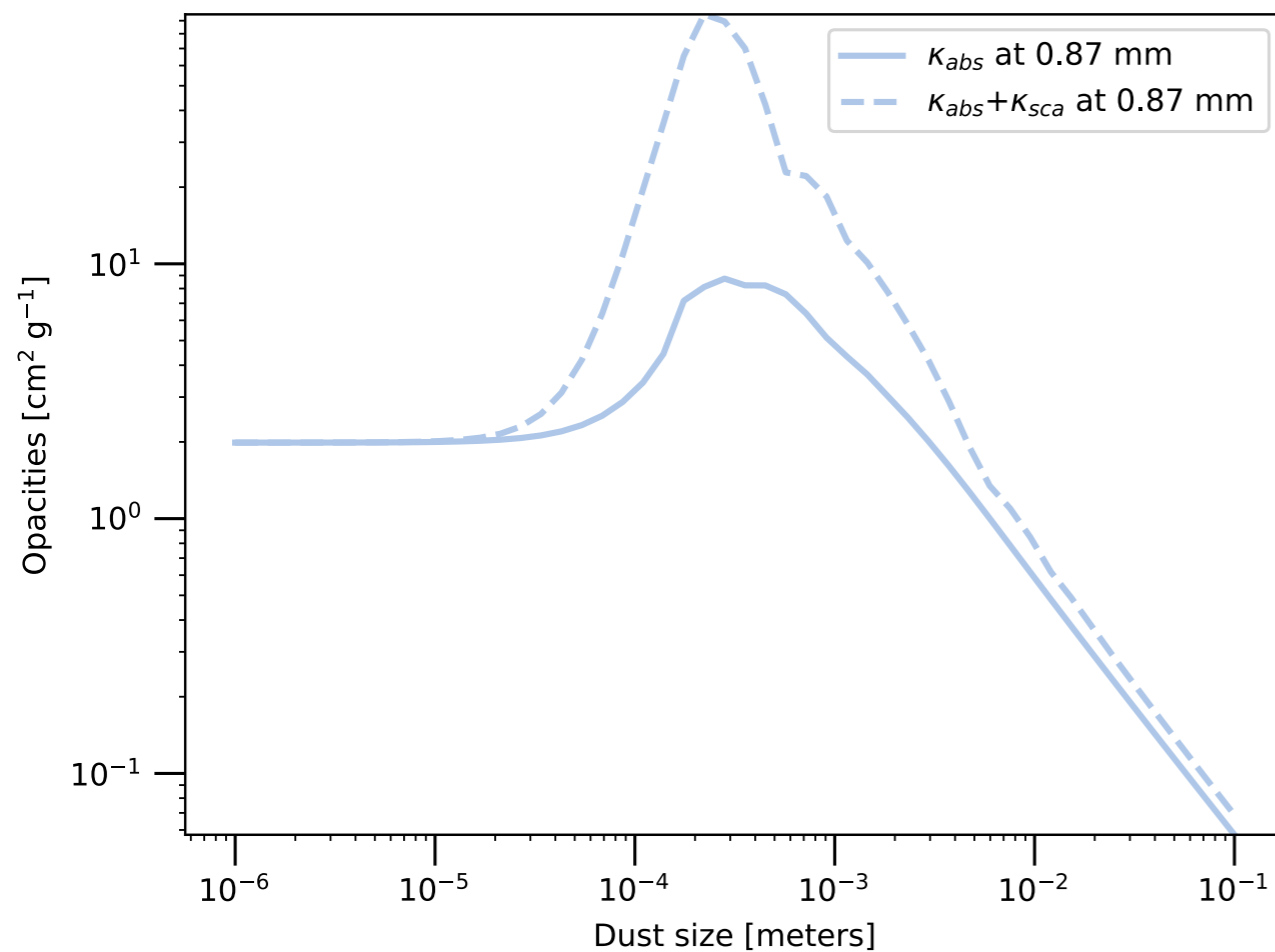
Bonus slides

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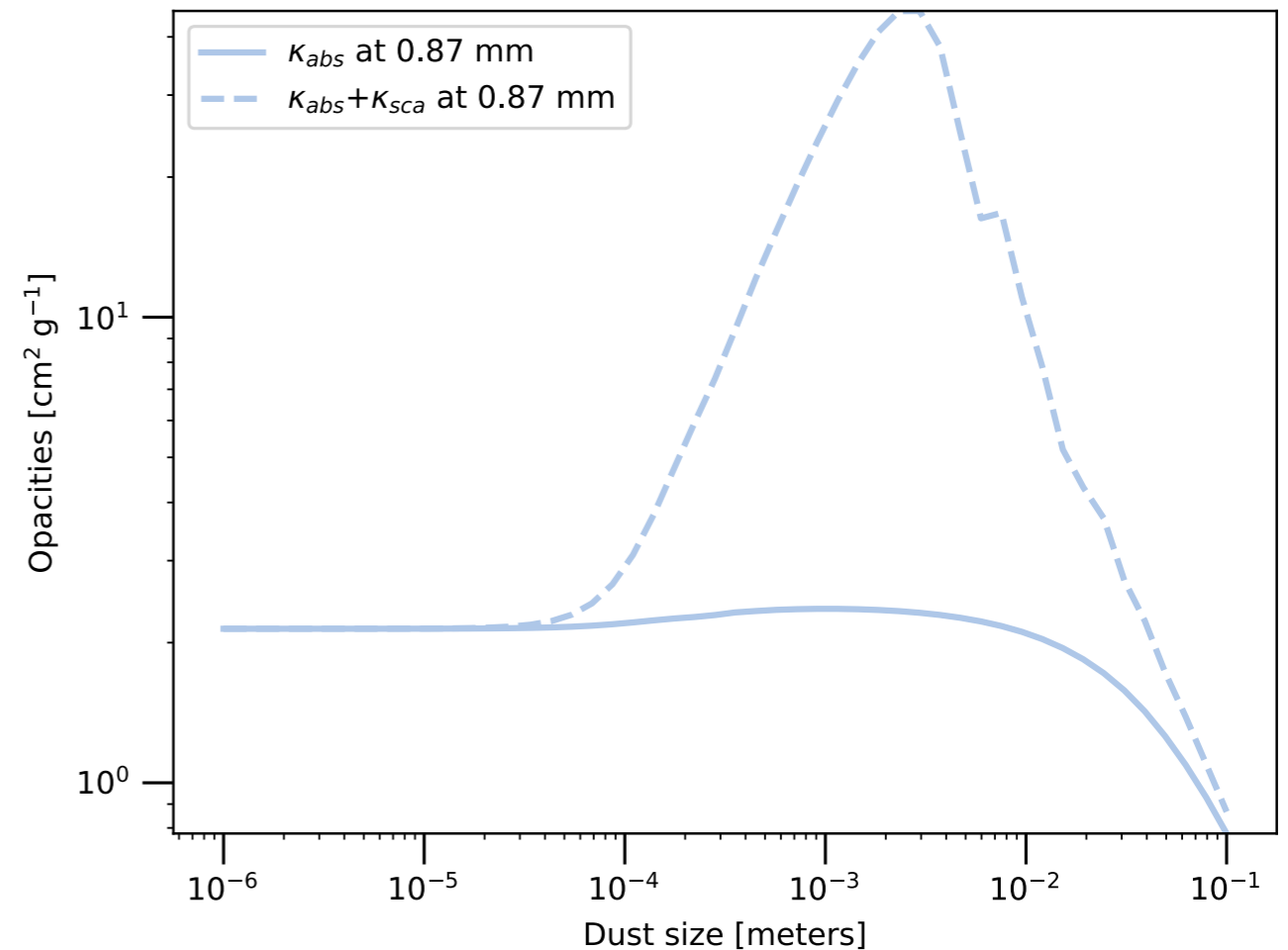
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compact dust ($\rho_{int} \sim 1.3 \text{ g/cc}$)

(mix aggregate has 70% of its solids in water ices, 30% in astrosilicates)



porous dust ($\rho_{int} = 0.1 \text{ g/cc}$)