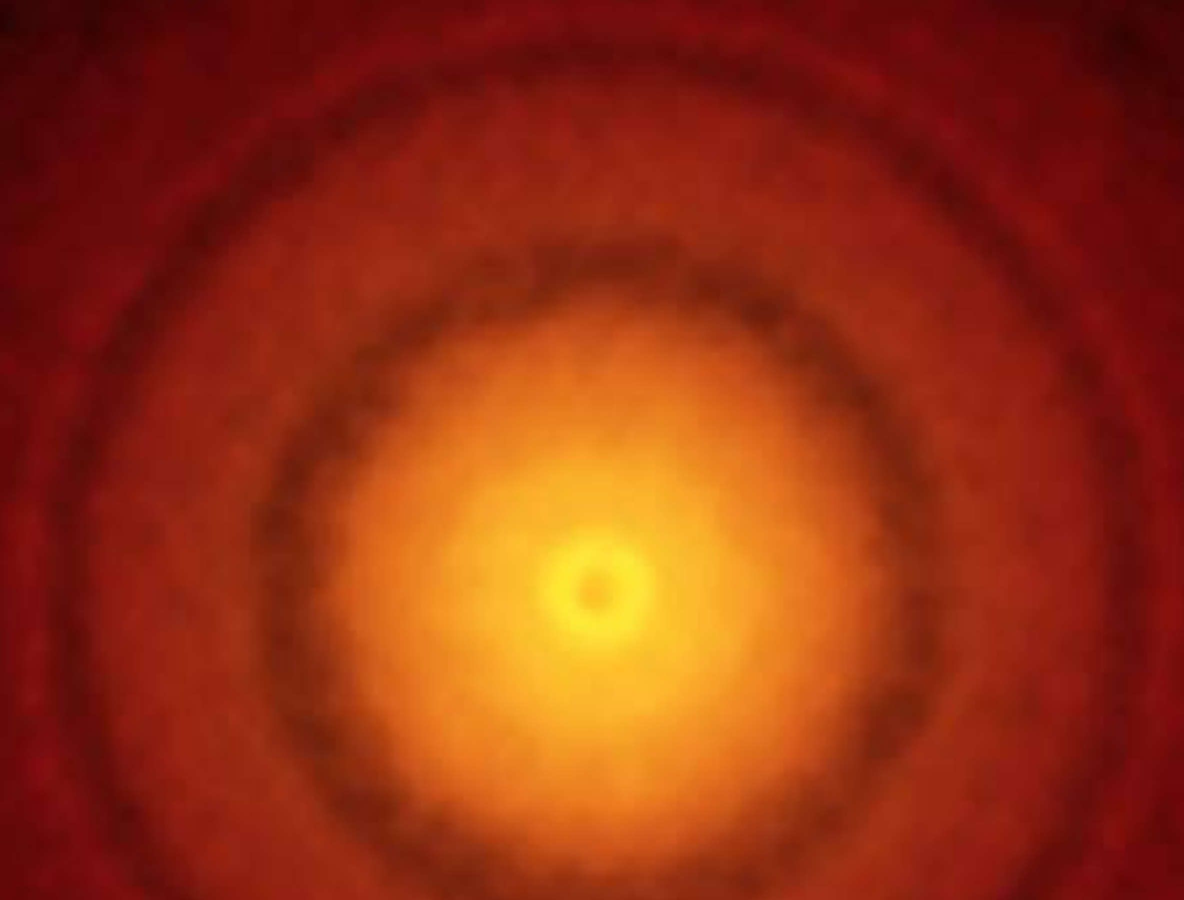


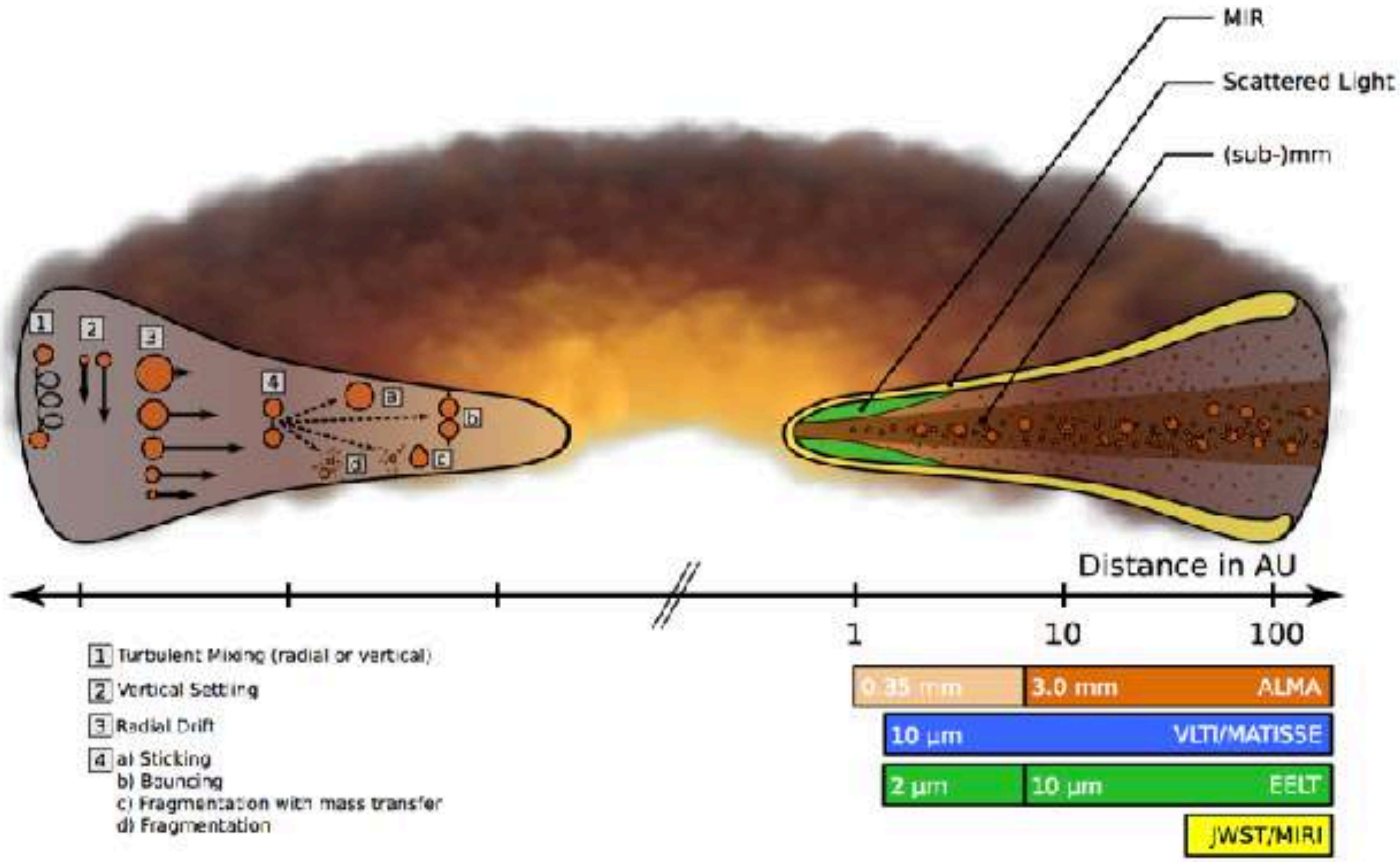
MONASH UNIVERSITY

DANIEL MENTIPLAY, DANIEL PRICE, CHRISTOPHE PINTE

PLANETS IN THE TW HYDRA DISC

PHANTOM WORKSHOP, JUNE 2018

DUST DYNAMICS IN PROTOPLANETARY DISCS



Dimensionless stopping time

St ≪ 1 (μm grains):

- Dust stuck to gas

St ≫ 1 (cm+ grains):

- Dust de-coupled from gas

St ~ 1 (mm/sub-mm grains):

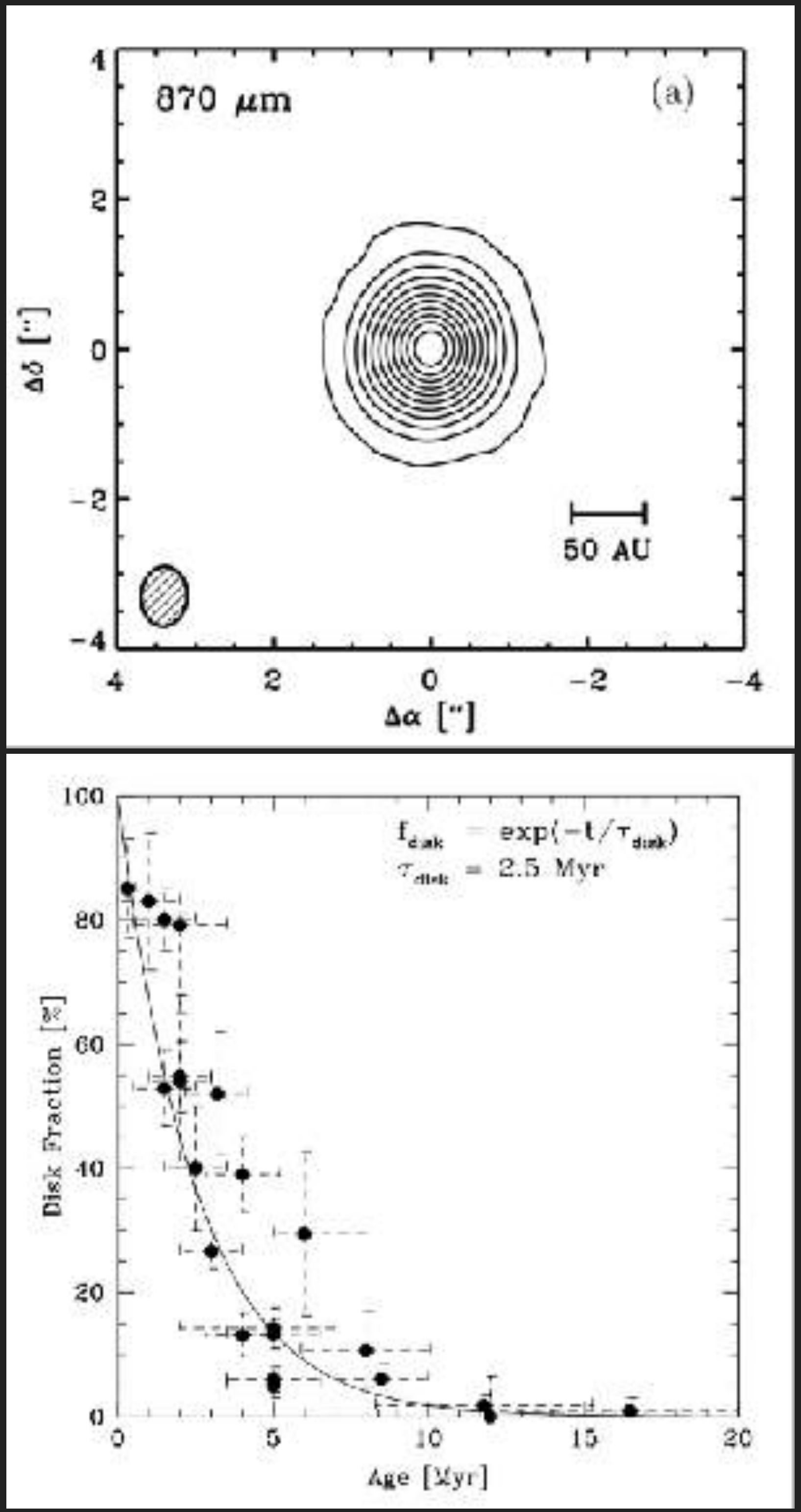
- Dust responds strongly via drag force

gas in sub-Keplerian orbit + dust in Keplerian orbit = dust drag

Credit: Testi+2014

THE NEAREST GAS-RICH PROTOPLANETARY DISC

- Distance: 60 pc (Gaia) ⇨ very close, cf. Taurus at 140 pc
- Age: ≈10 Myr ⇨ older than expected
- Disc mass (gas): ~10^{-4} – 10^{-1} $M_{\odot}$ ⇨ debate in literature
- Face-on: inclination ~7° ⇨ can see dust features (if there)

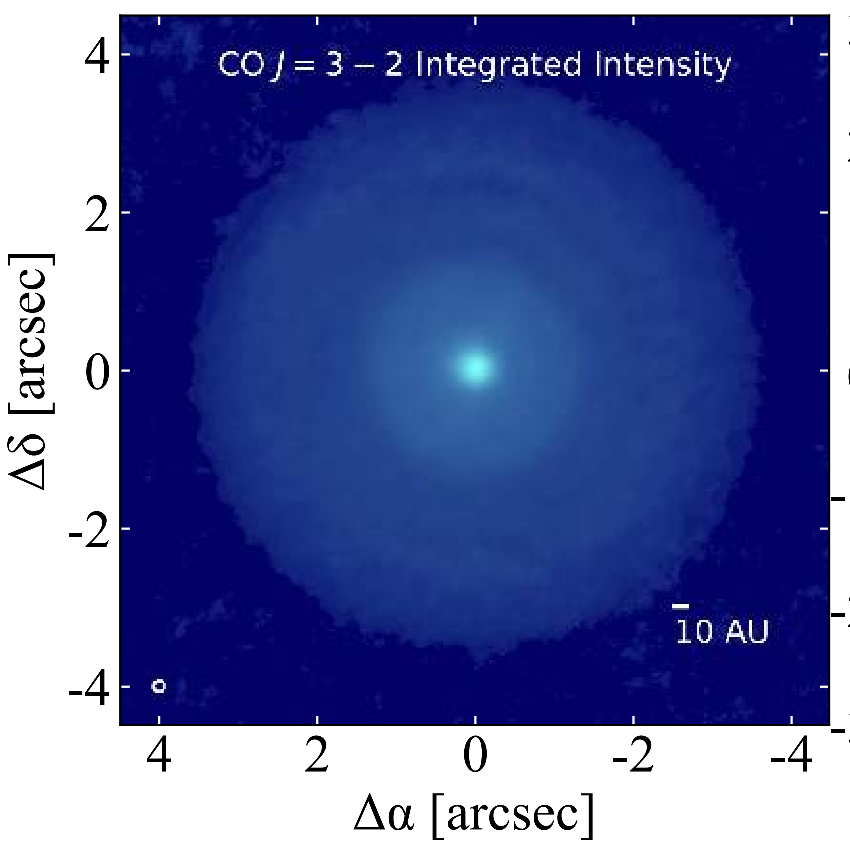


a blob

Credit: Andrews+2012, Mamajek2009

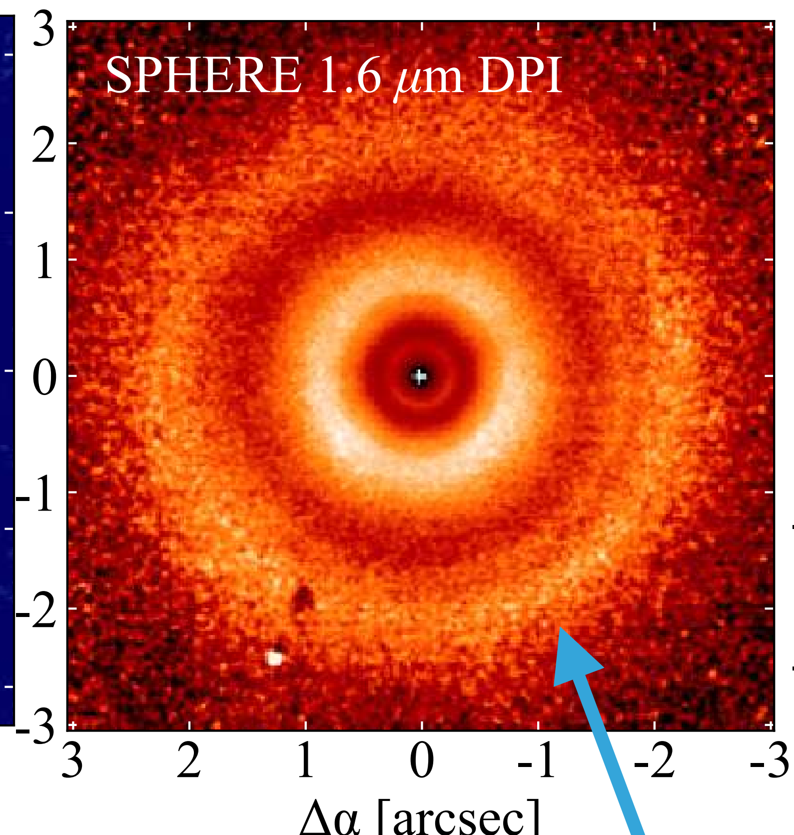
TW Hya: the nearest protoplanetary disc

Molecular lines



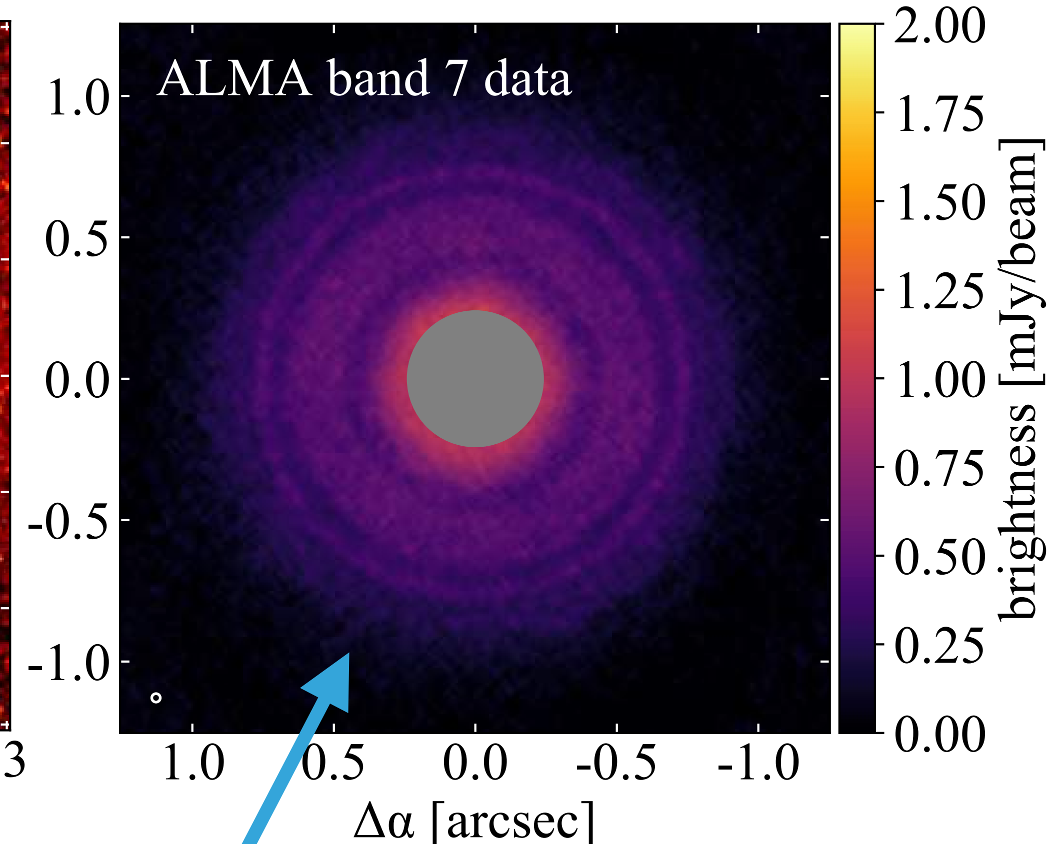
Huang+ 2018

Scattered light



Van Boekel+ 2017

Thermal emission



Andrews+ 2016

Gas + small grains

Large grains

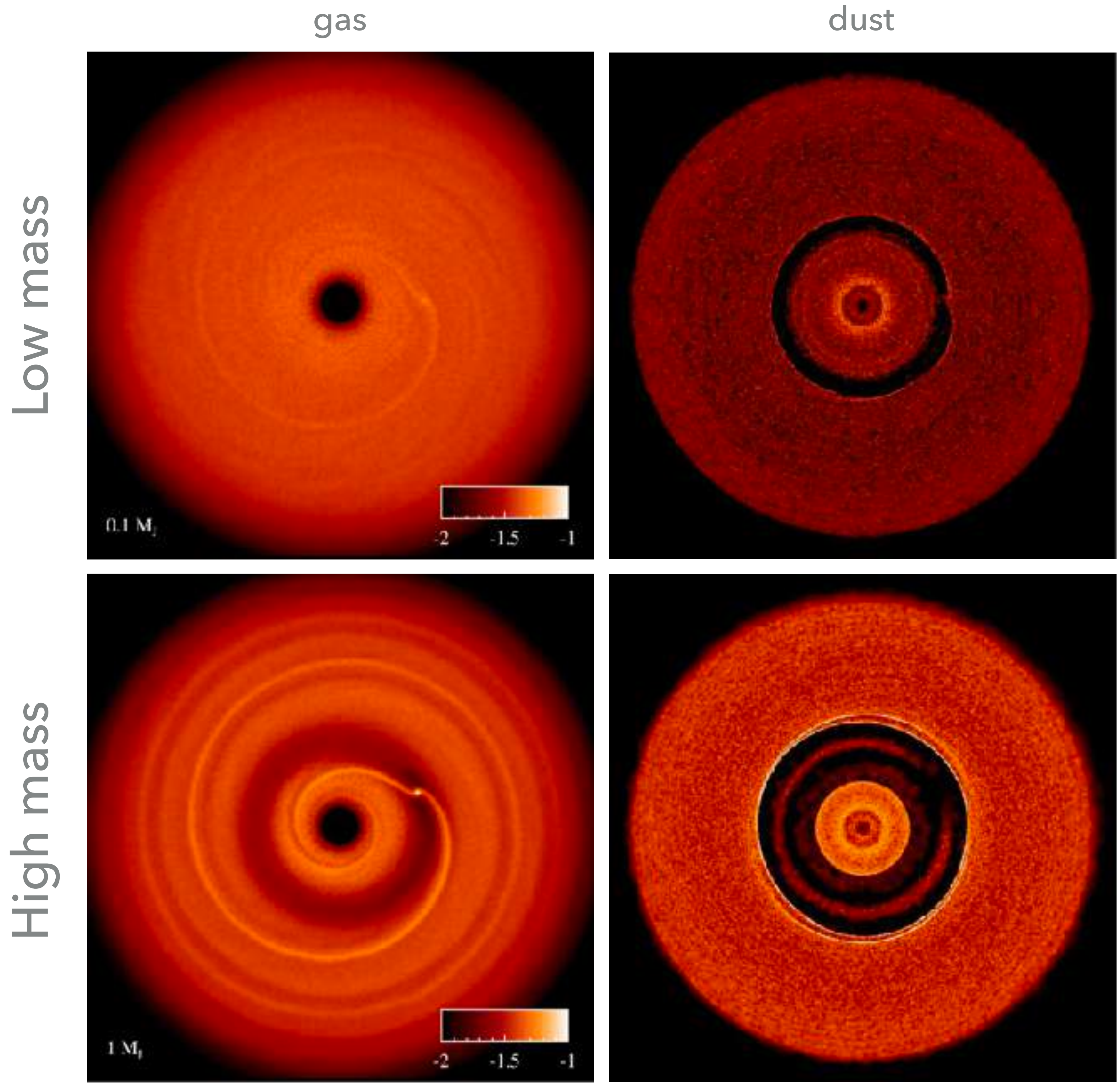
Gaps

not a blob

Planet-disc interaction: gap opening

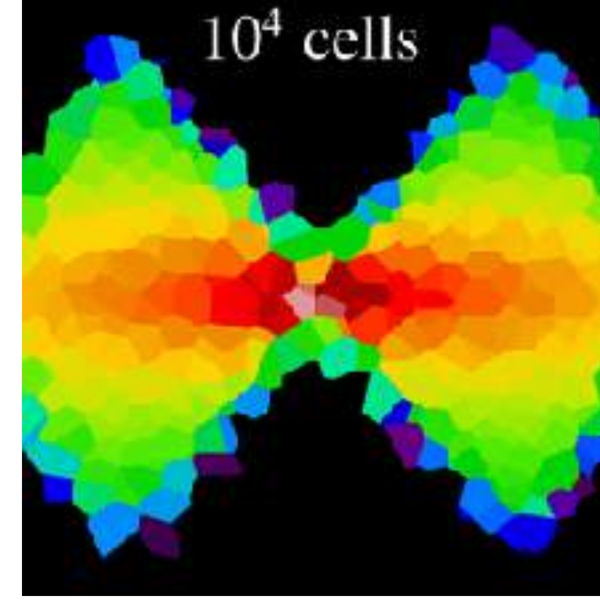
Drag *resisted* regime: gap opened by tidal torque alone

Drag *assisted* regime: gap opened by tidal torque + drag



Dipierro+2016

Methods



Camps 2013

Dust+gas hydro

Global 3d SPH – PHANTOM

Large dust grains – 2-fluid dust – one grain size per calc.

Embedded planets

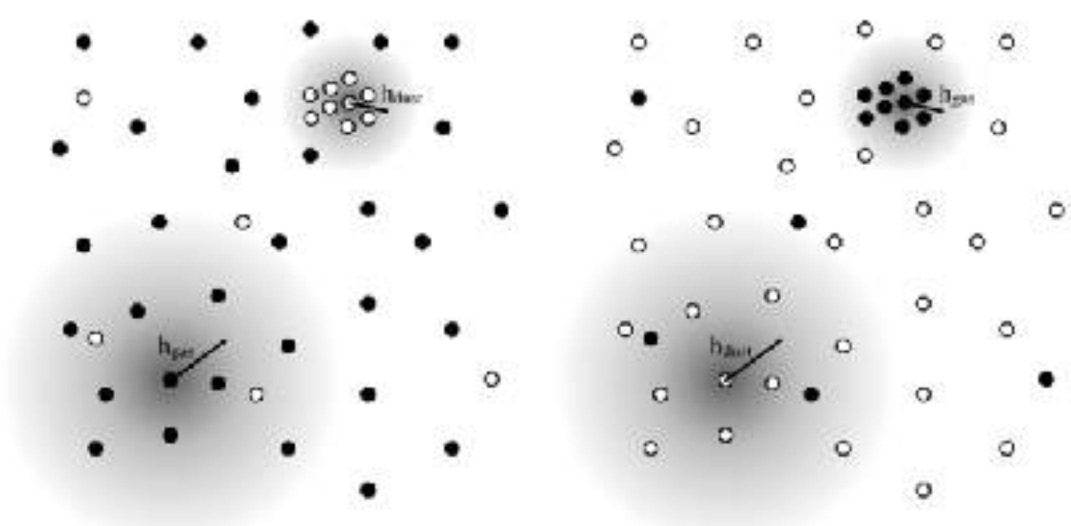
Back reaction

Radiative transfer

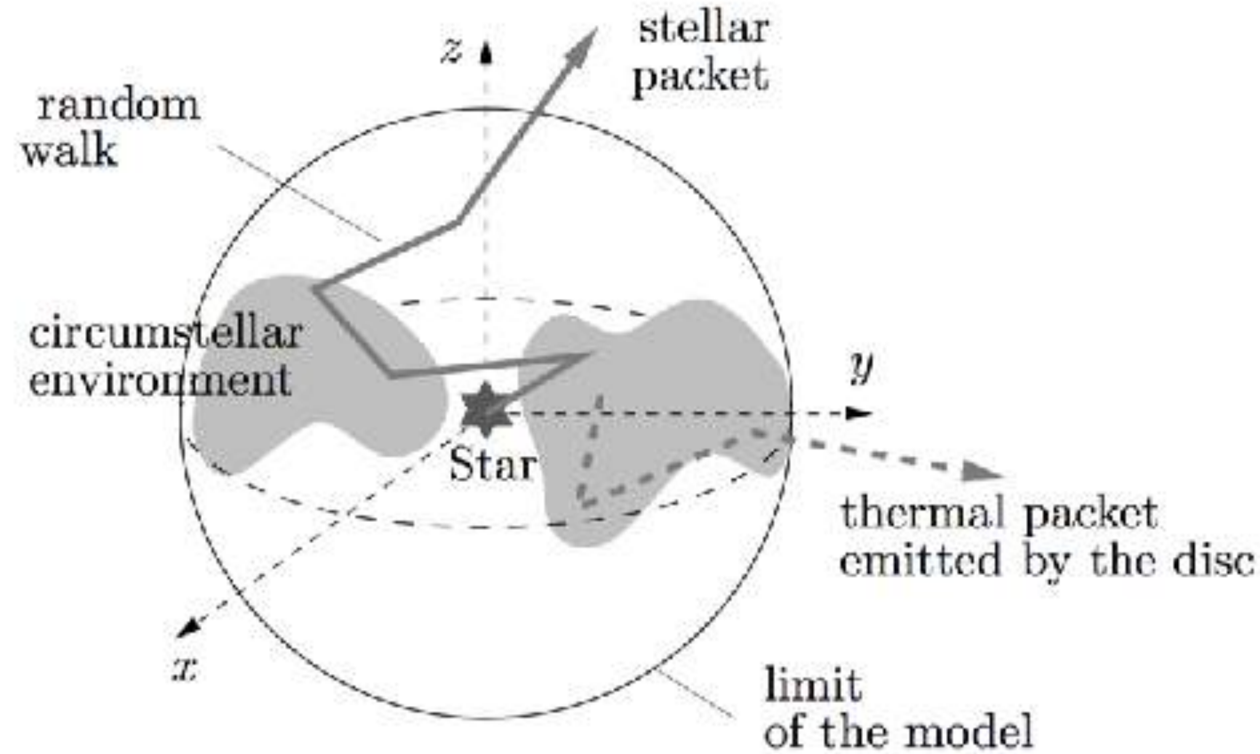
Post-processing – MCFOST

Voronoi tessellation

Synthetic observations – molecular lines, dust thermal emission, scattered light



Laibe+Price 2012



Pinte 2015

Disc model

Gas disc: 7.5×10^{-4} $M_\odot$ from 10–200 au with surface density $\Sigma \sim R^{-0.5}$

Dust: 100 μm to 1 cm, disc to 80 au

H/R (at R=10au) = 0.034

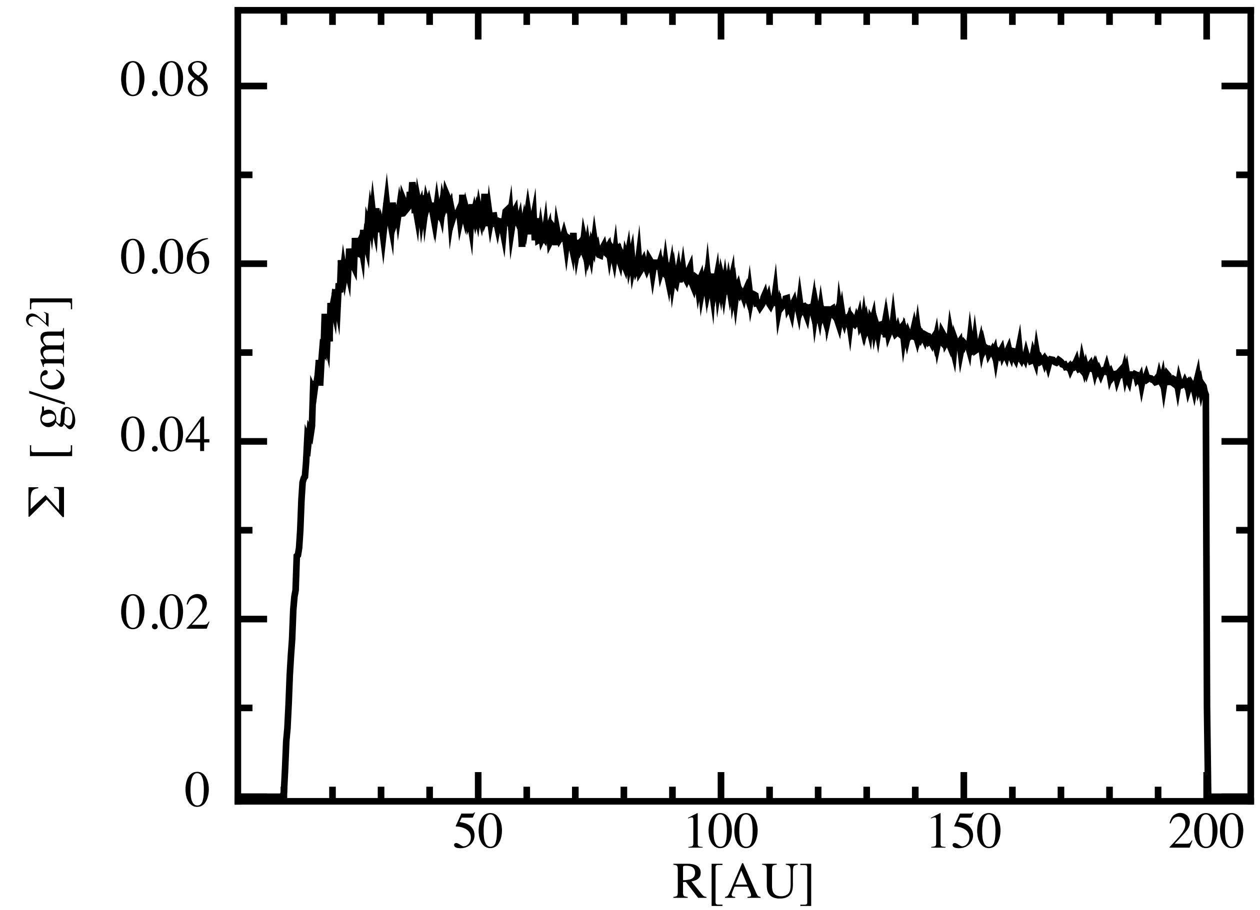
Resolution: 10^7 gas + 2.5×10^5 dust

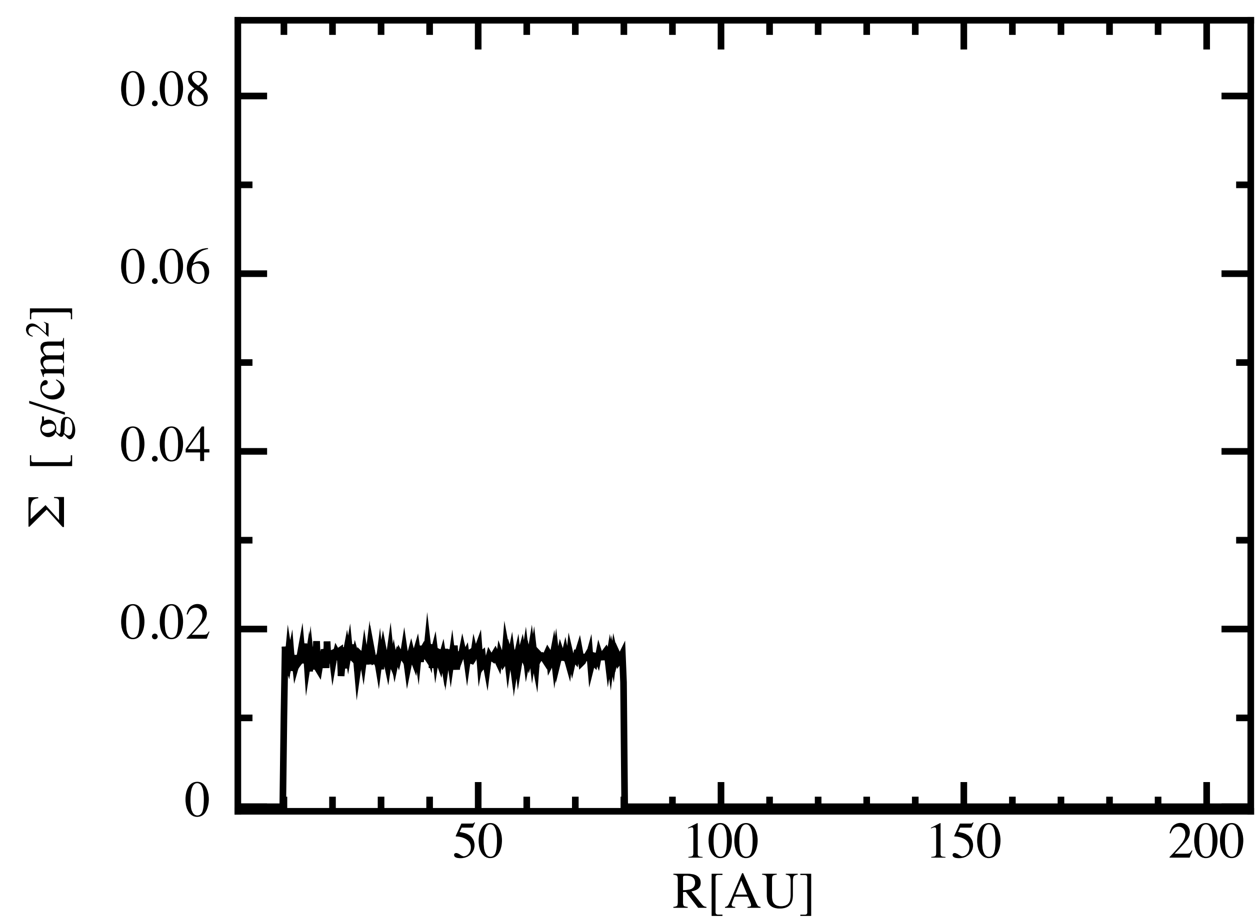
$\alpha \approx 10^{-3}$

Planets:

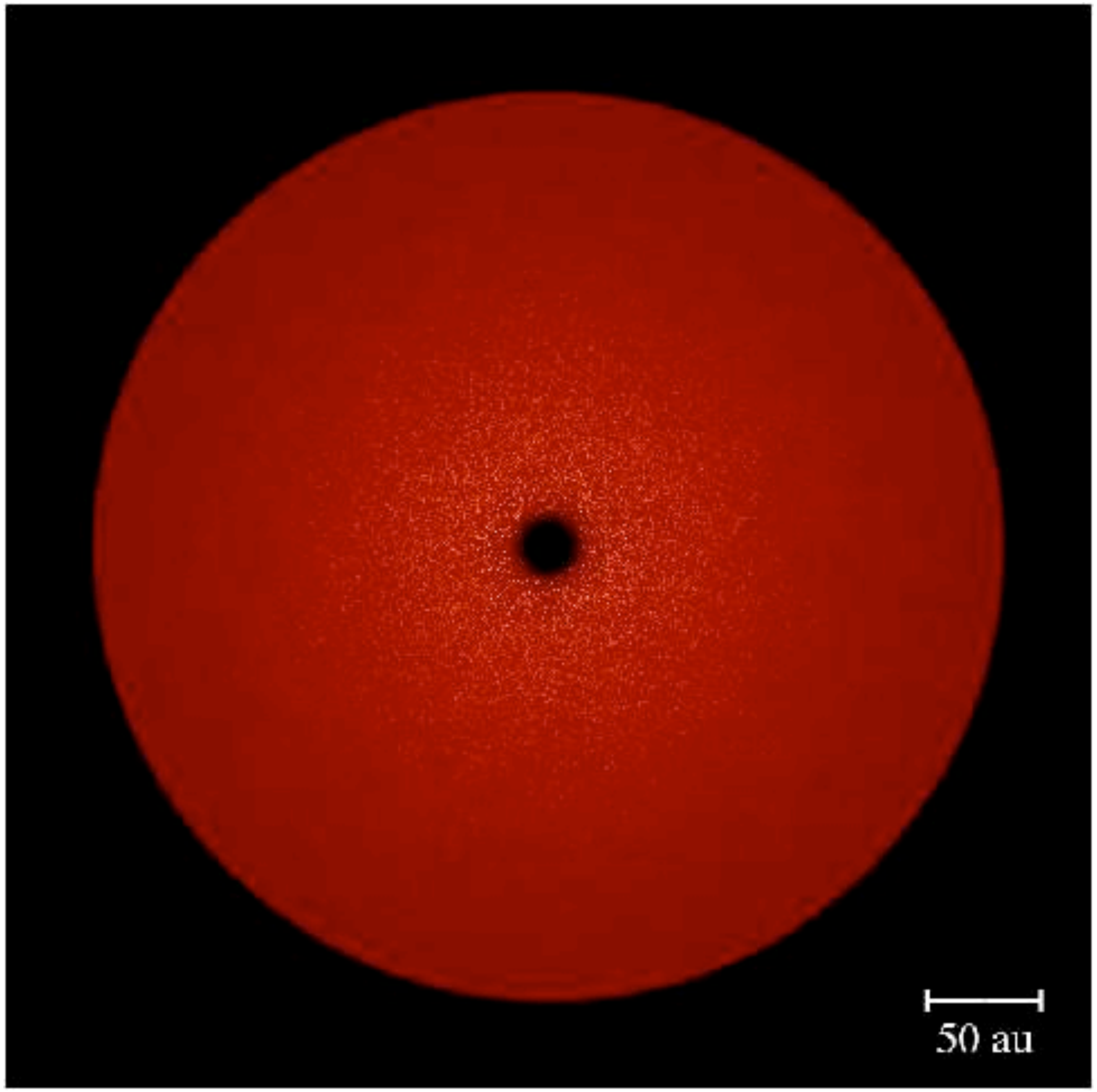
4–24 Earth-mass at 24 and 41 au

0.1–2 Jupiter-mass at 94 au

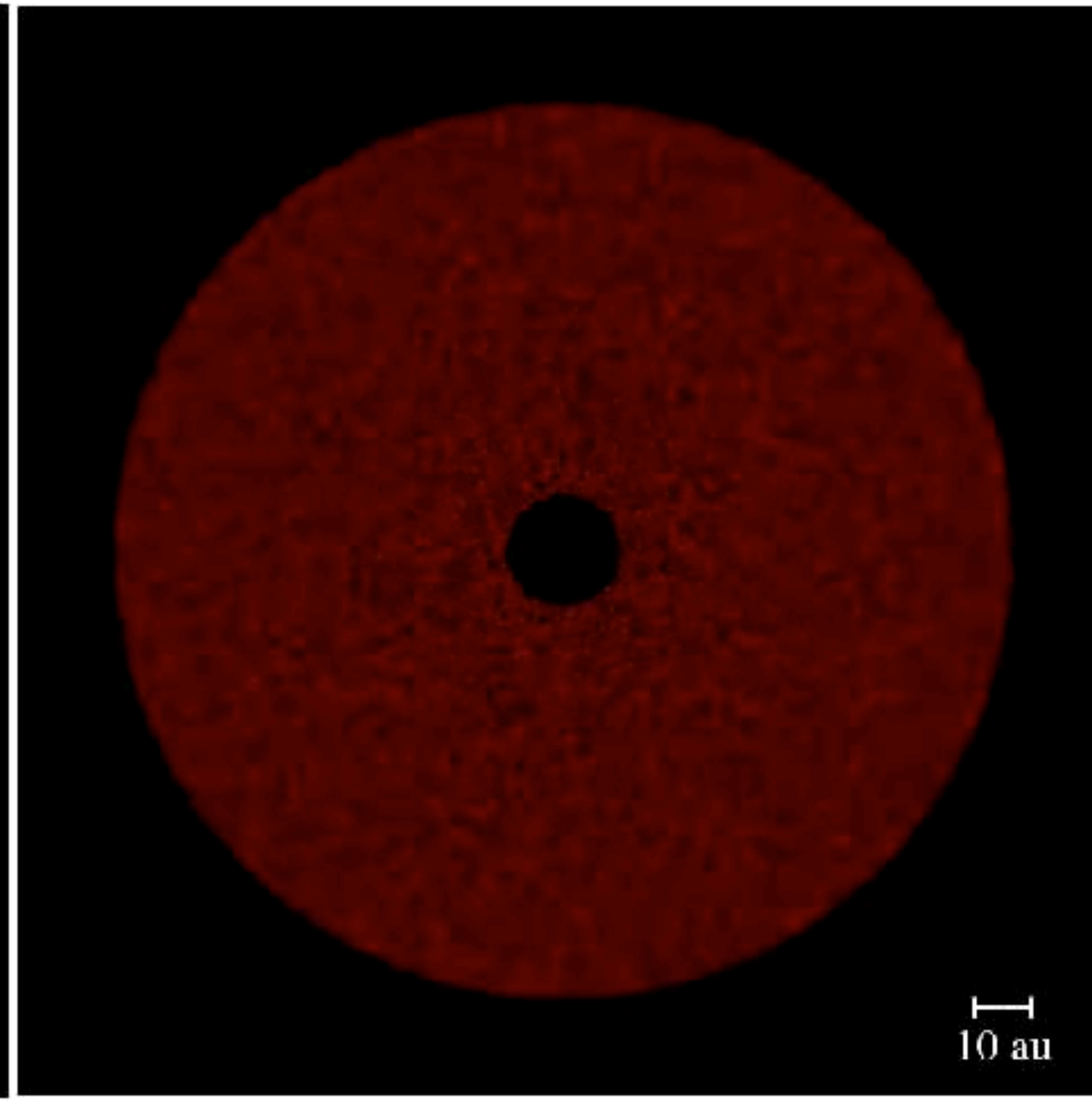




Gas and dust surface density

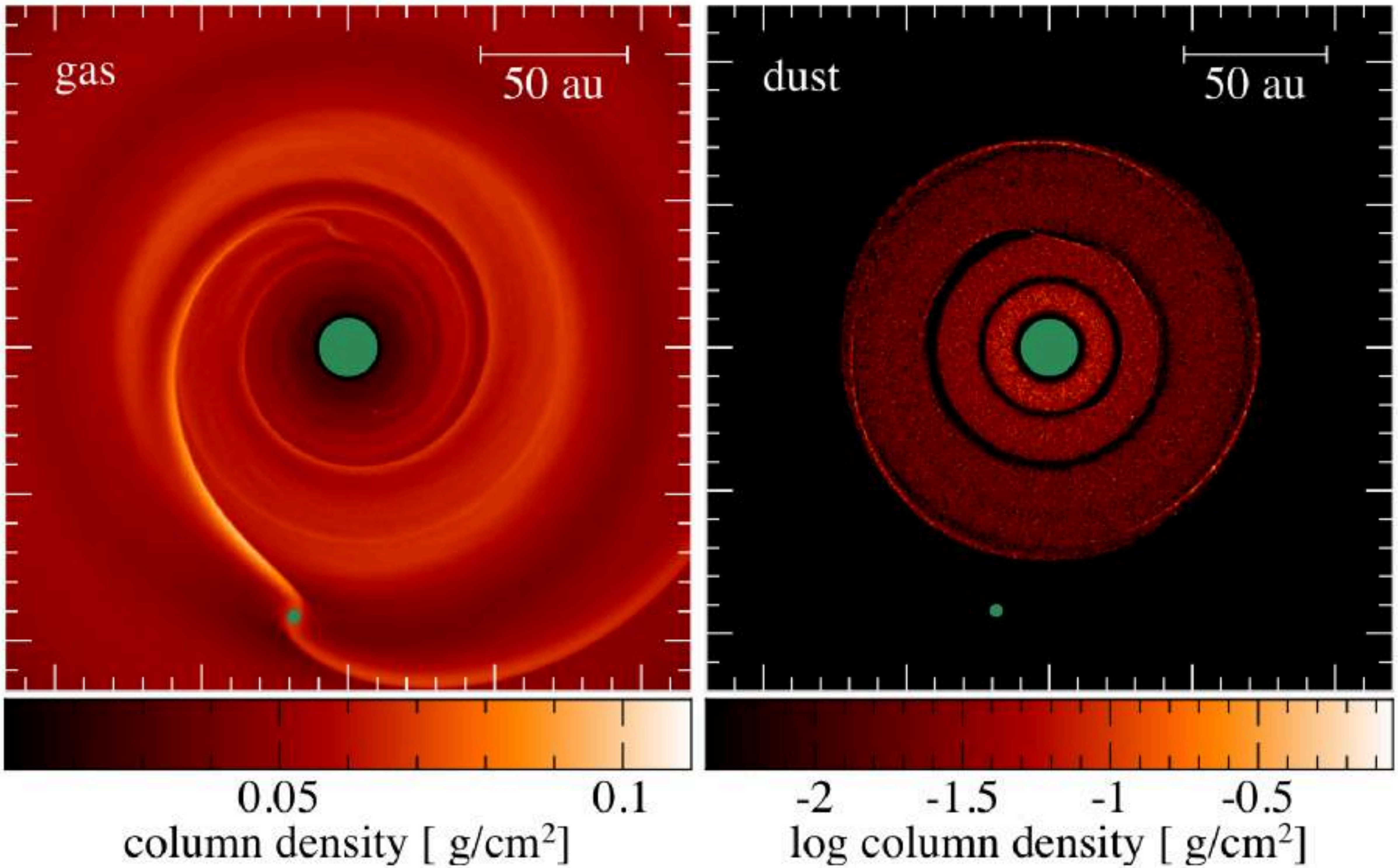


Gas



100 μm dust

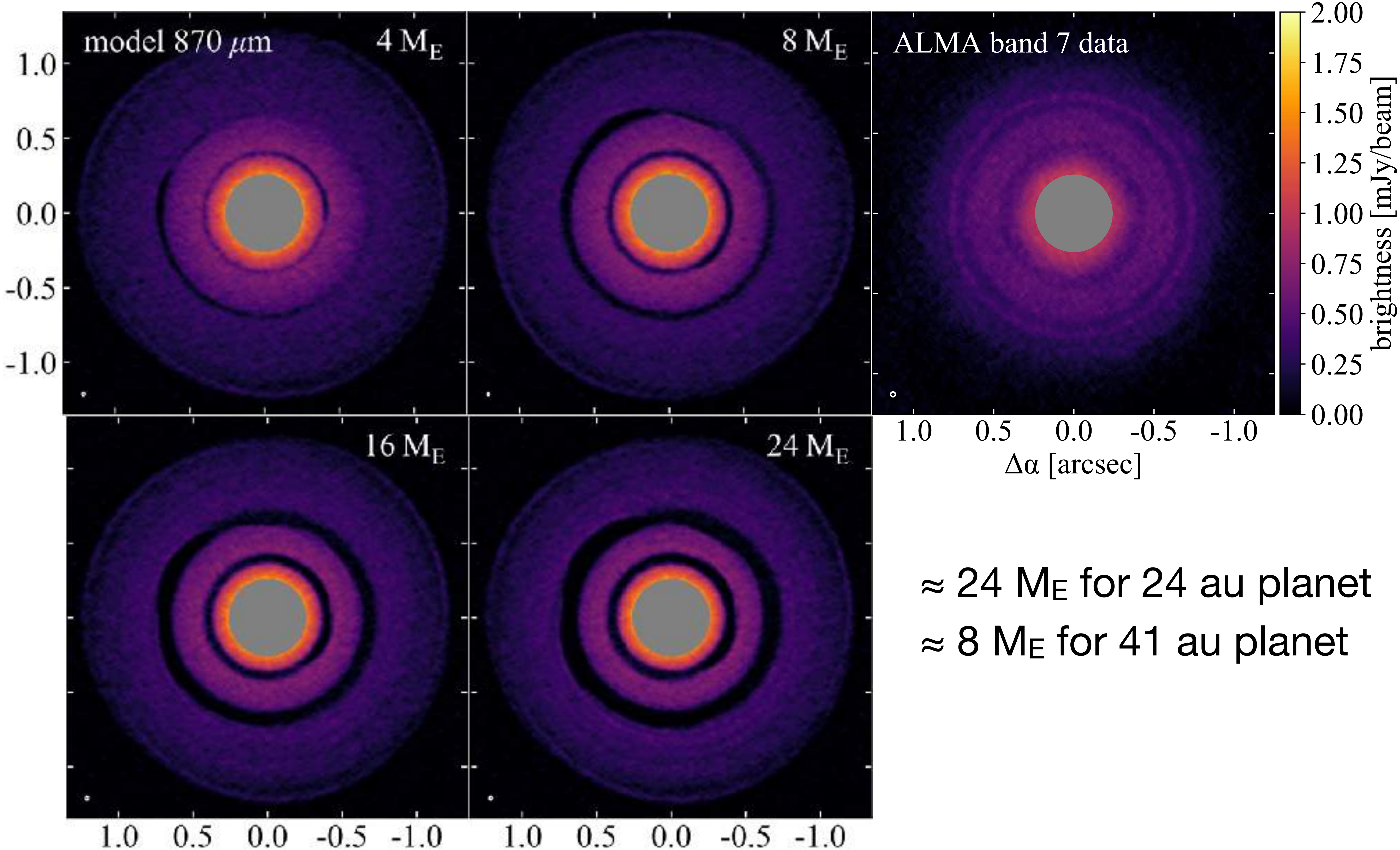
Gas and dust surface density



Mentiplay+ 2018

Dust continuum emission

Andrews+ 2016



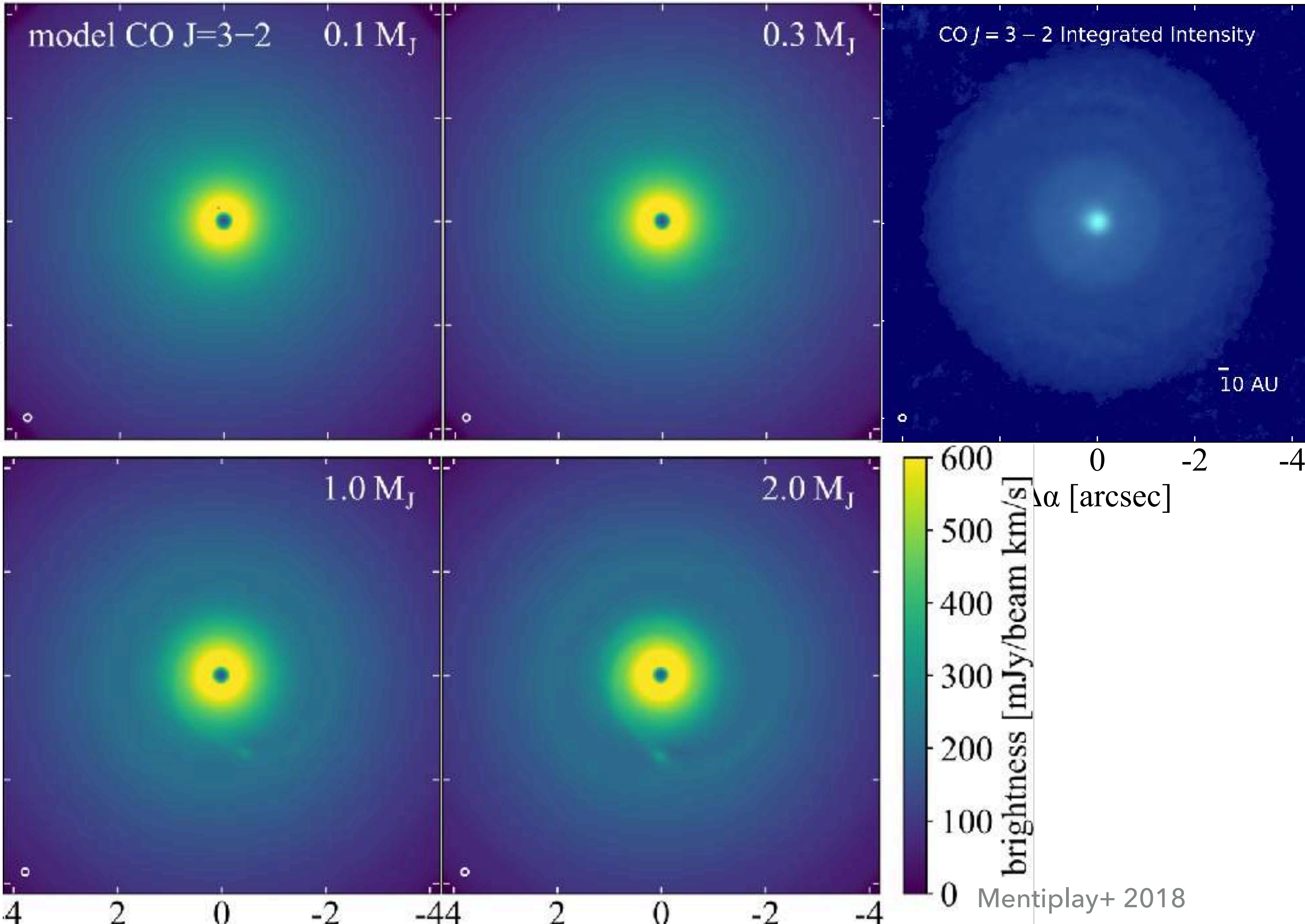
Mentiplay+ 2018

≈ 24 M_E for 24 au planet

≈ 8 M_E for 41 au planet

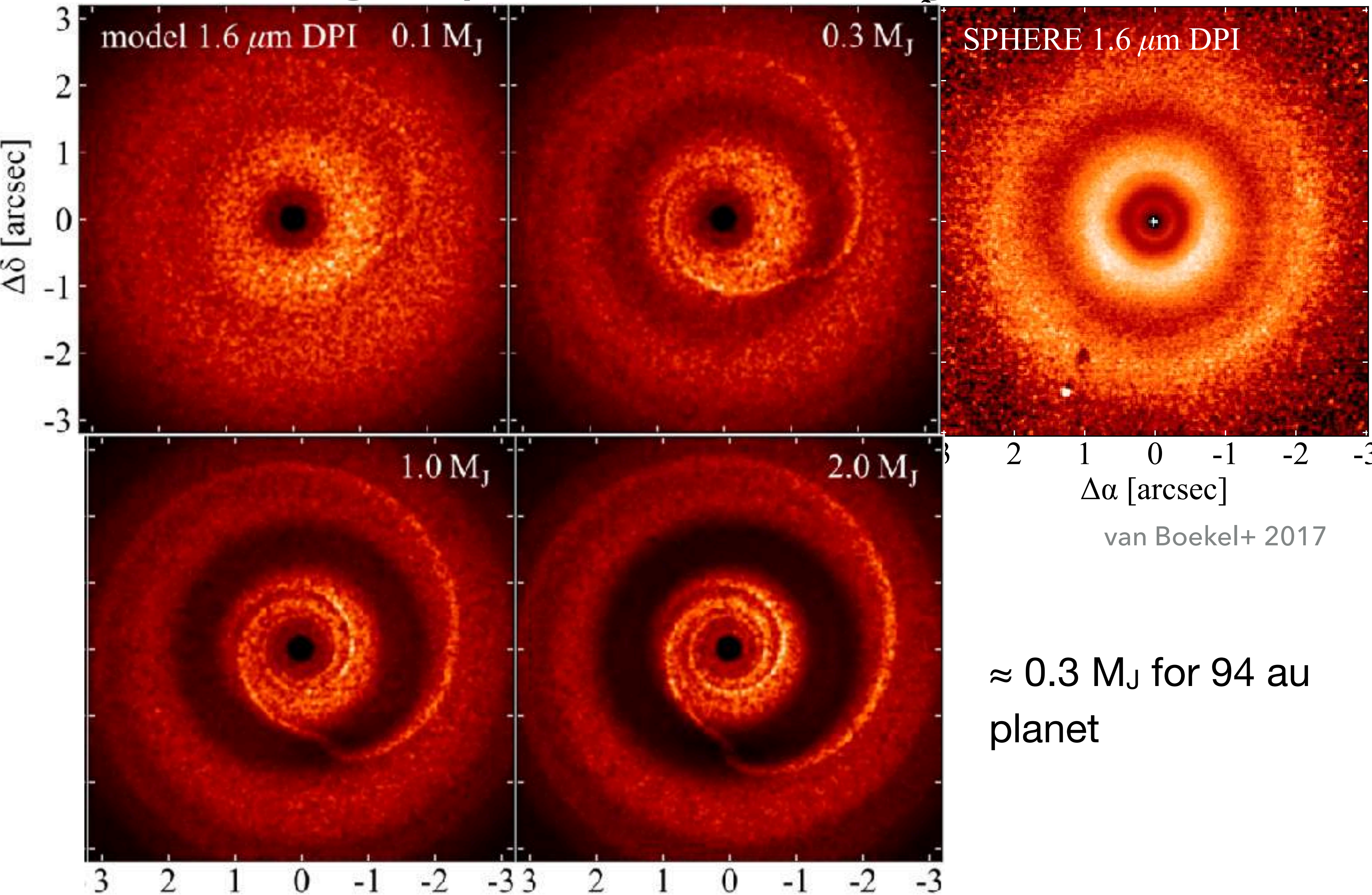
CO integrated intensity

Huang+ 2018



Mentiplay+ 2018

Scattered light: polarised intensity

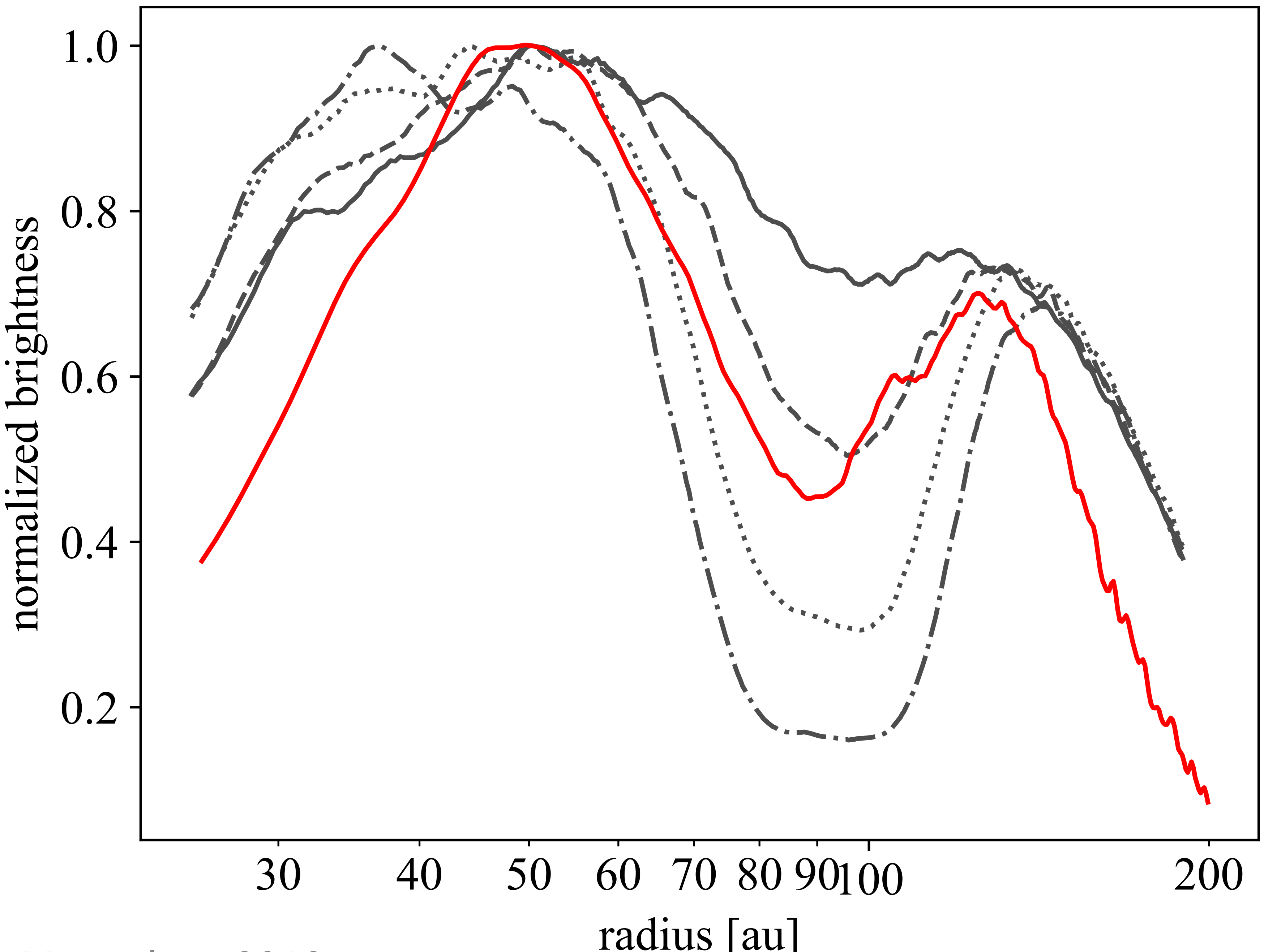


van Boekel+ 2017

Mentiplay+ 2018

≈ 0.3 M_J for 94 au planet

Scattered light: azimuthally-averaged polarised intensity



Mentiplay+ 2018

Solid: 0.1 M_J

Dashed: 0.3 M_J

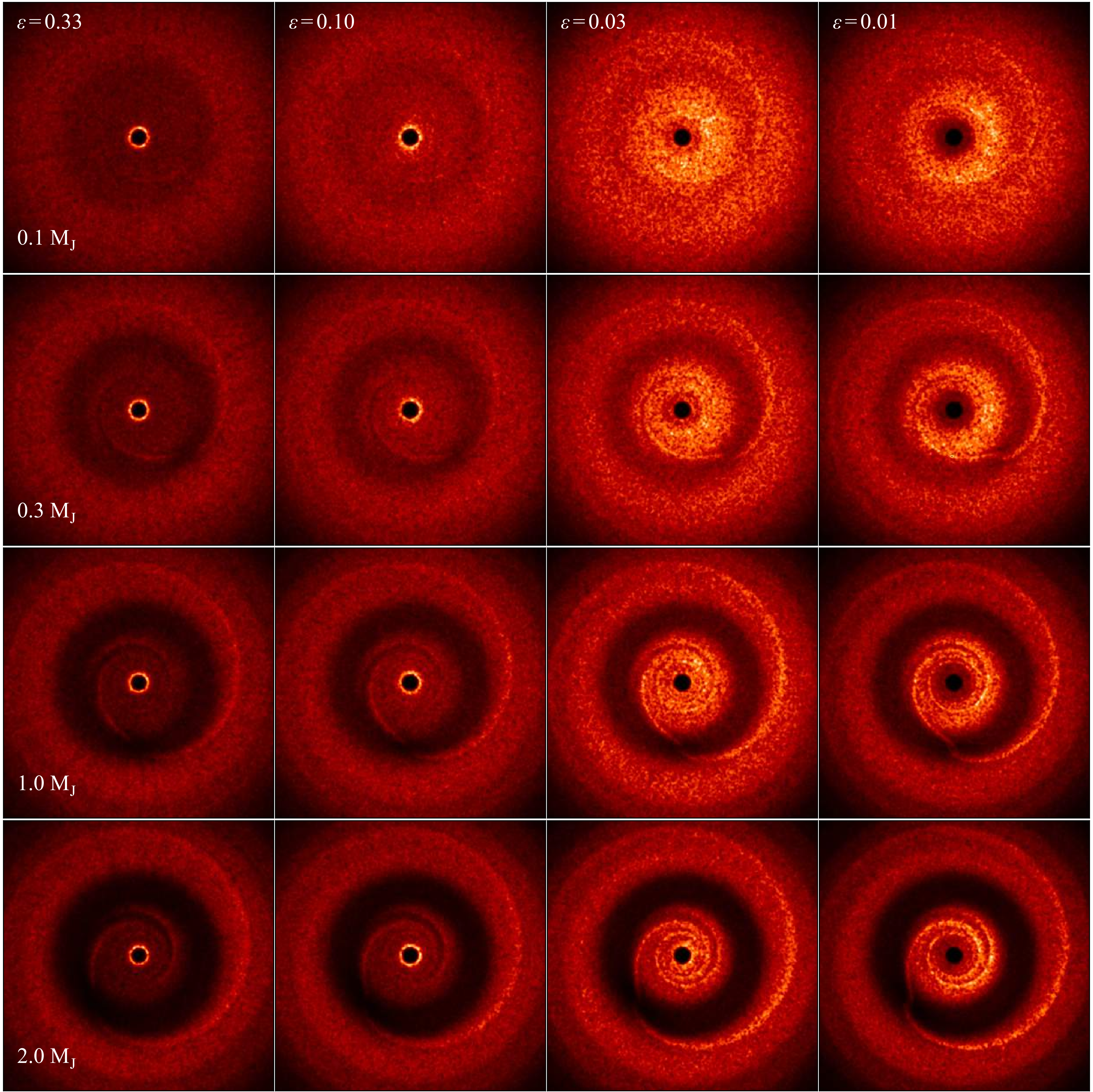
Dotted: 1.0 M_J

Dash-dotted: 2.0 M_J

Red: SPHERE data

≈ 0.3 M_J for 94 au planet

Scattered light: optical depth



Results

Super-Neptune & super-Earth mass planets at 24 and 41 au

Saturn mass planet at 94 au

Summary

Global 3d dust+gas hydrodynamical simulations + Radiative transfer modeling and synthetic images

→ Interpret observations at multiple wavelengths

To do

Multiple large grains – correct back reaction, better synthetic observations

PHANTOM + MCFOST live – correct temperature profile