Radial structure in planetesimal discs

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26 July 2019

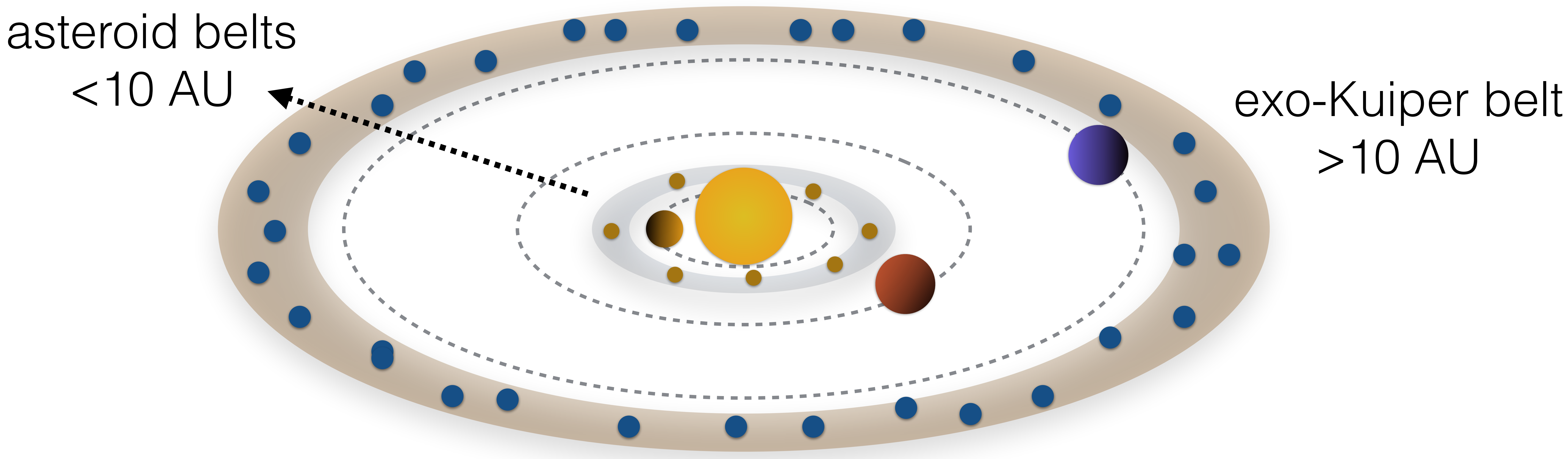
In collaboration with Mark Wyatt, Luca Matrà, Grant Kennedy, and many other people

Credit: NASA/JPL-Caltech

Planetesimal discs

- Planetary systems are not only composed of planets.

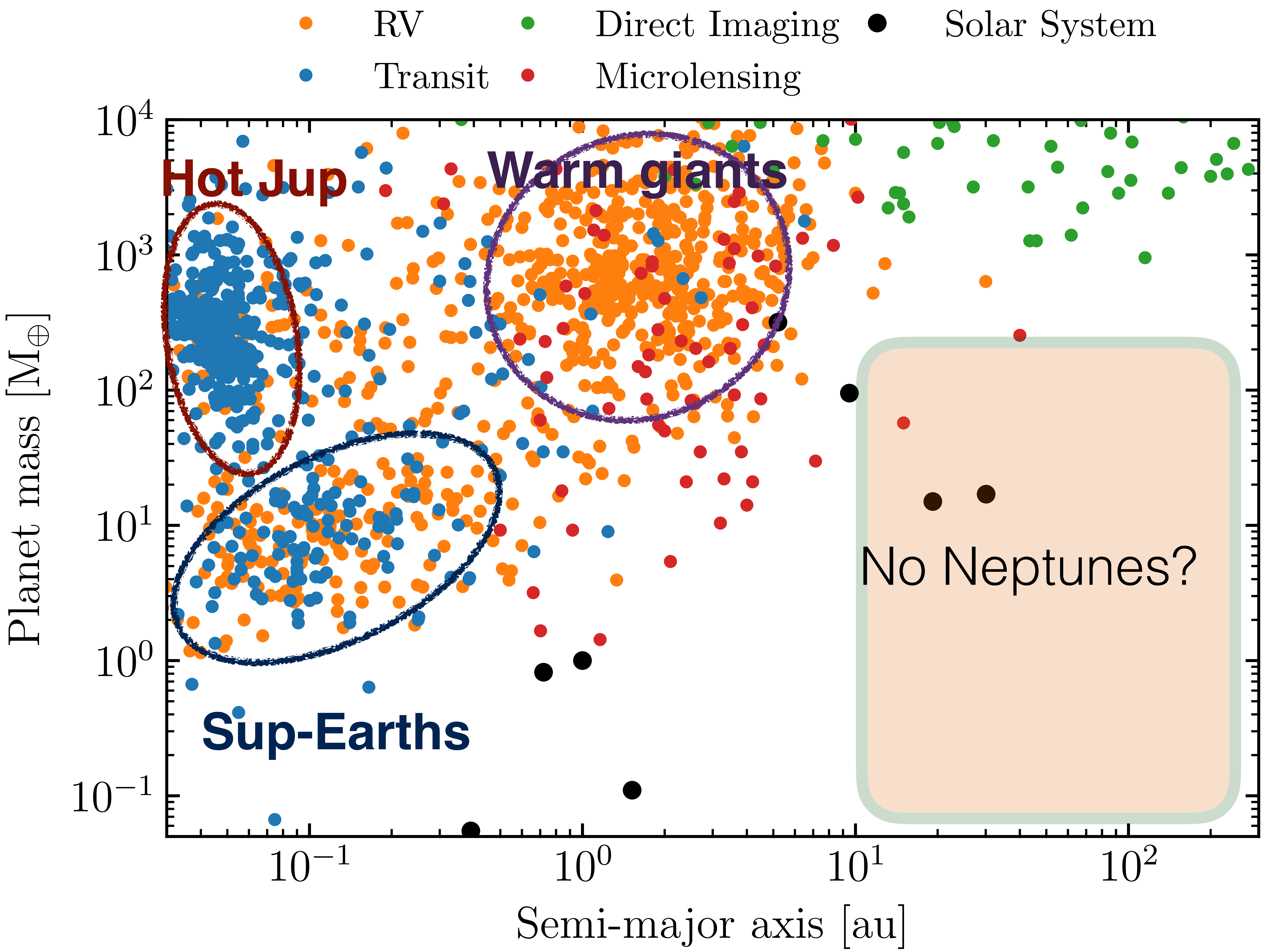
- Asteroid and Kuiper belt analogues are also products of planet formation.



- exo-Kuiper belts present at least around 20% of FGK stars (e.g. Sibthorpe+2018).

Exoplanet population

From exoplanet census we know little about the outer regions of planetary systems.

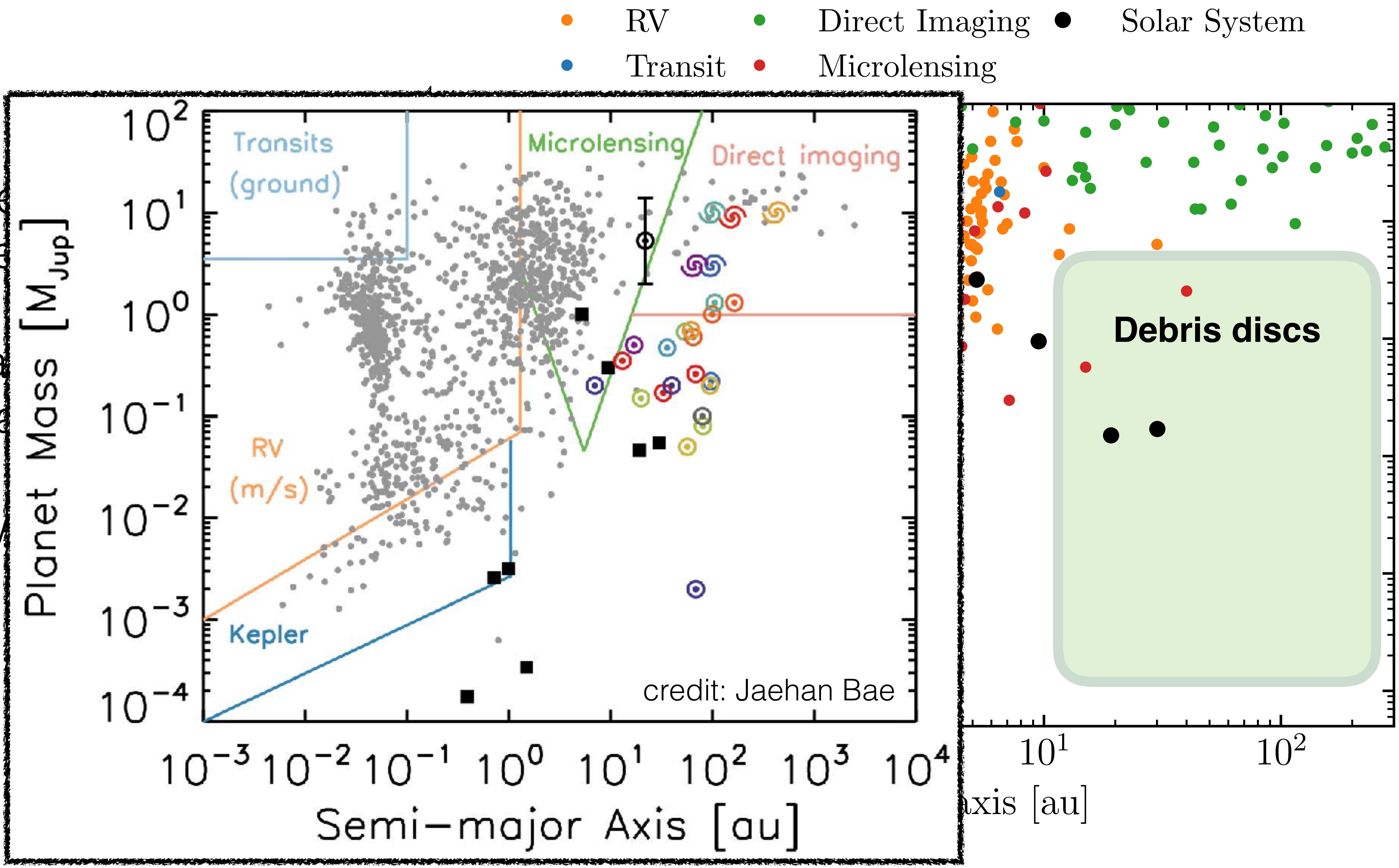


Debris discs

Debris discs provide
window into the oute

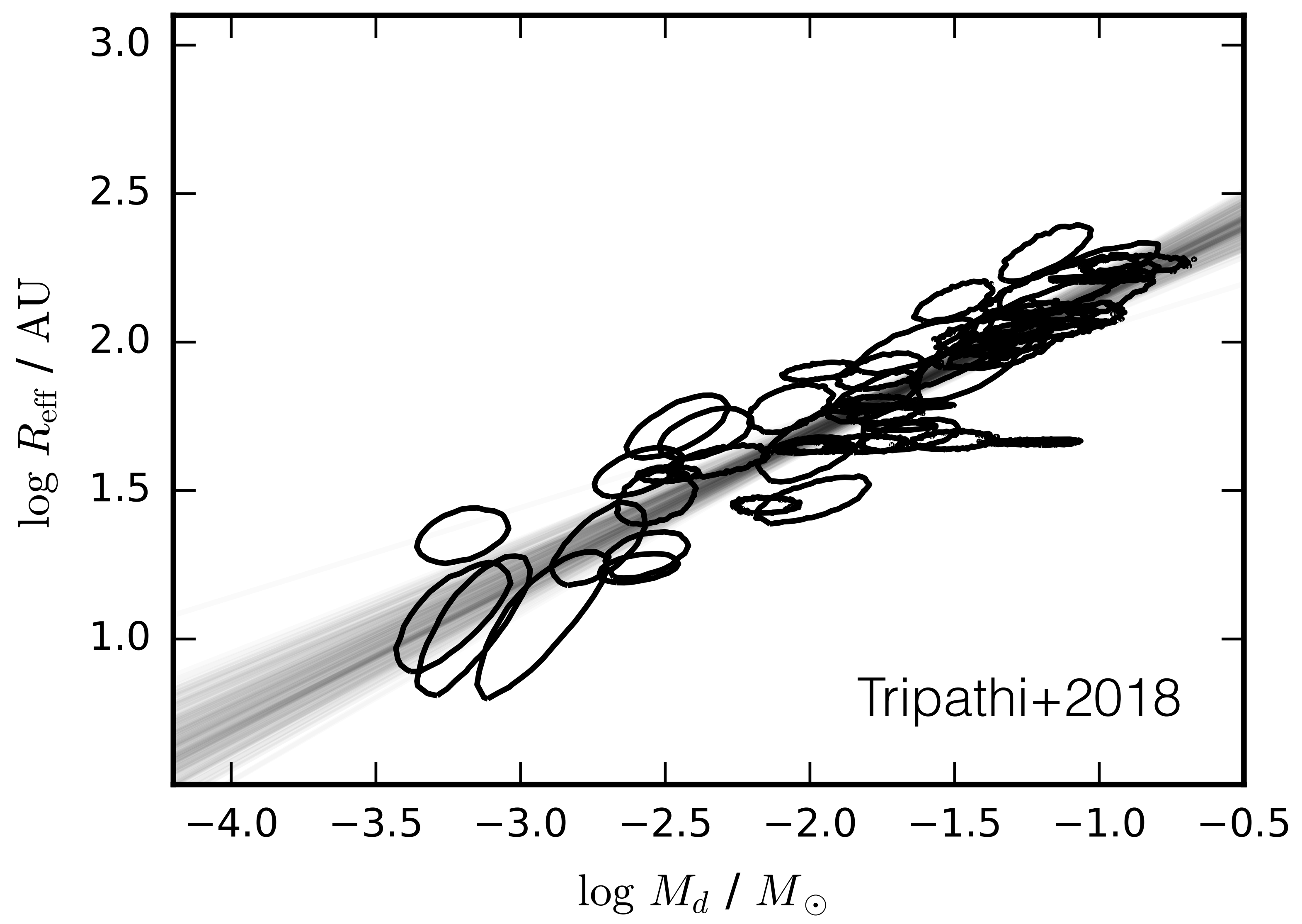
Structure can indica
of planets and forma

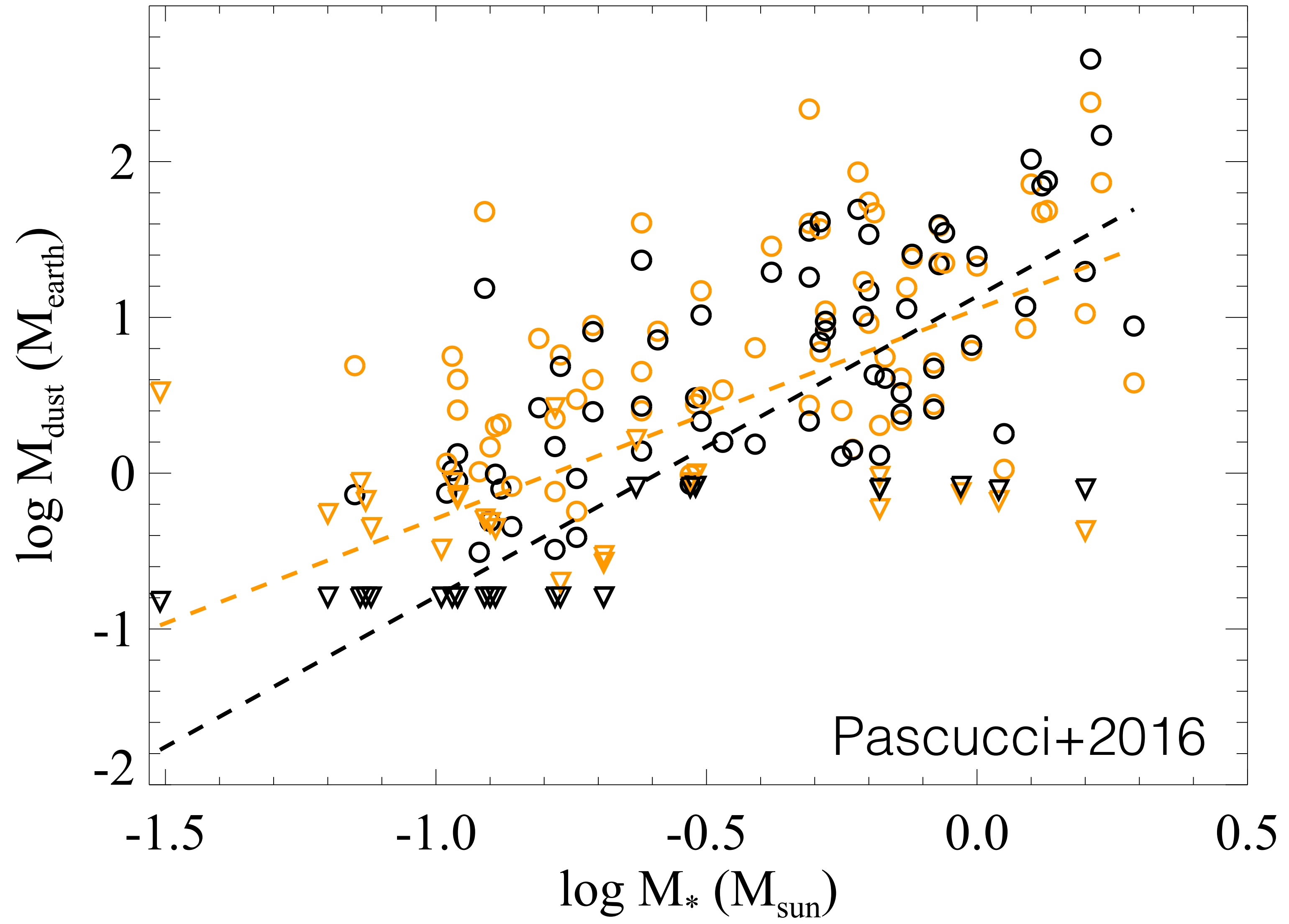
Also sensitive to low
planets

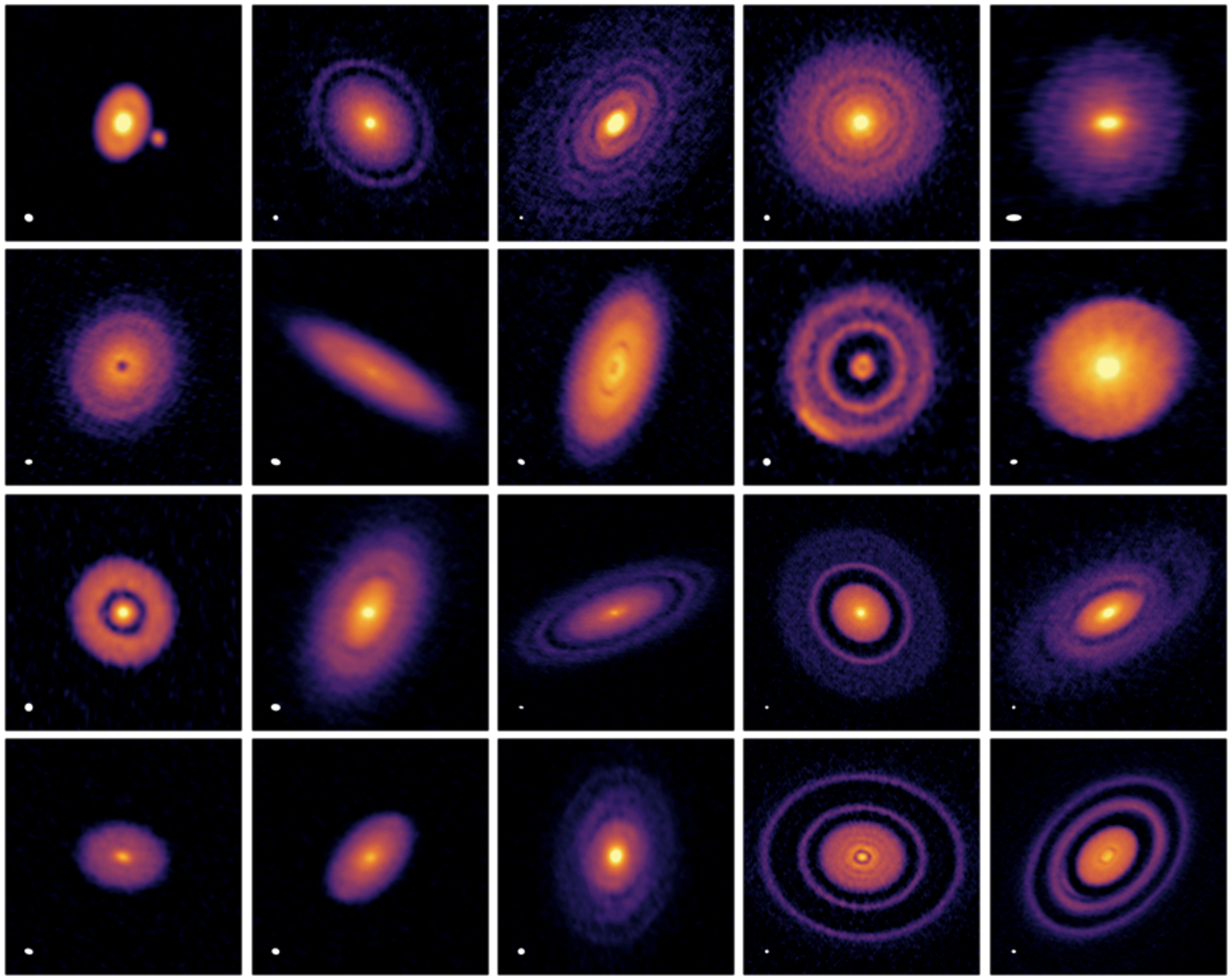


What do we see in circumstellar discs?

Protoplanetary discs

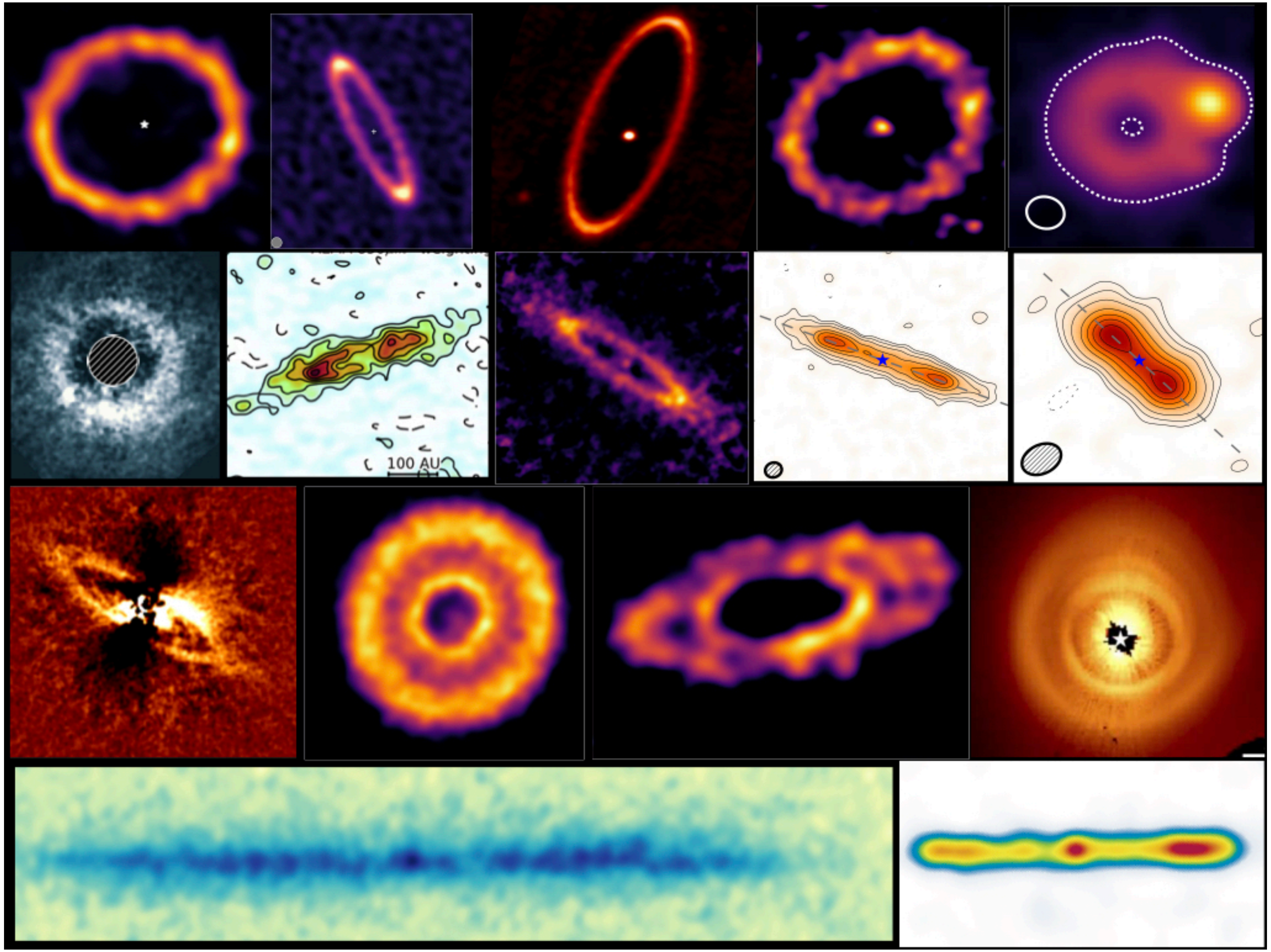






DSHARP, S. Andrews et al. 2019

Debris discs show a variety of structure too



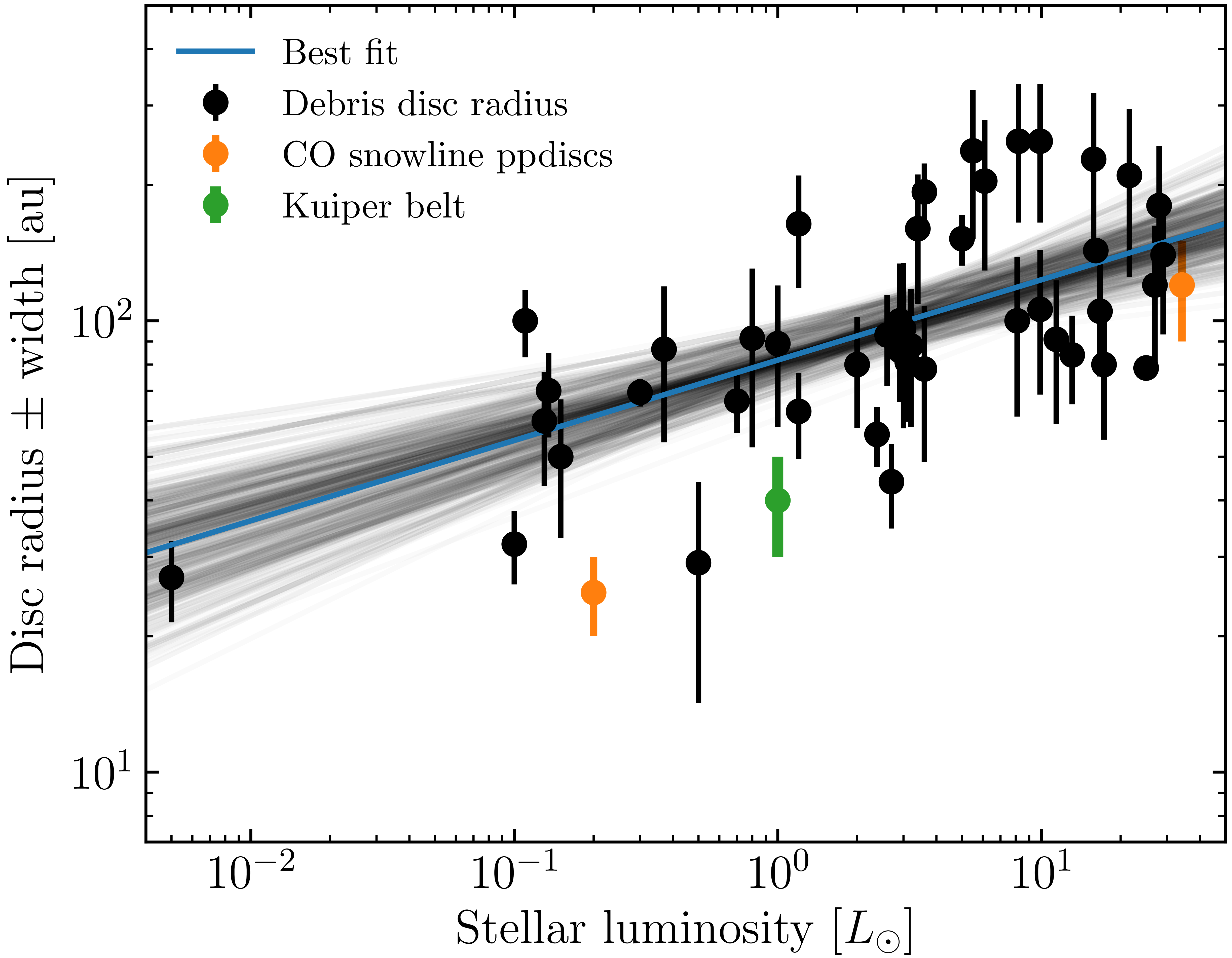
Marino+2016,2017,2018,2019, Kennedy+2018, MacGregor+2013,2017,2018, Hughes+2017, Olofsson+2018, Feldt+2017, Konishi+2016, Matrà+2019 Lovell+in prep

Debris discs

Debris discs are overall larger around more massive stars. However, relation is different compared to ppdisks.

What sets the location of exo-Kuiper belts?

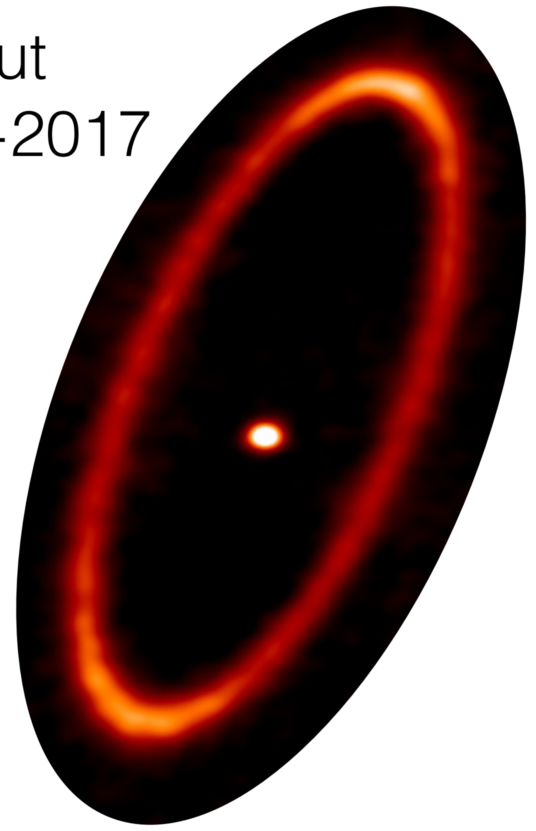
- Outermost planet?
- Snowlines?
- Collisional evolution?



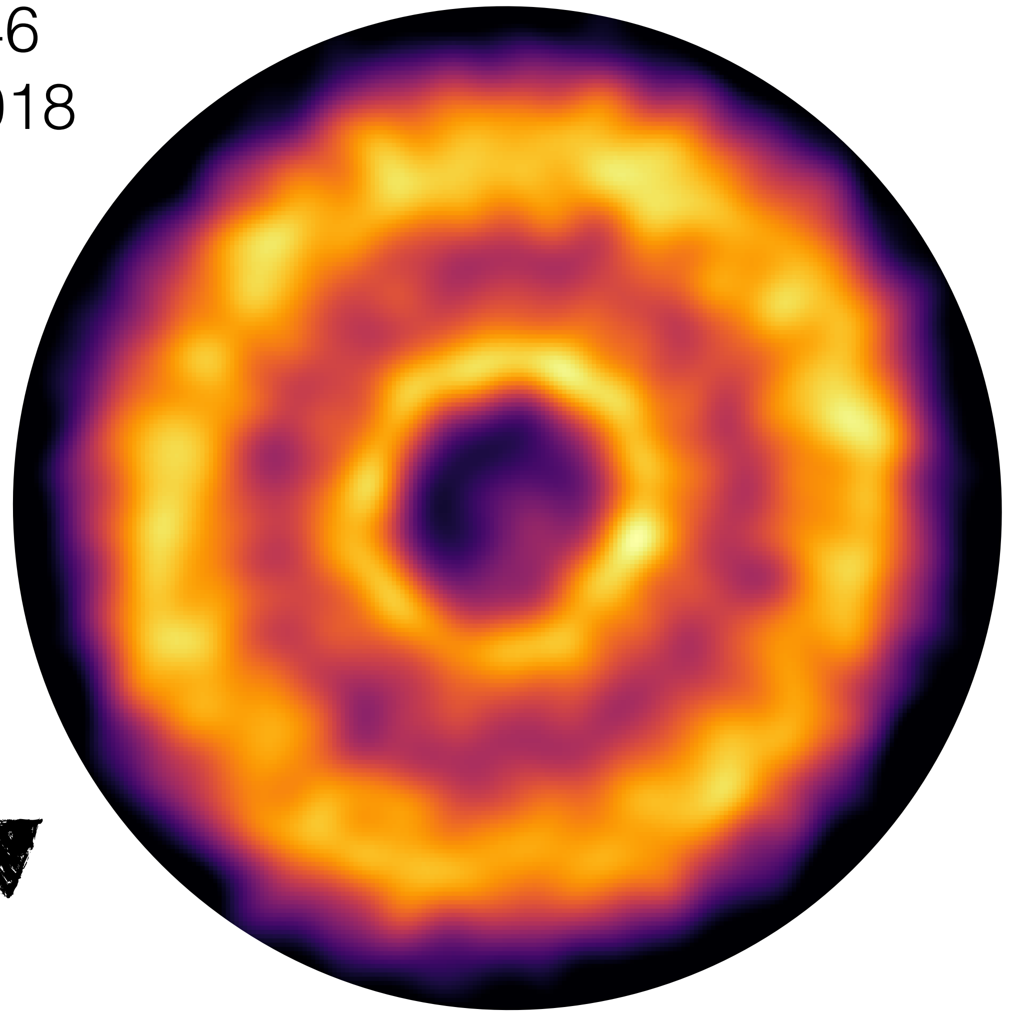
Matrà, Marino+2018
+REASONS survey +unpublished results

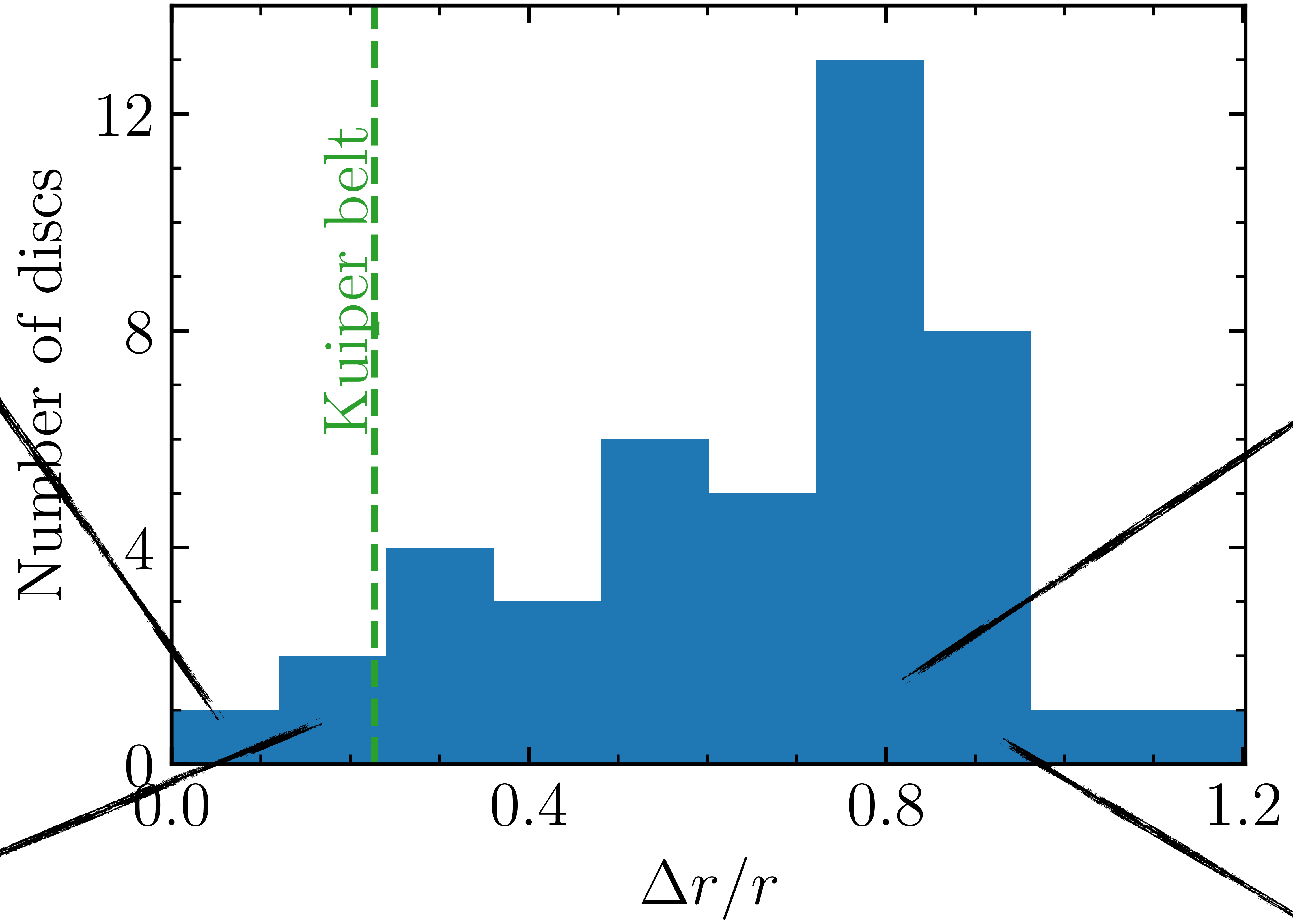
Detectable debris discs tend to be wide

Fomalhaut
MacGregor+2017

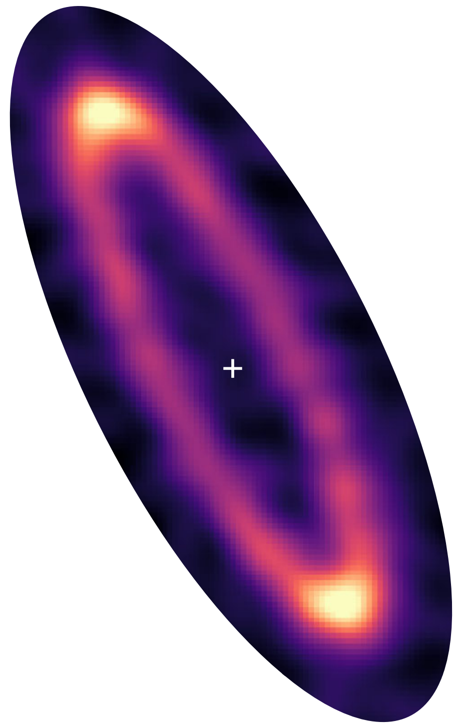


HD107146
Marino+2018

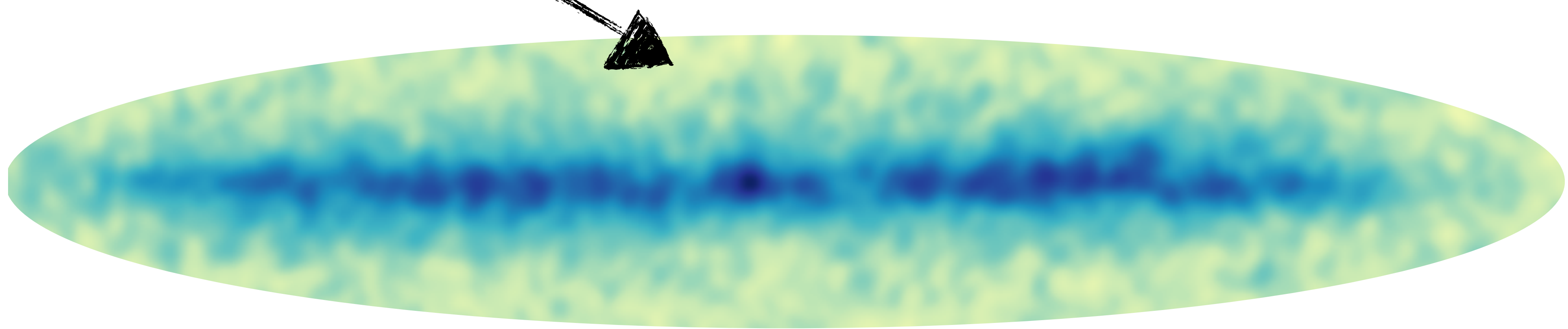




HR4796
Kennedy+2018



Beta Pic
Matrà+2019



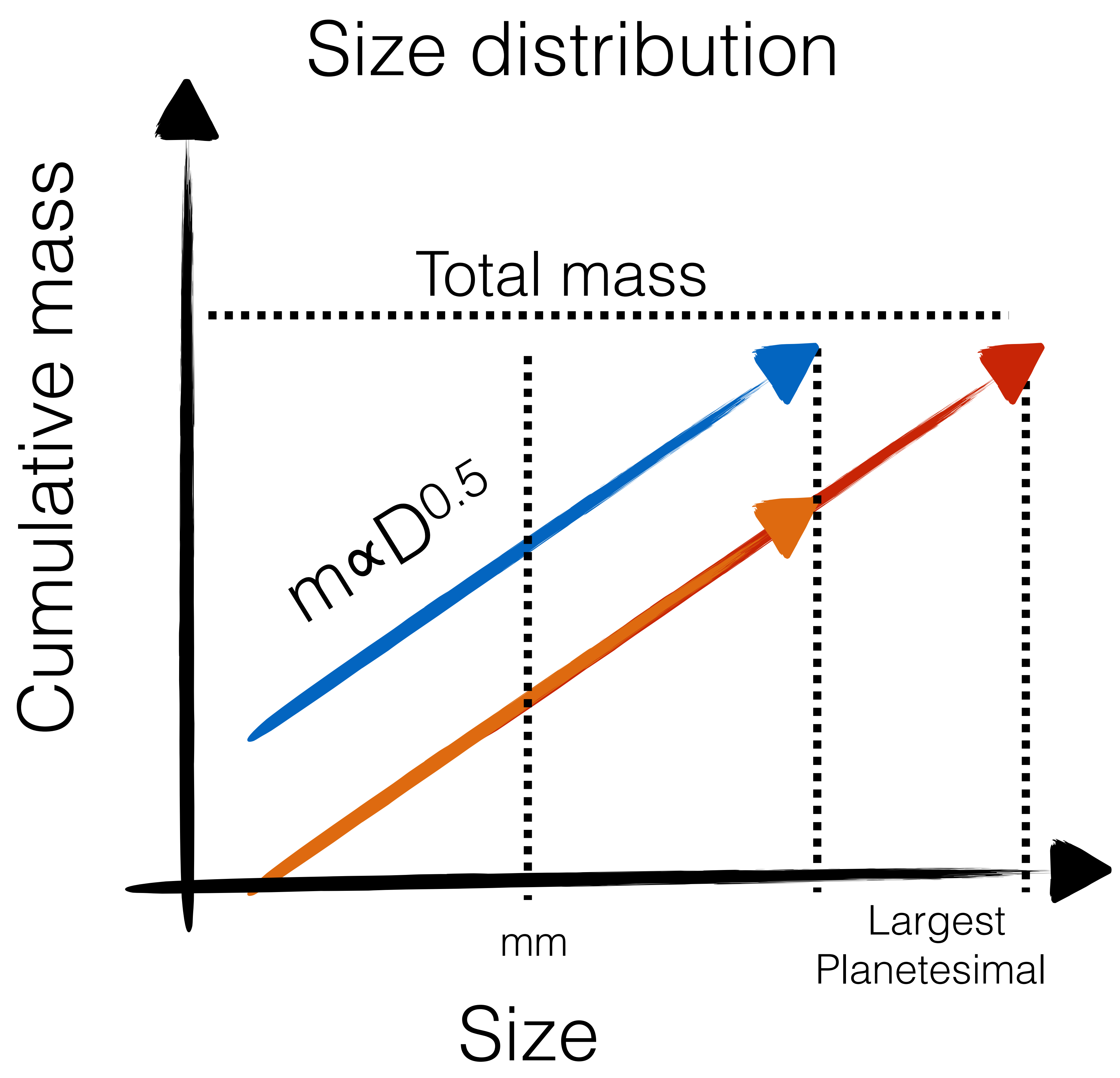
Marino+2016,2017,2018,2019, Kennedy+2018, MacGregor+2013,2017,2018, Hughes+2017, Olofsson+2018, Feldt+2017, Konishi+2016, Matrà+sub, Lovell+in prep

Gaps in wide planetesimal discs

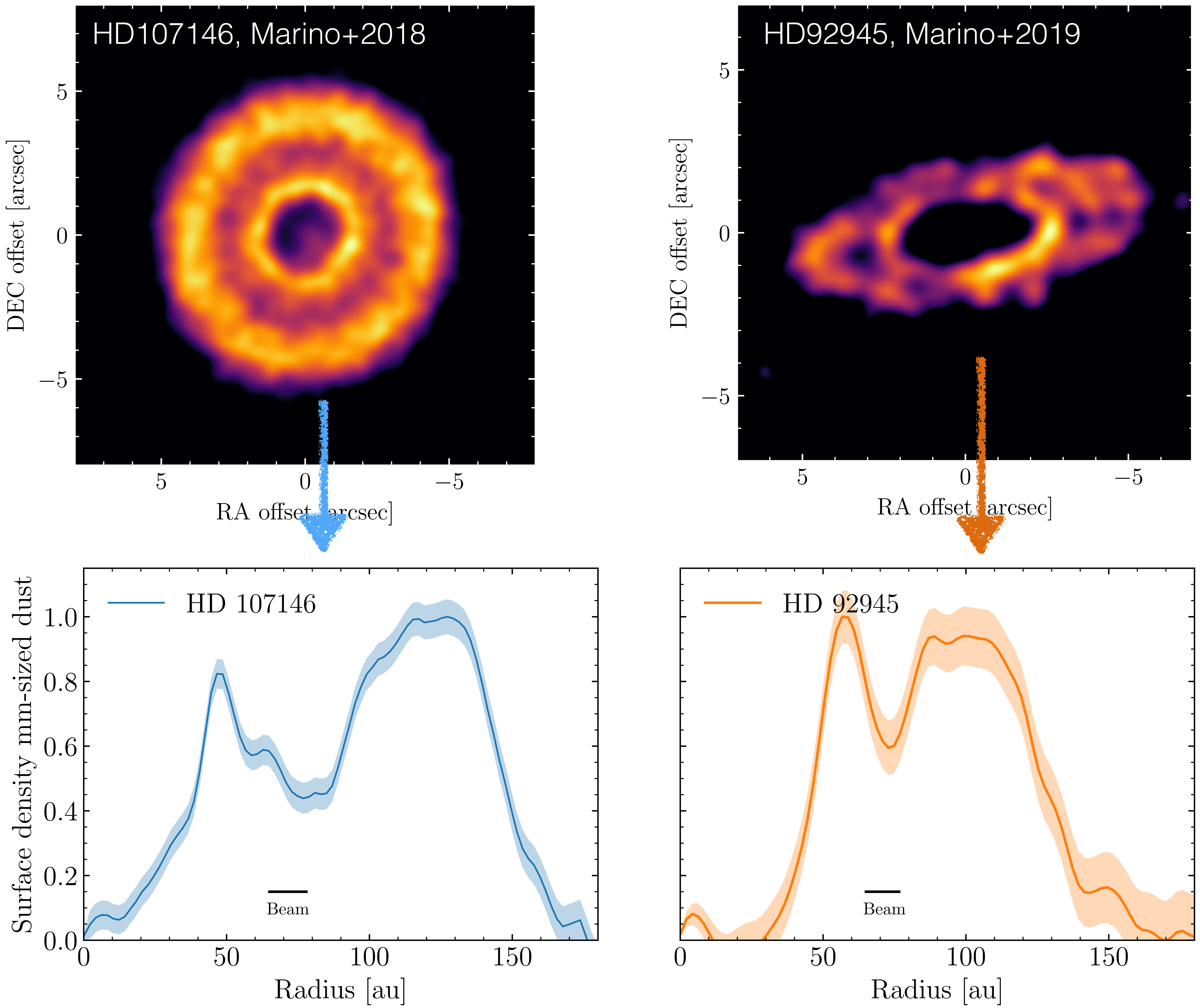
What is the origin of the gaps?

"Seeing Dust, Thinking of Planetesimals" A. Krivov

Depletion of solids or larger planetesimals?

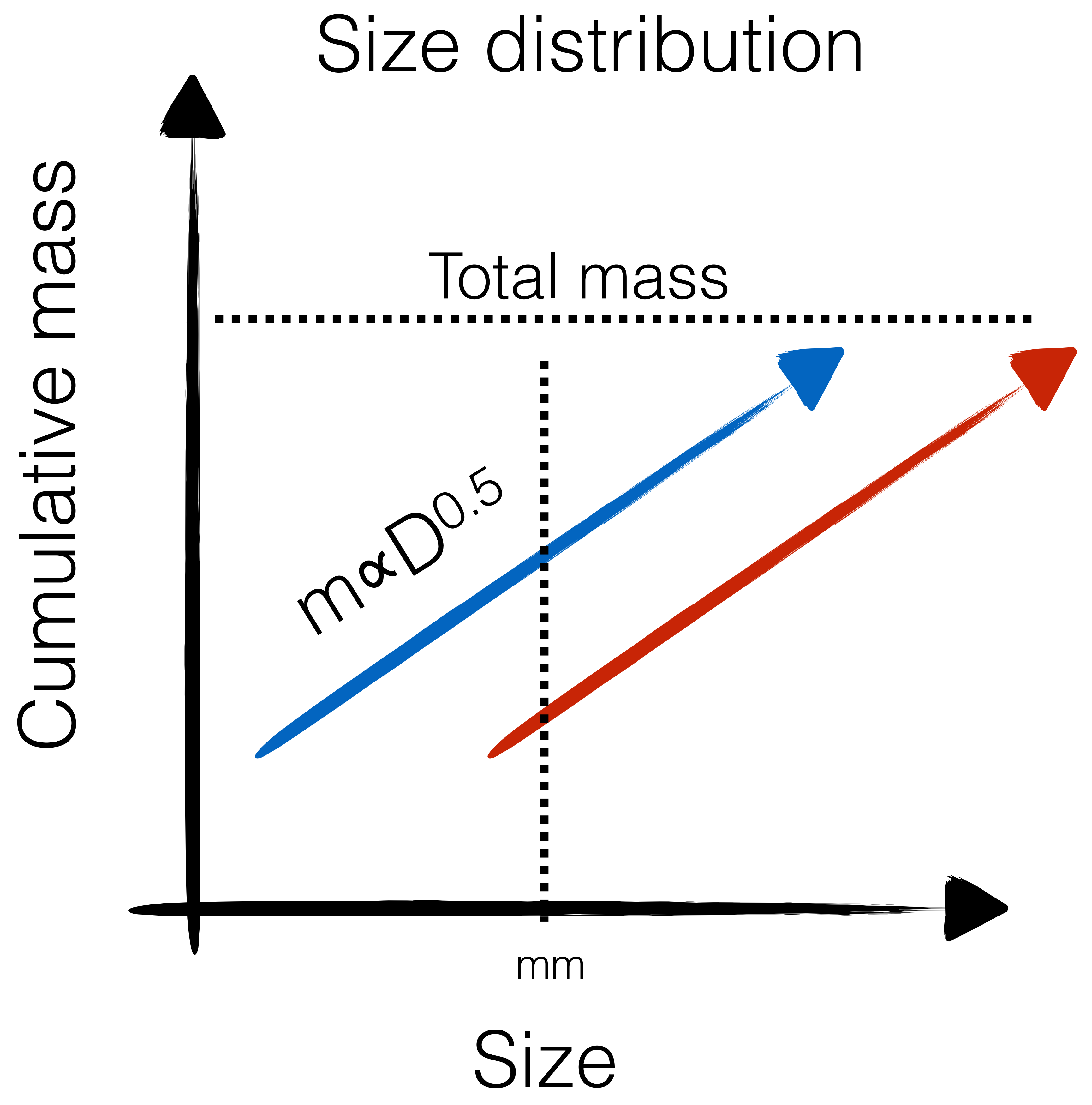


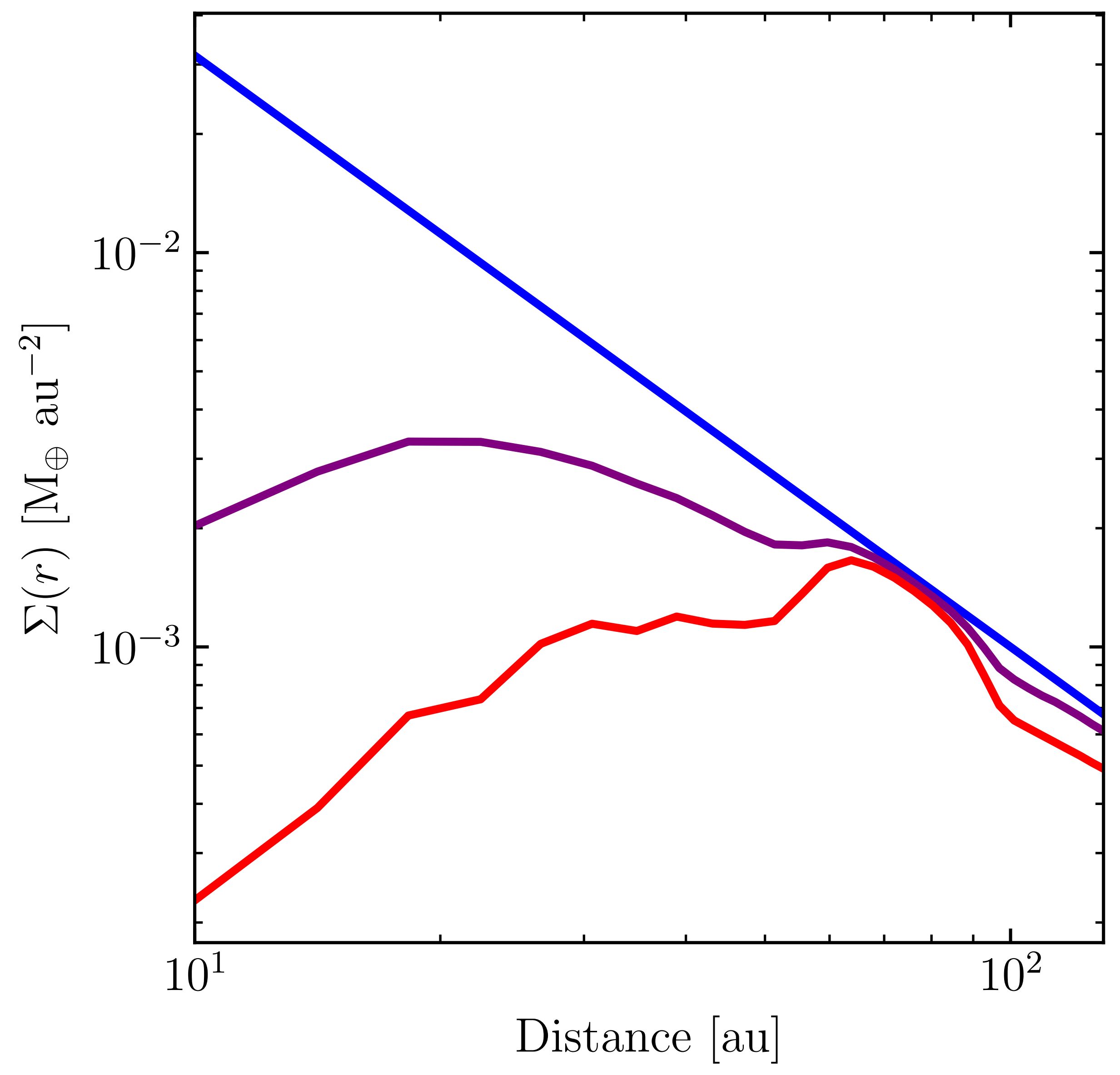
Solar type stars, ~100-200 Myr old

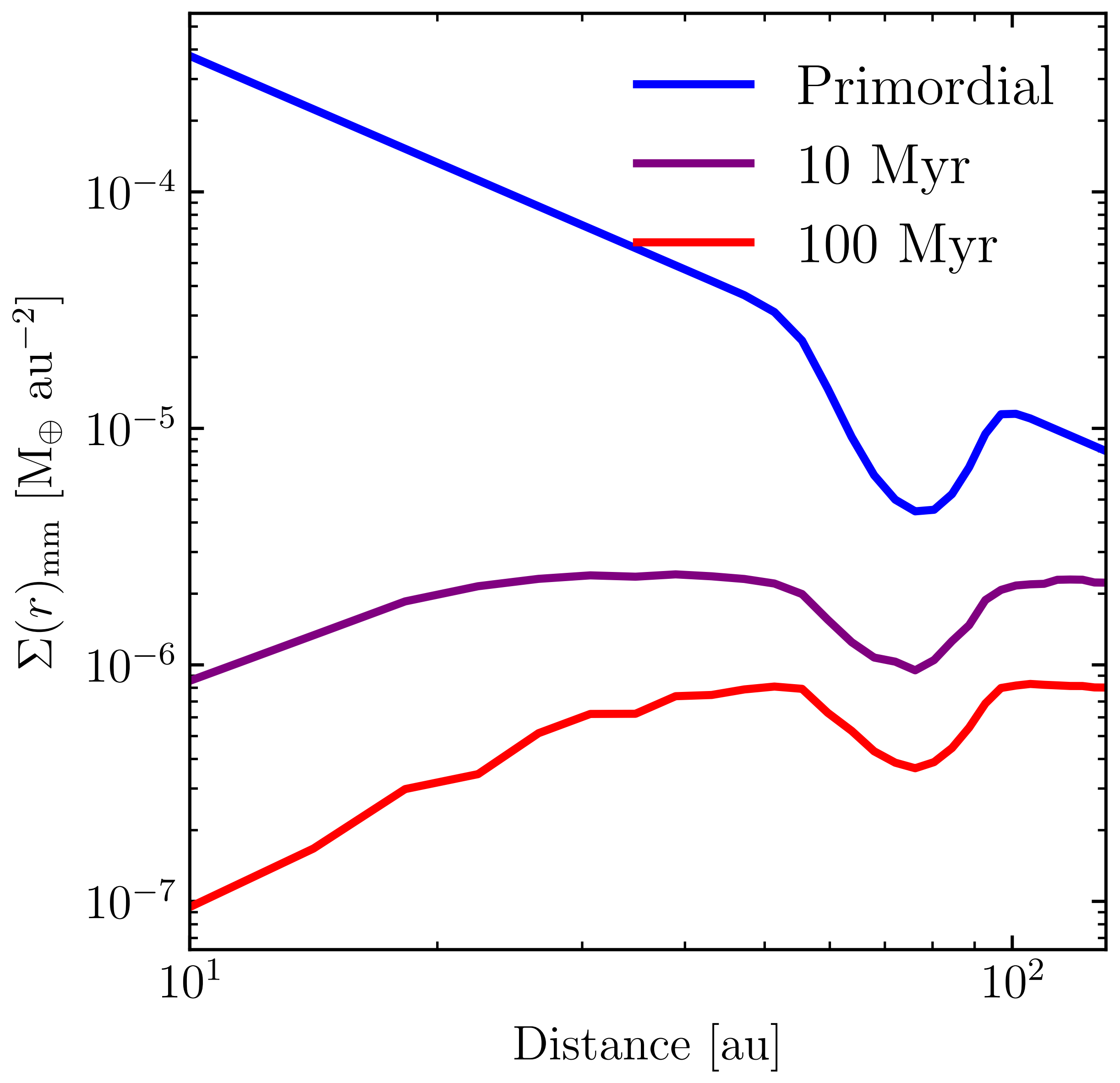


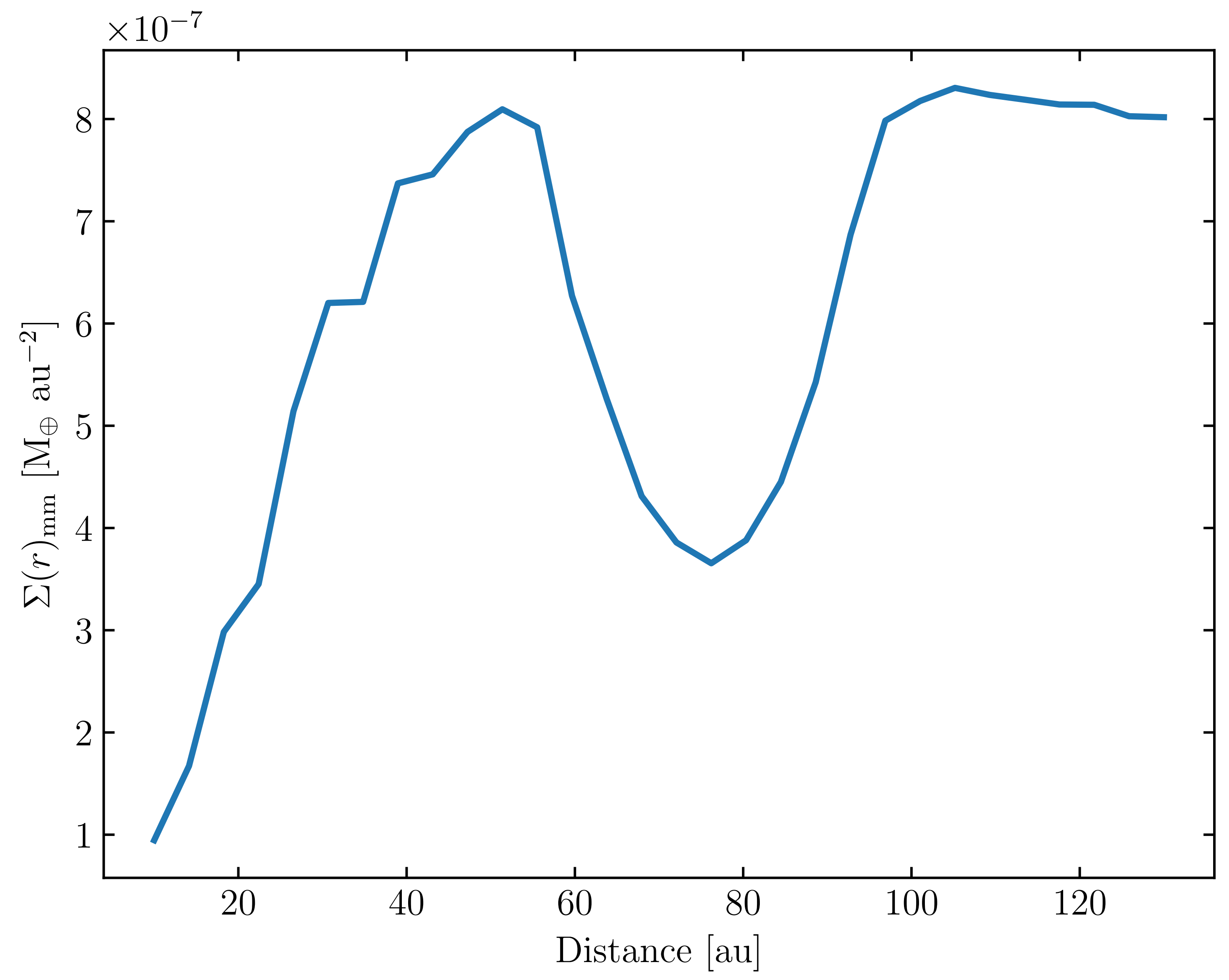
Larger planetesimals?

What could cause the formation of ~100x larger planetesimals at a specific radius?









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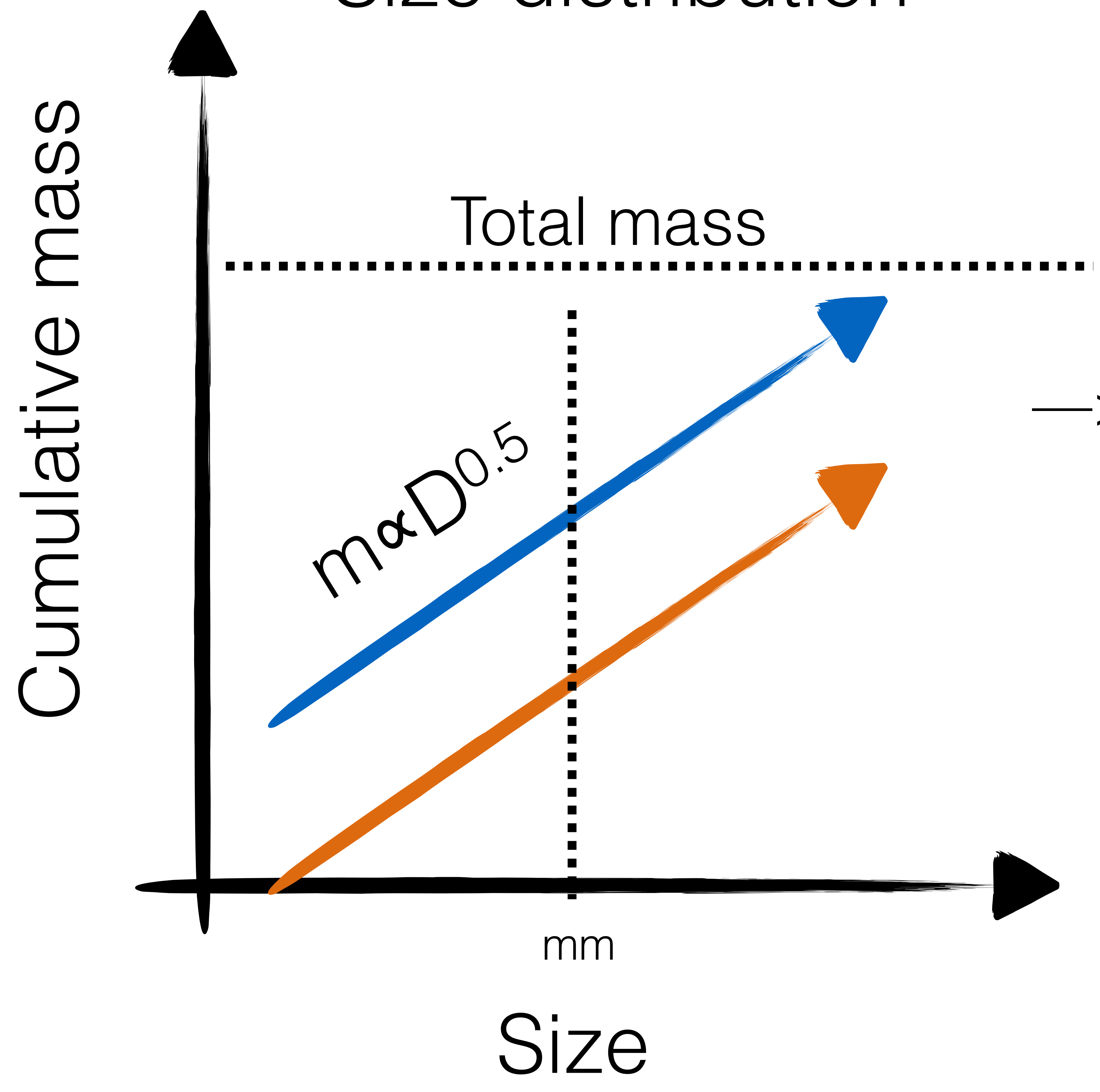
Solid depletion

Where are the planets?
How massive do they need to be?

Size distribution



3 mechanisms to open gaps through planet disc interactions (no gas)

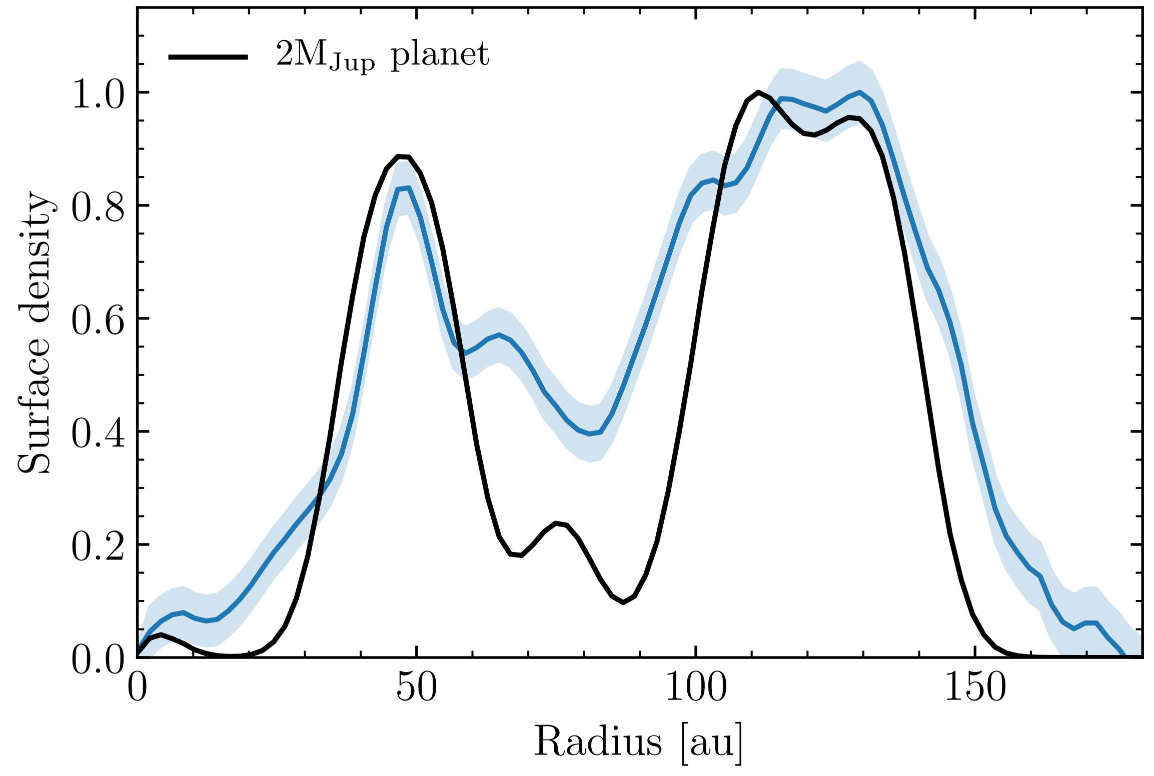
a) Scattering
—> planet in the gap
Mass ∝ gap size$^{7/2}$
(e.g. Morrison+2015)

b) Secular interactions
—> planet at disc inner edge
Mass ~ disc mass
(Pearce+2015)

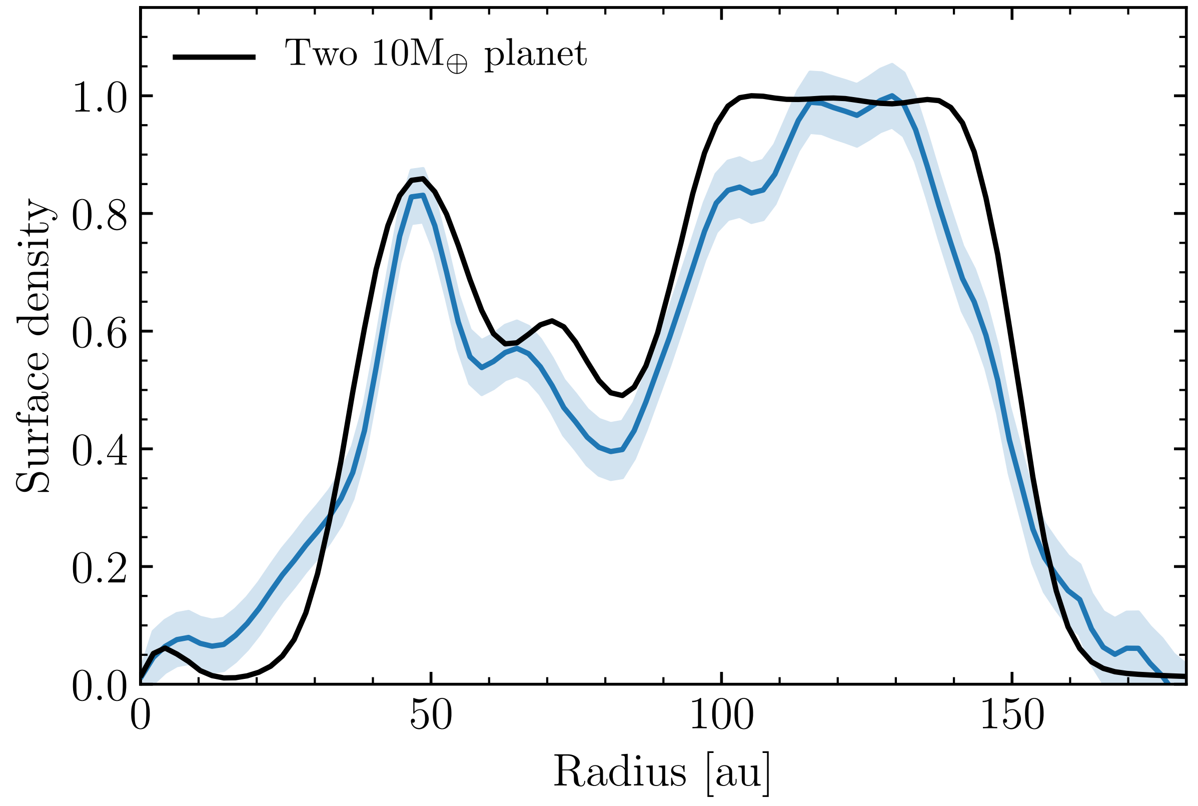
c) Secular resonances
—> 2 planets interior to disc
(Yelverton+2018)

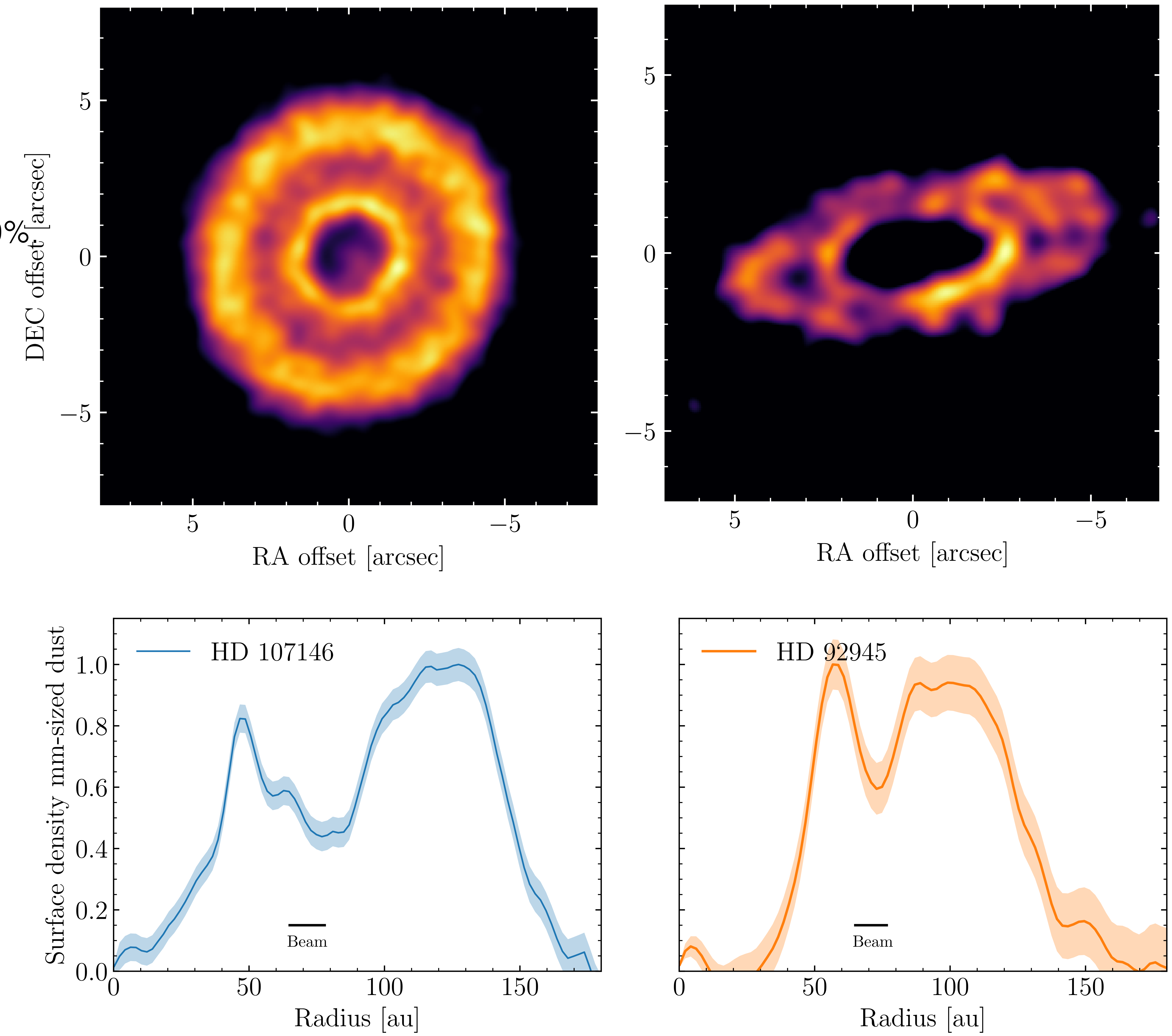
A) Planet in the gap

- Gap ~40au wide; symmetric
- Planet mass ∝ gap size$^{7/2}$
  —> 2 M_{Jup} planet
- However, gap is only depleted by ~50%

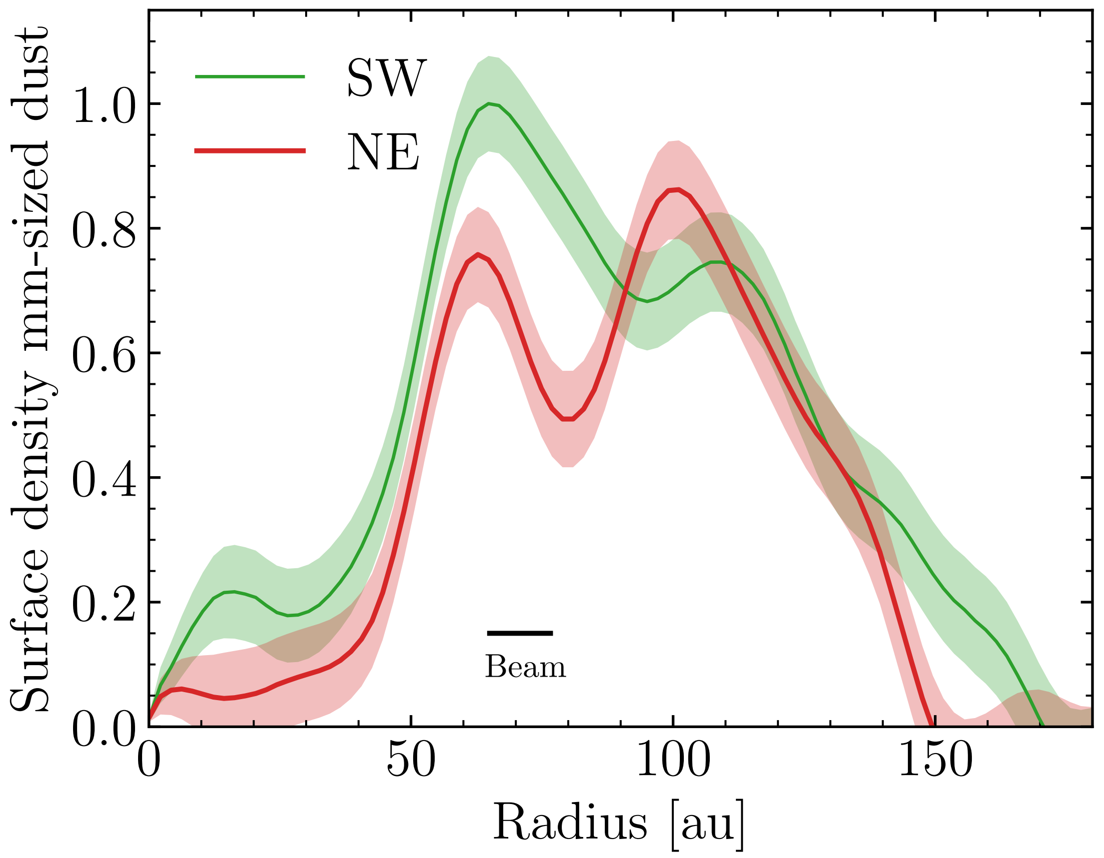


Two low mass planets?





- Gap is marginally resolved
- Width<< 50 au
  —> M_p<<5 M_{Jup}
- Depleted by 40-100%
- However, potential asymmetry
  —> disfavouring scenario "a"



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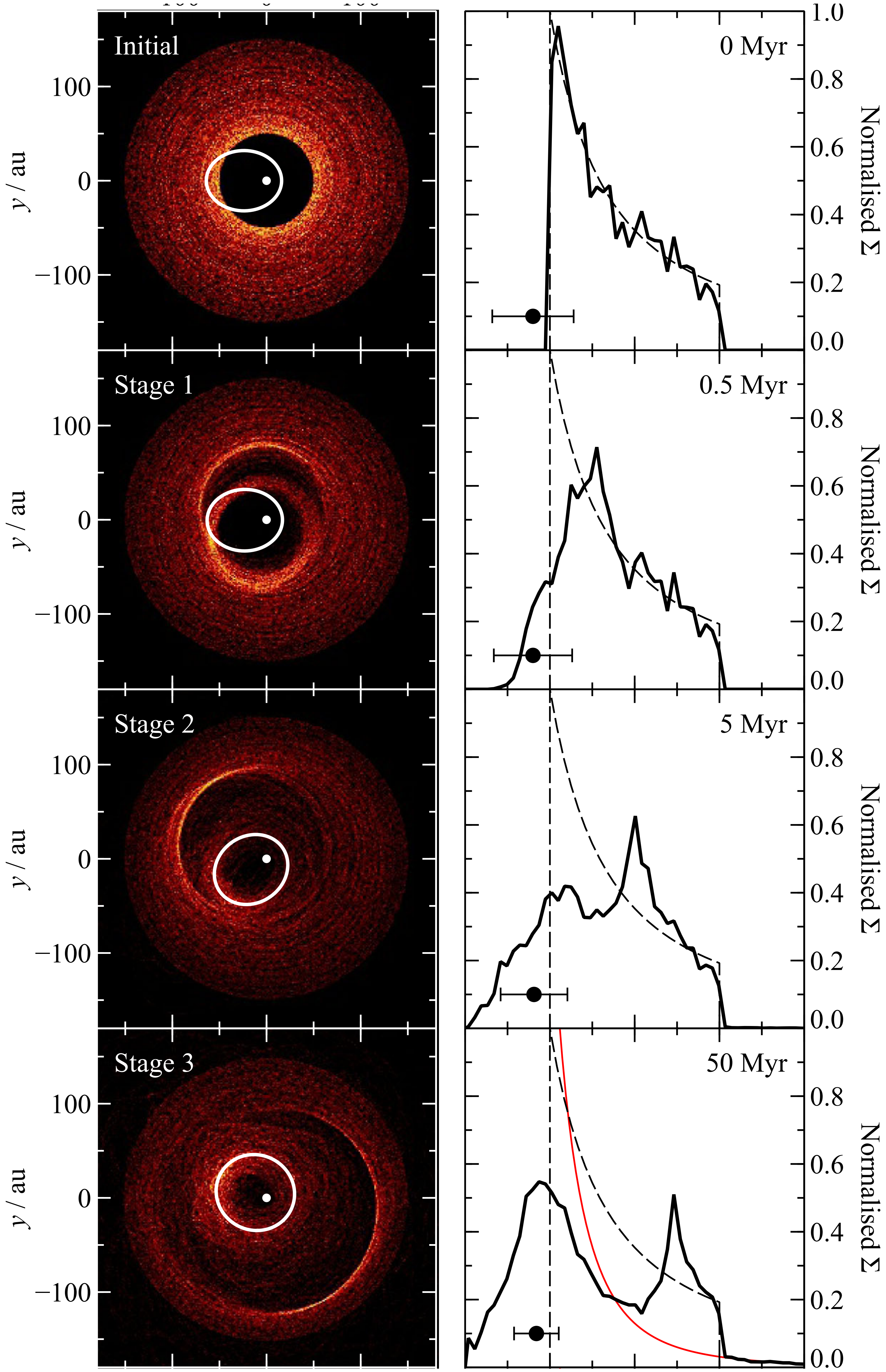
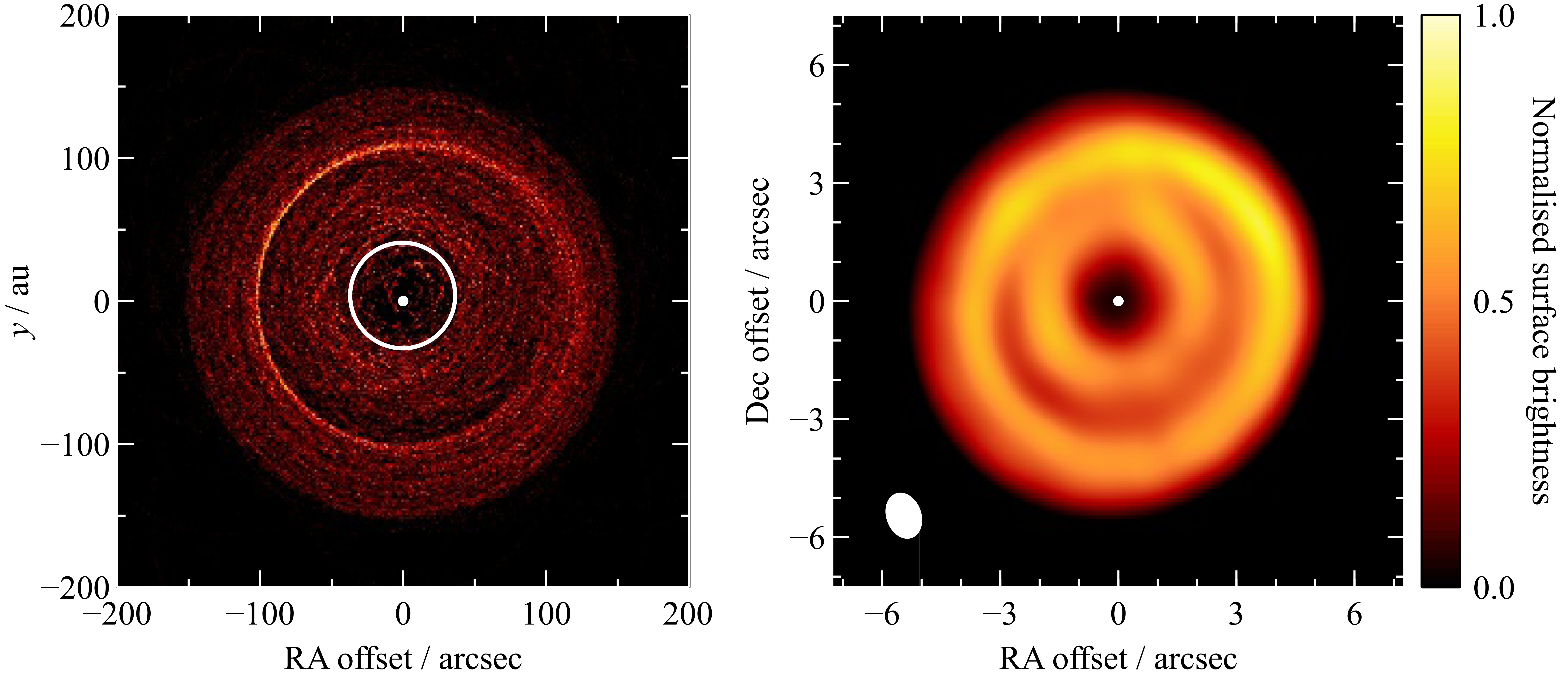
b) A gap opened by an ECCENTRIC planet?



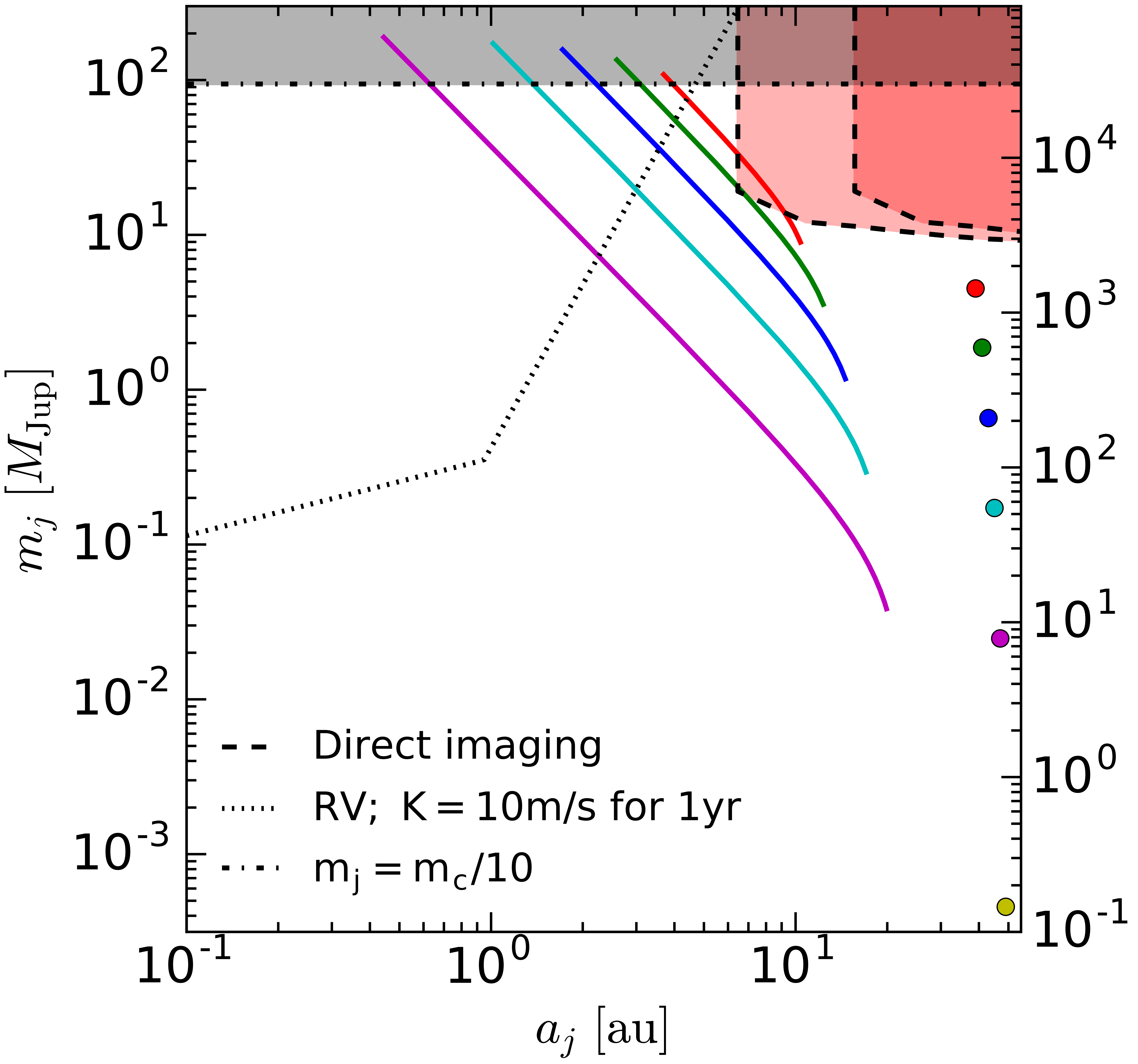
Planet is scattered out from inner regions, opens a gap through secular interactions

Pearce & Wyatt 2015

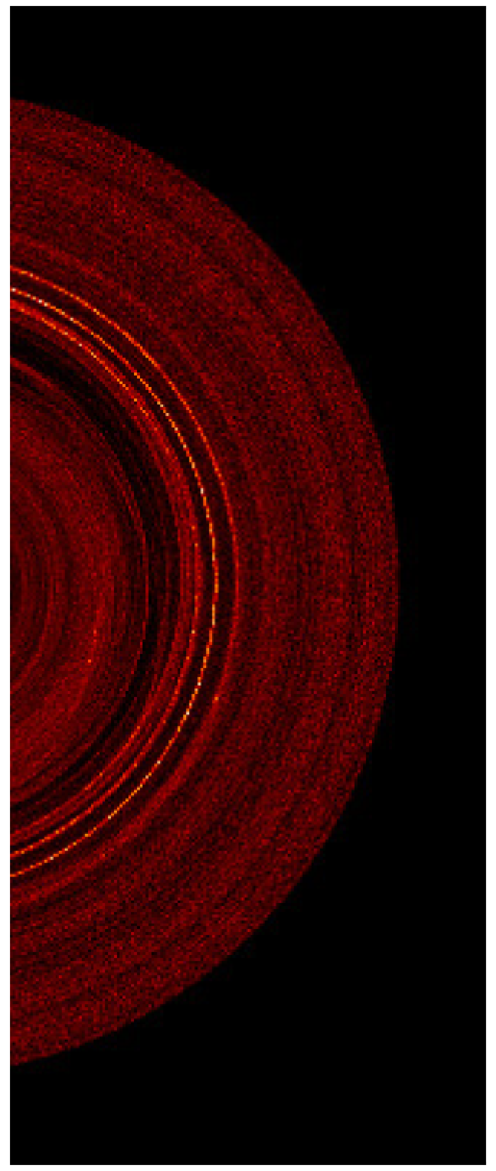


Planet formed closer in and is orbiting now at disc inner edge

C) A gap opened by inner planets?



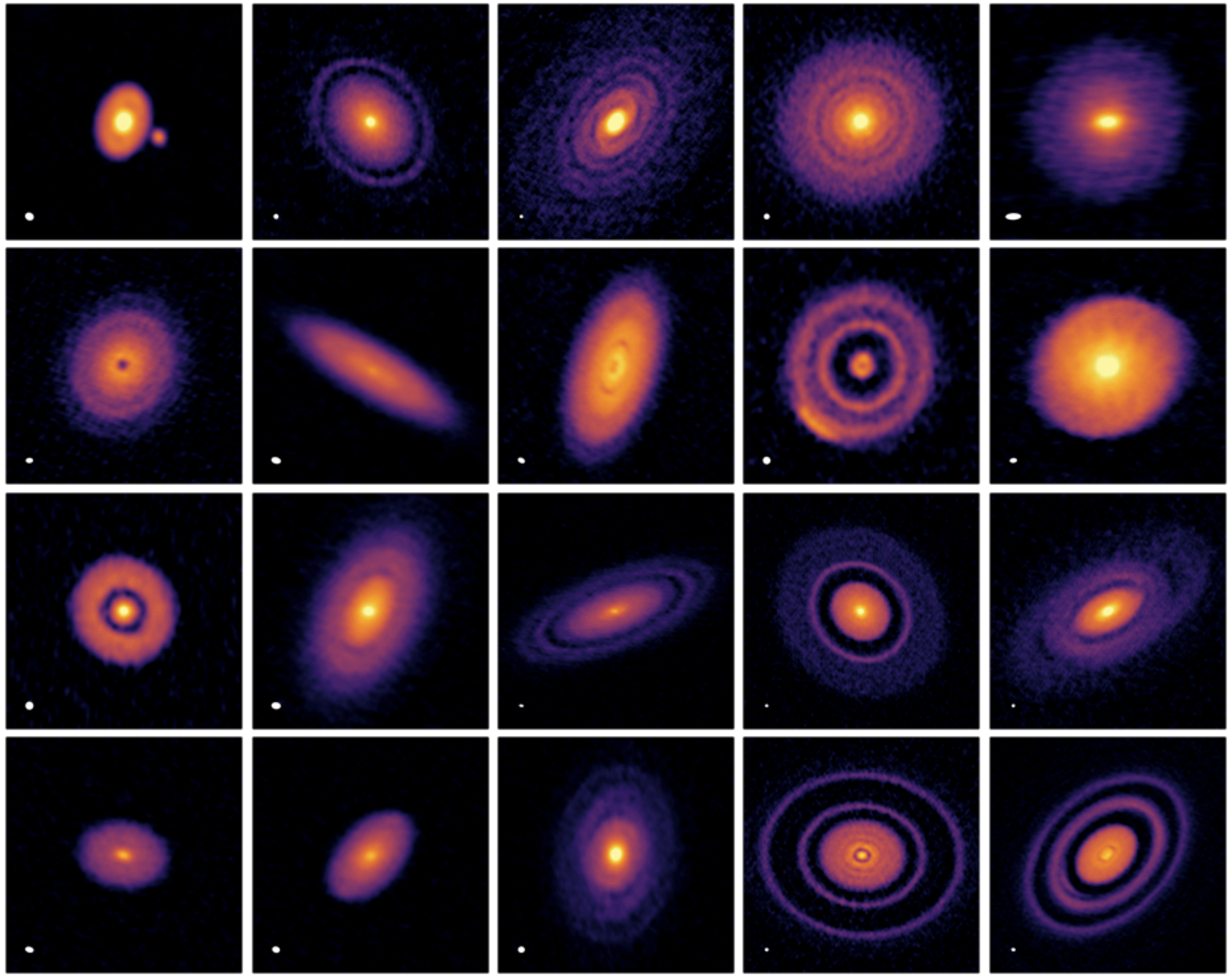
nets in low e orbits precess interior to disc
emi-major axes where the precession rate is
net's will reach high e



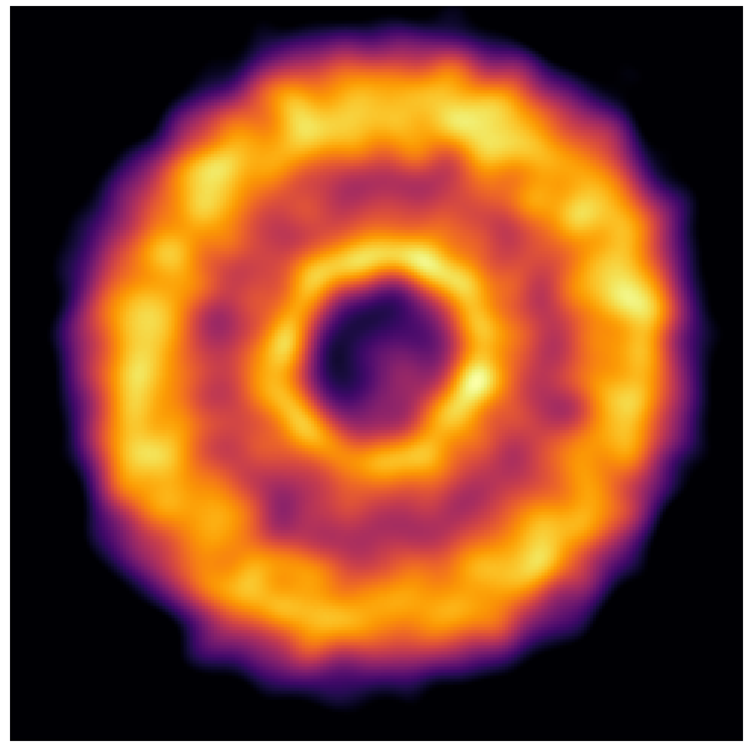
lel is consistent with HD92945,
redicts two inner planets

Gaps/rings in planetesimal belts are becoming more common

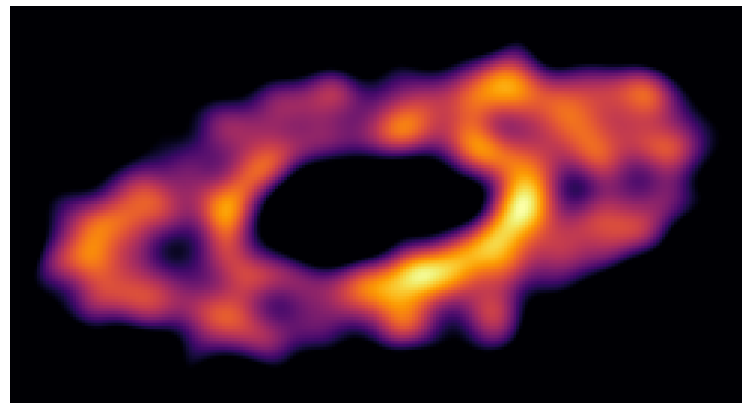
Substructure in dust



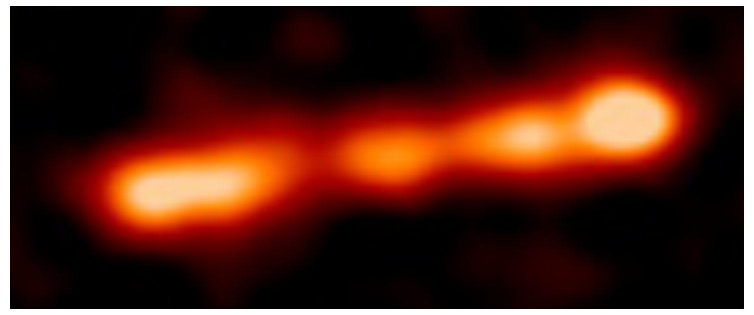
?



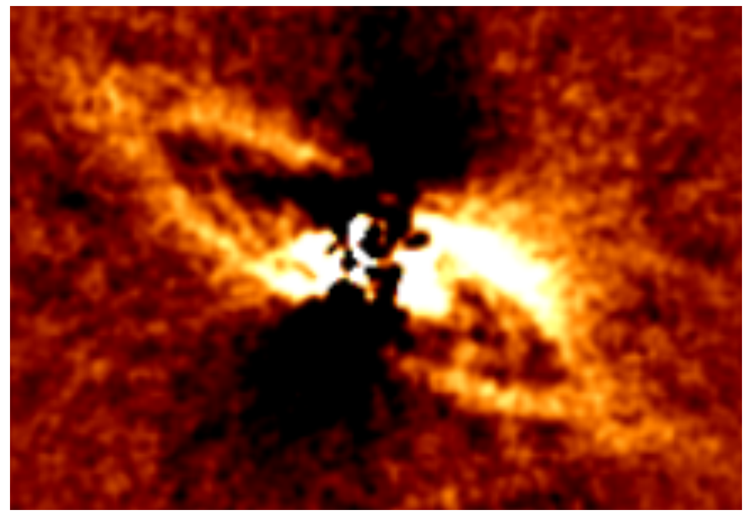
HD107146
Marino+2018



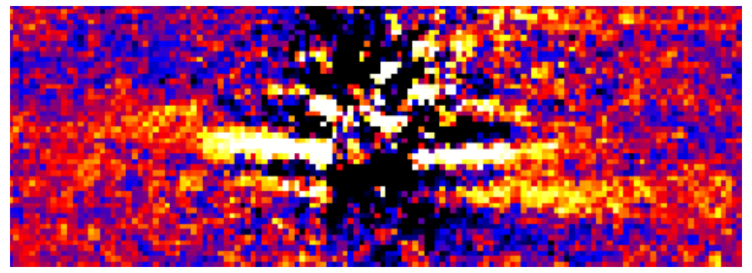
HD92945
Marino+2019



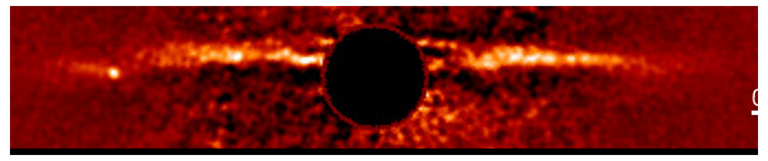
HD15115
MacGregor+2019



HD131835
Feldt+2017



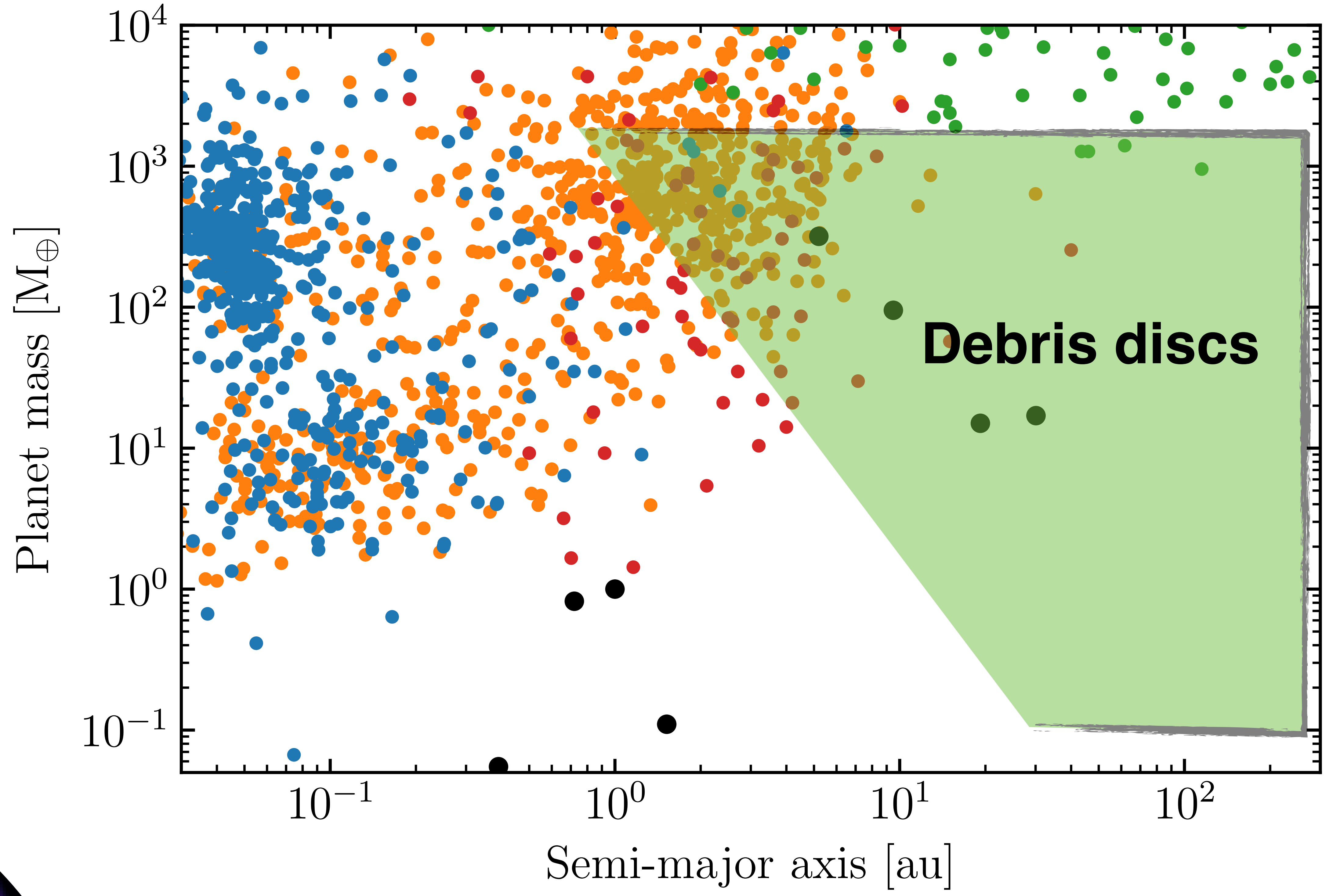
HD67497
Bonnefoy+2017

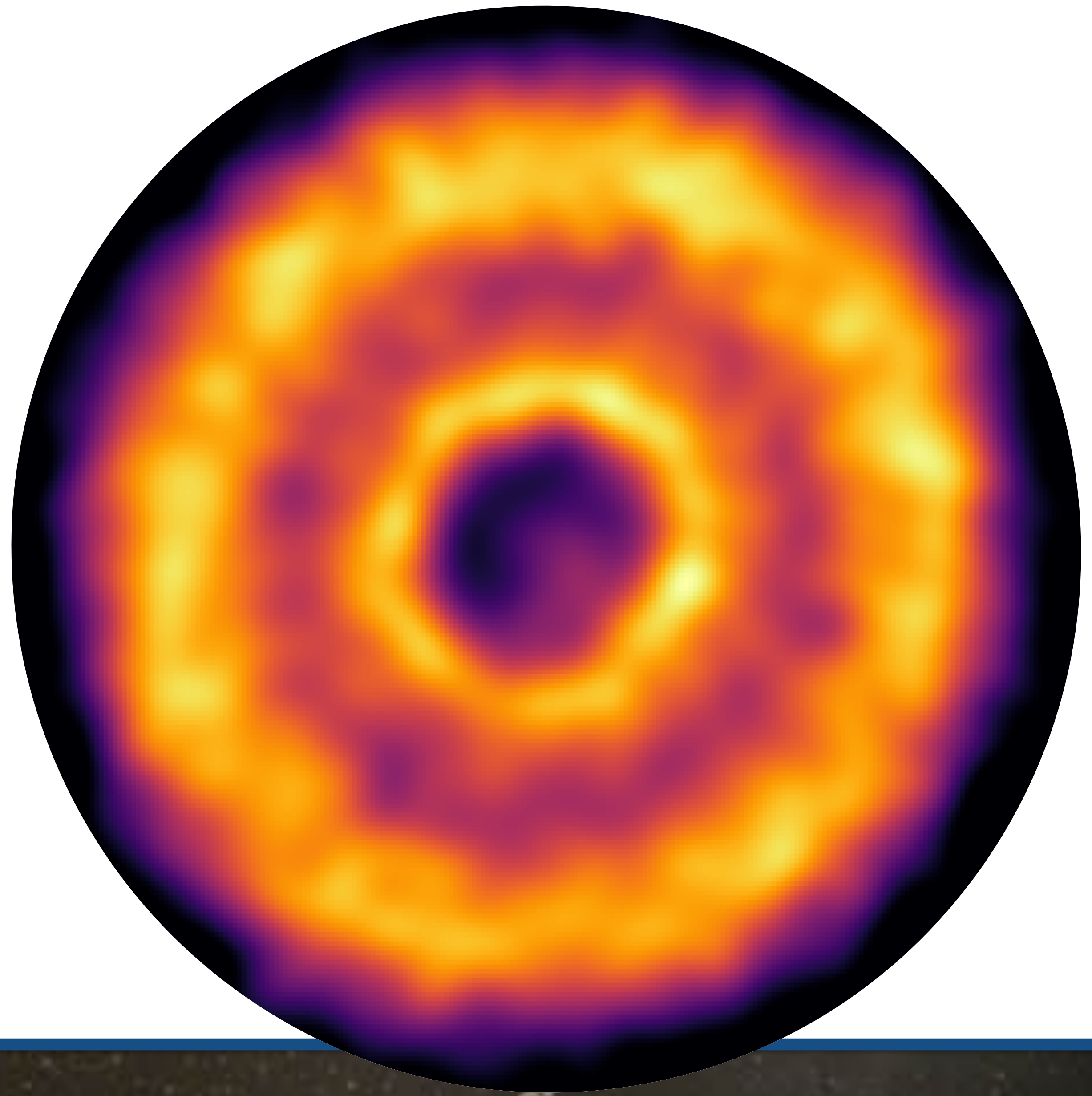


NZ Lup
Boccaletti+2019

Take home messages

- Debris discs present a rich radial structure
- Most of them seem wide
- The structure can hint at the presence of planets
- How are the observed structures connected with ppdisk observations?






Thanks for listening
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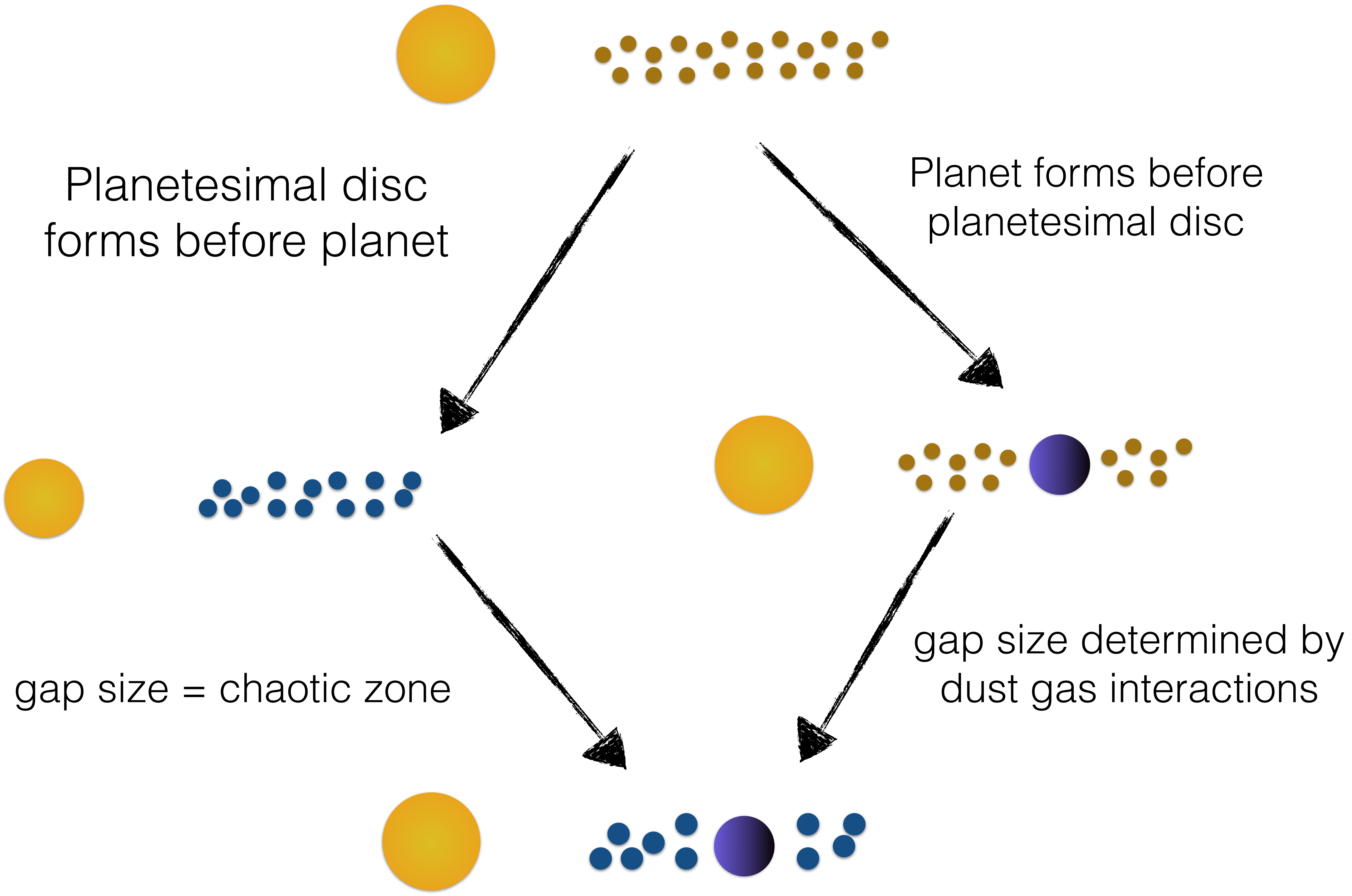
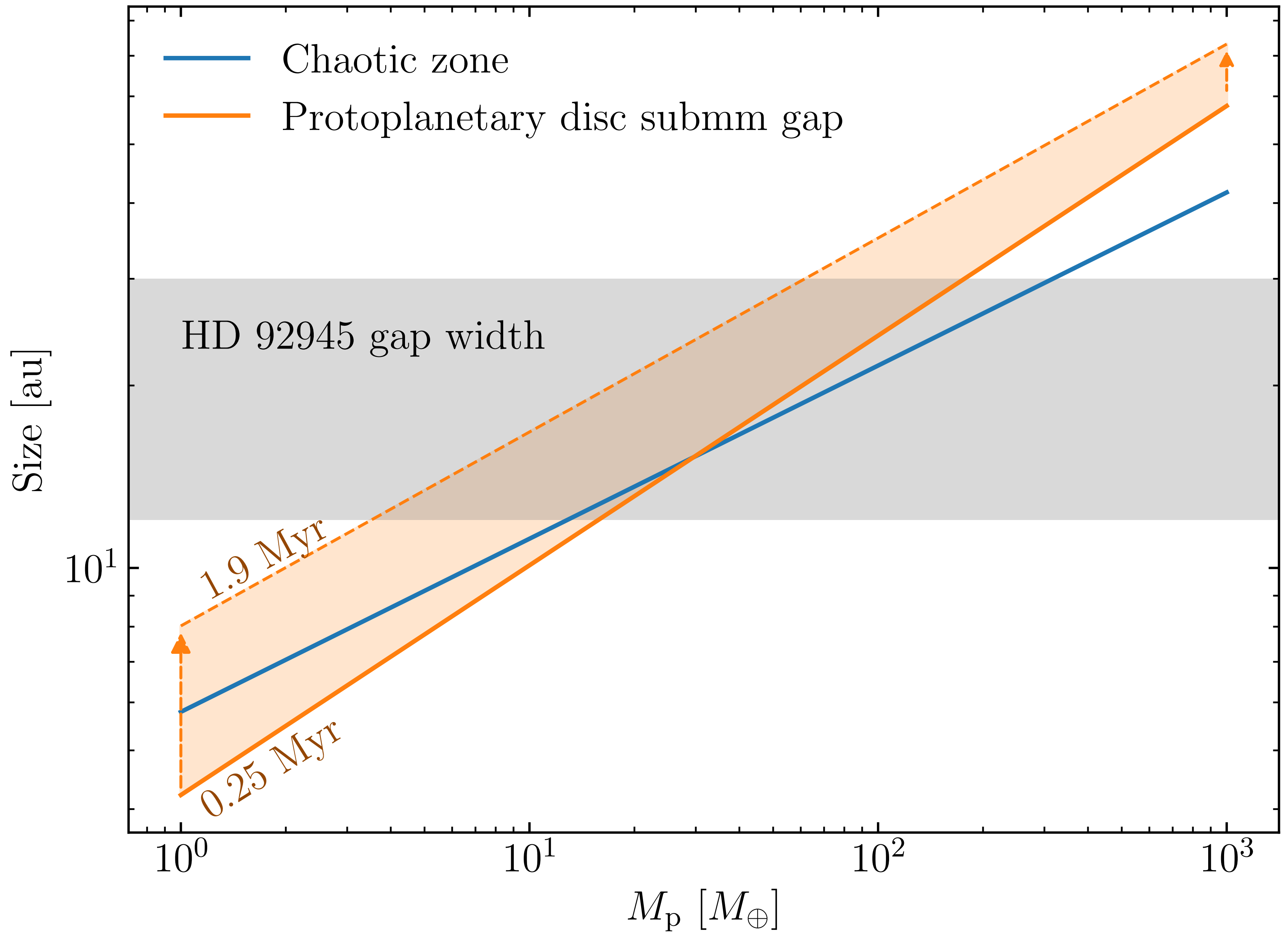
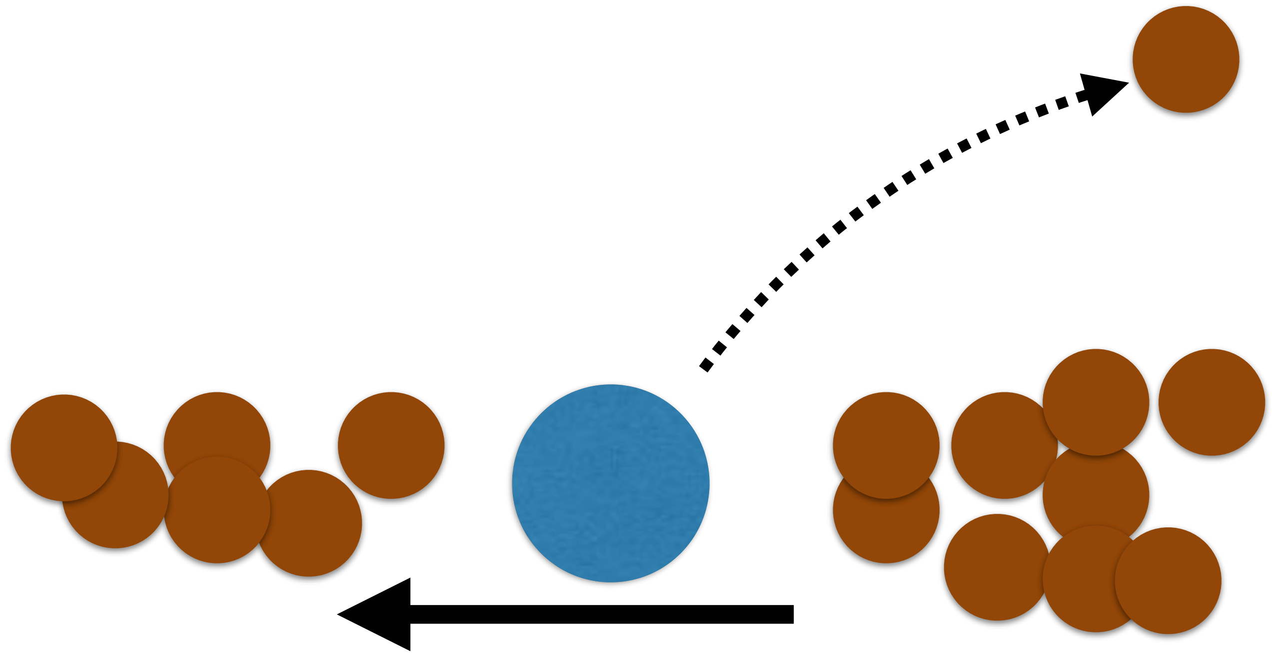
What forms first, planetesimals or gaps?

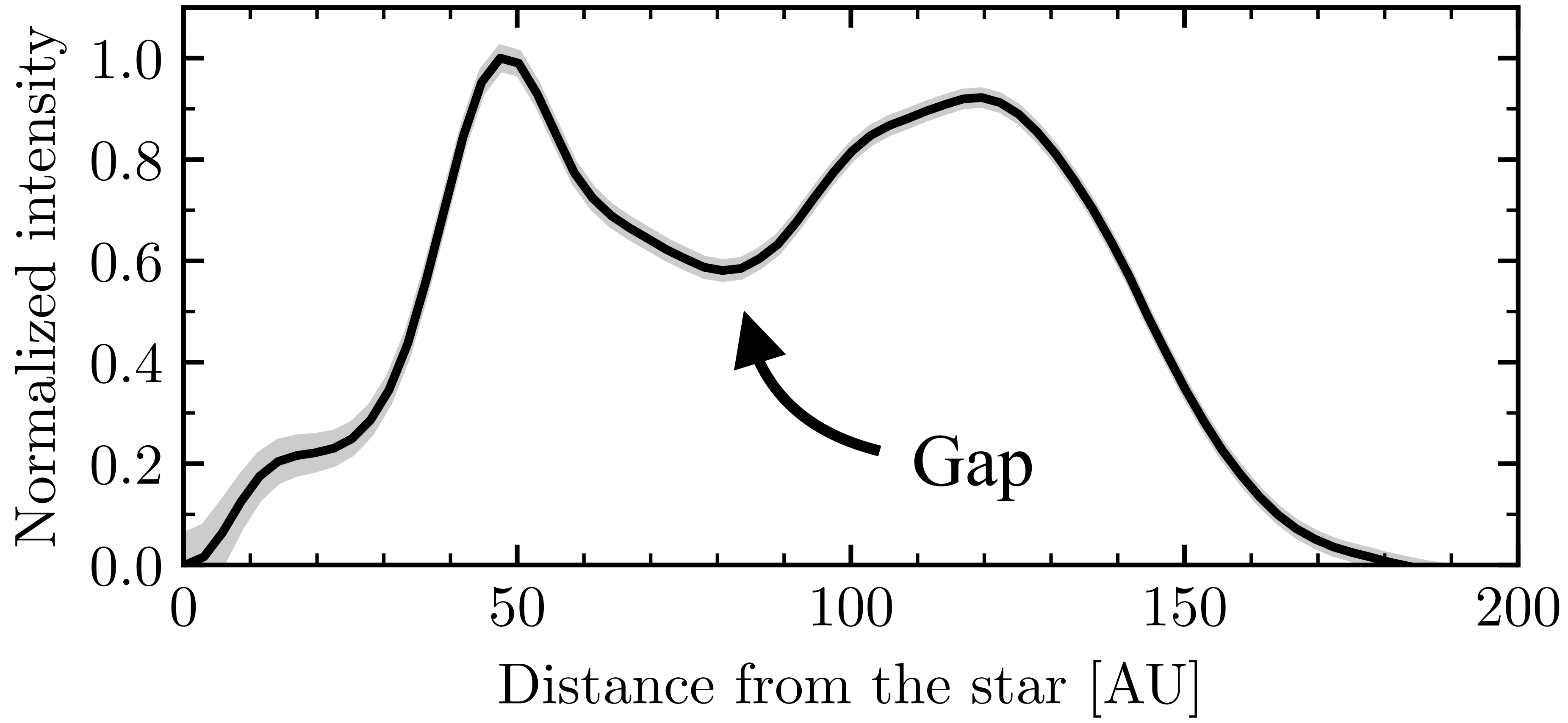




gap size could be larger than chaotic zone and thus hinder planetesimal driven migration

Planet migration?

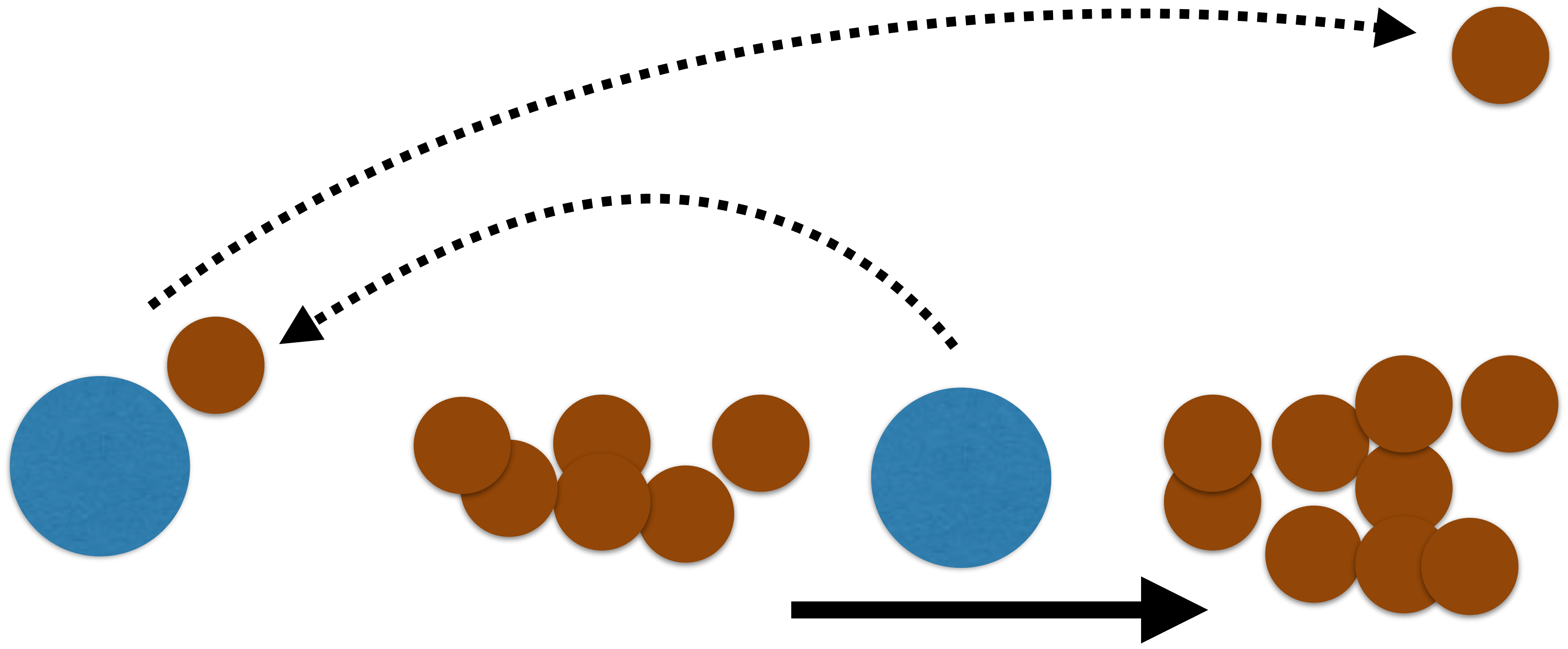




Disc mass ~10-100 Mearths —> inward migration

e.g. Fernandez&Ip 1984; Ida+2000; Kirsh+2009, Ormel+2012

Unless there are inner planets ejecting the material that is scattered in (Solar System)

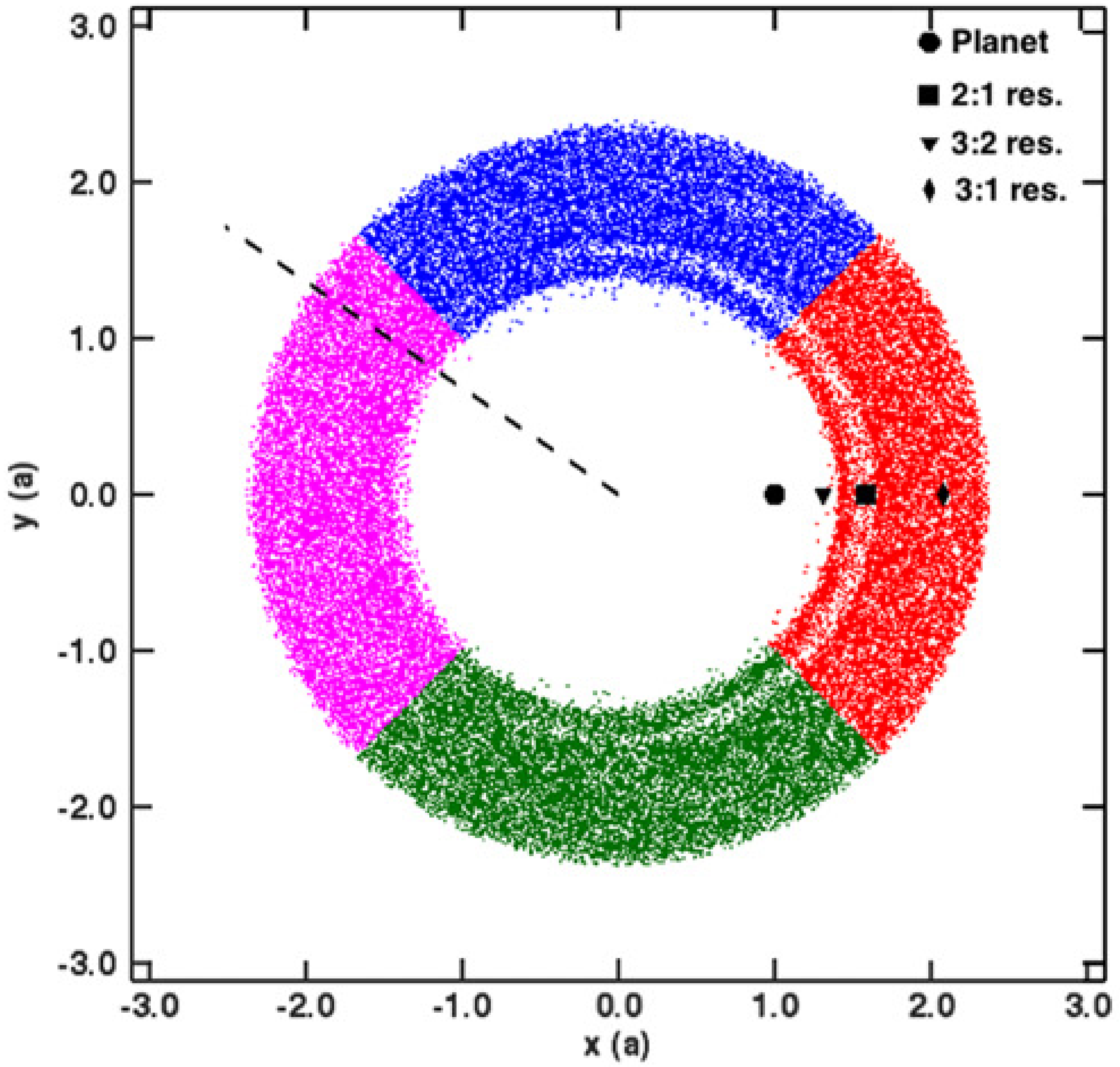


Higher resolution needed

How should planet-disc interaction look like?

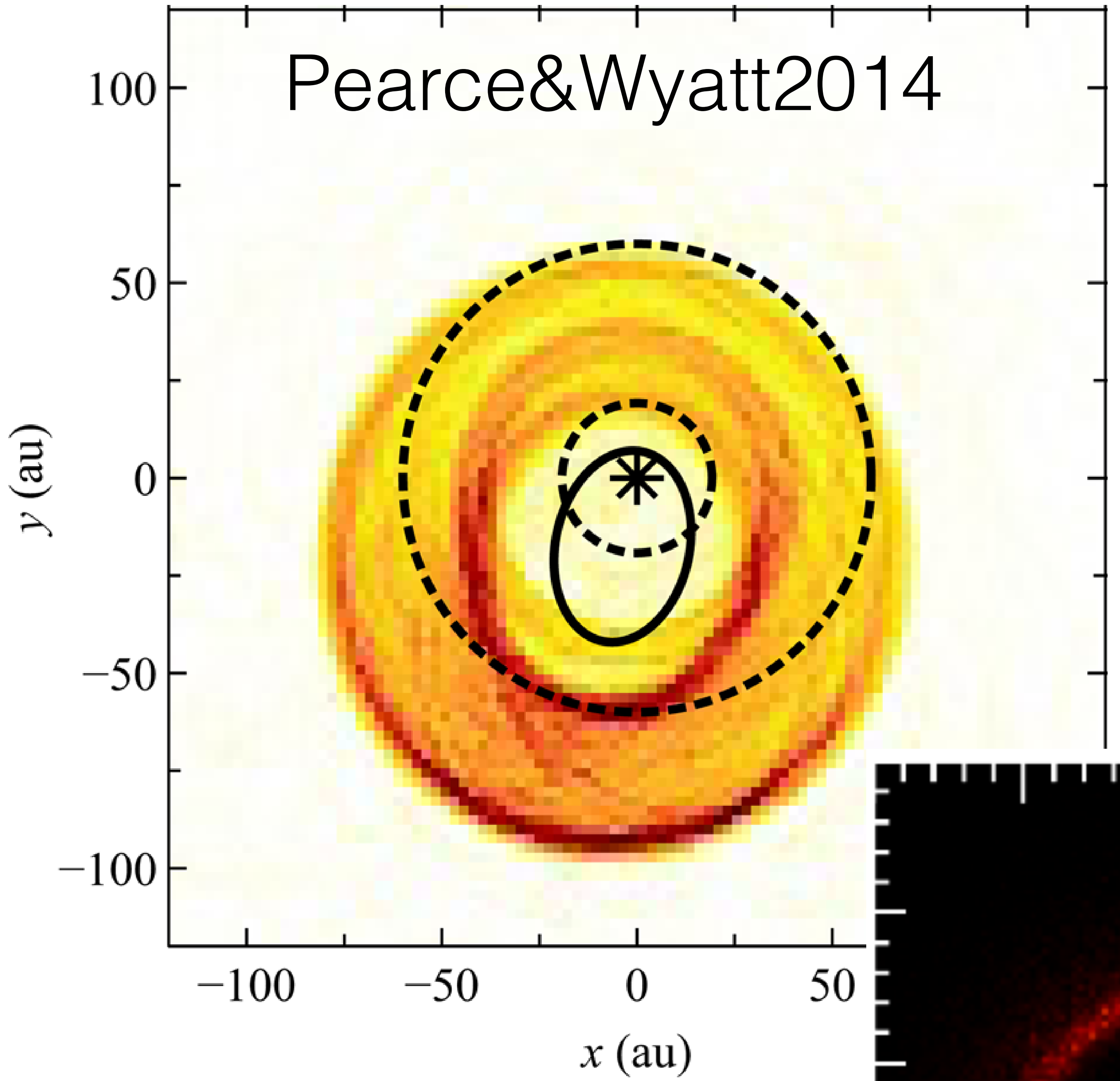
Planet interior to disc

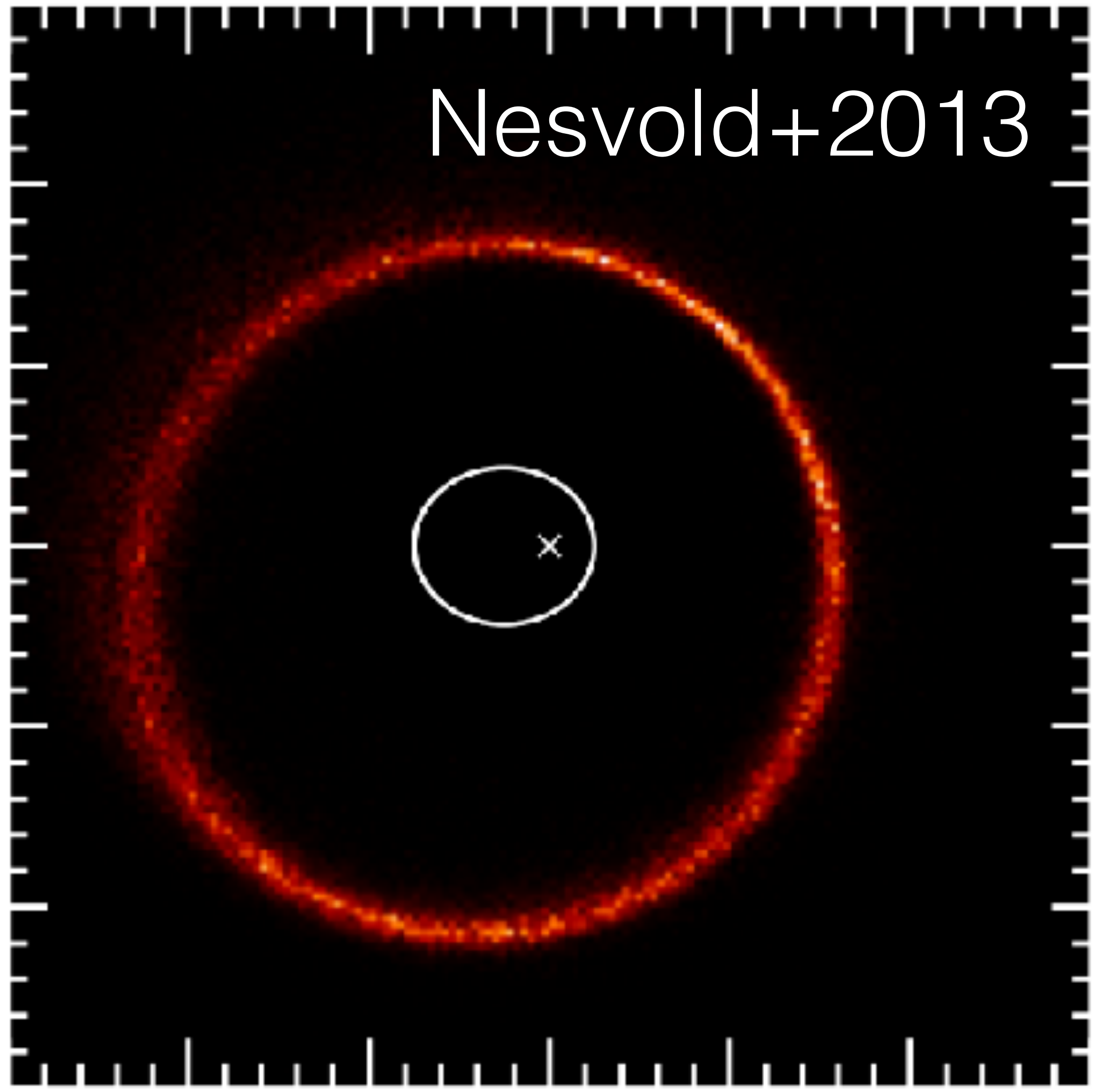
gaps due to MMR



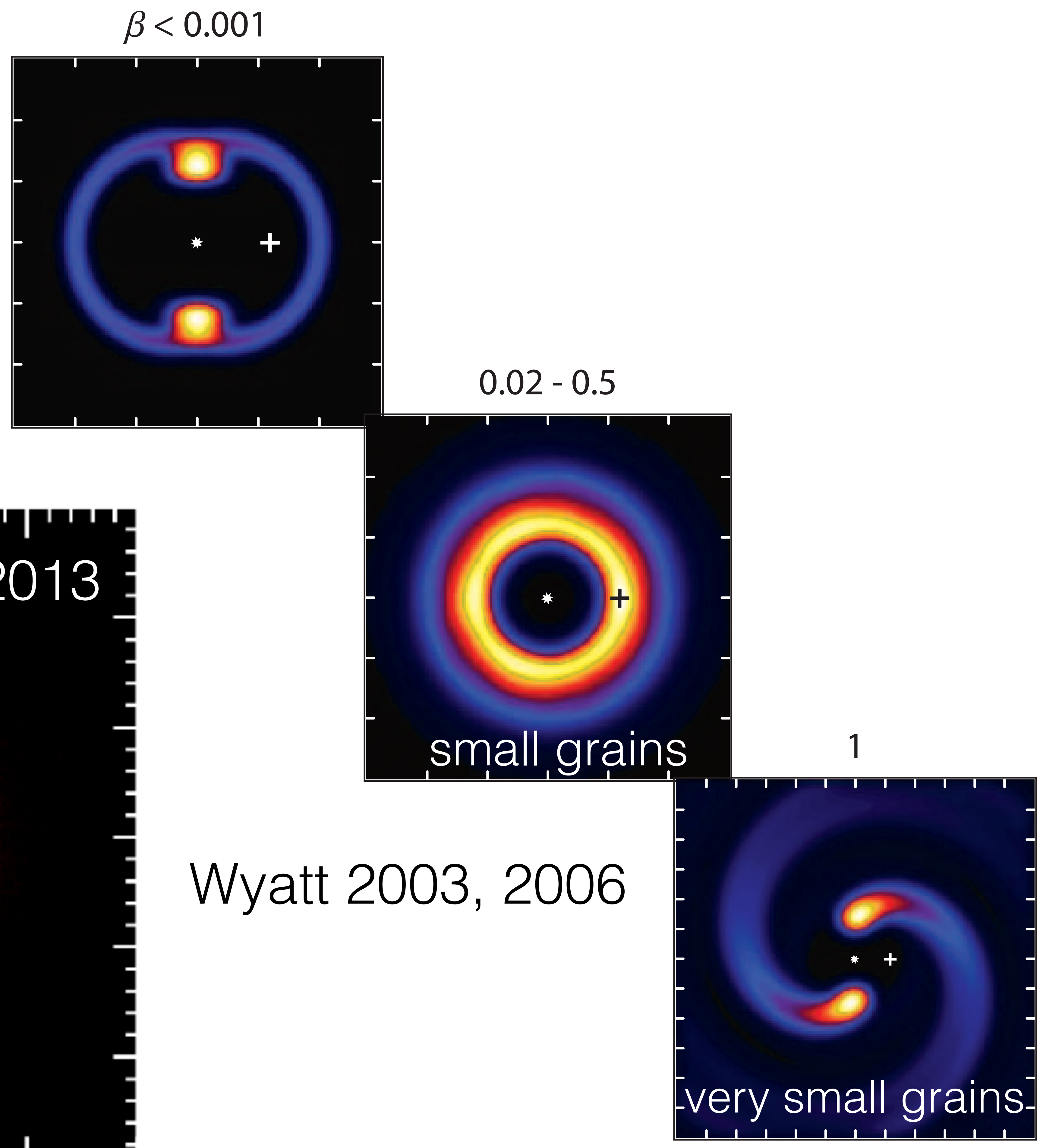
Tabeshian&Wiegert 2016

Eccentric planet





Migrating planet

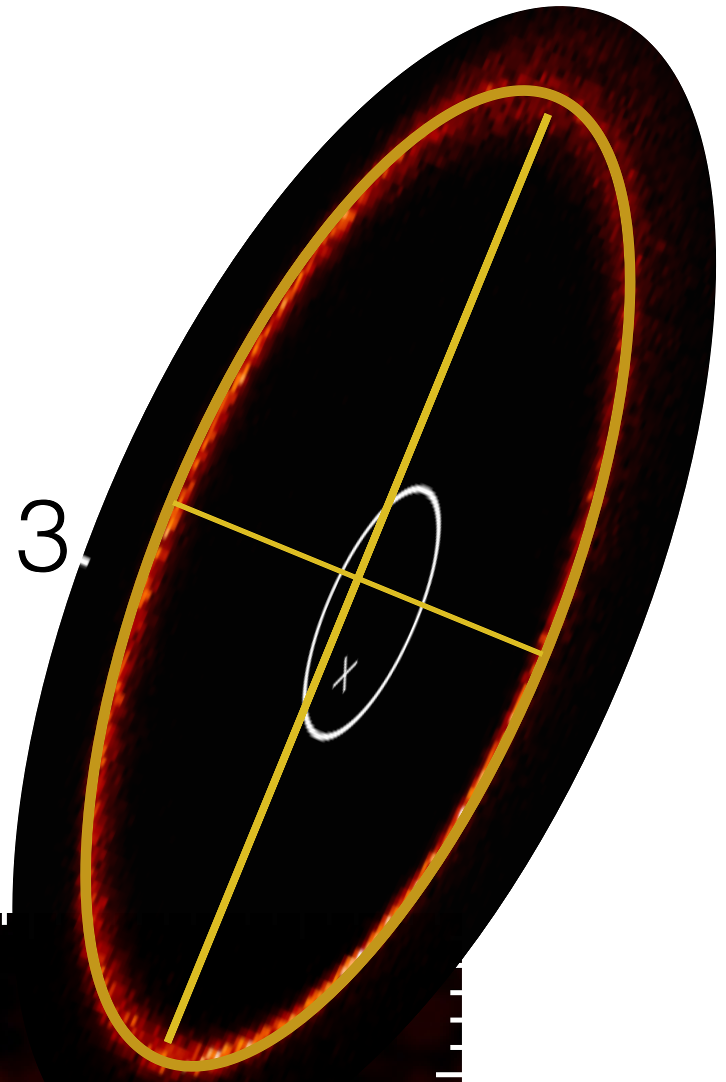


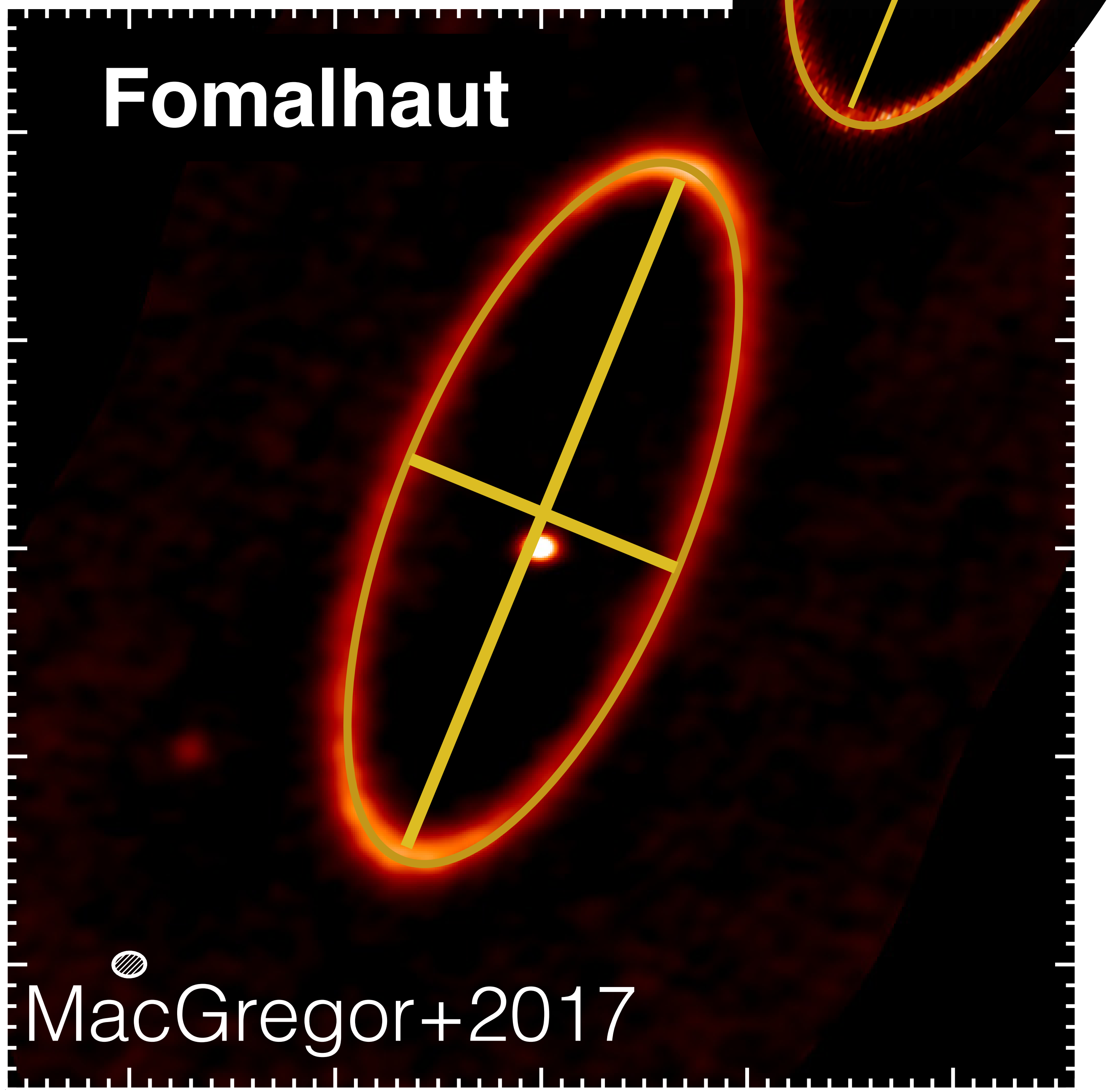
Wyatt 2003, 2006

Evidence of planet disc interaction

Eccentric rings

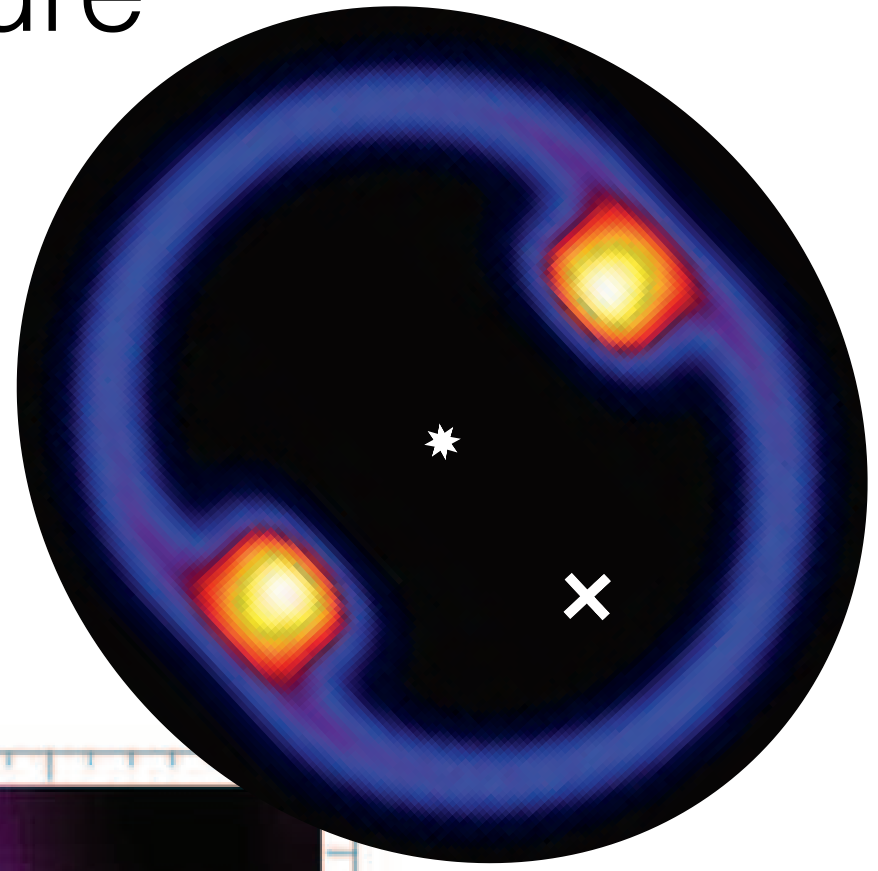
Nesvold+2013

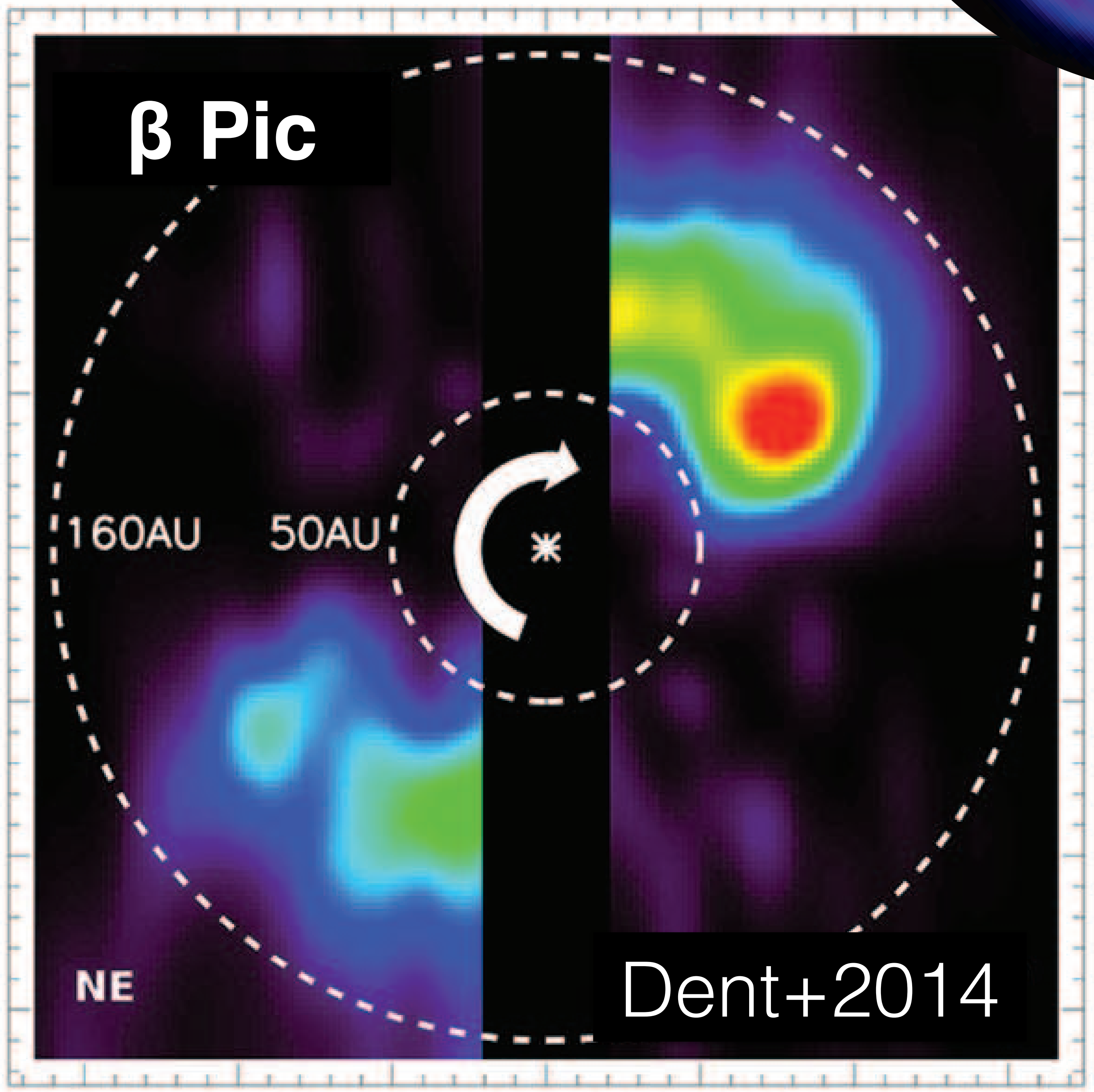




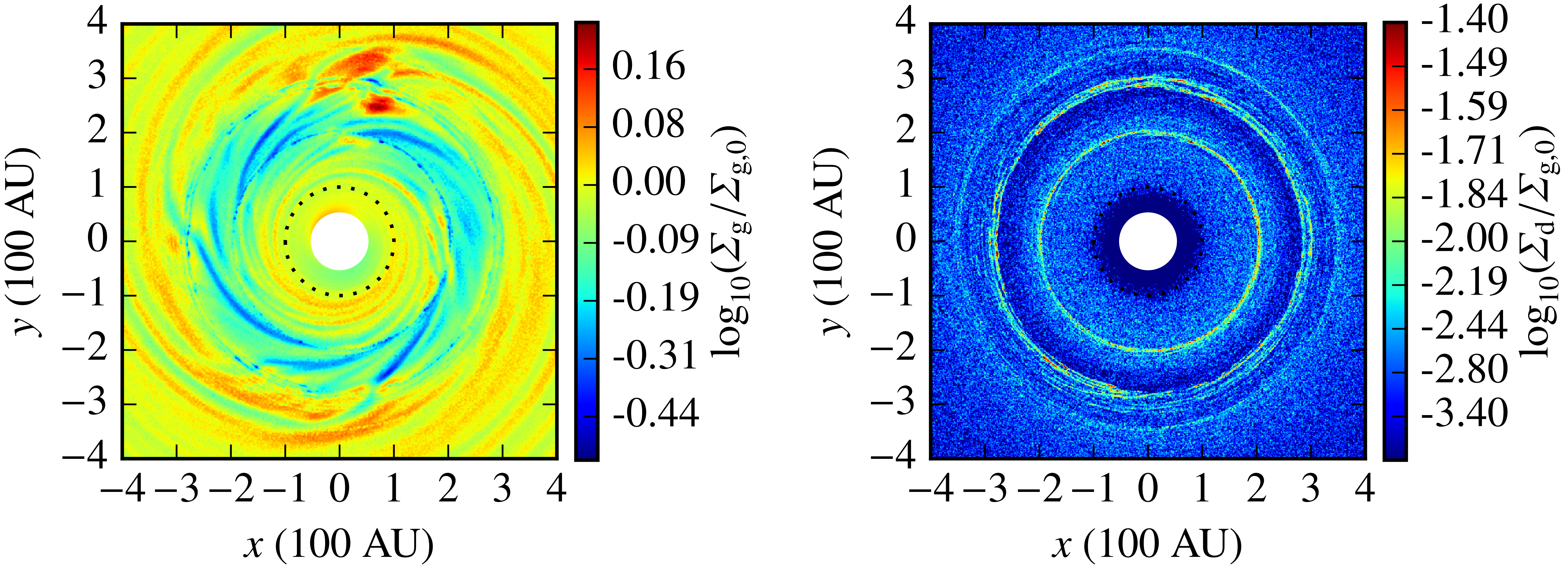
Clumpy gas structure

Wyatt+2006





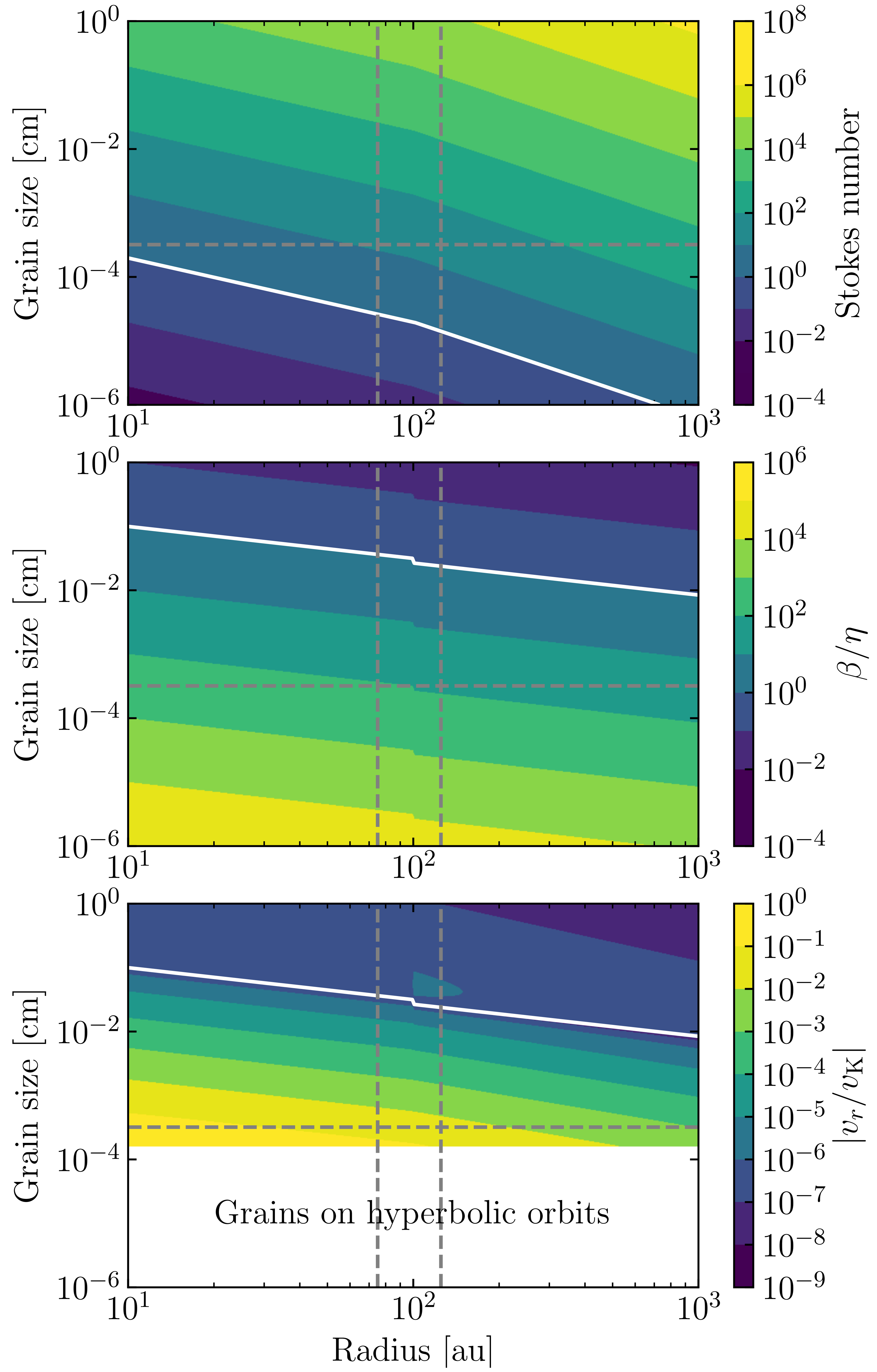
Gas induced rings

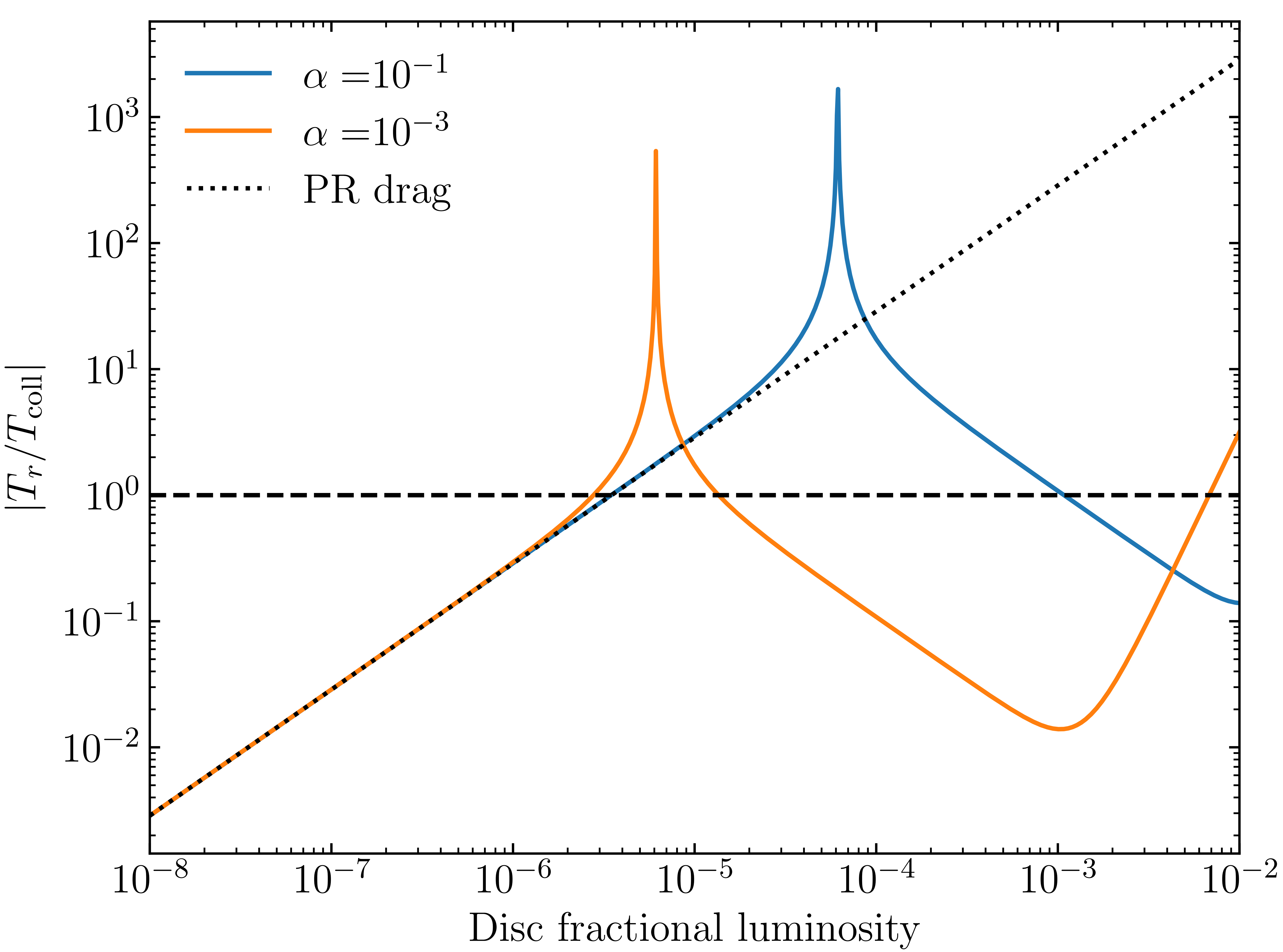


Caveats: The observed structure is dependent on the grain size, gas/dust ratio, and not yet shown to work when a wide size distribution is considered

Klahr & Lin 2005, Lyra & Lin 2013, Richert+2018

Gas induced rings





Marino et al. in prep