"Great Barriers in Planet Formation", Palm Cove, Australia, 21-26.07.2019

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

DUST GROWTH AND PLANETESIMAL FORMATION

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LMU Munich

erc
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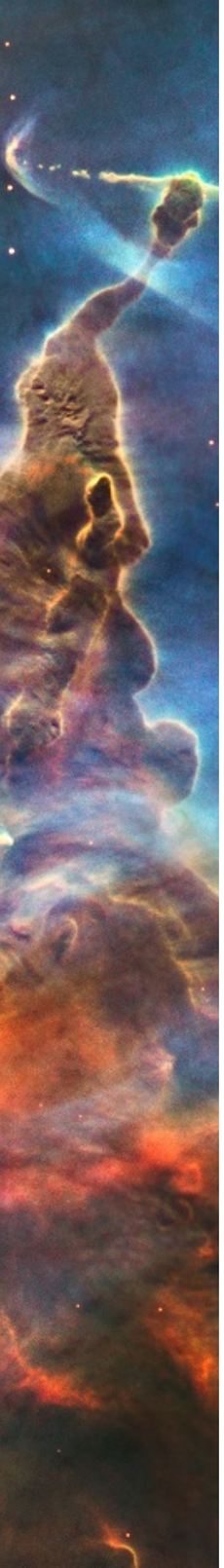
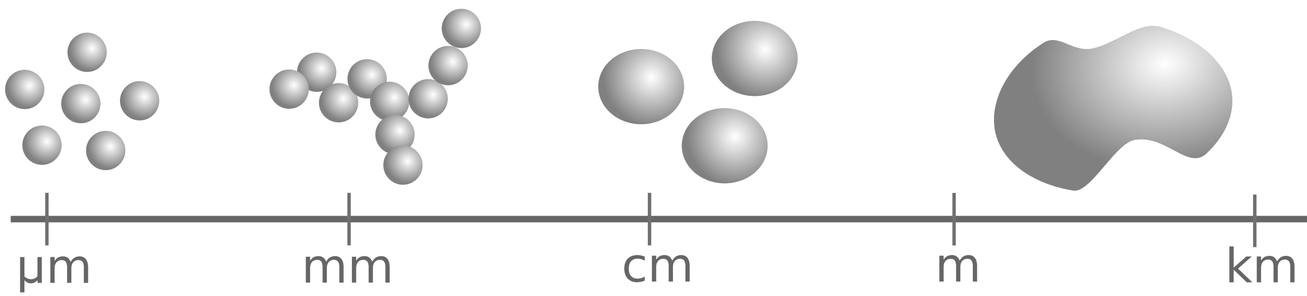
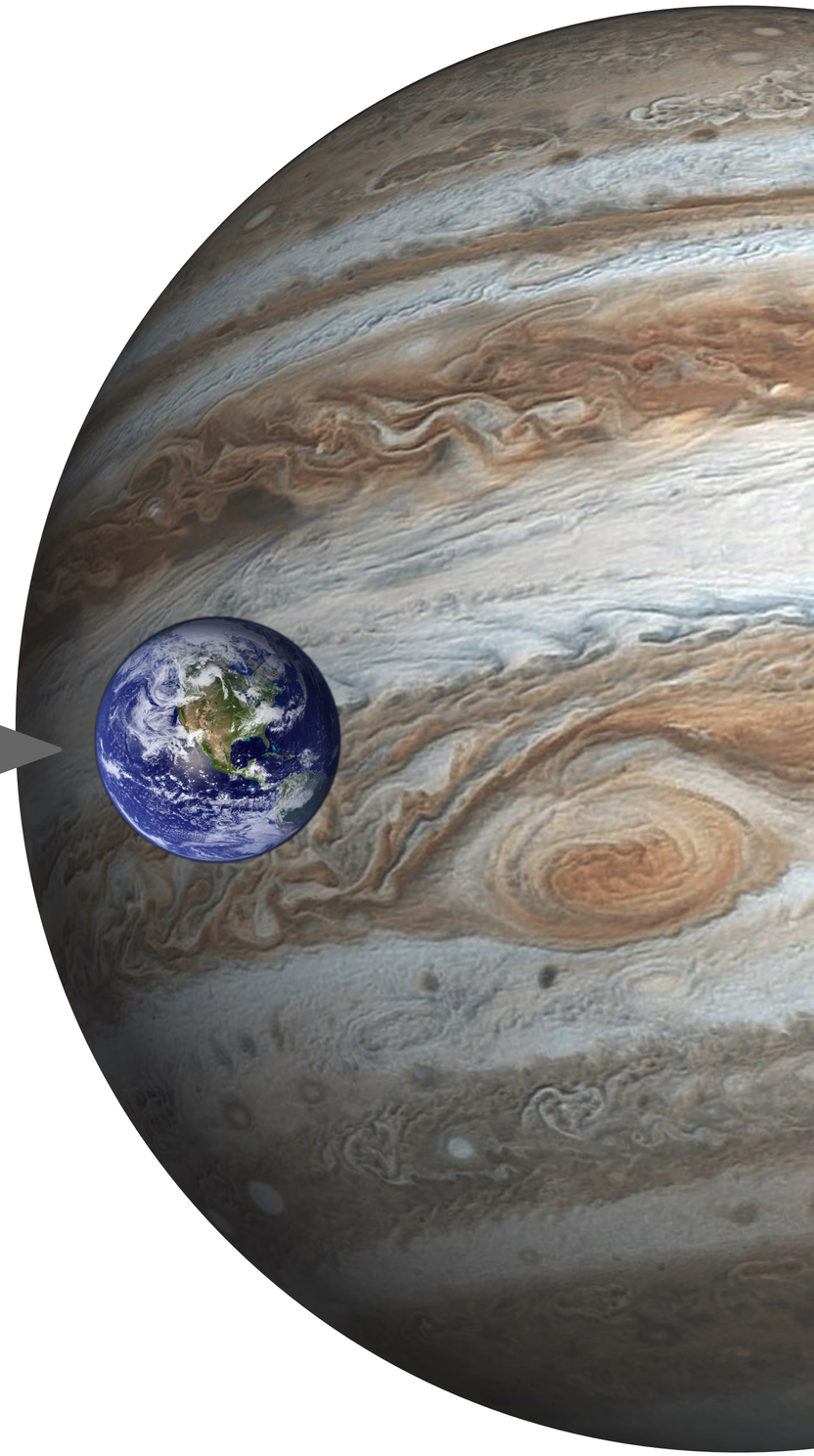
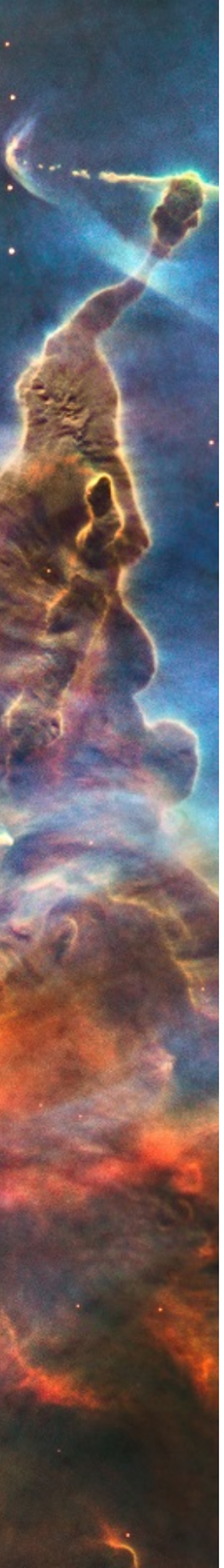


MAKING PLANETS IS HARD

- 40 orders of magnitude in mass to make an Earth
- Even longer way to make a Jupiter



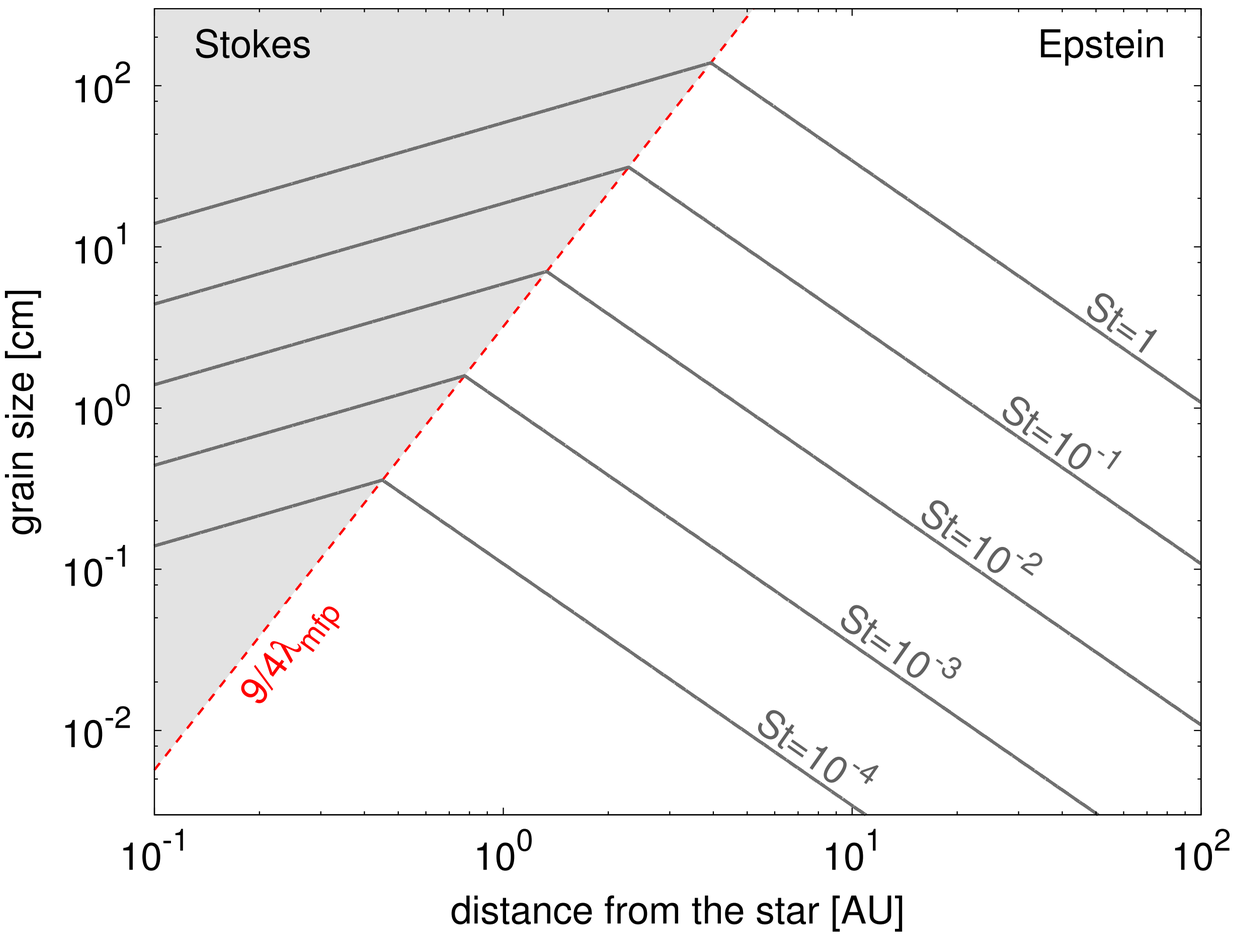


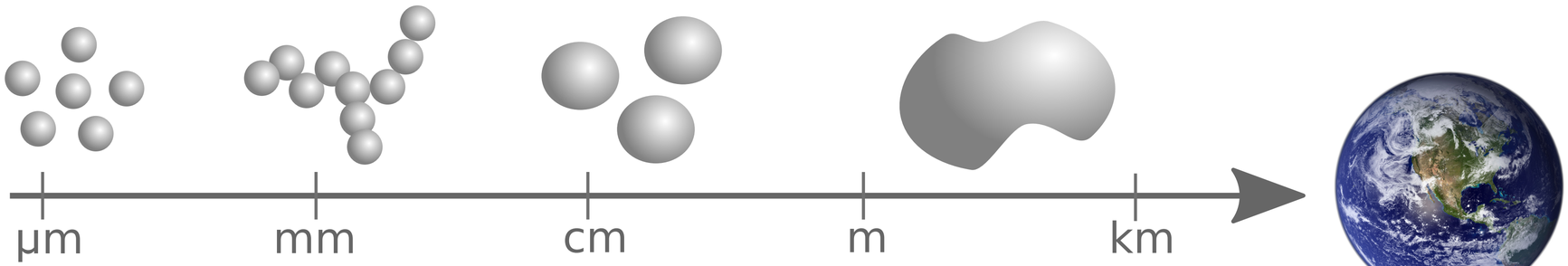


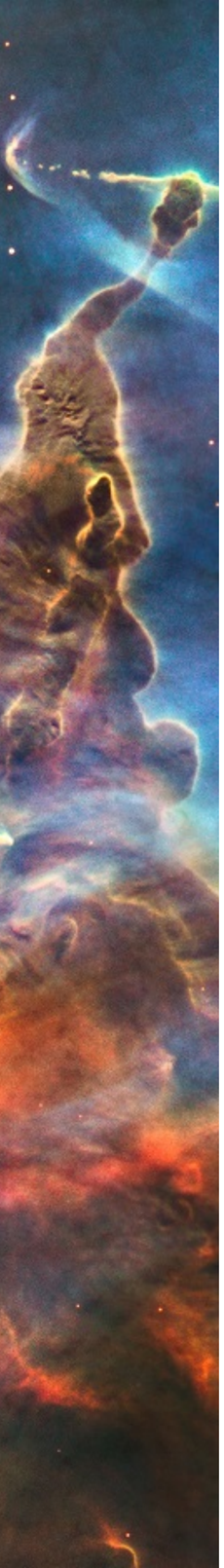
INTRODUCTION: STOKES NUMBER

(Size doesn't matter, Stokes number does)

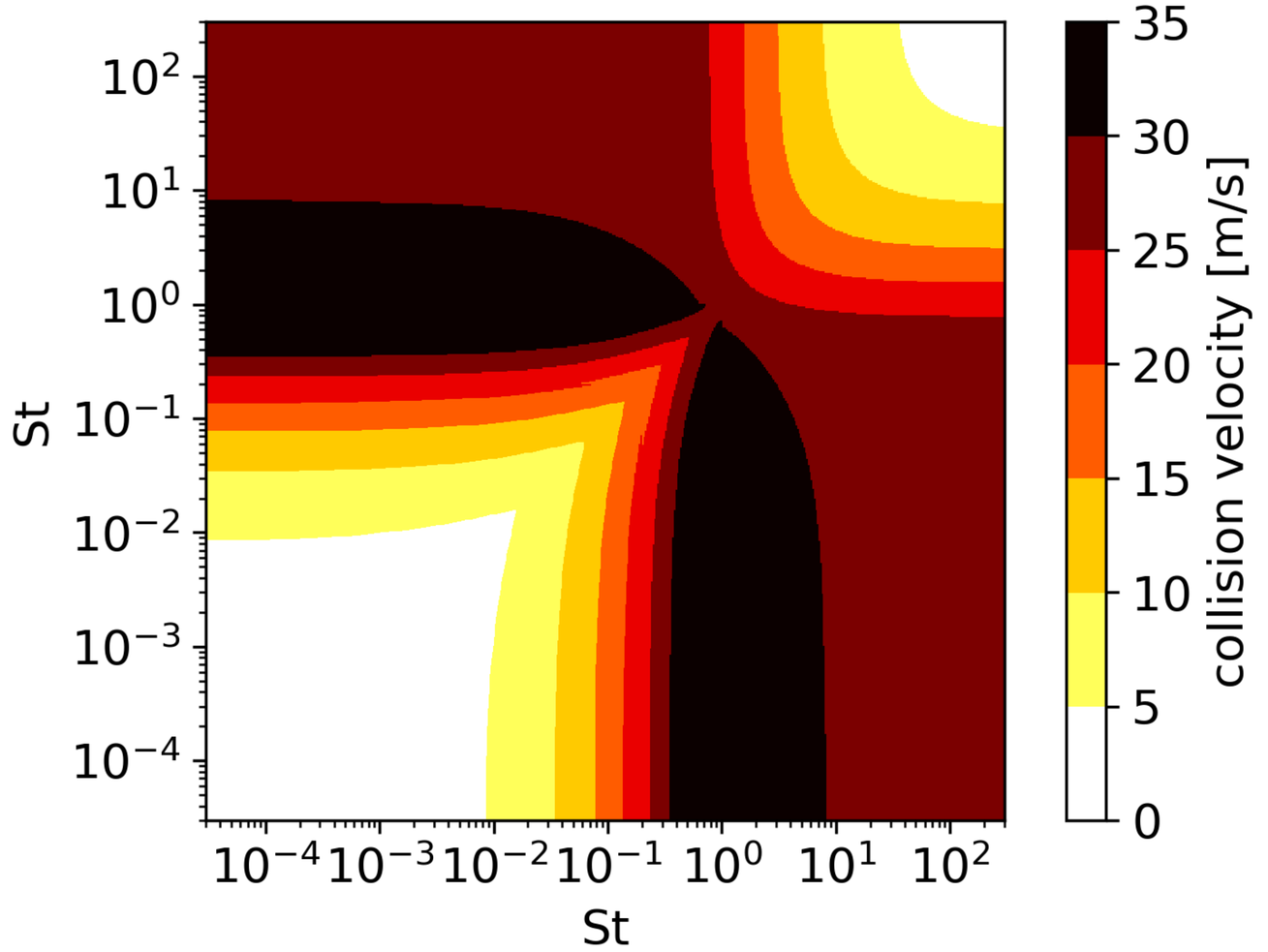
$$\mathrm{St} = \frac{\text{stopping time}}{\text{local orbit}}$$

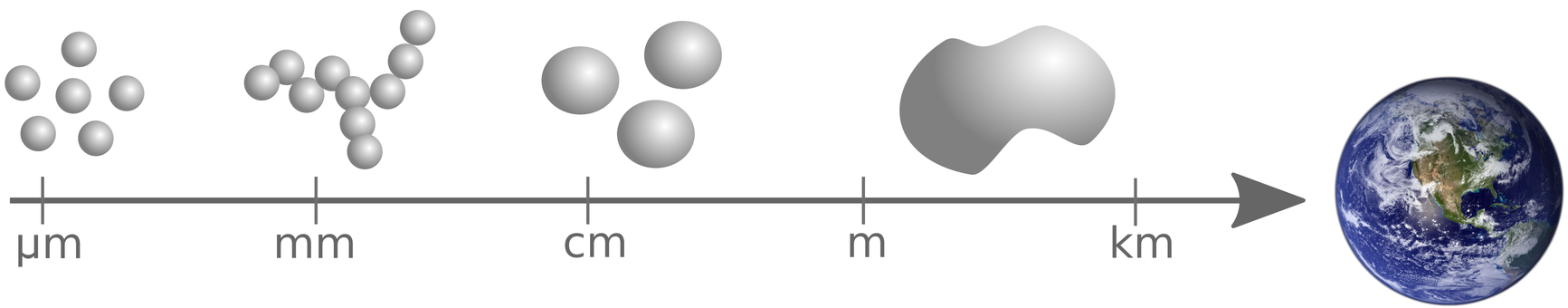


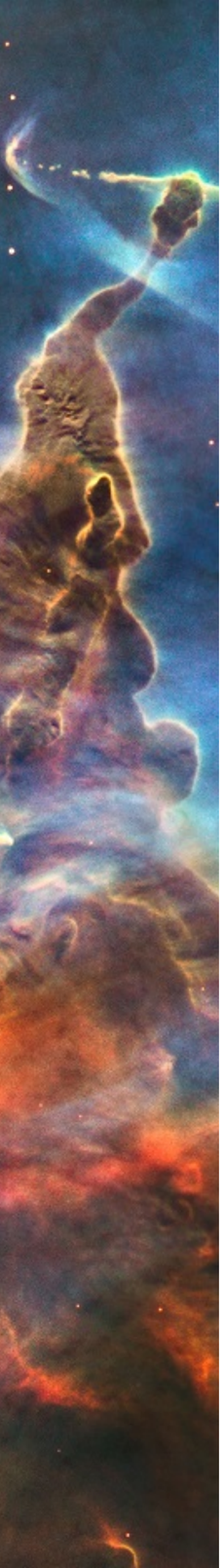




INTRODUCTION: IMPACT SPEEDS







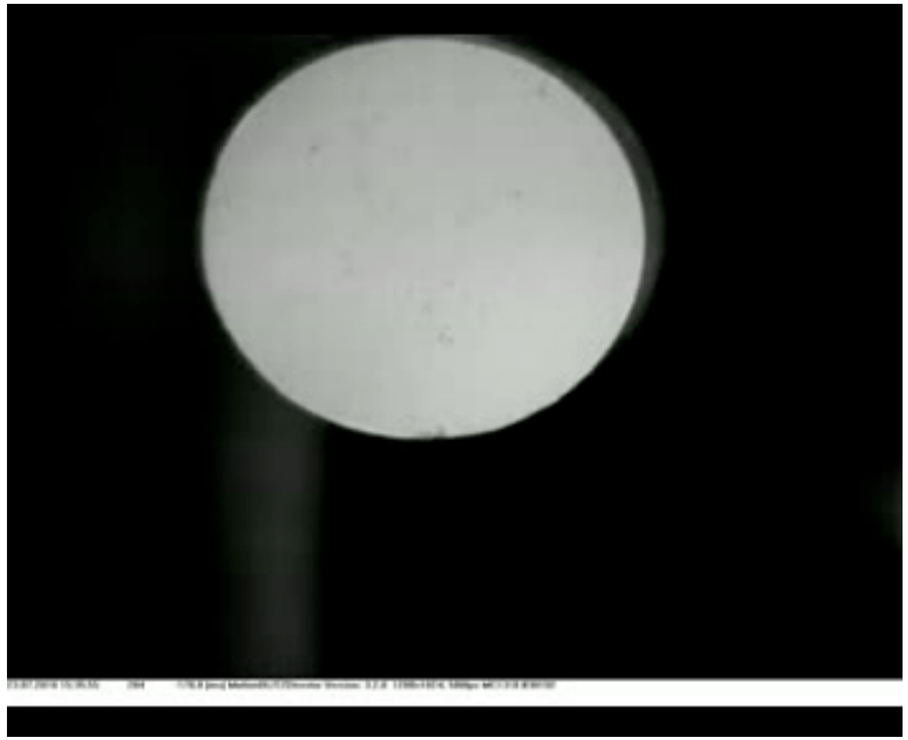
GROWTH BARRIERS: COLLISIONS

R. Weidling, C. Güttler, J. Blum, Free Collisions in a Microgravity Many-Particle Experiment. I. Dust Aggregate Sticking at Low Velocities, submitted to Icarus, 2011

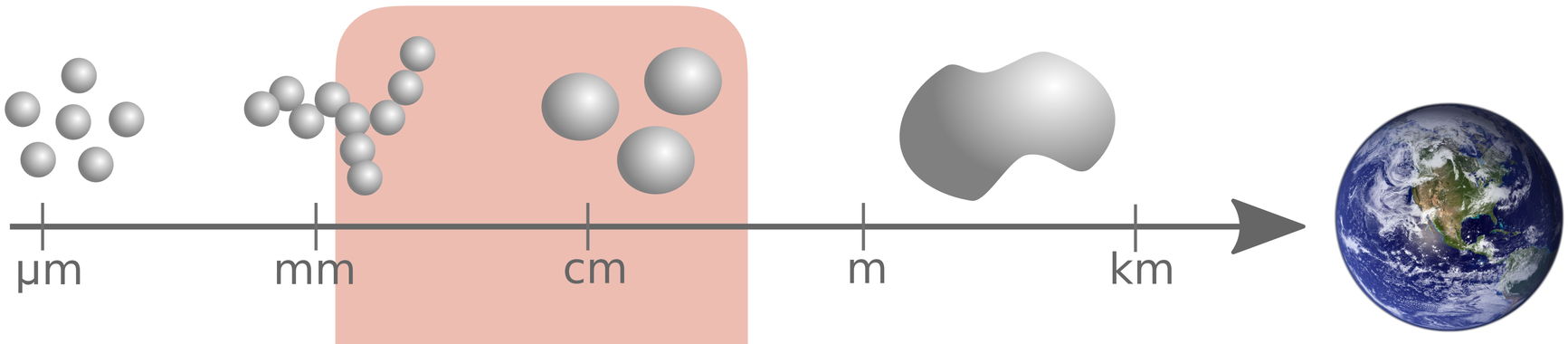
Particle-Aggregate-Collision

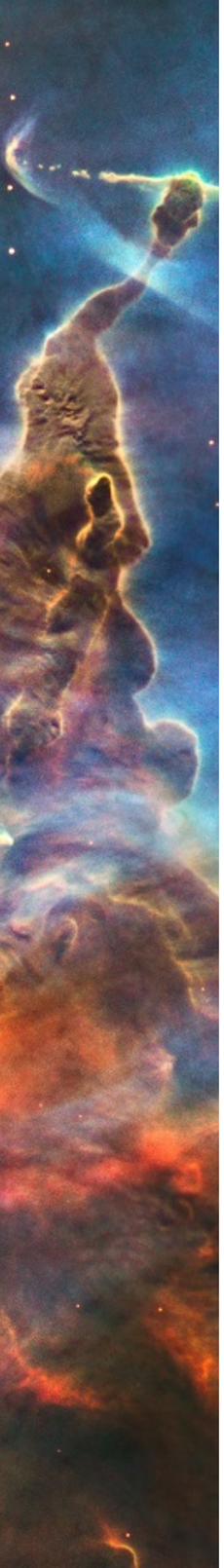
collision velocity:
17 mm/s
fov size:
17 mm x 17 mm

Weidling et al. 2011

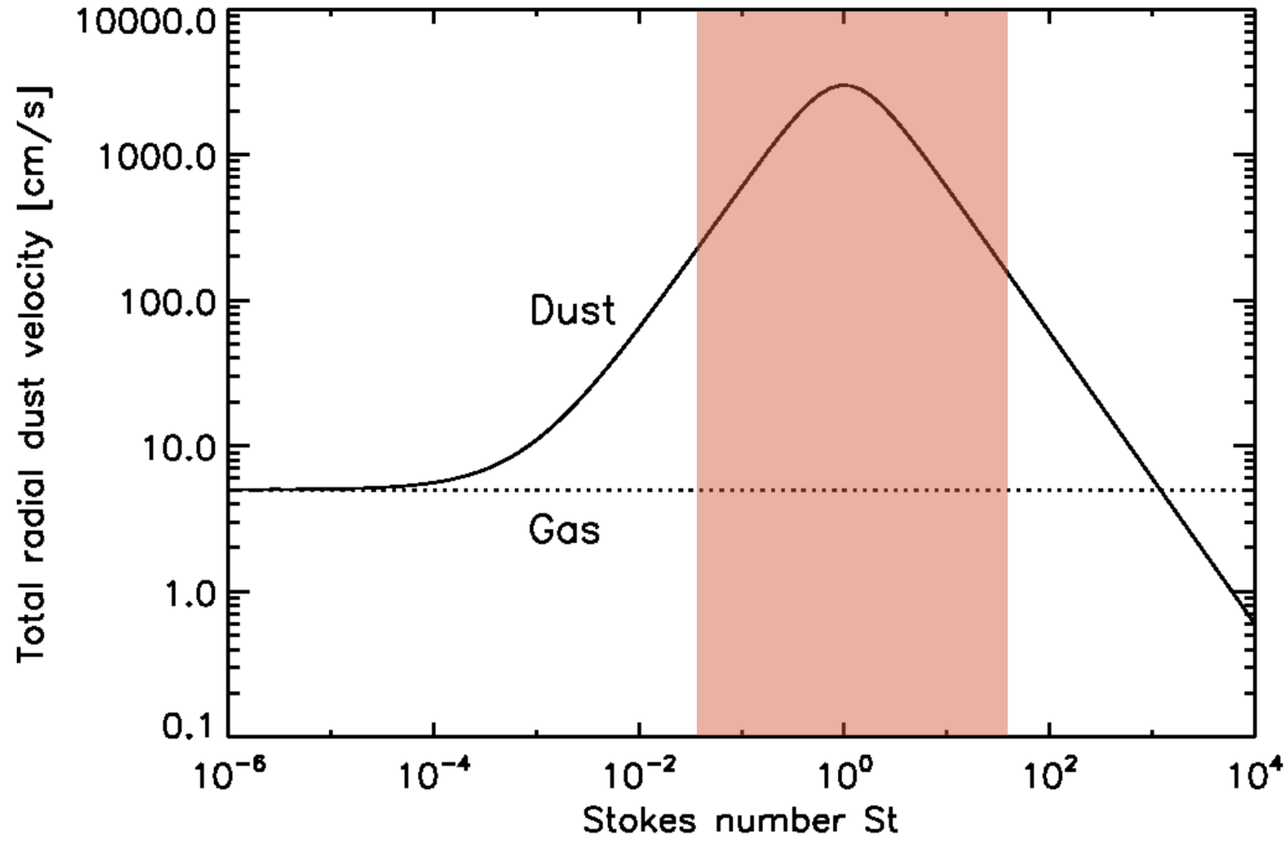


Beitz et al. 2011

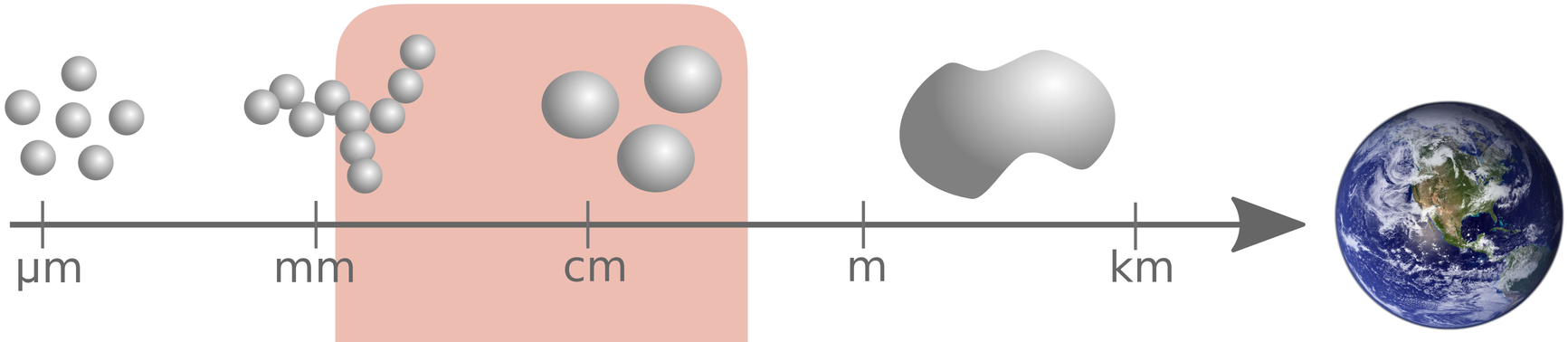


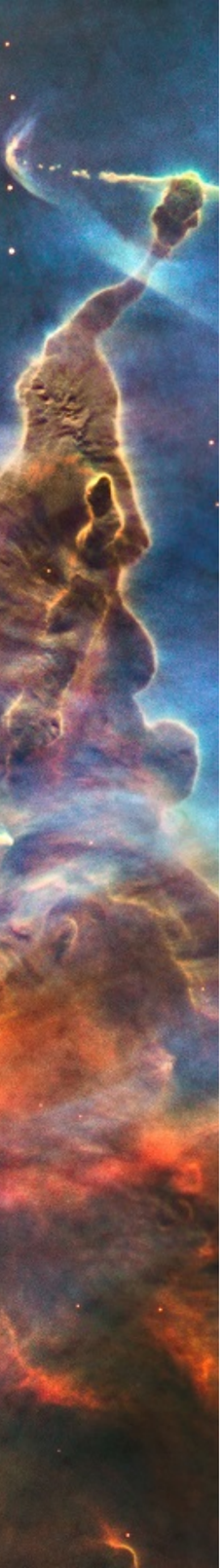


GROWTH BARRIERS: RADIAL DRIFT

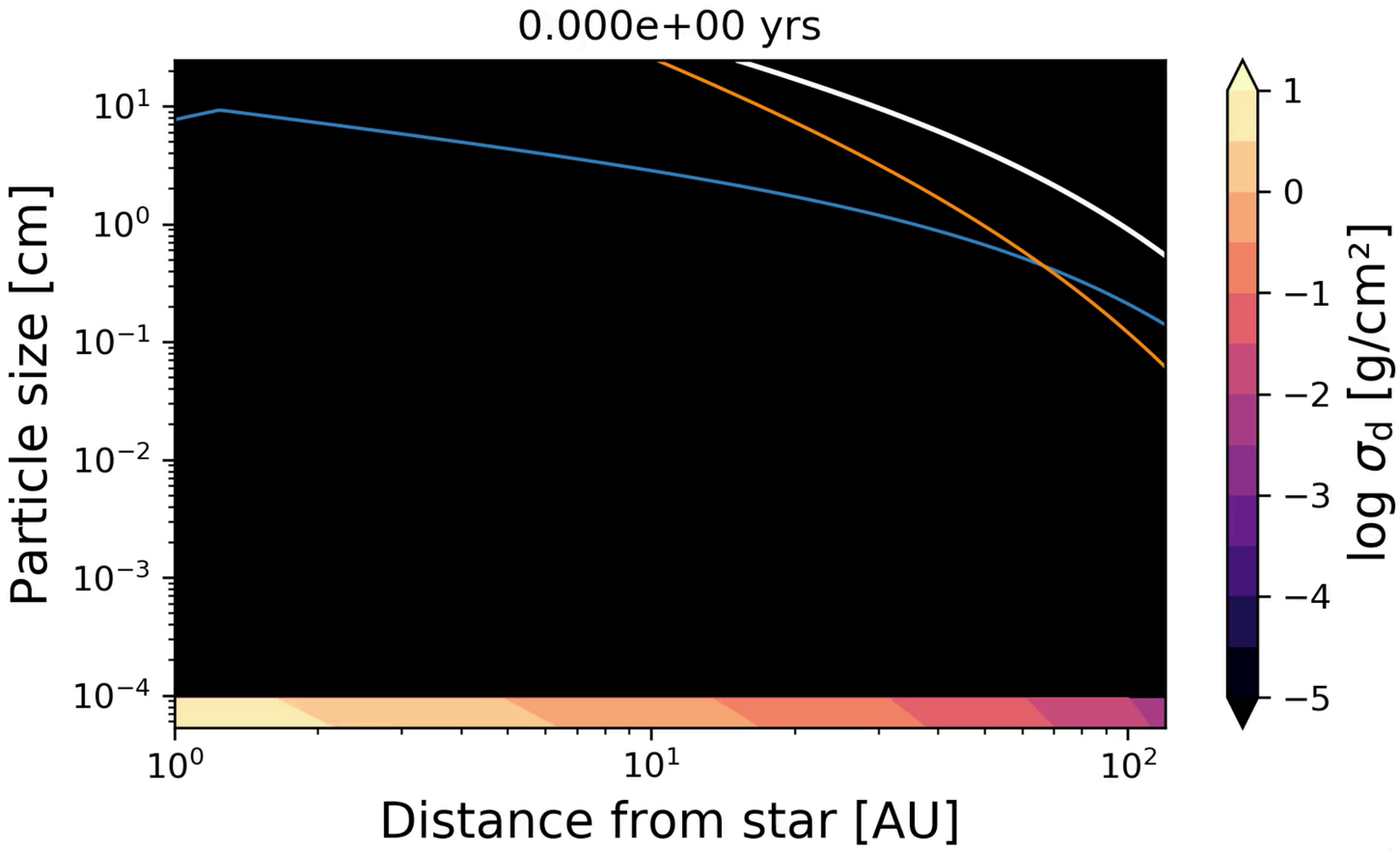


Brauer et al. 2008





TYPICAL OUTCOME OF DUST COAGULATION

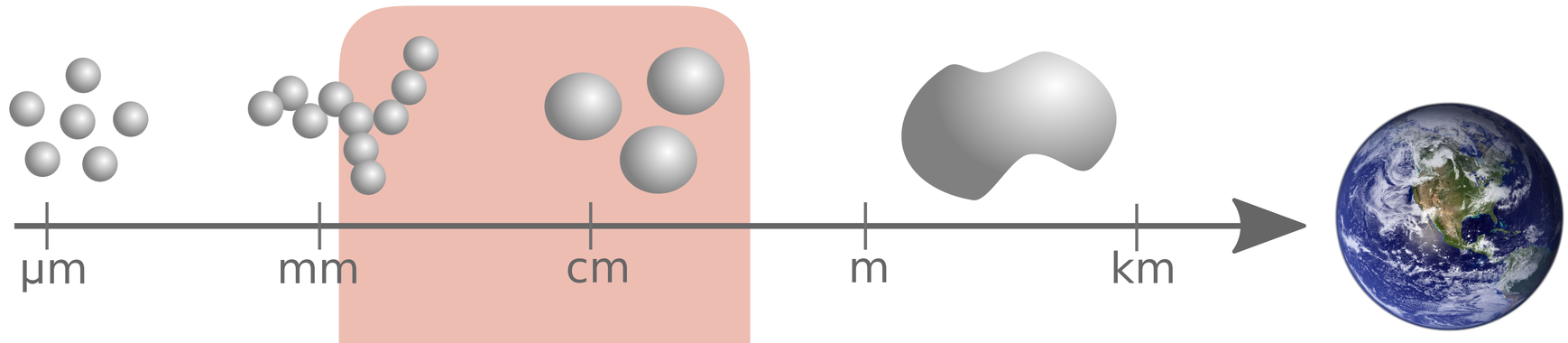


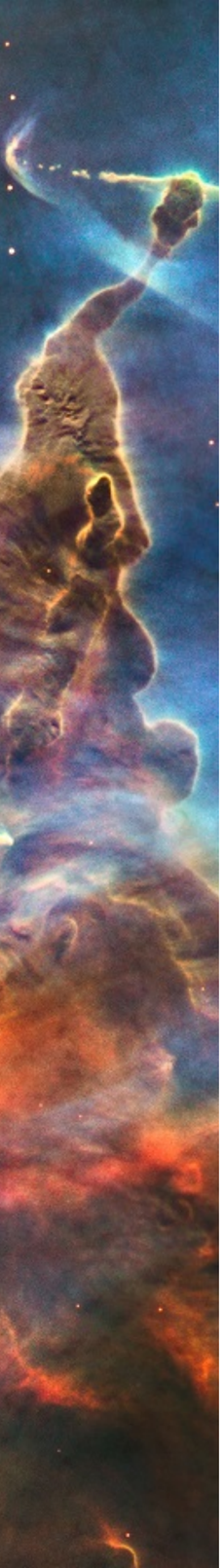
- drift barrier

- fragmentation barrier

made with DUSTPY *code by Stammler & Birnstiel*

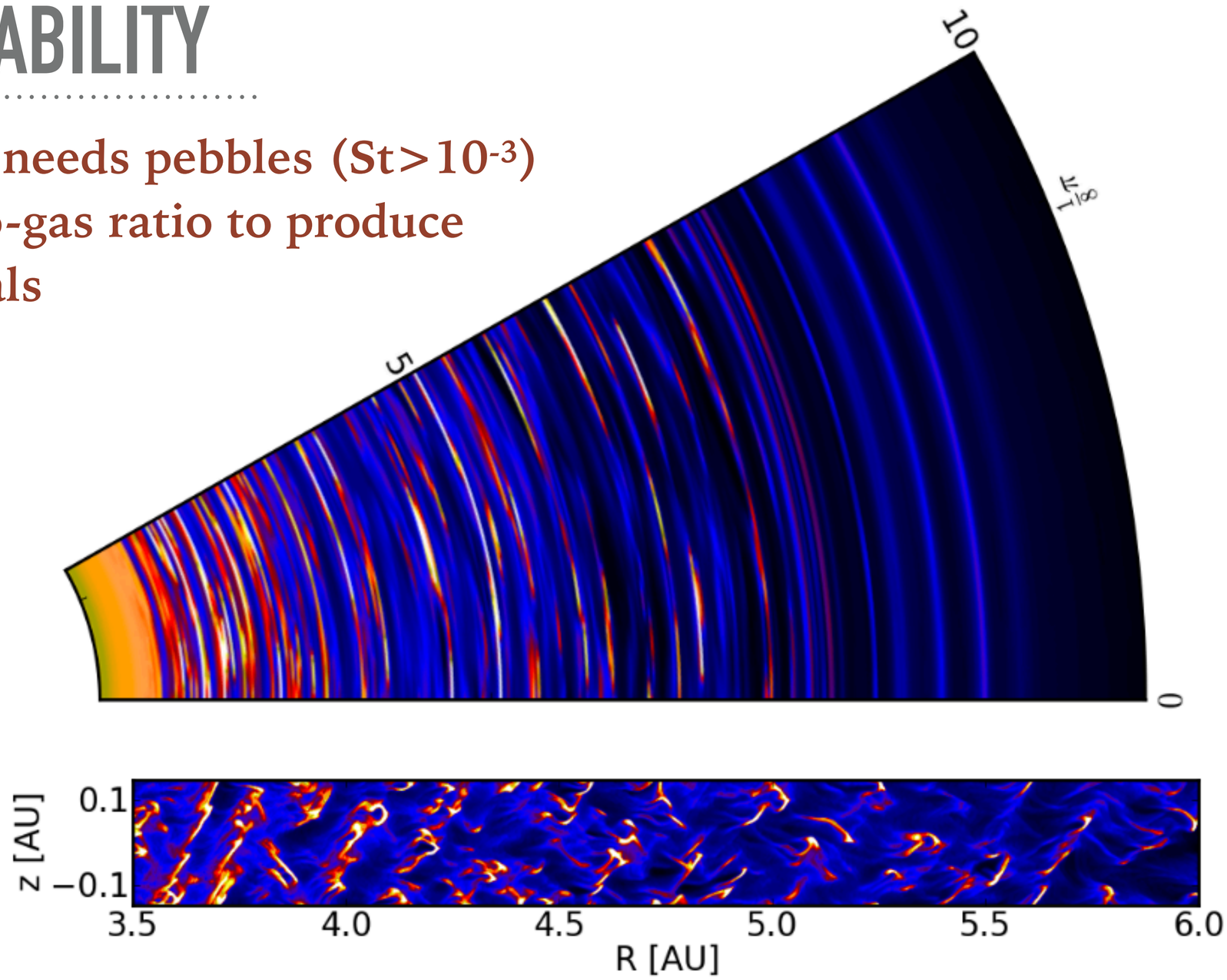
analytical predictions for growth barriers: Birnstiel, Klahr, & Ercolano 2012





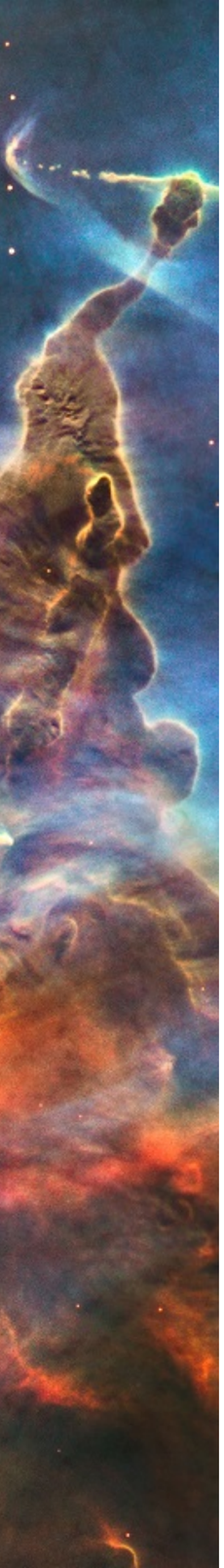
STREAMING INSTABILITY

Streaming instability needs pebbles ($St > 10^{-3}$) and enhanced dust-to-gas ratio to produce km-sized planetesimals

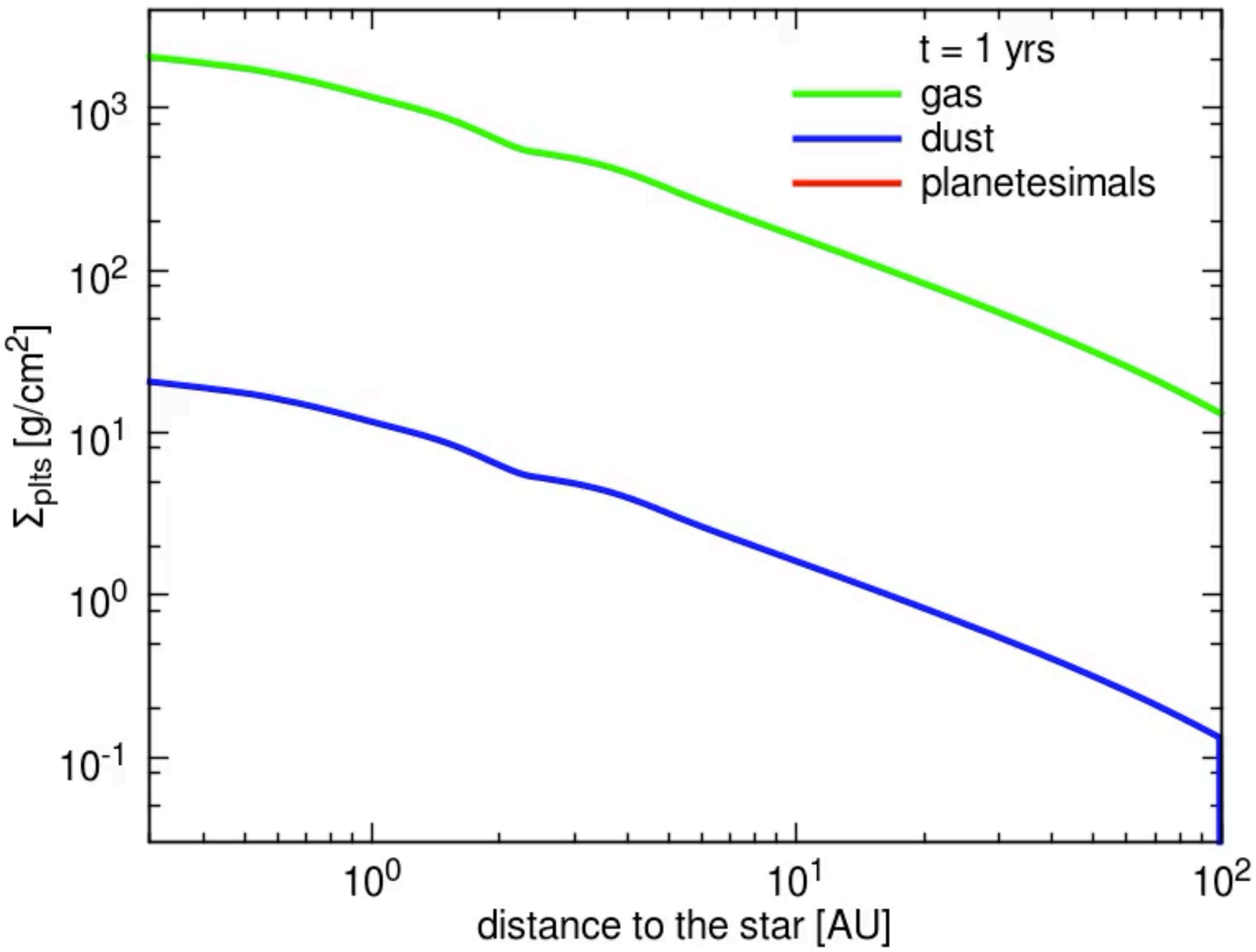


Kowalik et al. 2013

see also: Johansen et al. 2007, Bai & Stone 2010, Drążkowska & Dullemond 2014, Carrera et al. 2015, Simon et al. 2016, Abod et al. 2018, …

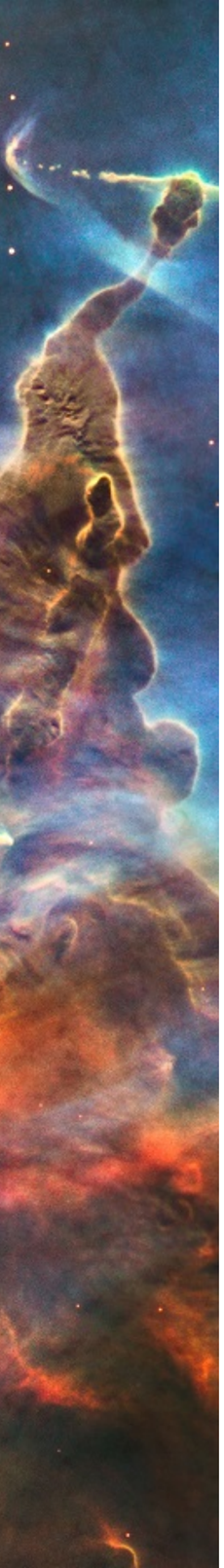


DUST GROWTH + STREAMING INSTABILITY



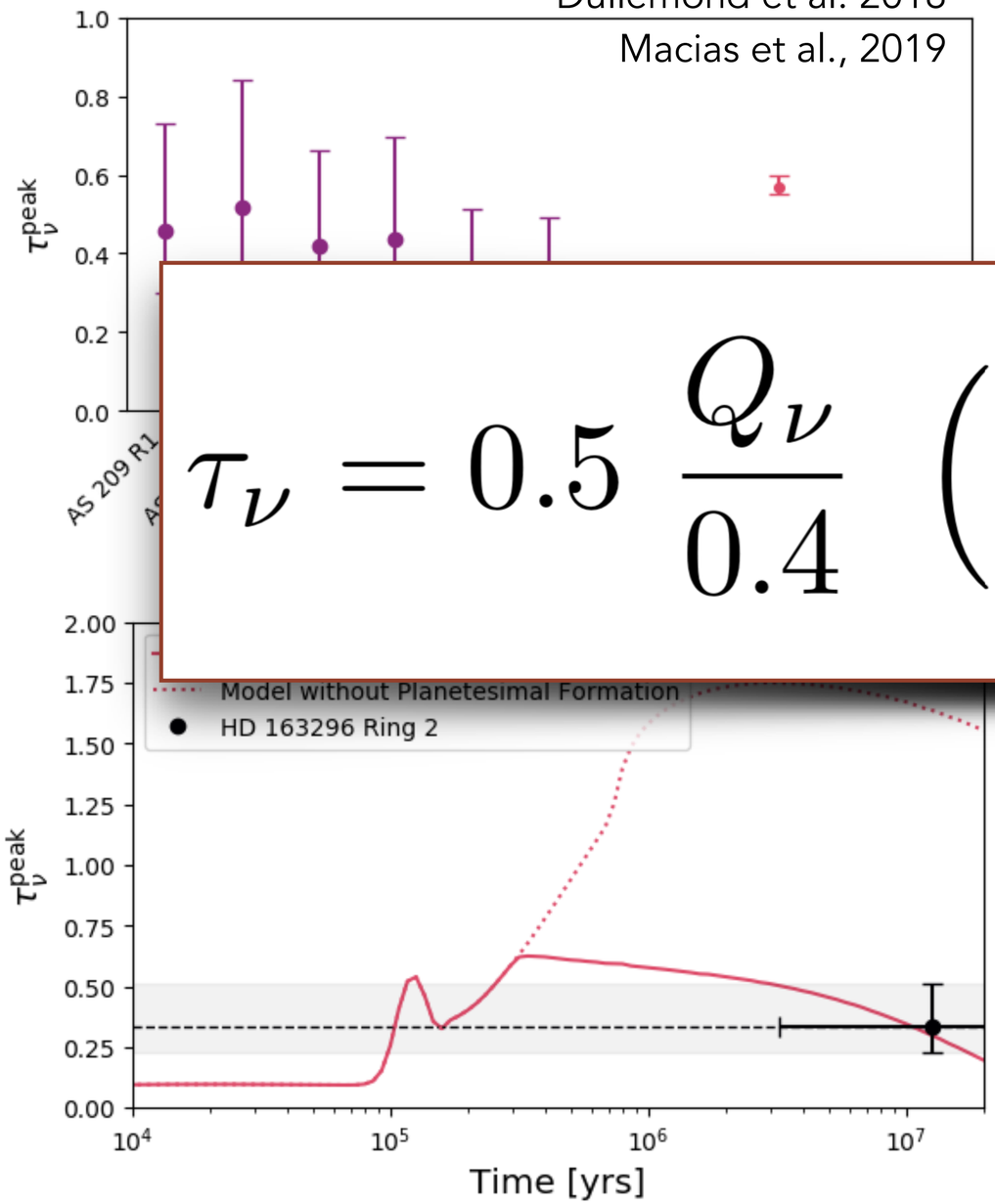
Drążkowska et al. 2016

see also:
Drążkowska & Alibert 2017
Schoonenberg & Ormel 2017
Drążkowska & Dullemond 2018
Pignatale et al. 2018



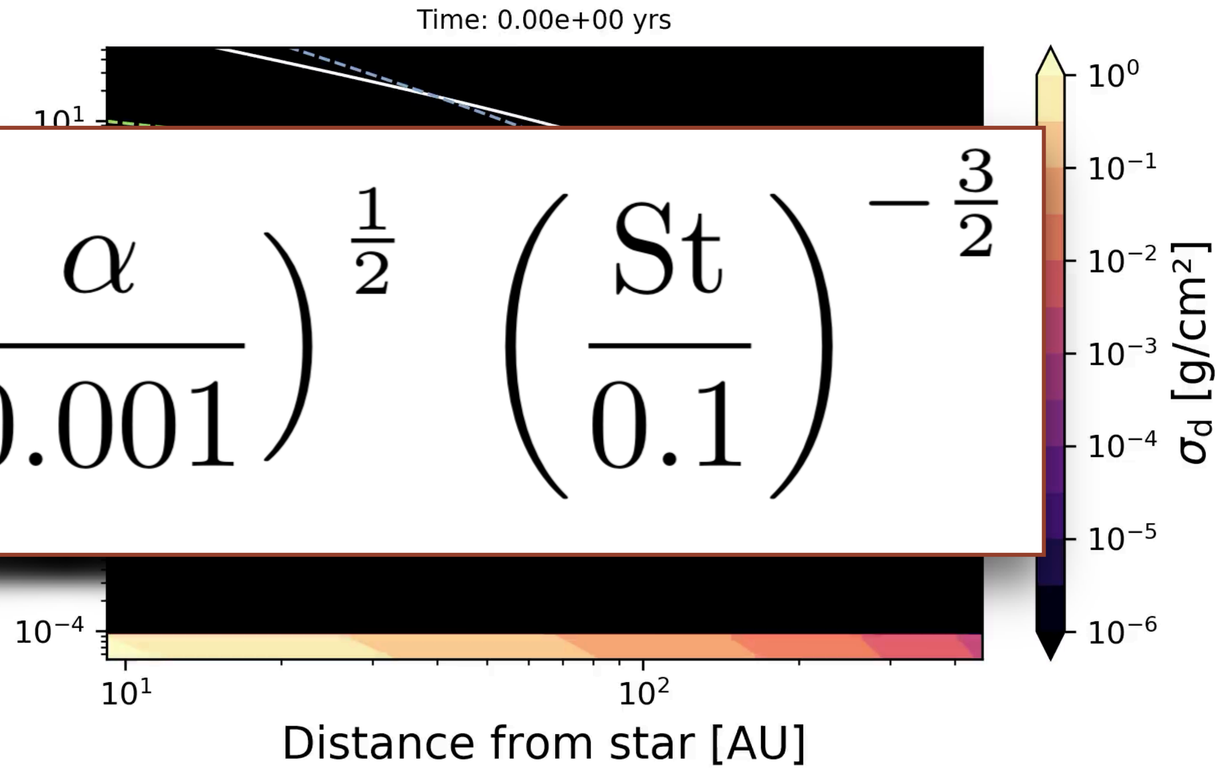
PLANETS TRIGGER PLANET(ESIMAL) FORMATION?

Dullemond et al. 2018
Macias et al., 2019

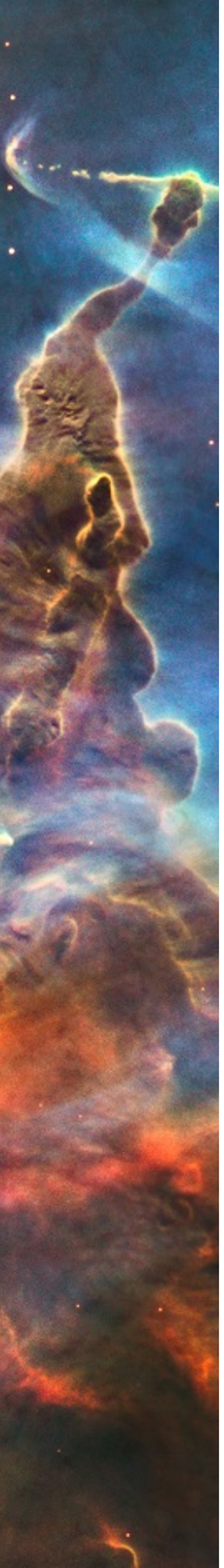


$$\tau_\nu = 0.5 \, \frac{Q_\nu}{0.4} \left(\frac{\alpha}{0.001} \right)^{\frac{1}{2}} \left(\frac{\mathrm{St}}{0.1} \right)^{-\frac{3}{2}}$$

HD 163296



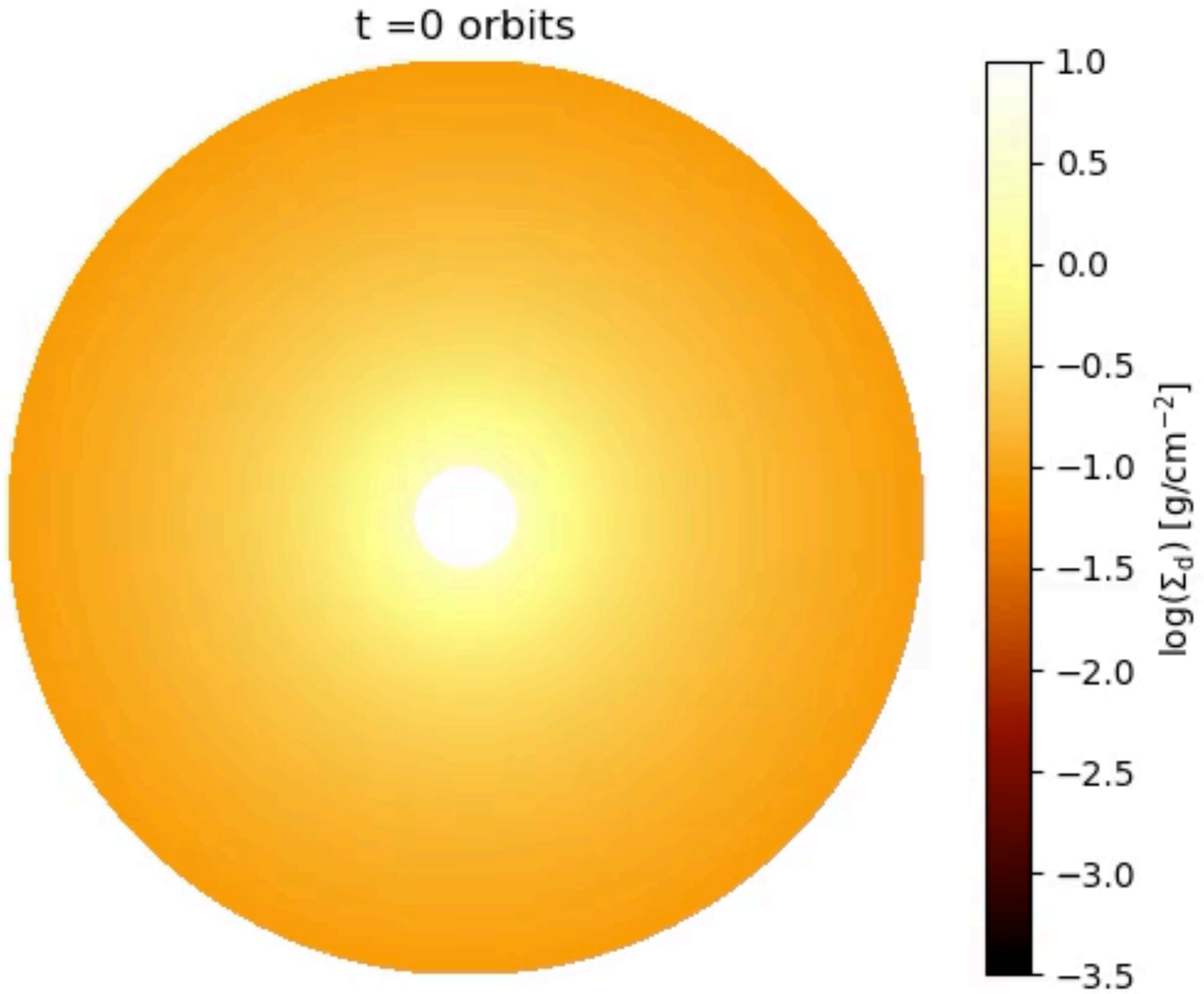
Stammler, Drążkowska, et al., submitted



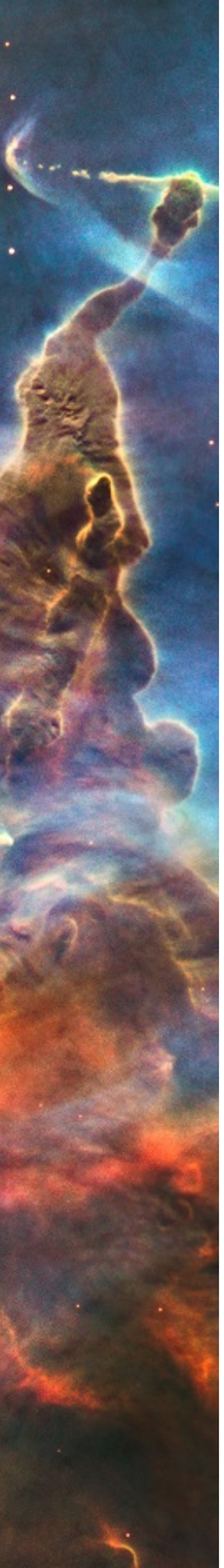
PLANETS TRIGGER PLANET(ESIMAL) FORMATION?

Los Alamos NATIONAL LABORATORY EST.1943

made with
(COA)LA-COMPASS
by Li et al.



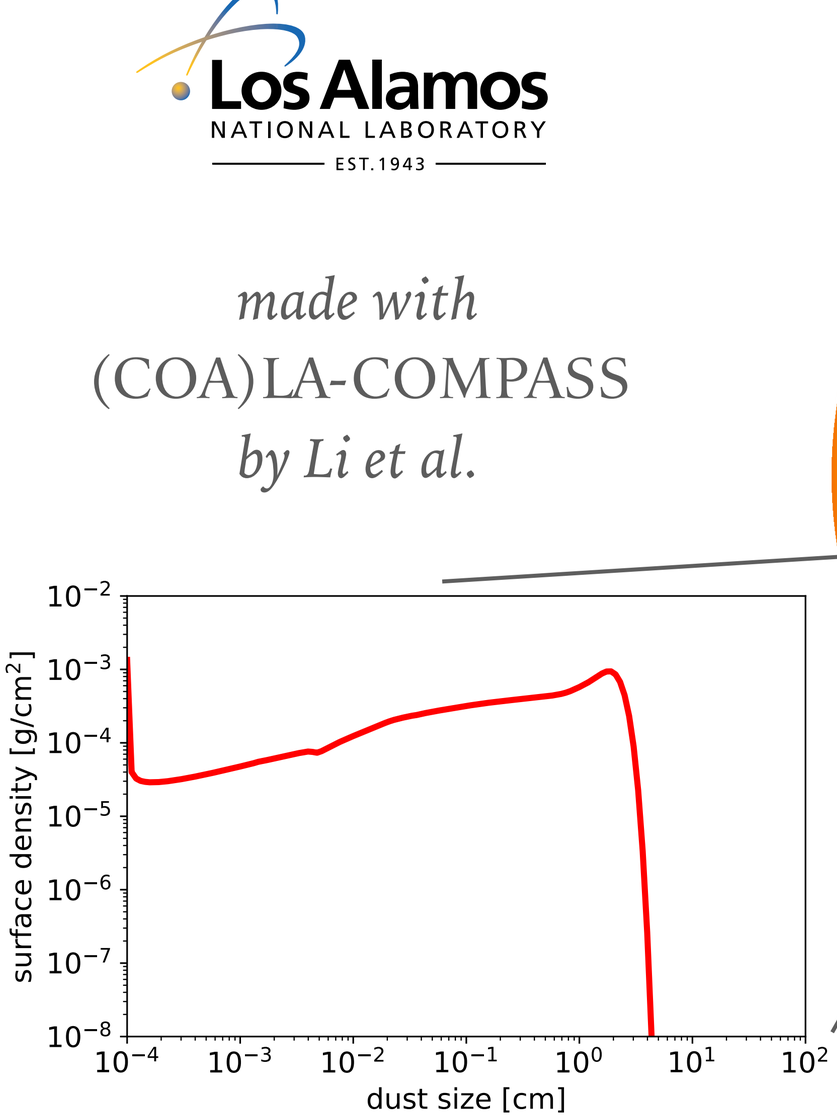
Drążkowska et al., submitted

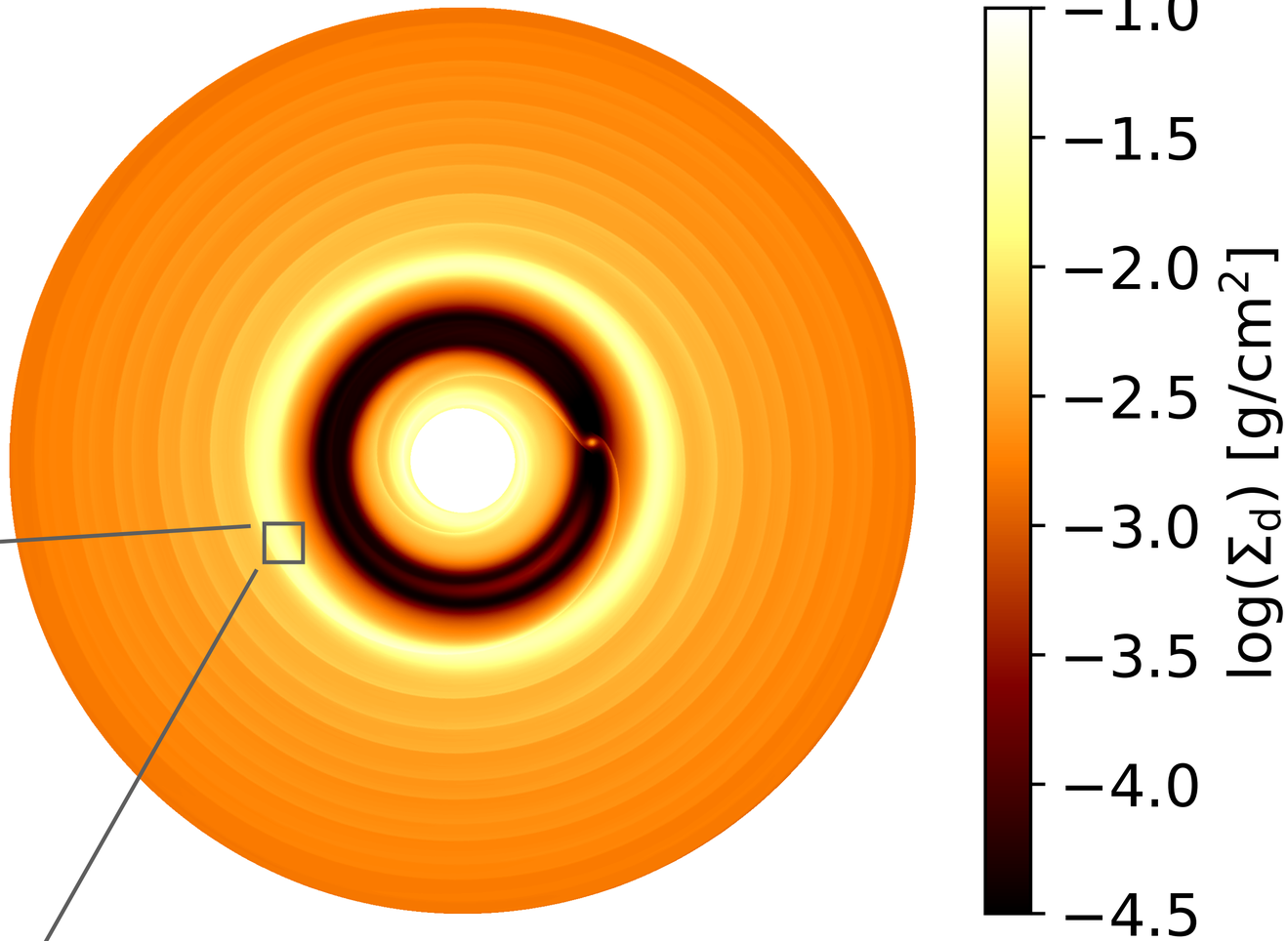


DUST COAGULATION IN 2-D

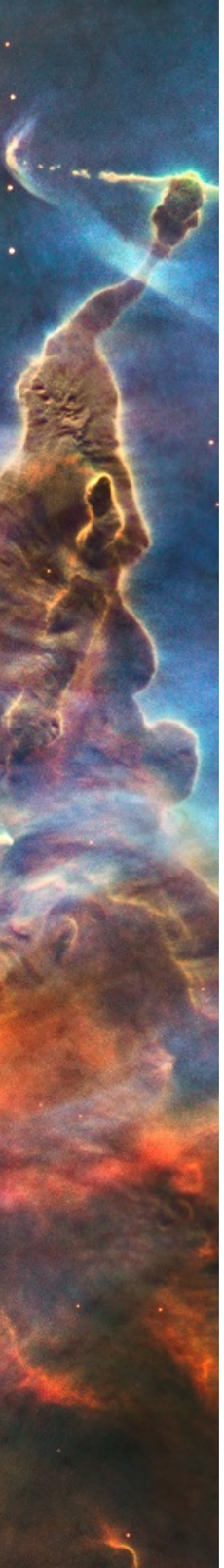
Los Alamos NATIONAL LABORATORY EST. 1943

made with
(COA)LA-COMPASS
by Li et al.



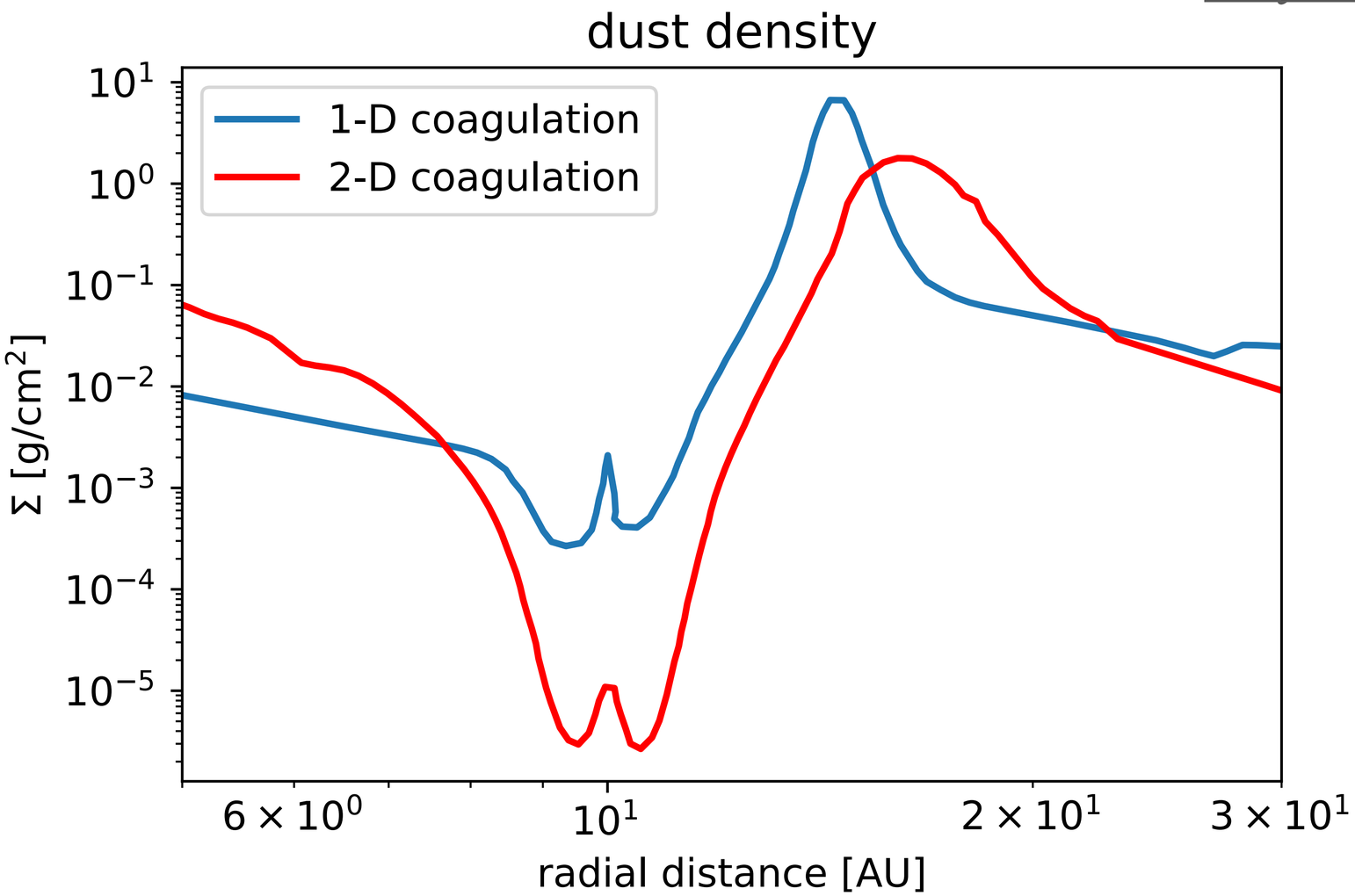


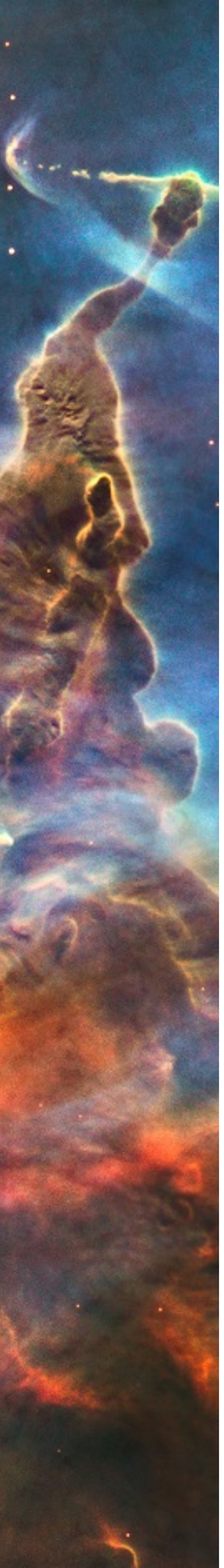
Drążkowska et al., submitted



DUST COAGULATION IN 2-D VS 1-D

Drążkowska et al., submitted





TAKE HOME MESSAGES

- It seems very unlikely that planetesimals form by direct growth of dust aggregated to kilometre sizes
- Even with the help of the streaming instability, planetesimals only form at some particular locations in the disk (pebble pile-ups, pressure traps, snow lines?)
- We have indirect evidence of ongoing planetesimal formation in dust ring of HD 163296
- Modelling of dust coagulation in 2-D gives significantly different results from previous 1-D models
  (also: including dust coagulation gives significantly different results from fixed size models…)