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Investigating Dust Growth in Proto-planetary Discs

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Midlands Discs Meeting
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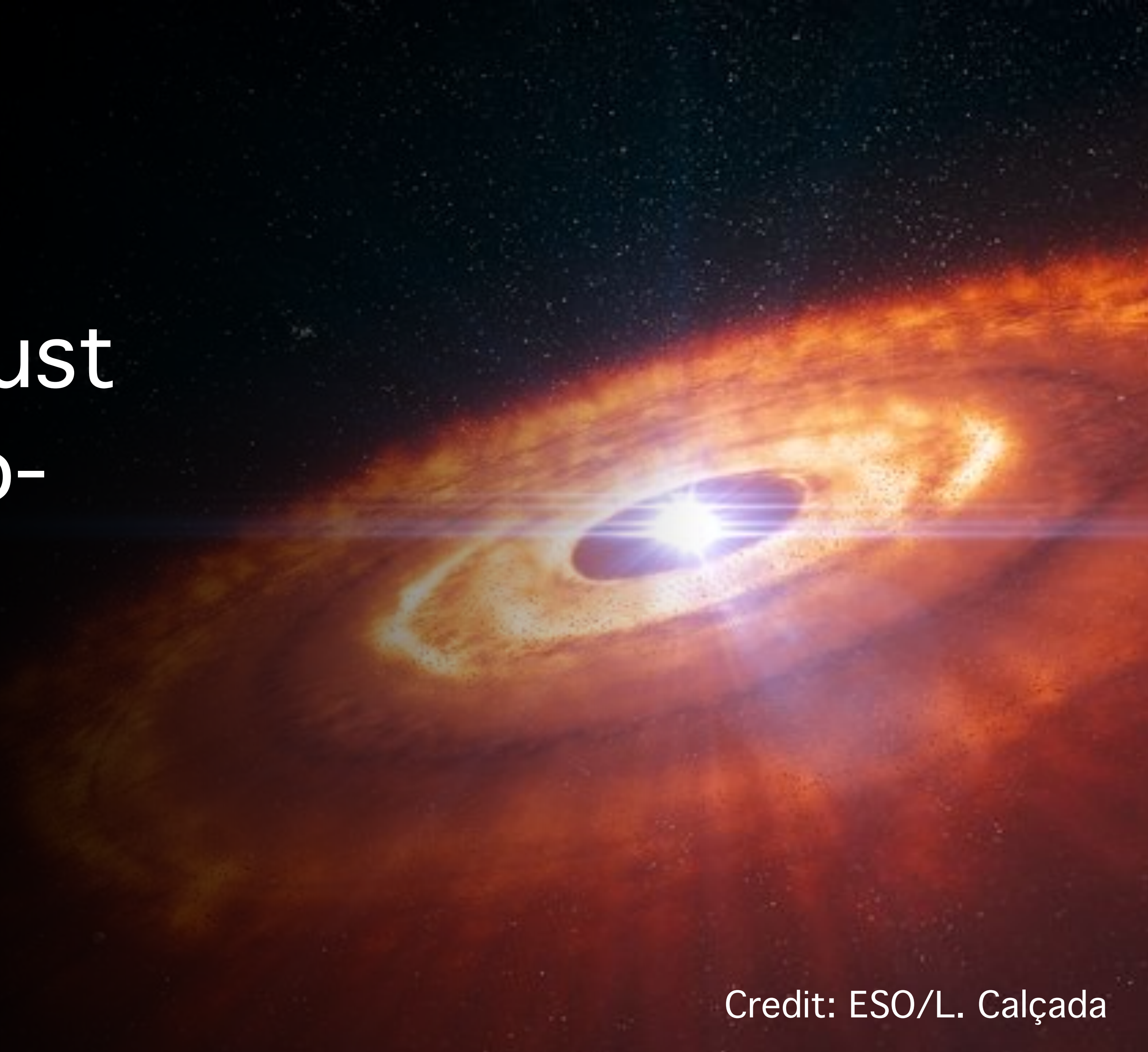
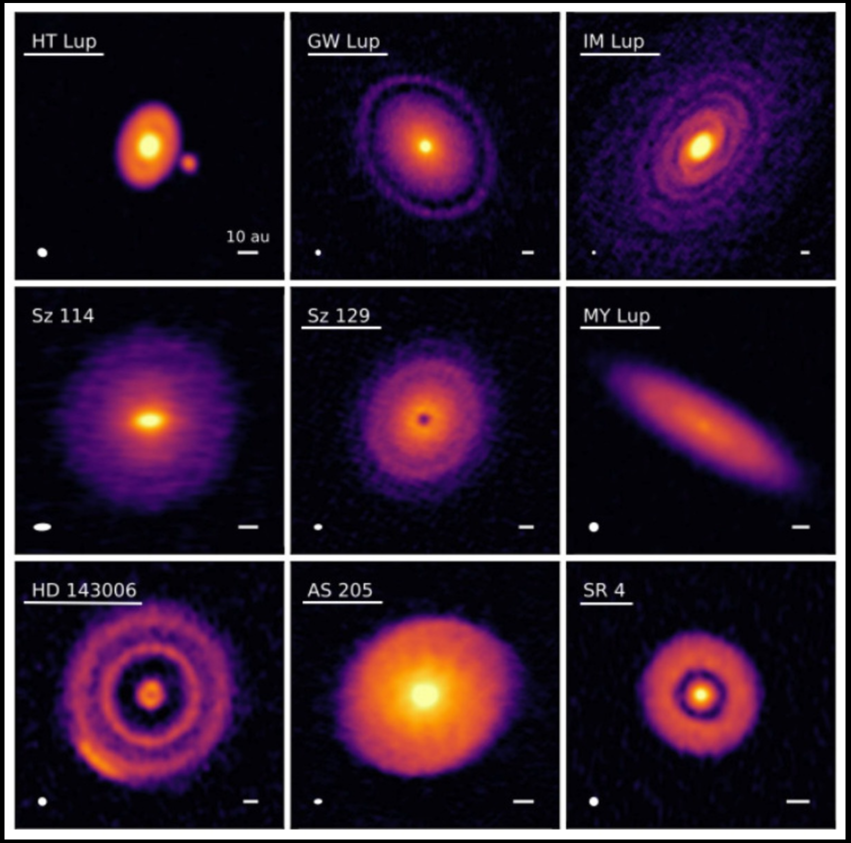


Credit: ESO/L. Calçada

Background & Motivation

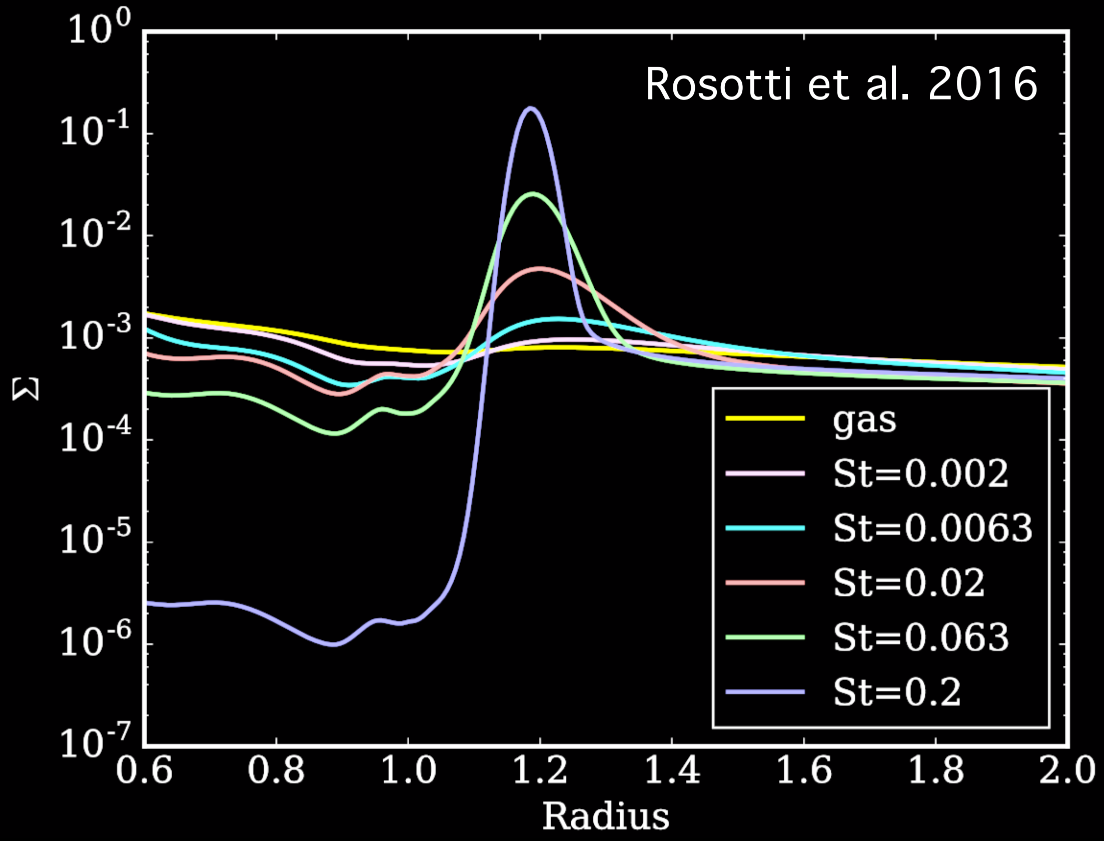
- Observed rings & gaps may indicate the presence of an embedded planet.
- Planet perturbs disc, carving out a gap and creating gas pressure bumps which trap dust.
- ~800 multi-planet systems found – further study into how existing planets affect the formation of additional planets is required.



Source: ALMA Partnership, 2015

Past Studies

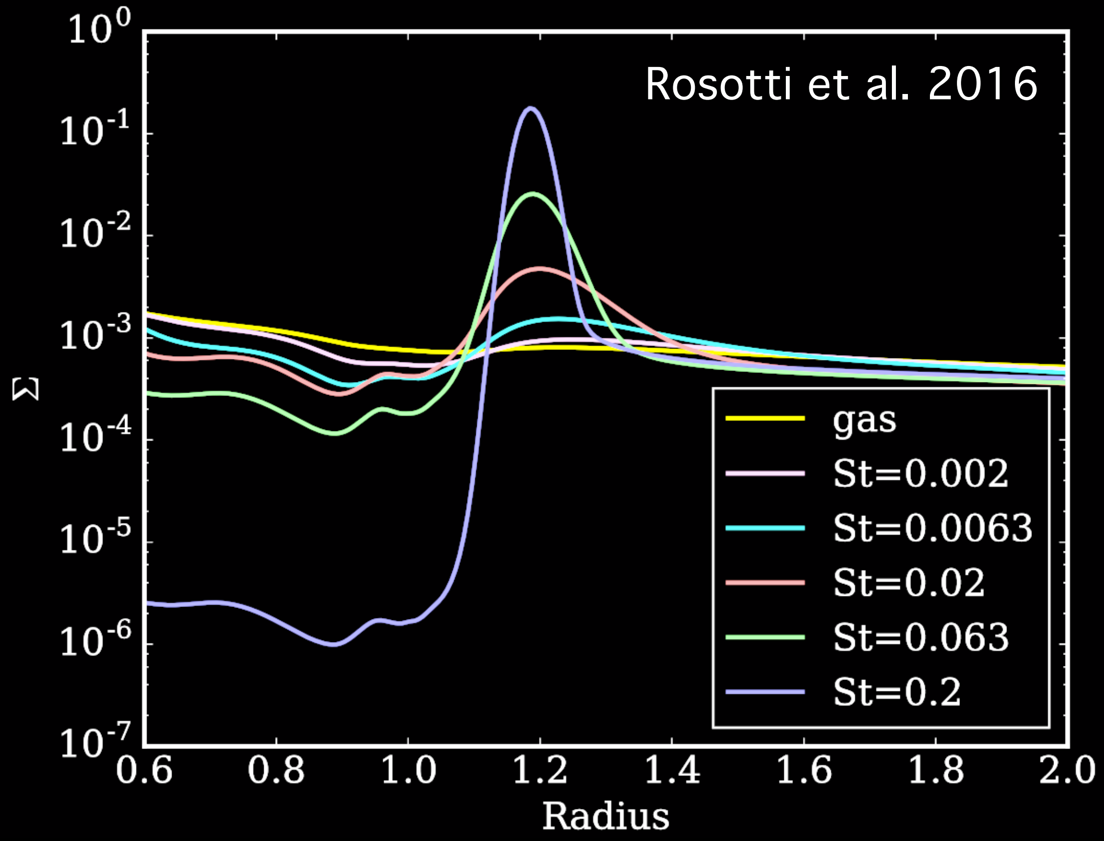
- Rosotti et al. 2016 - modelled planet embedded in disc at a fixed location with fixed dust grain sizes.
- Meru et al. 2019 – modelled migrating planet embedded in disc with fixed dust grain sizes.



Past Studies

- Rosotti et al. 2016 - modelled planet embedded in disc at a fixed location with fixed dust grain sizes.
- Meru et al. 2019 – modelled migrating planet embedded in disc with fixed dust grain sizes.

Neither included effects of dust coagulation/fragmentation but the planet's presence was found to alter the dust density profile.



Past Studies

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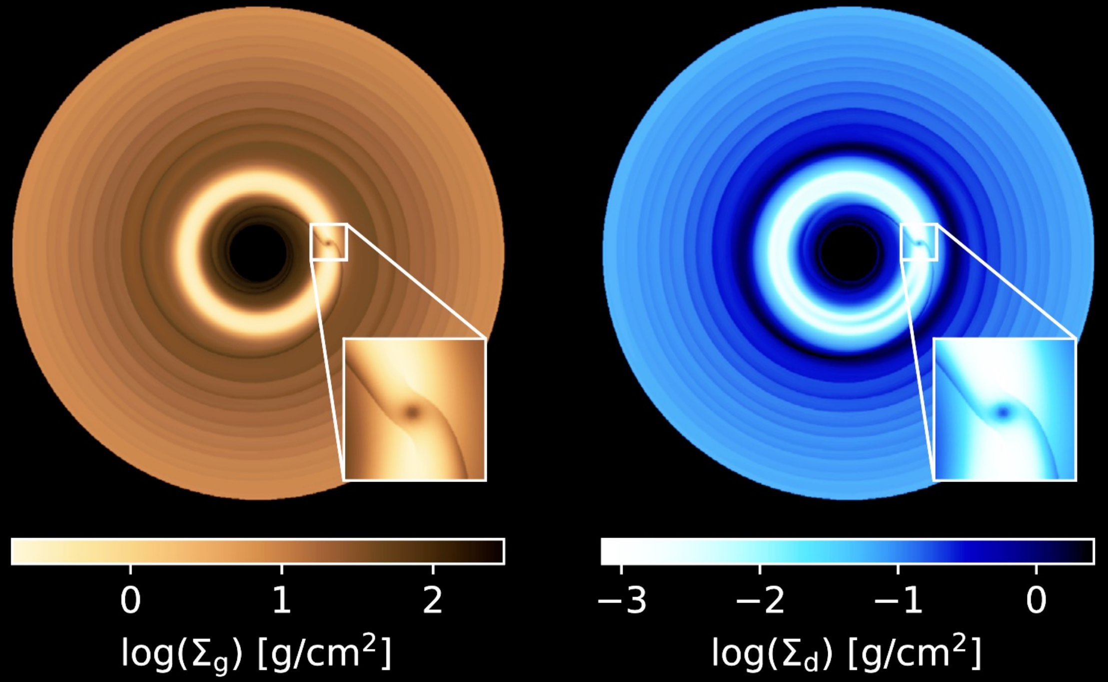
- Lau et al. 2021 – 1D HD models of dust growth in an axisymmetric disc with a gap (no planet).
- Drążkowska et al. 2019 – 2D HD models of dust growth with a Jupiter-mass planet at a fixed location.



Drążkowska et al. 2019

Past Studies

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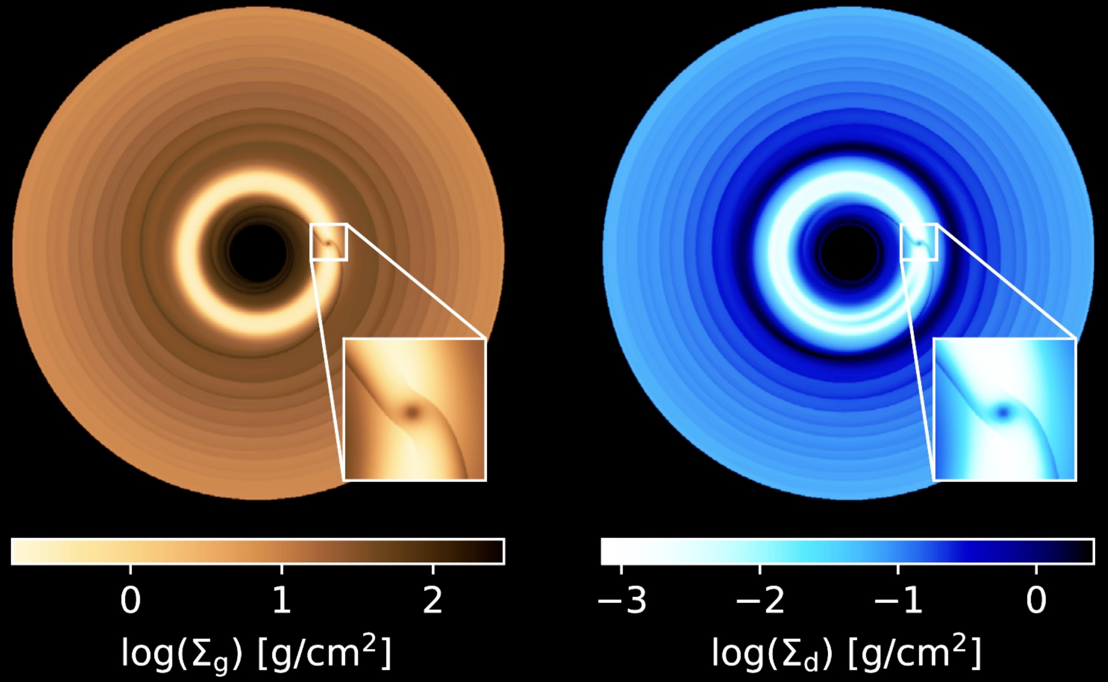
- Lau et al. 2021 – 1D HD models of dust growth in an axisymmetric disc with a gap (no planet).
- Drążkowska et al. 2019 – 2D HD models of dust growth with a Jupiter-mass planet at a fixed location.

Confirmed that full treatment of coagulation/fragmentation necessary for modelling dust growth in rings.



Drążkowska et al. 2019

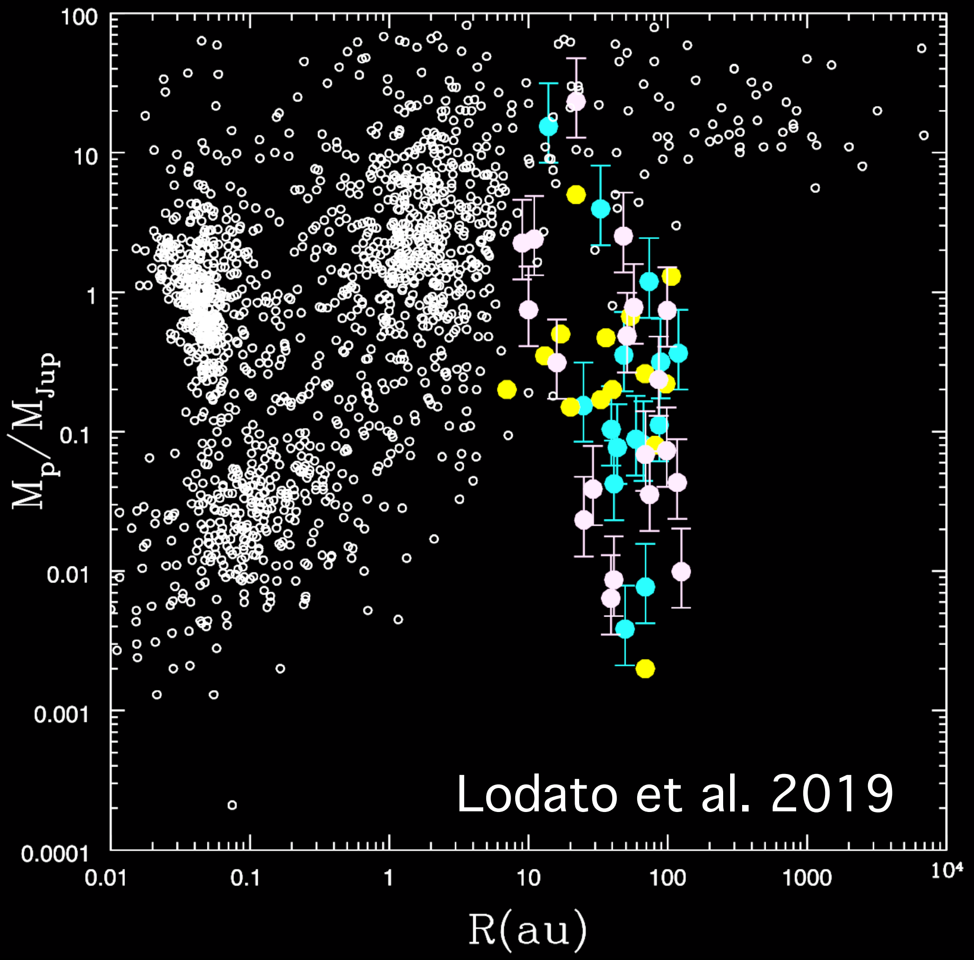
Project Goals

Build on work of past studies to model dust growth in the presence of lower mass planets.

- How is the formation of gap/ring structures affected by the inclusion of growth (if at all)?
- How does the overdensity of dust affect dust growth in rings?
- What does this tell us about sequential planet formation?
- How do these answers change if the planet is migrating?

Model Considerations

- Effect of planet masses and locations - ideally use planets with masses $M_p < M_{Jupiter}$, located within a few 10s of AU of the disc inner edge.
- Planet to disc mass ratio must be high enough for planet to perturb disc (see Rosotti et al. 2016).
- Star to disc mass ratio must be high enough to prevent GI.

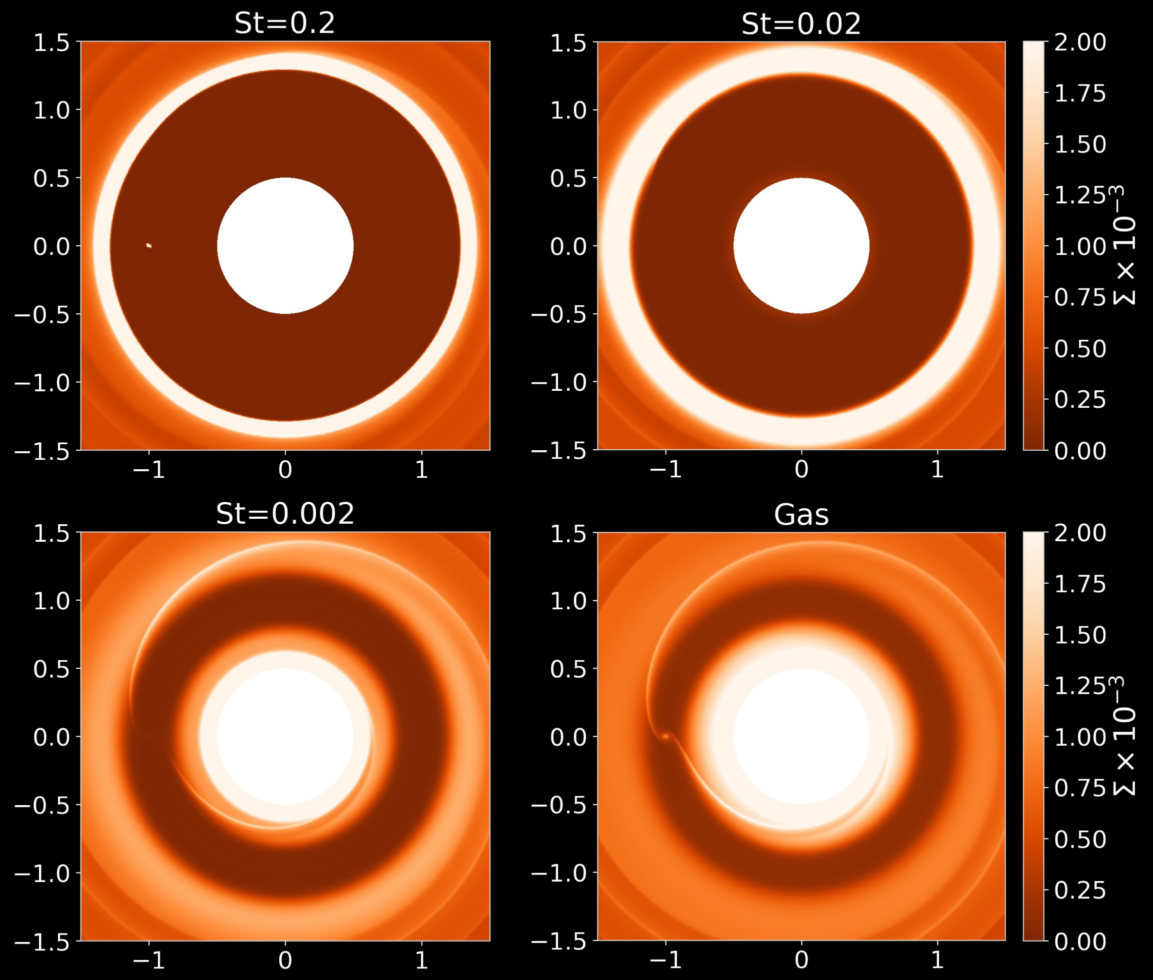


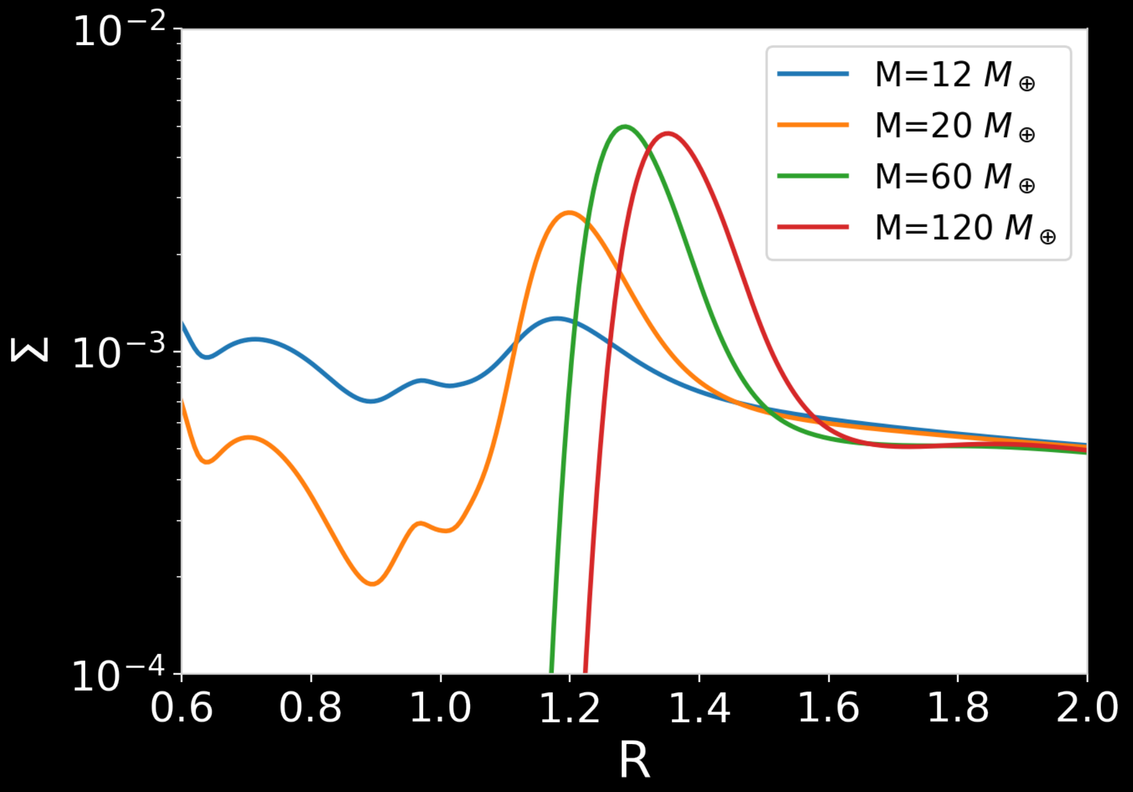
Computational Tools

FARGO3D + coagulation toolkit (Garaud et al. 2013) used to run 2D $(r + \phi)$ HD models of dust advection and growth.

	Planet?	Growth?	Dimensions?	Migration?	
1	✓	✗	2	✗	Complete
2	✗	✓	1	✗	Complete
3	✓	✓	2	✗	In progress
4	✓	✓	2	✓	To do...

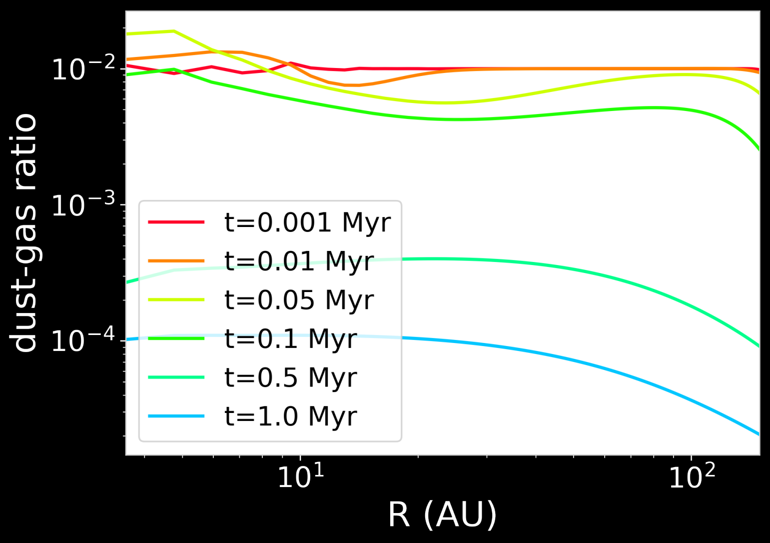
Results – Planet, Fixed Dust Size

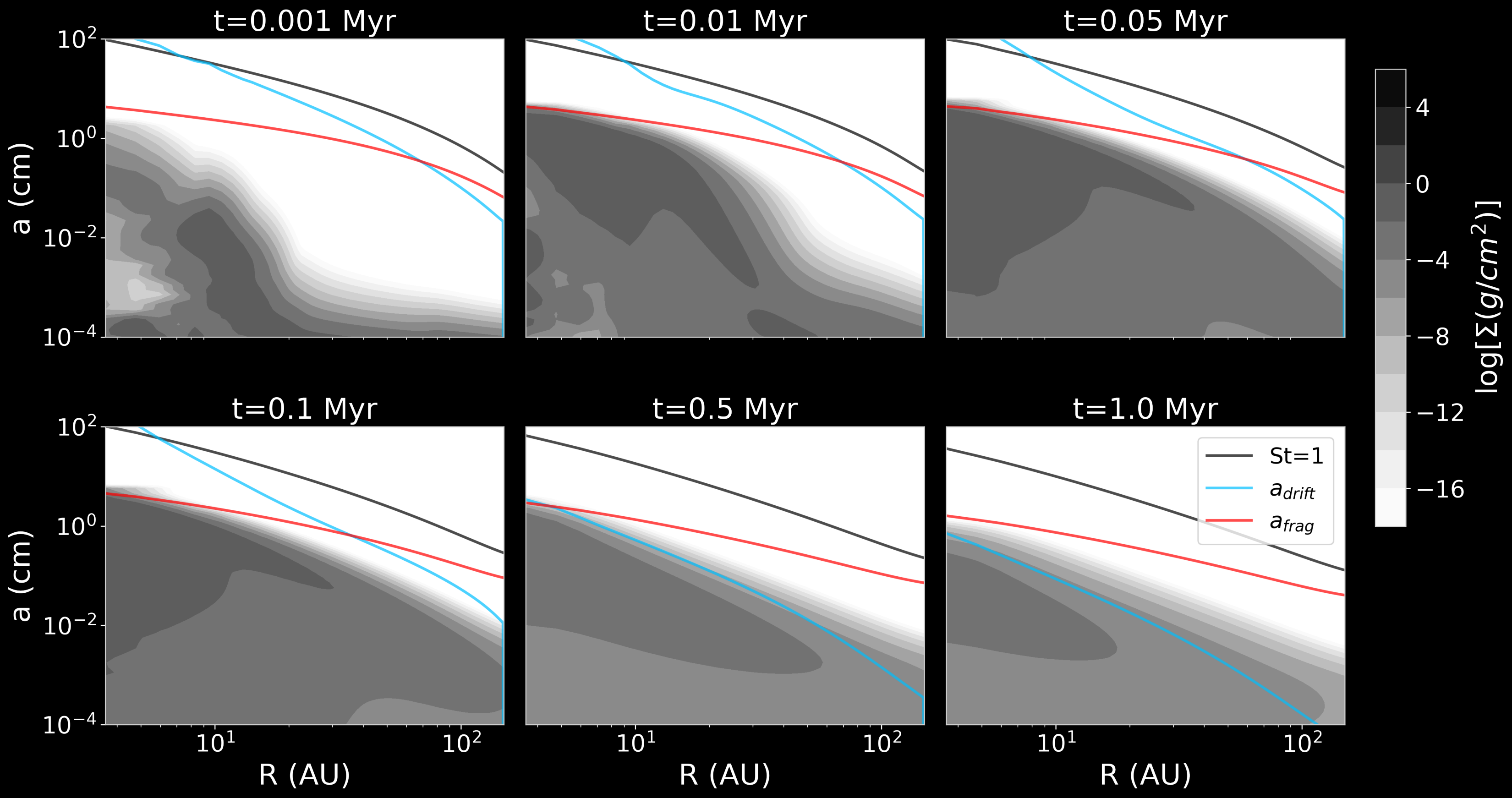




Gap formed for planet masses $M \geq 8\, M_\oplus$

Results – No Planet, Dust Growth



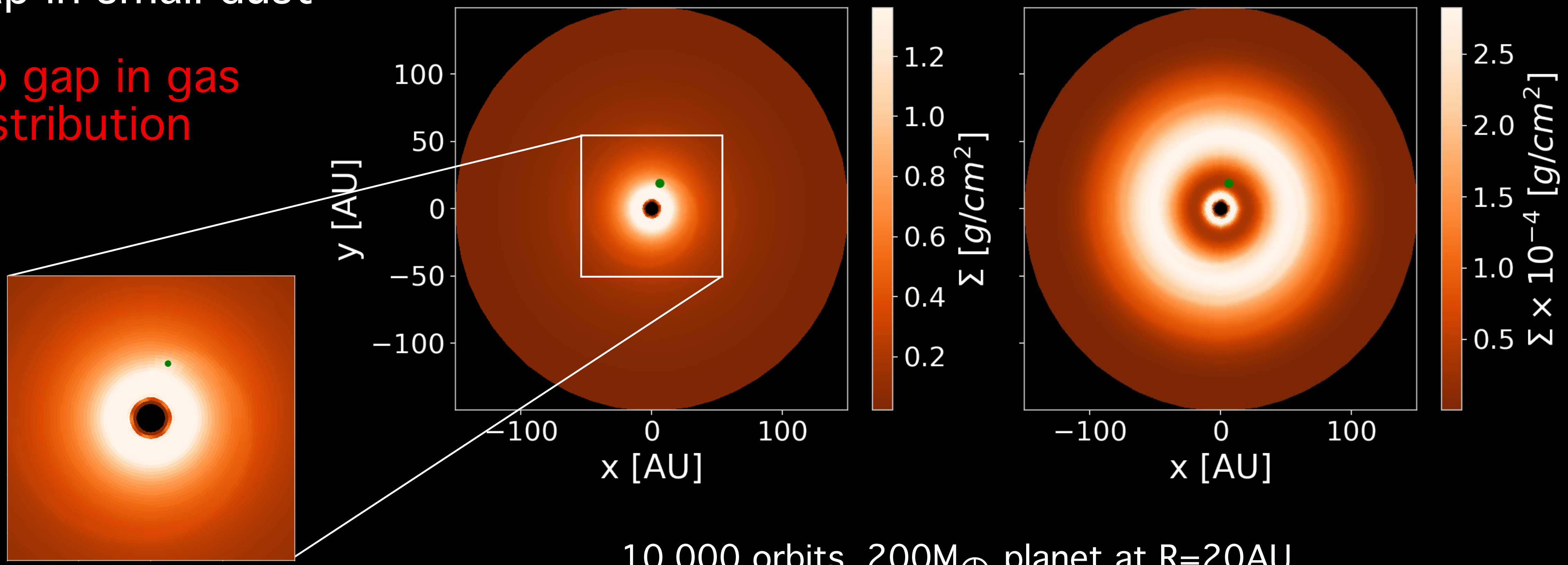


1. Dust growth limited by fragmentation.
2. Dust growth limited by radial drift.
3. Dust accretion.

(Preliminary) Results – Planet, Growth

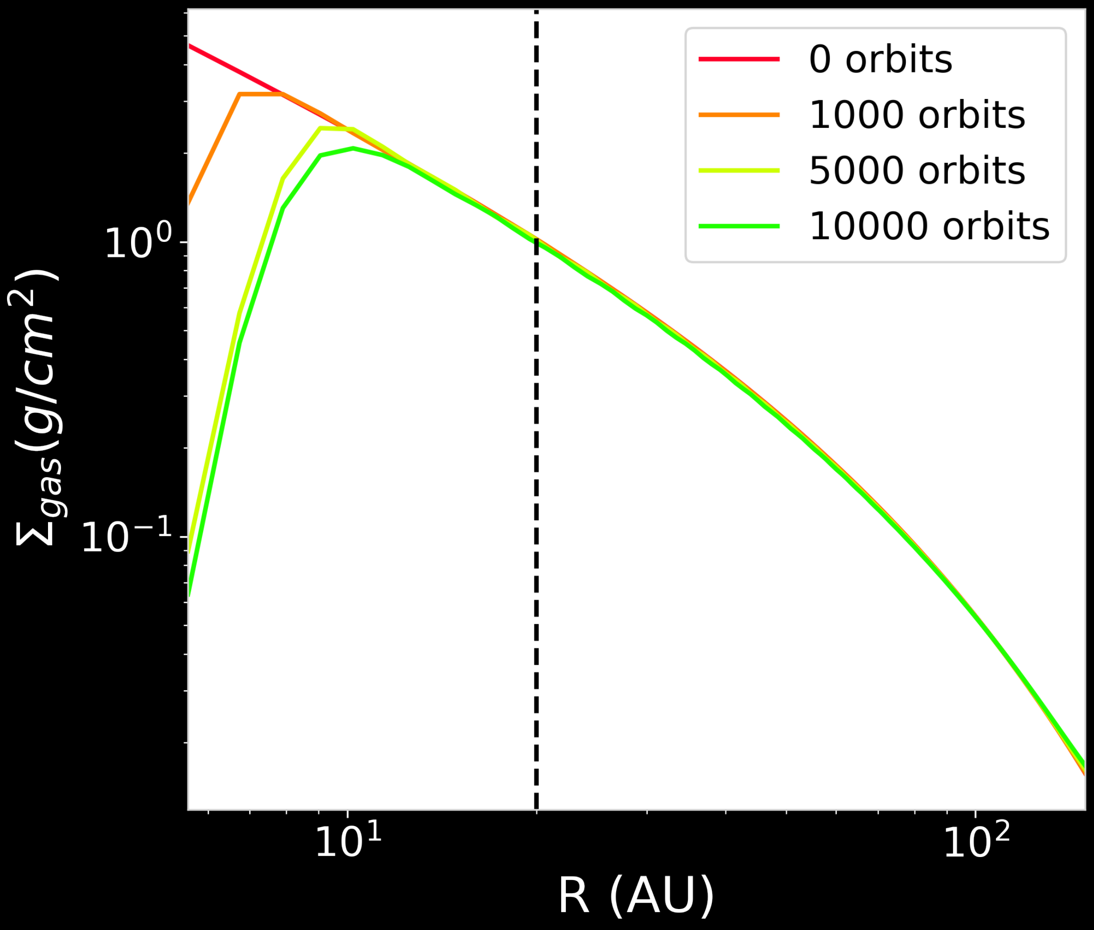
Gap in small dust

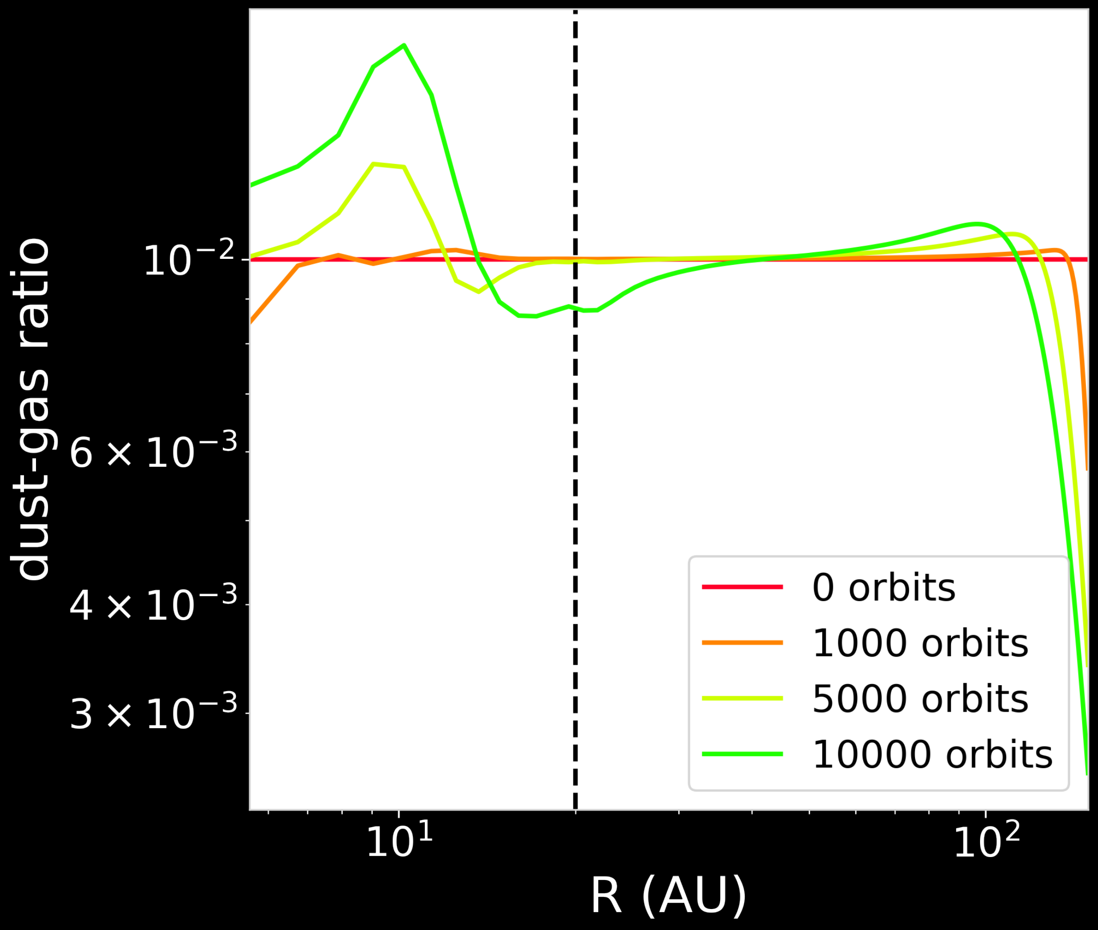
No gap in gas distribution



10,000 orbits, $200M_{\oplus}$ planet at R=20AU

(Preliminary) Results – Planet, Growth





Ongoing & Future Work

1. Investigate absence of gap in gas disc.
   - Resolution too low?
   - Planet/disc mass?
   - Number of orbits elapsed?
2. Model dust growth in the presence of a fixed, embedded planet
   (a) Using higher resolution models
   (b) Testing a full parameter space – different planet masses, planet locations, disc masses, etc.
3. Model dust growth with planet able to migrate.

Conclusions

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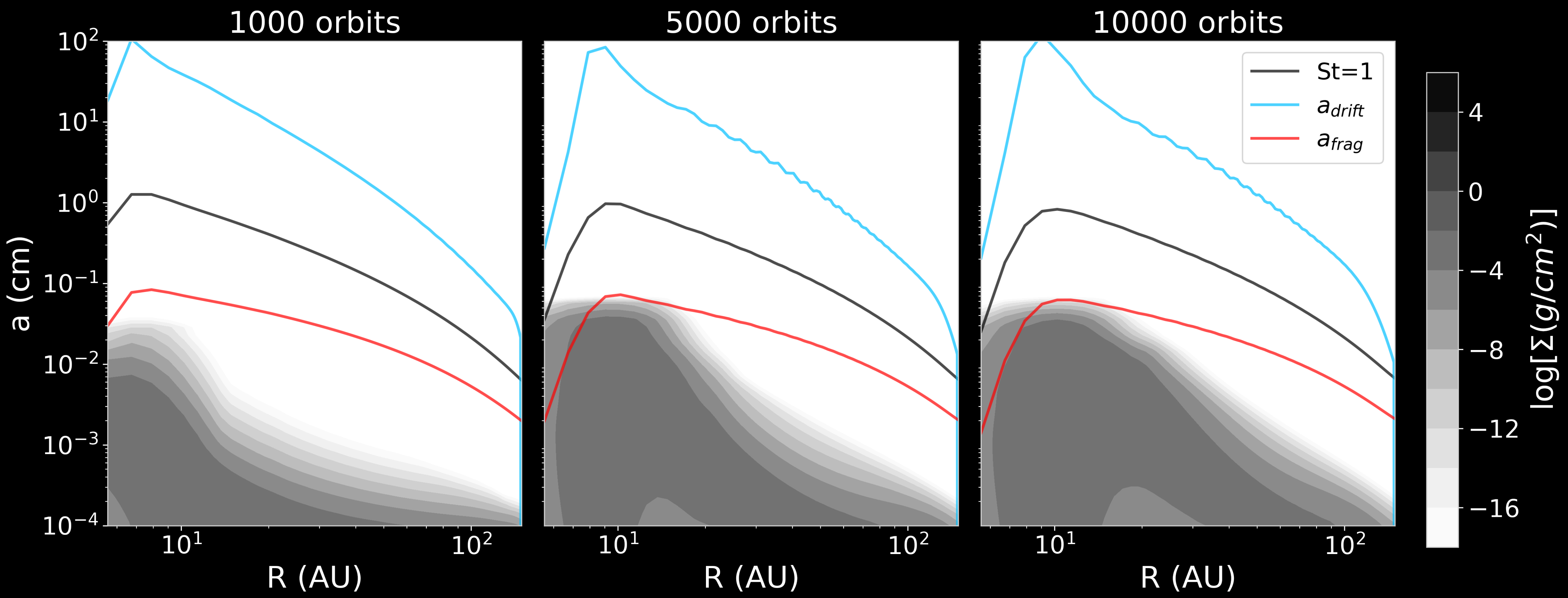
- ✓ Modelled production of a gap and ring in a protoplanetary disc due to a planet (dust size fixed, no growth).
- ✓ Modelled dust growth in axisymmetric protoplanetary discs.
- ❑ In process of modelling dust growth in rings formed by an embedded planet.
  - Address absence of gap in gas component of disc.
  - Consider how model parameters will impact dust growth.
  - Improve model resolution and accuracy.

Dust Size Distribution



Methods Implemented

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Coagulation/fragmentation rate computed via methods described in:

- Brauer et al. 2008
- Filbet & Laurençot 2004
- Booth et al. 2018

Overall dust evolution (advection and growth) computed via one of the kernels described in:

- Birnstiel et al. 2012
- Garaud et al. 2013

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Coagulation/fragmentation rate computed via methods described in:

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Used in results shown so far

Overall dust evolution (advection and growth) computed via one of the kernels described in:

- Birnstiel et al. 2012
- Garaud et al. 2013

Slower, but more accurate (particularly for larger grains)