

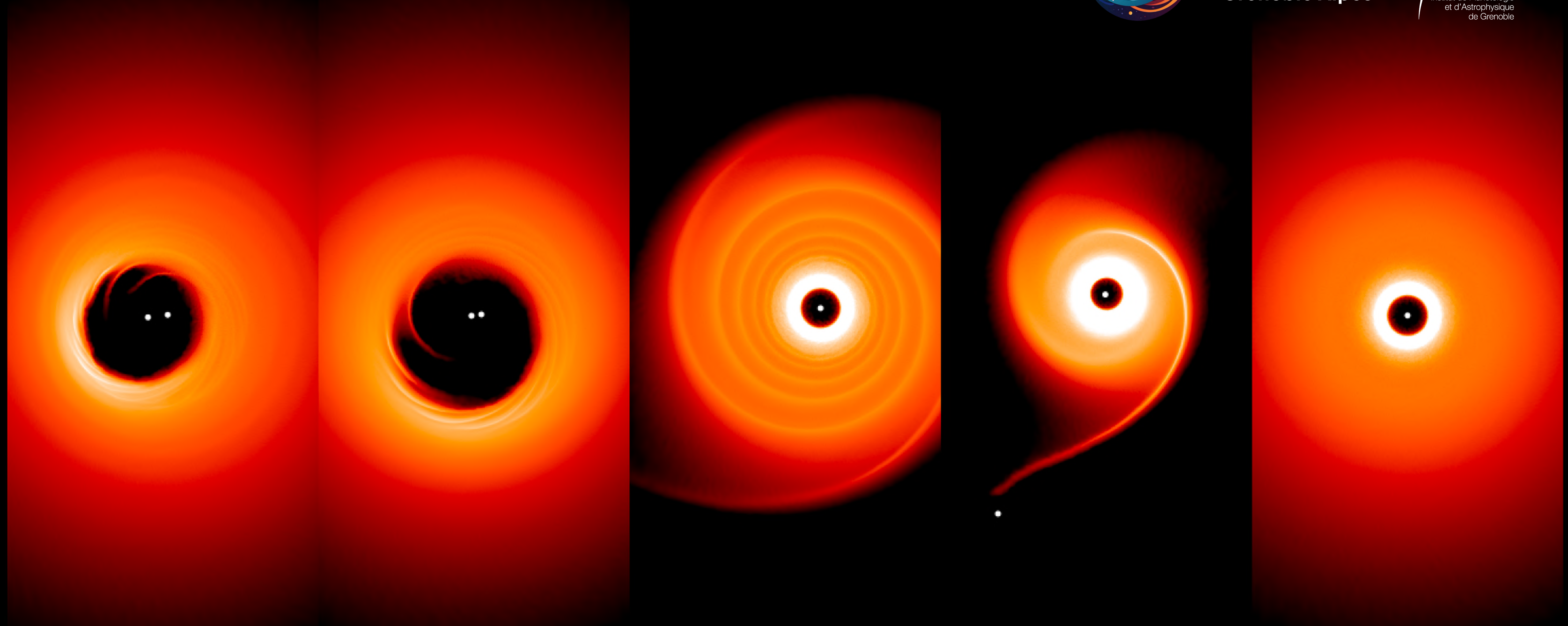
Multiple systems: friends or foes of planet formation?

Antoine Alaguero

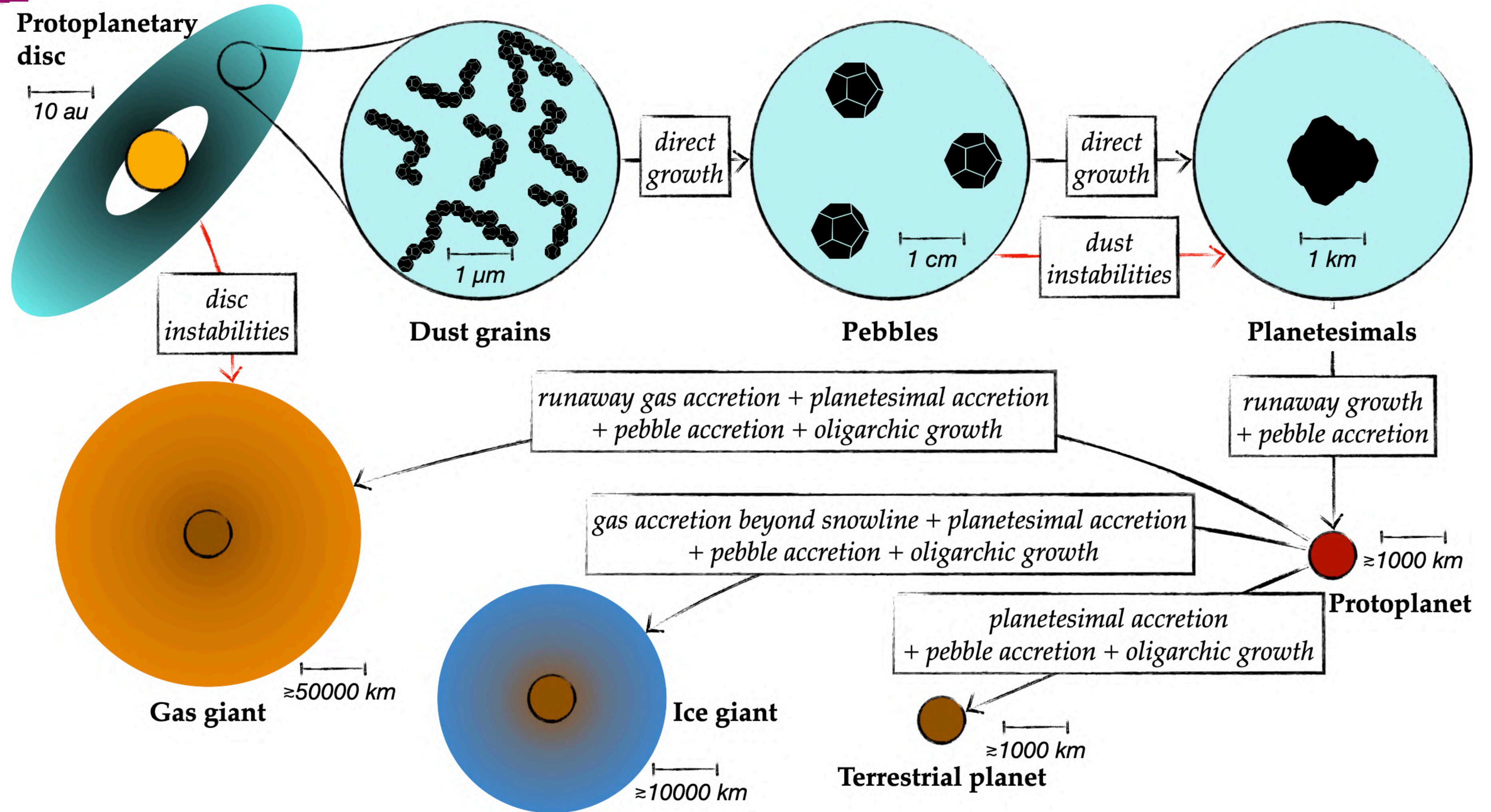
SF2A 2026 - 24/06/2026



UGA
Université
Grenoble Alpes

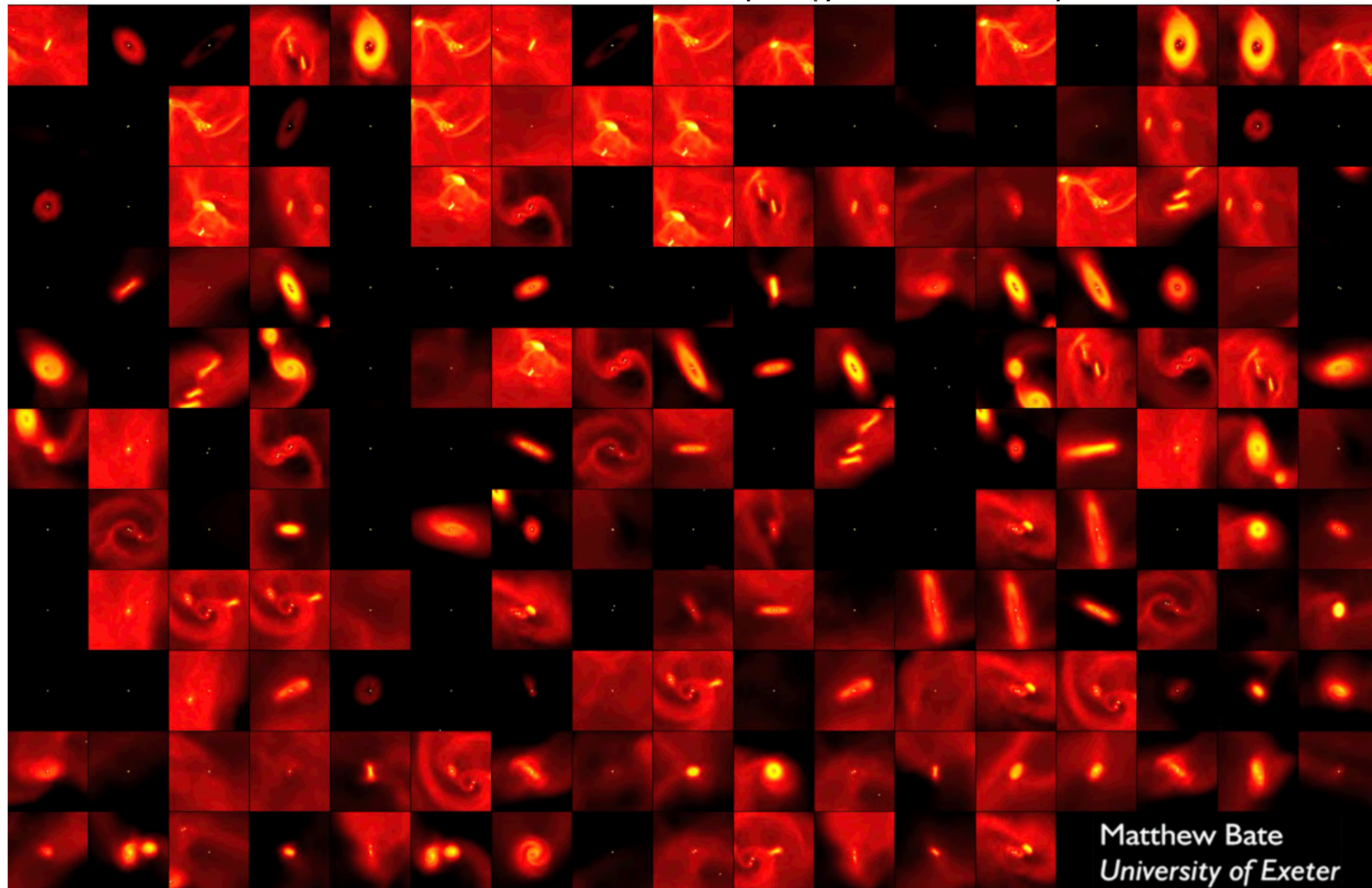


Planet formation



Stellar multiplicity

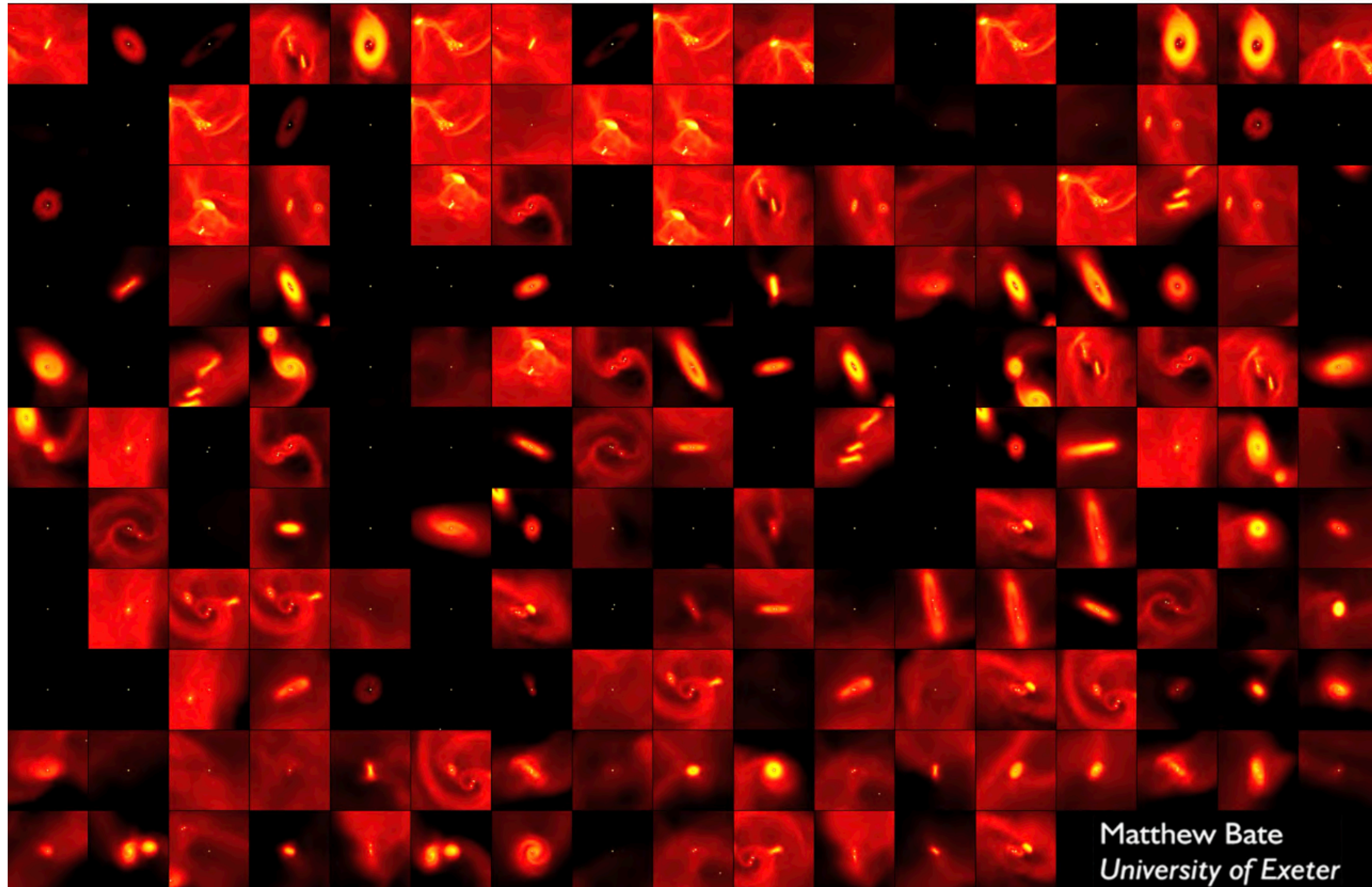
Simulation of a collapsing cloud - each panel follows a star



Matthew Bate
University of Exeter

Stellar multiplicity

Simulation of a collapsing cloud - each panel follows a star



OBSERVATIONS

~14% of Sun-like stars are in triple systems.

~50% of field stars are in multiple systems.

~65% of young stellar systems are multiple.

Offner+2023

Raghavan+2010

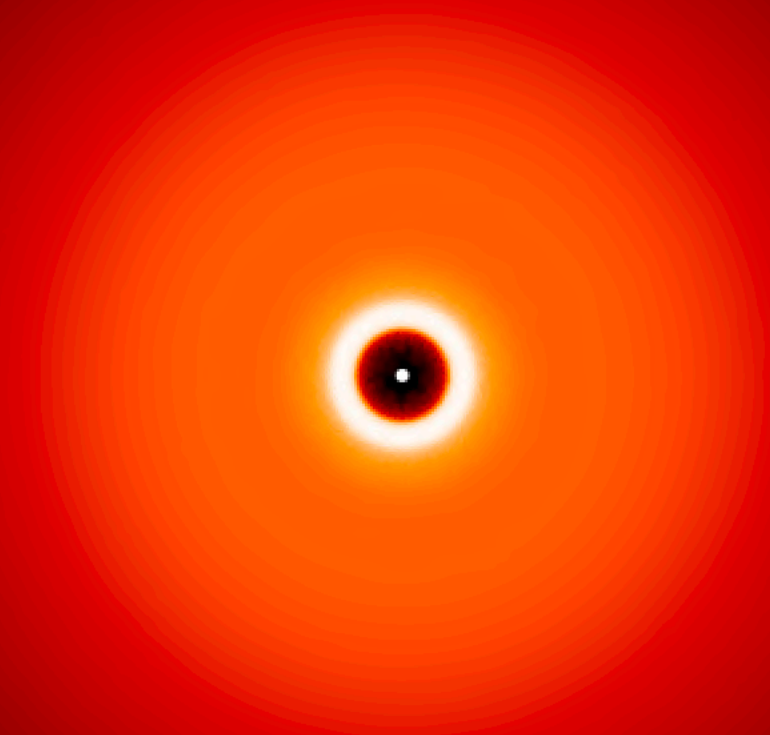
Chen+2013

Multiplicity cannot be ignored!

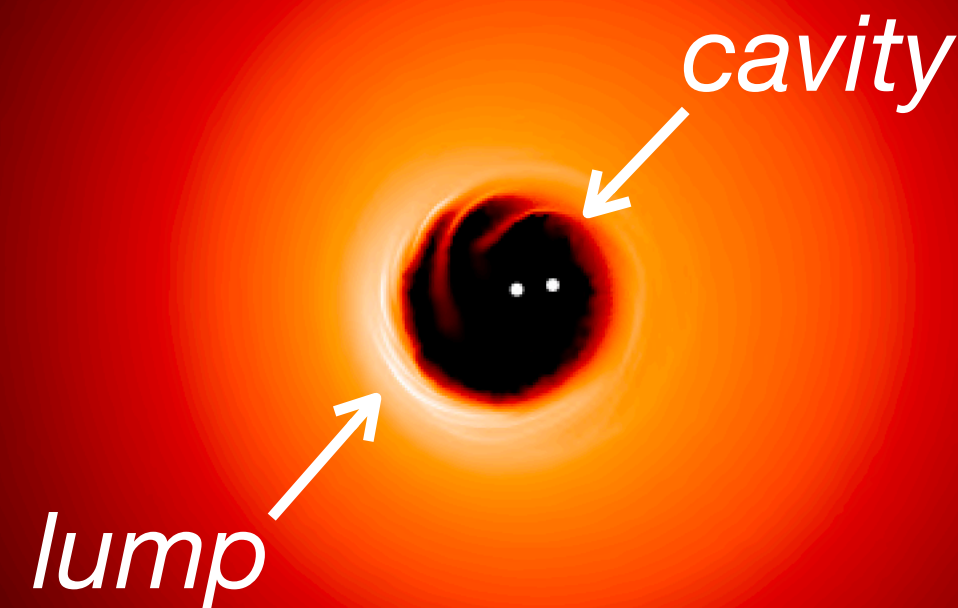
Stellar companions perturb the **density** and **kinematics** of discs.

Isolated disc

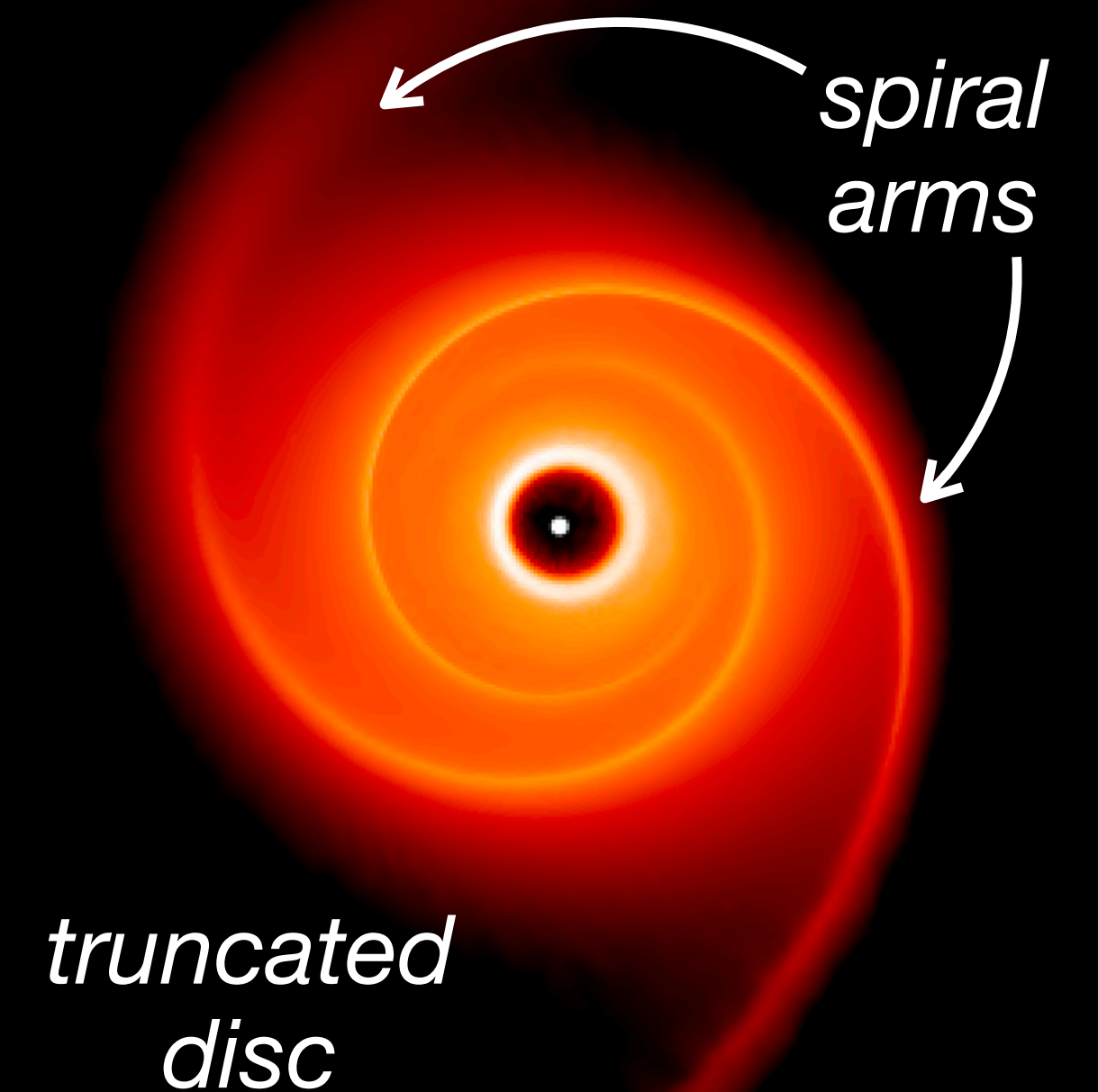
the boring one



Circumbinary disc



Circumstellar disc in a binary



How does stellar multiplicity affect dust growth?

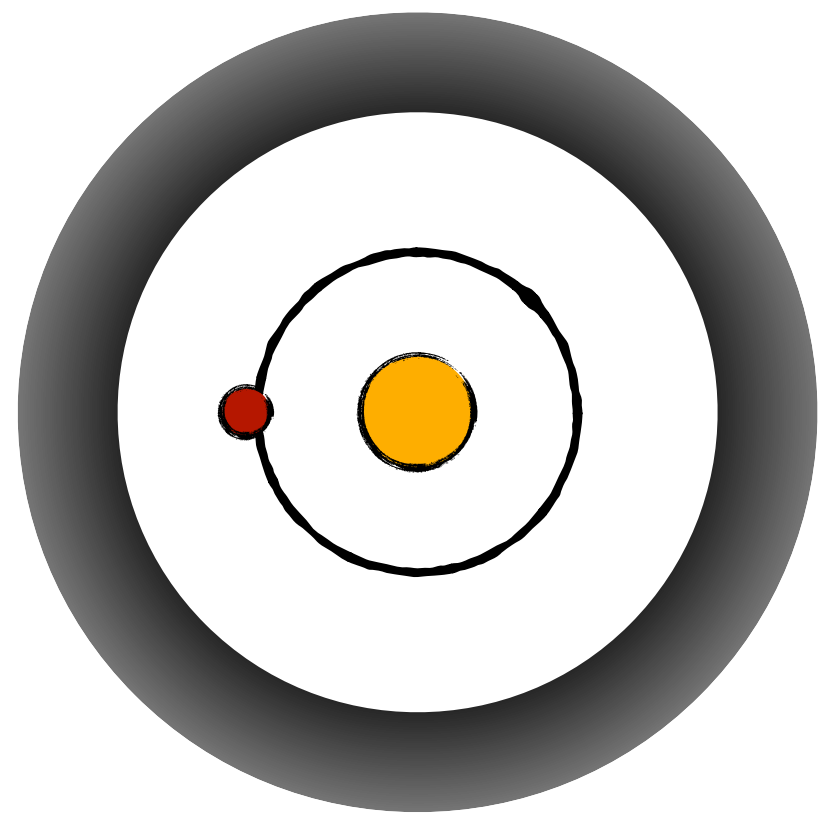
Numerical setup

Price+2018
 Vericel+2021
 Michoulier+2024 + **SPH SIMULATIONS**
 + **1 500 000 GAS-DUST PARTICLES**
 + **DUST GROWTH**

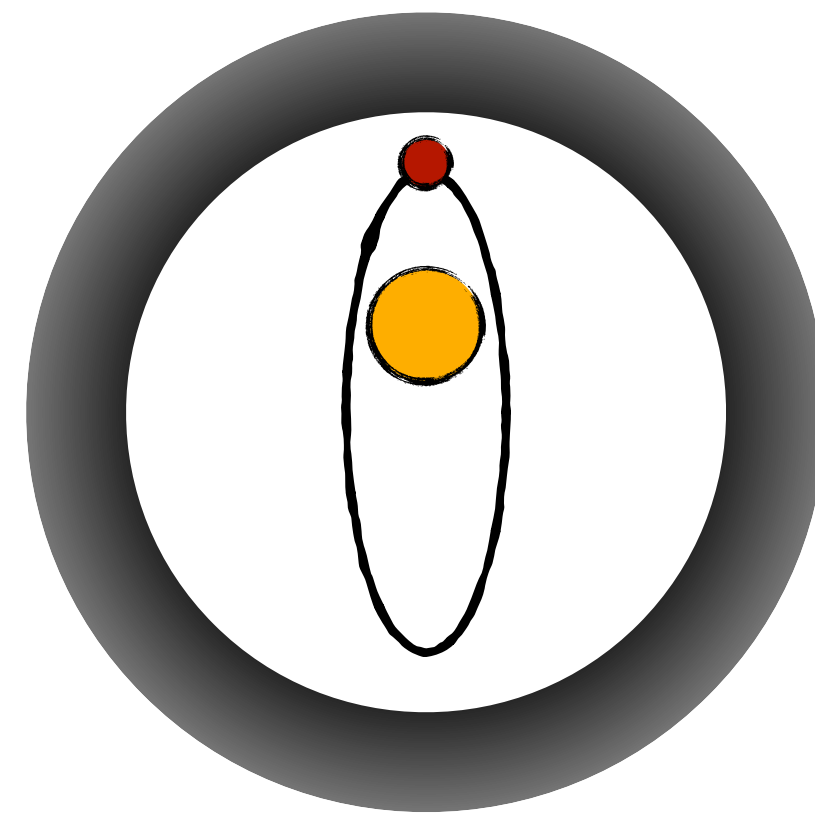


$$\dot{m} = \pm 4\pi s^2 V_{rel} \rho_d \delta$$

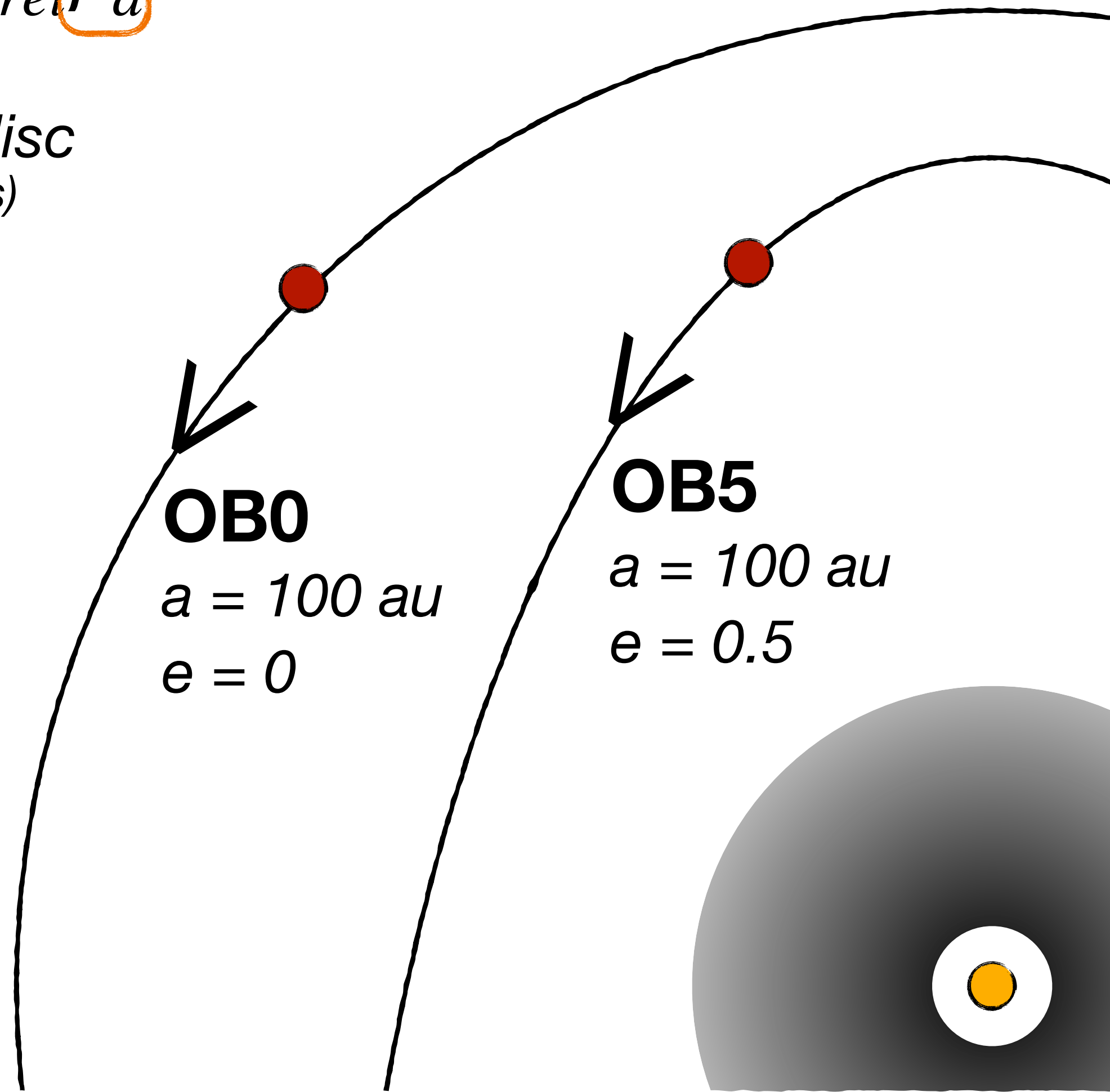
*prescribed for a Keplerian disc
 (=not calculated from disc kinematics)*



IB0
a = 5 au
e = 0



IB5
a = 5 au
e = 0.5



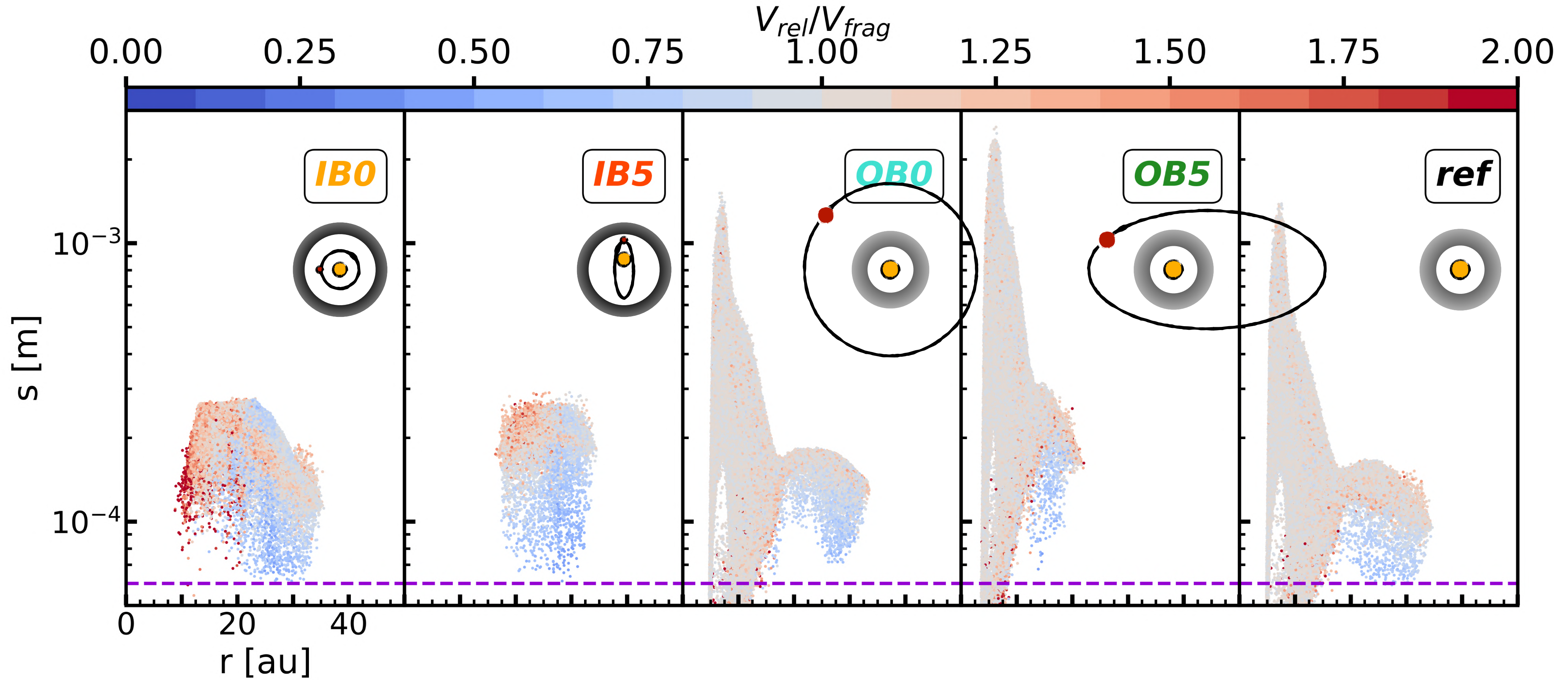
OB0
a = 100 au
e = 0

OB5
a = 100 au
e = 0.5

Density-driven Dust Growth in Binary Systems: Inhibition of dust settling and growth in circumbinary discs

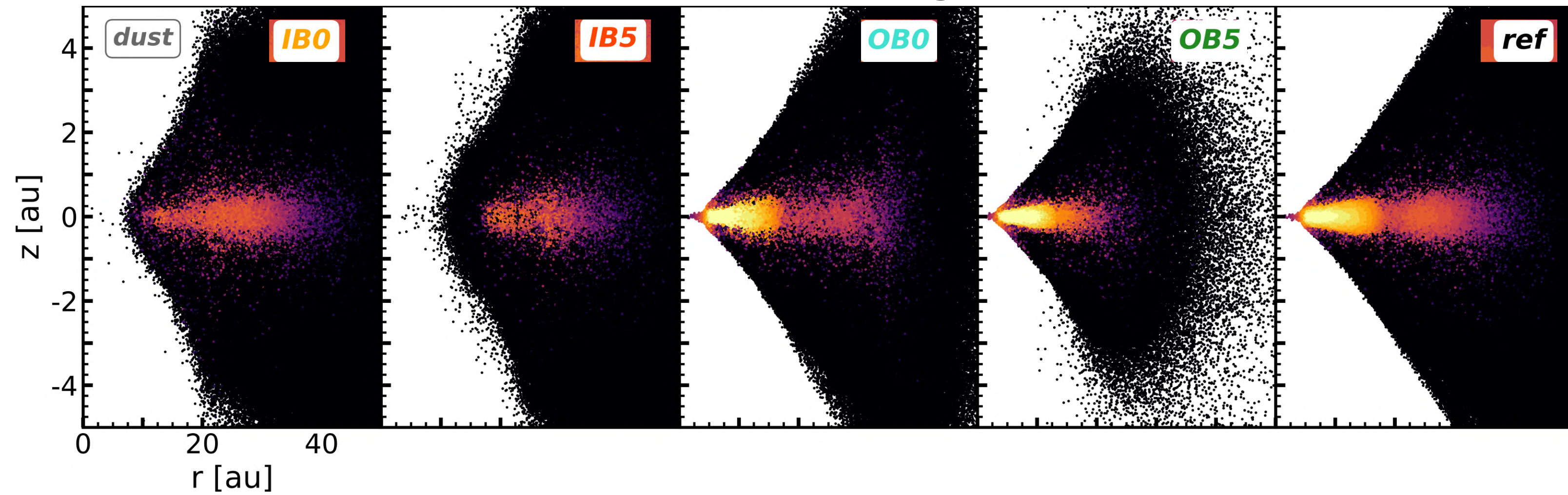
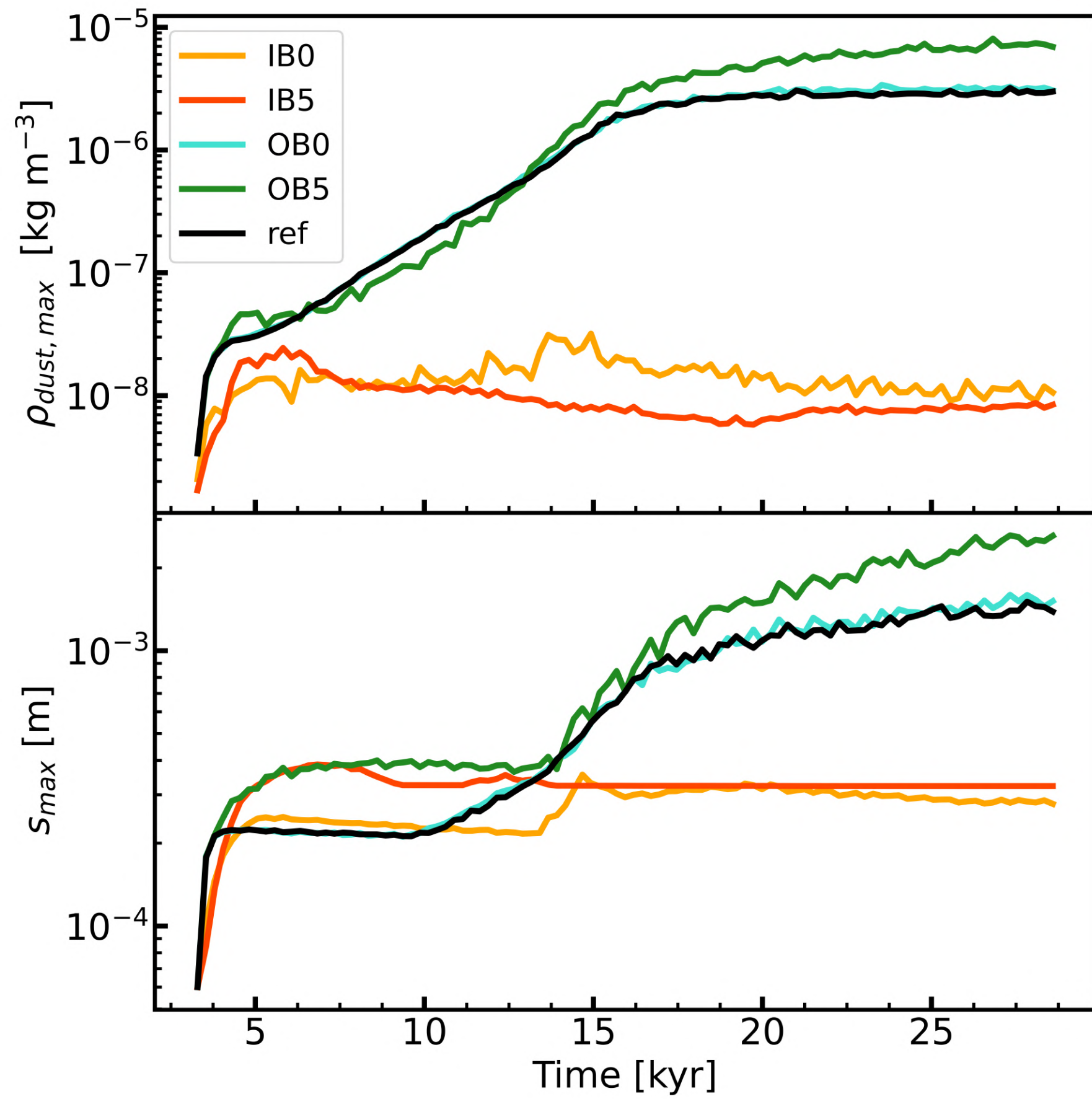
Antoine Alaguero¹, Nicolás Cuello¹, Jean-François Gonzalez², Daniel J. Price³, Maxime Lombart⁴, Jeremy L. Smallwood⁵, and Philippe Thébault⁶

**soon accepted*

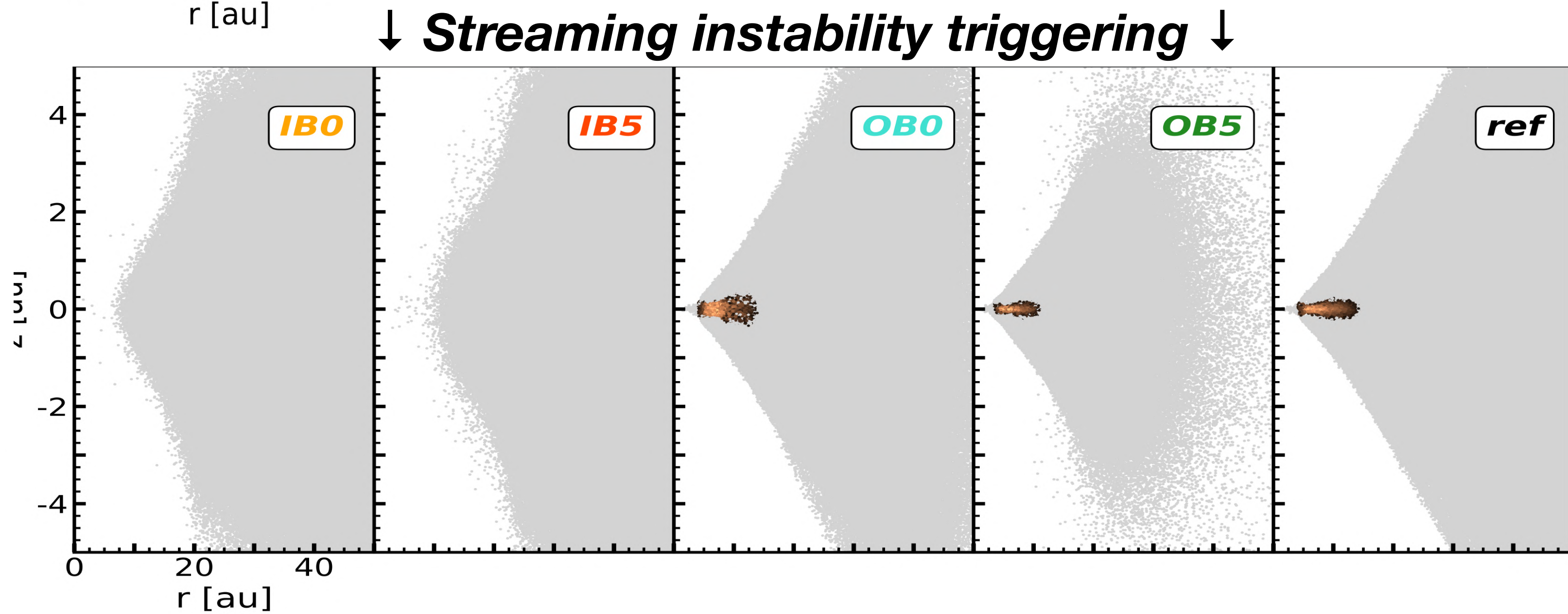
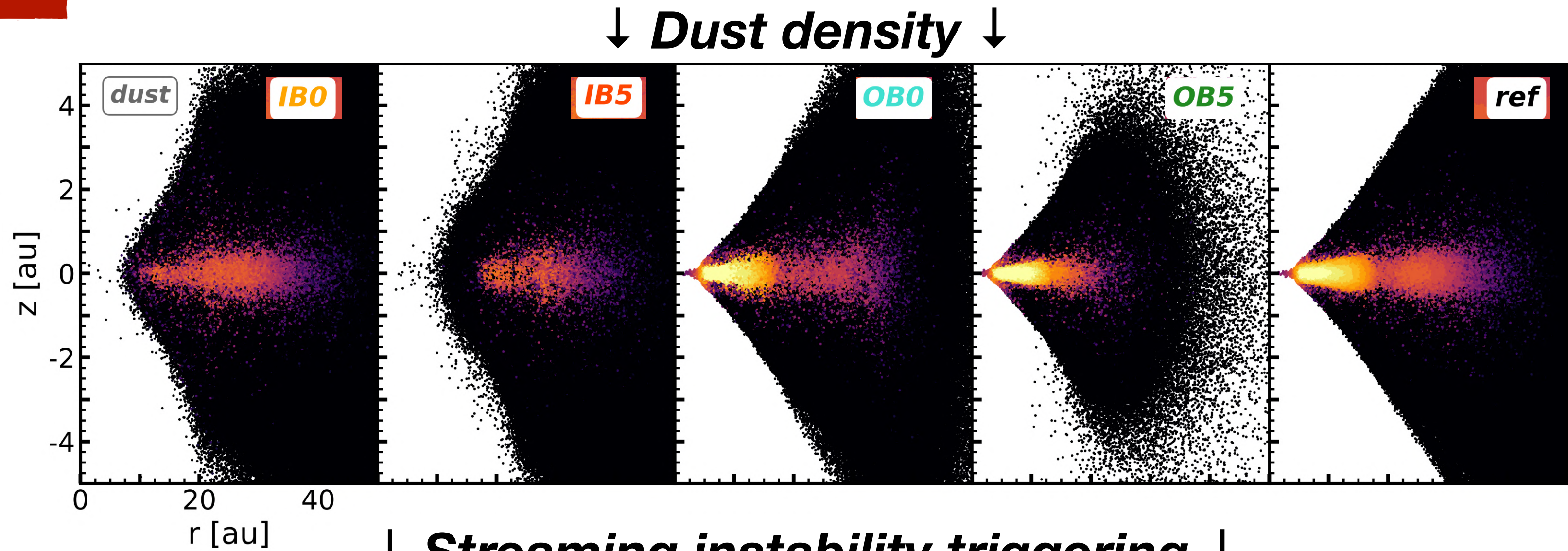
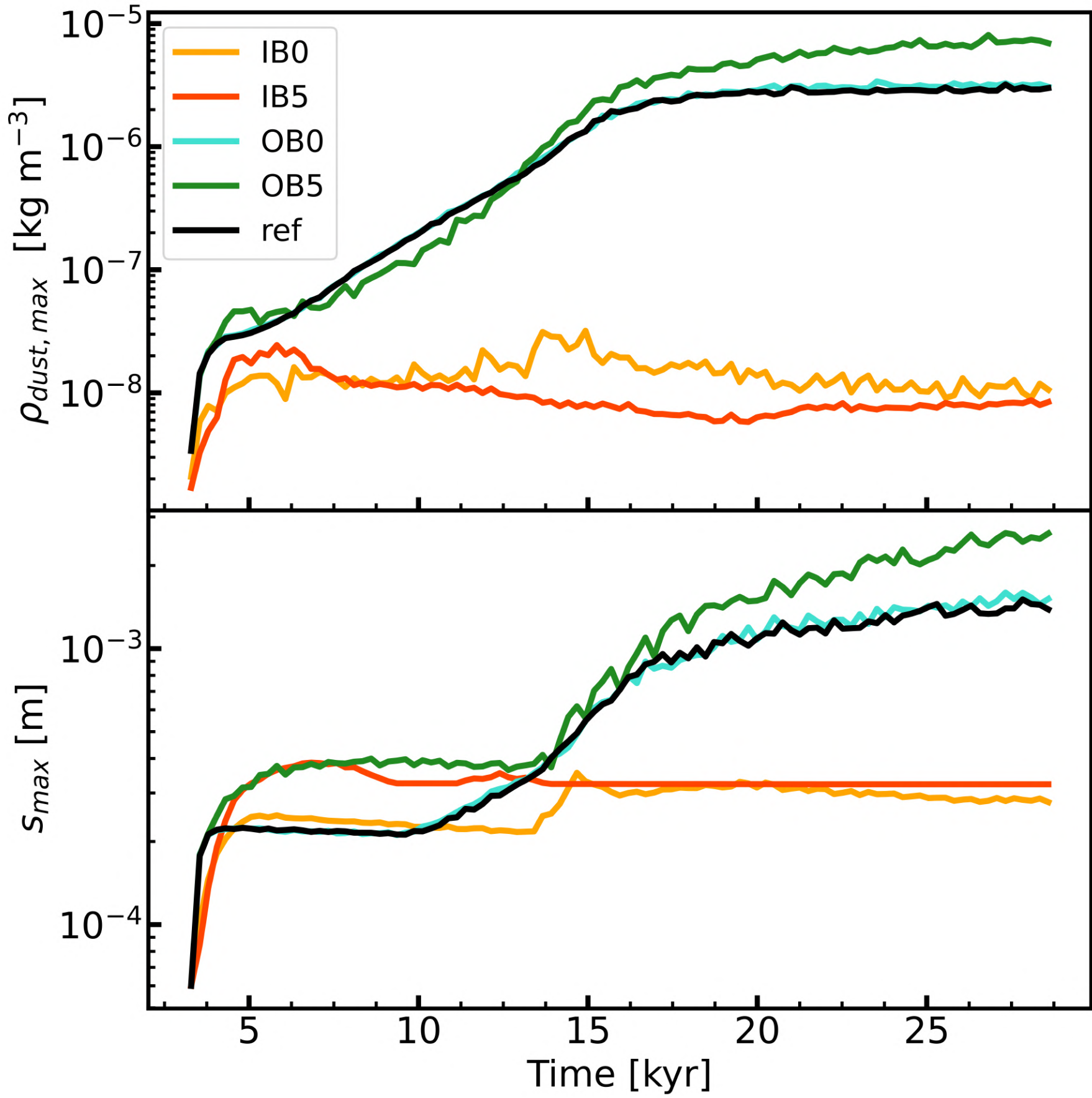


Where is the disc dense?

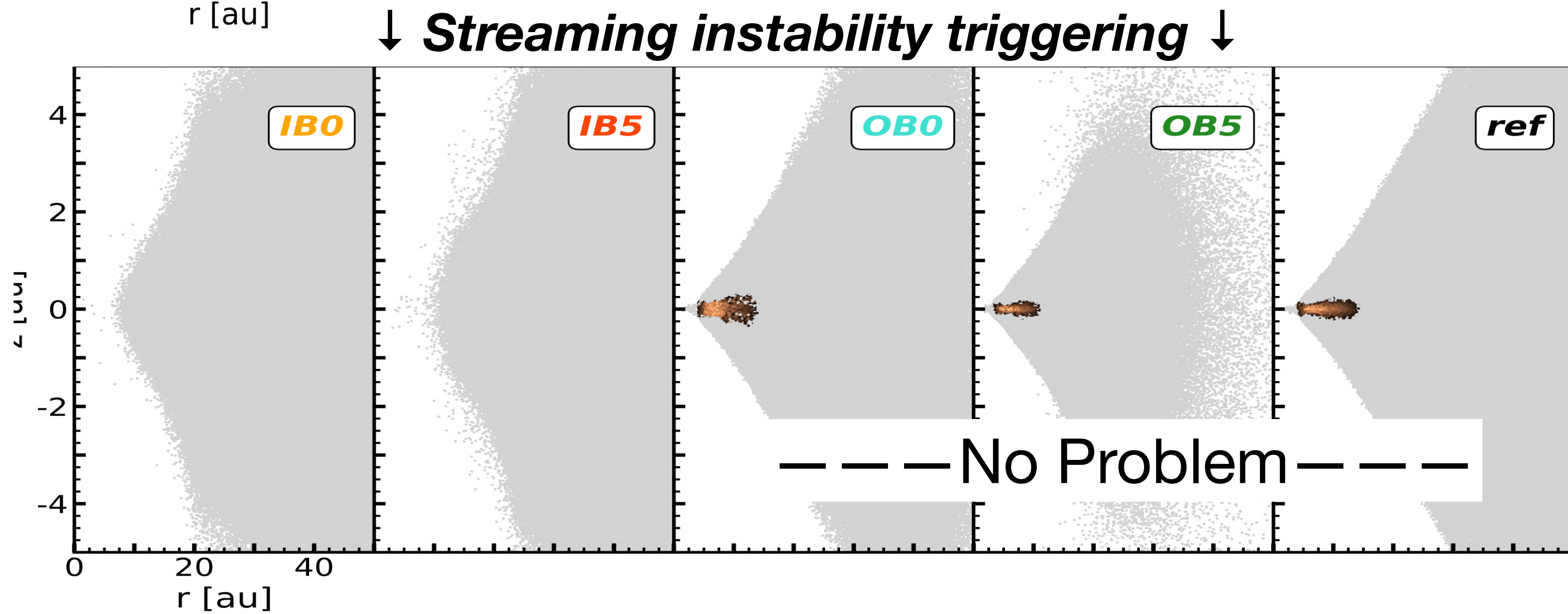
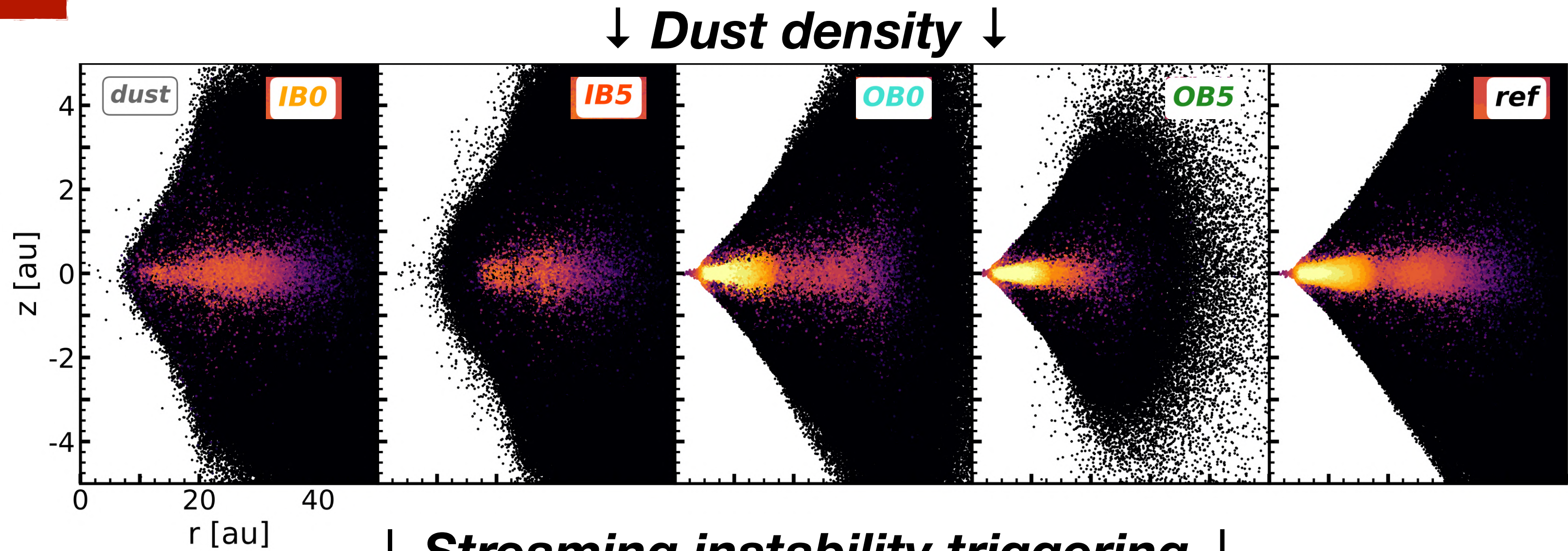
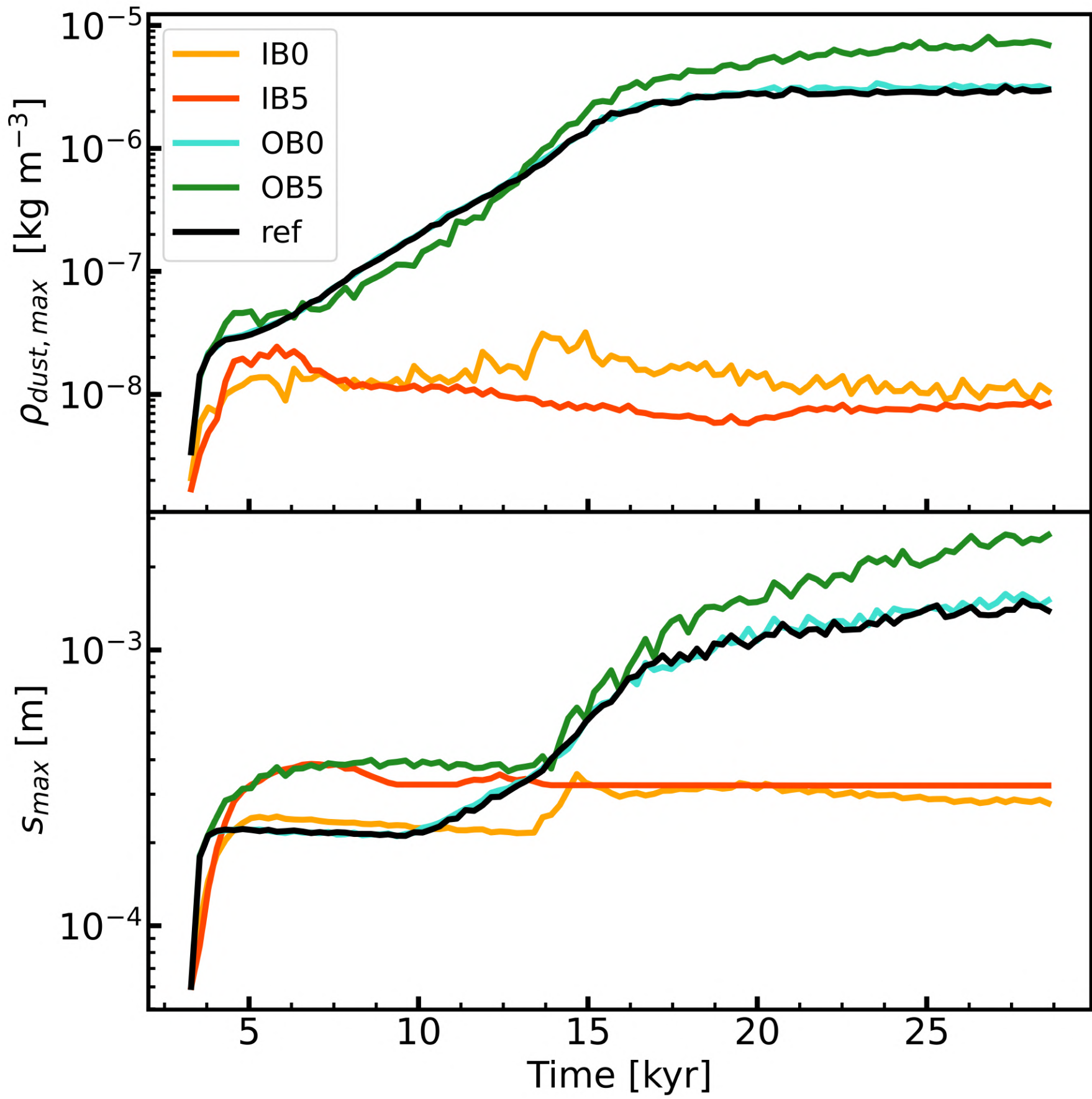
↓ *Dust density* ↓



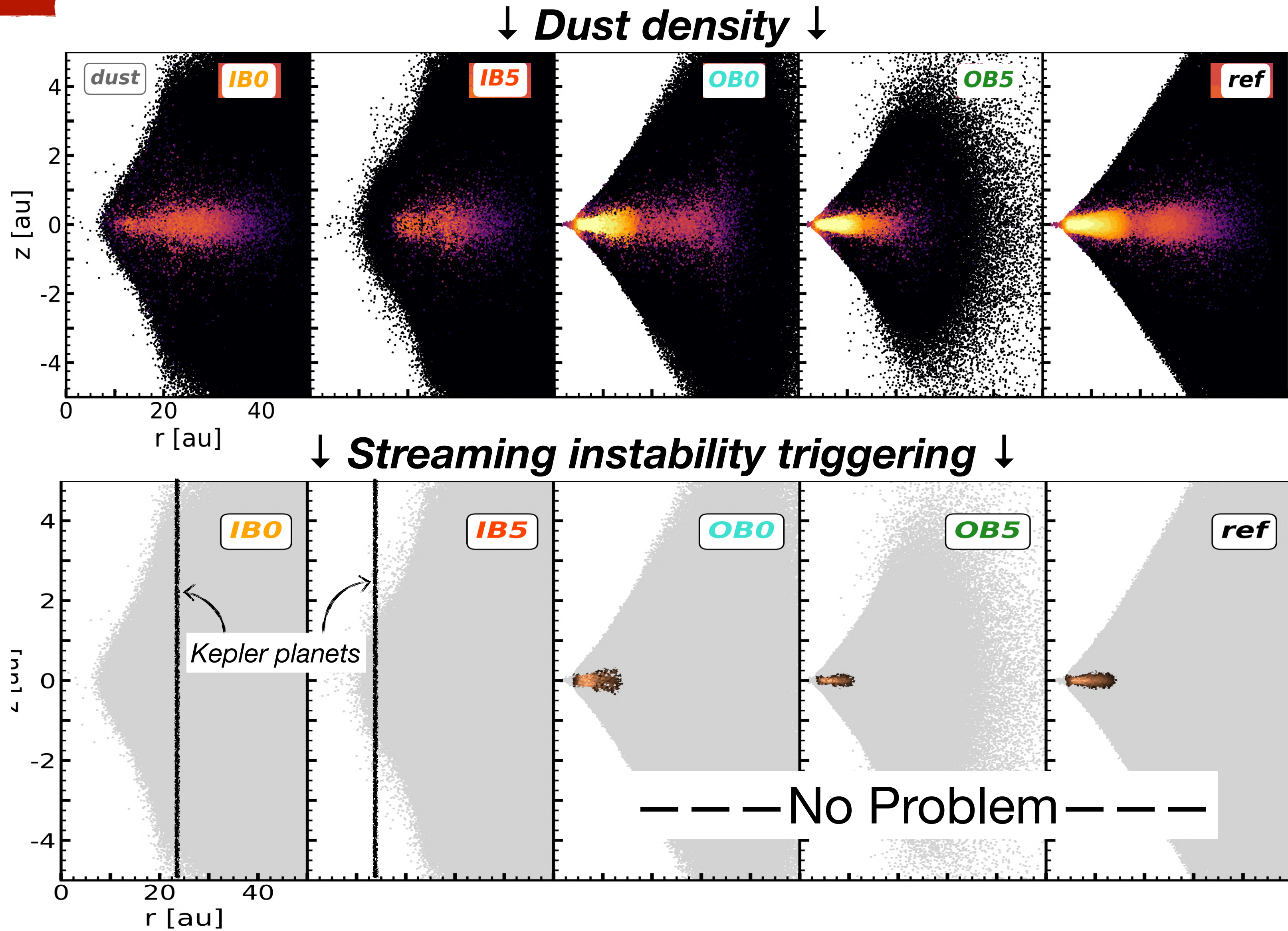
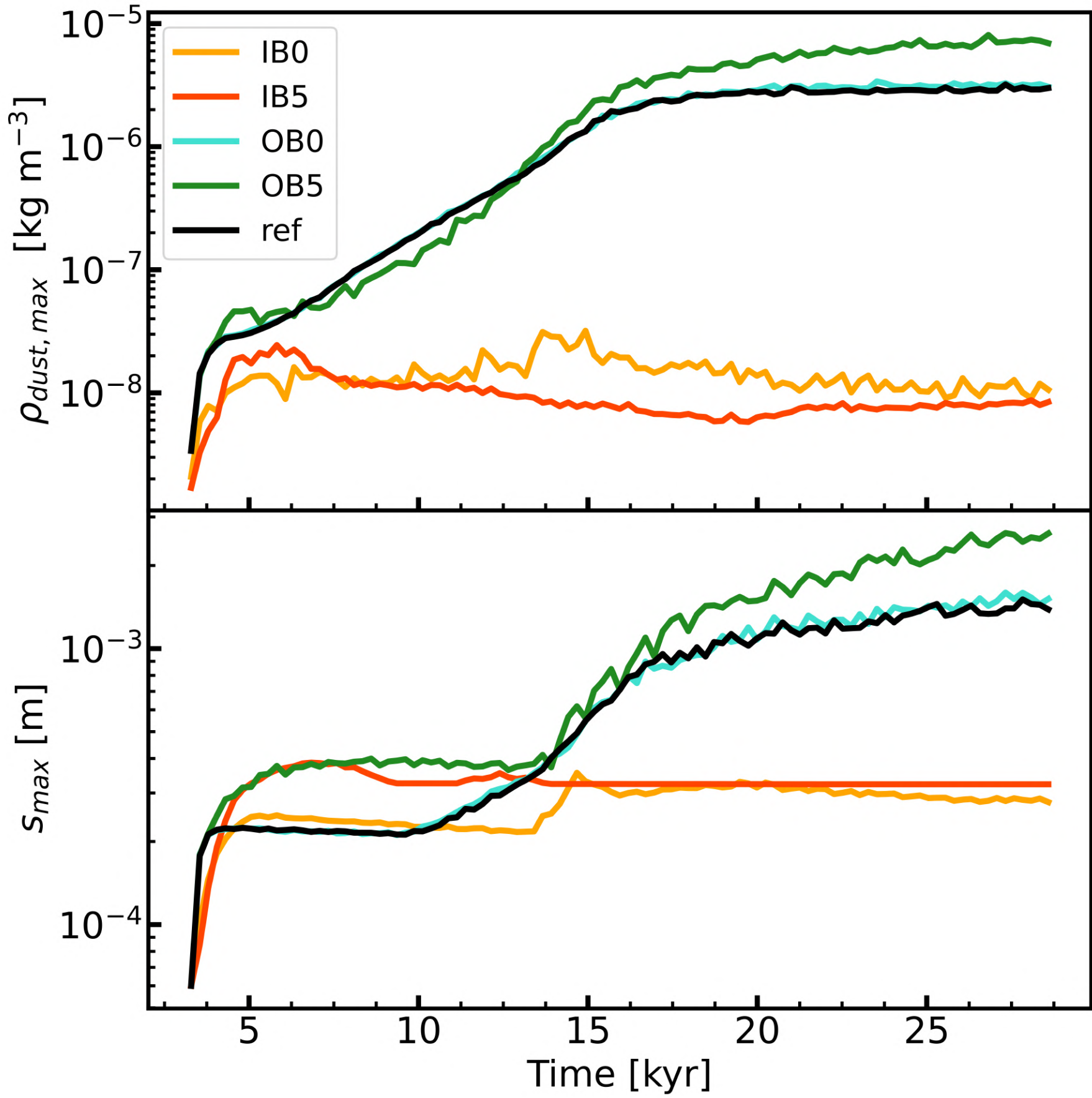
Where is the disc dense?



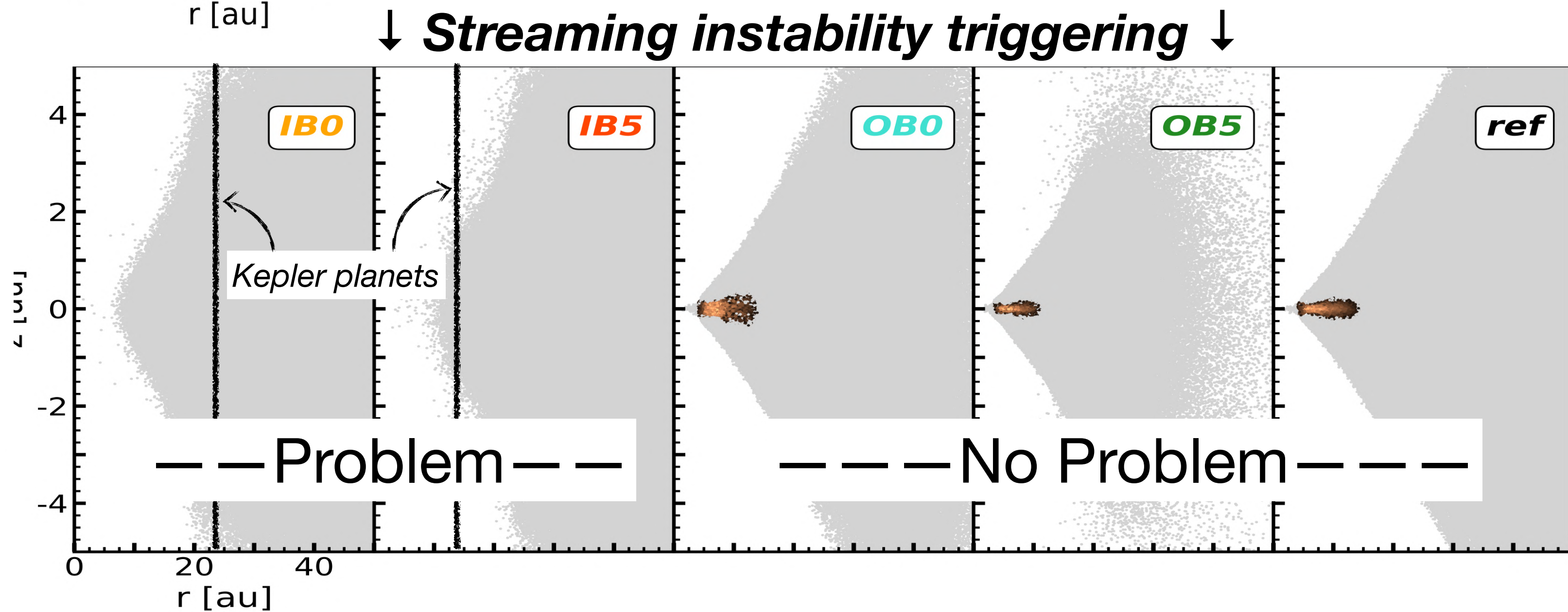
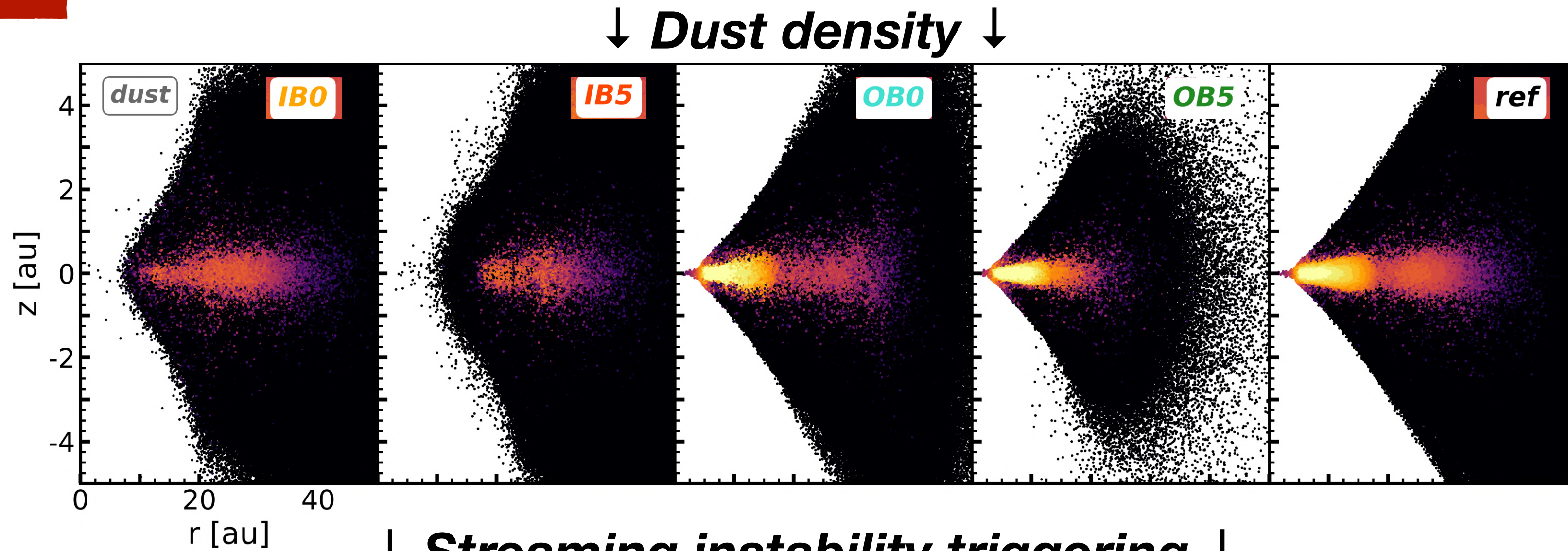
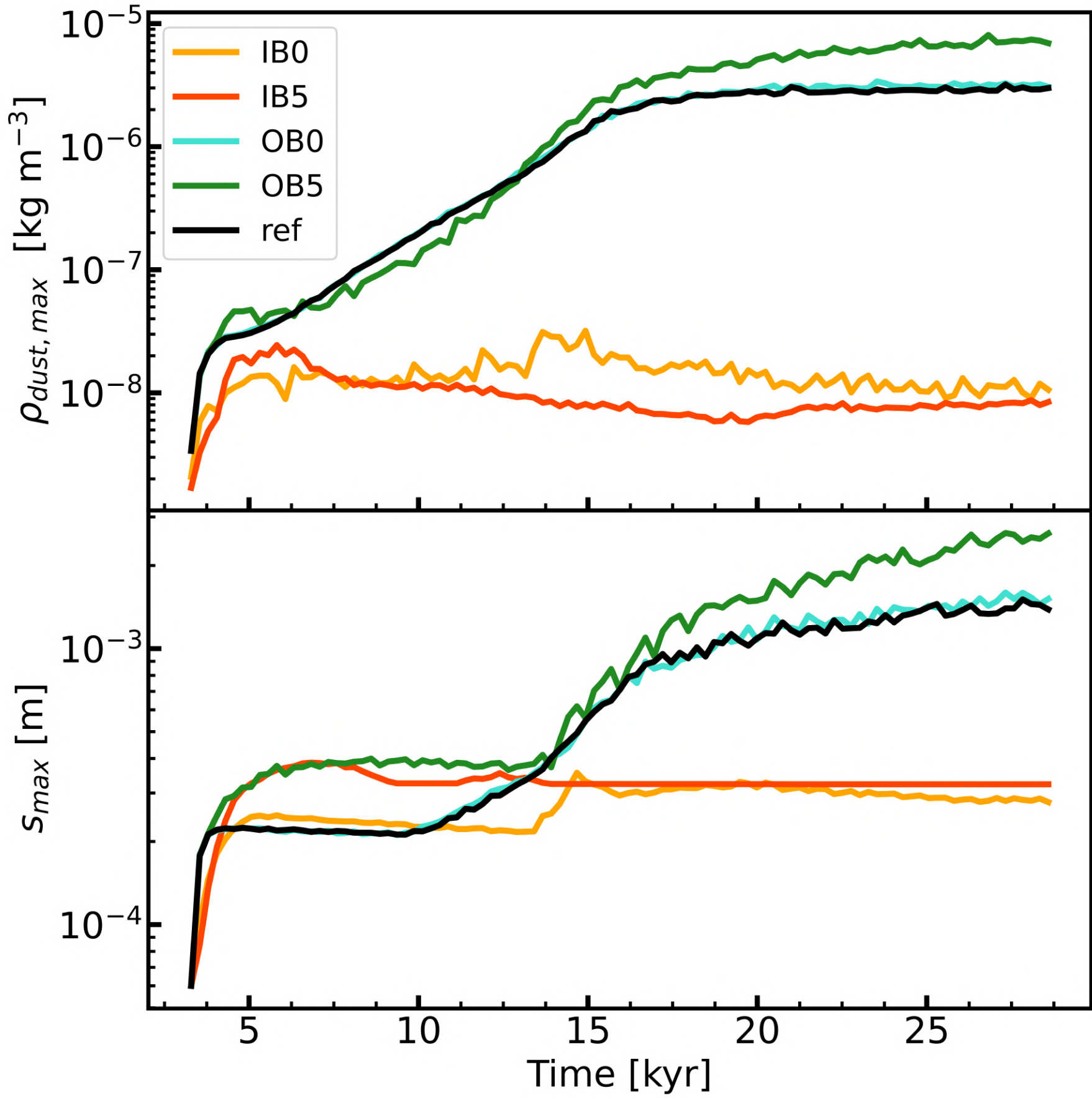
Where is the disc dense?



Where is the disc dense?



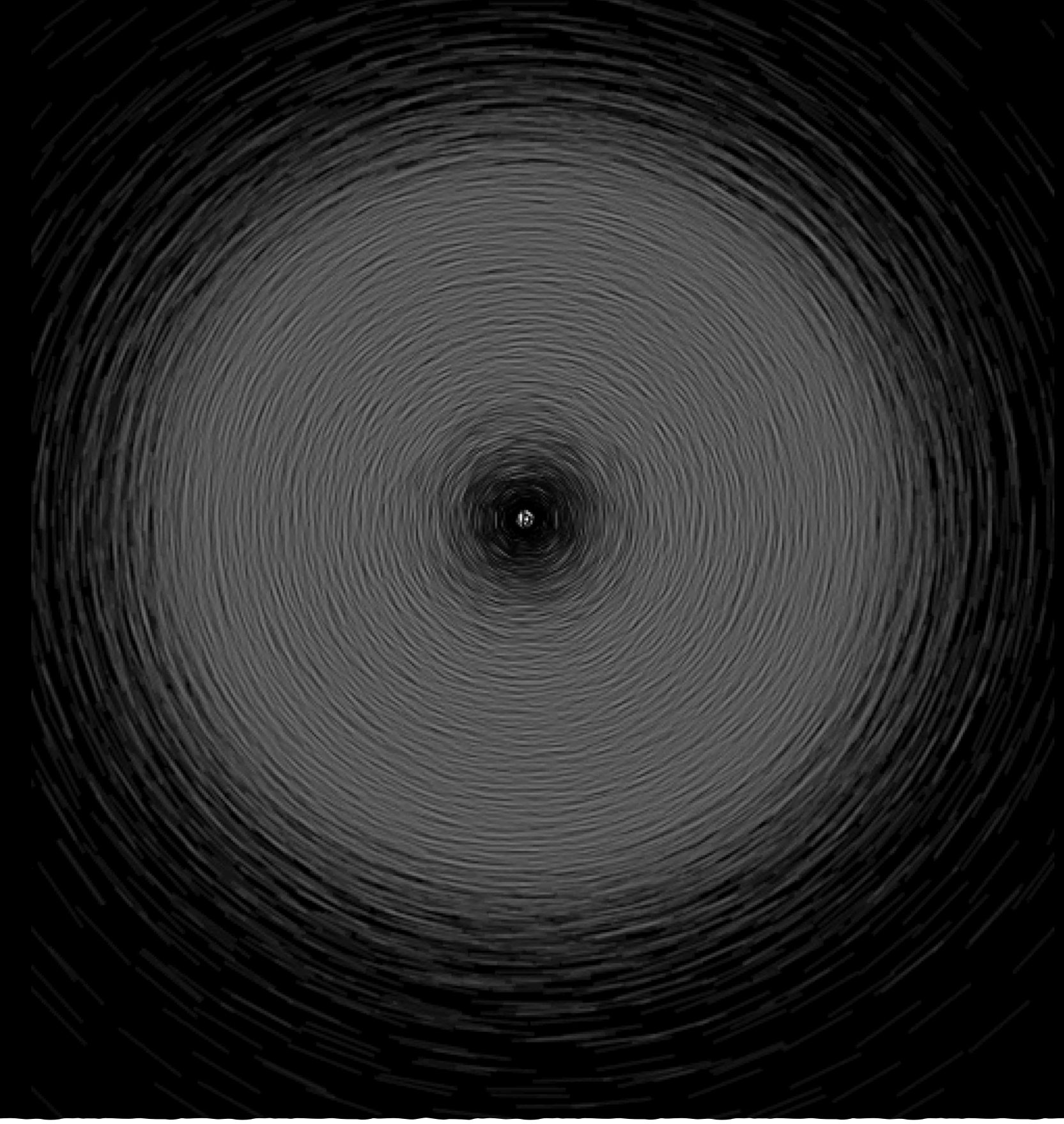
Where is the disc dense?



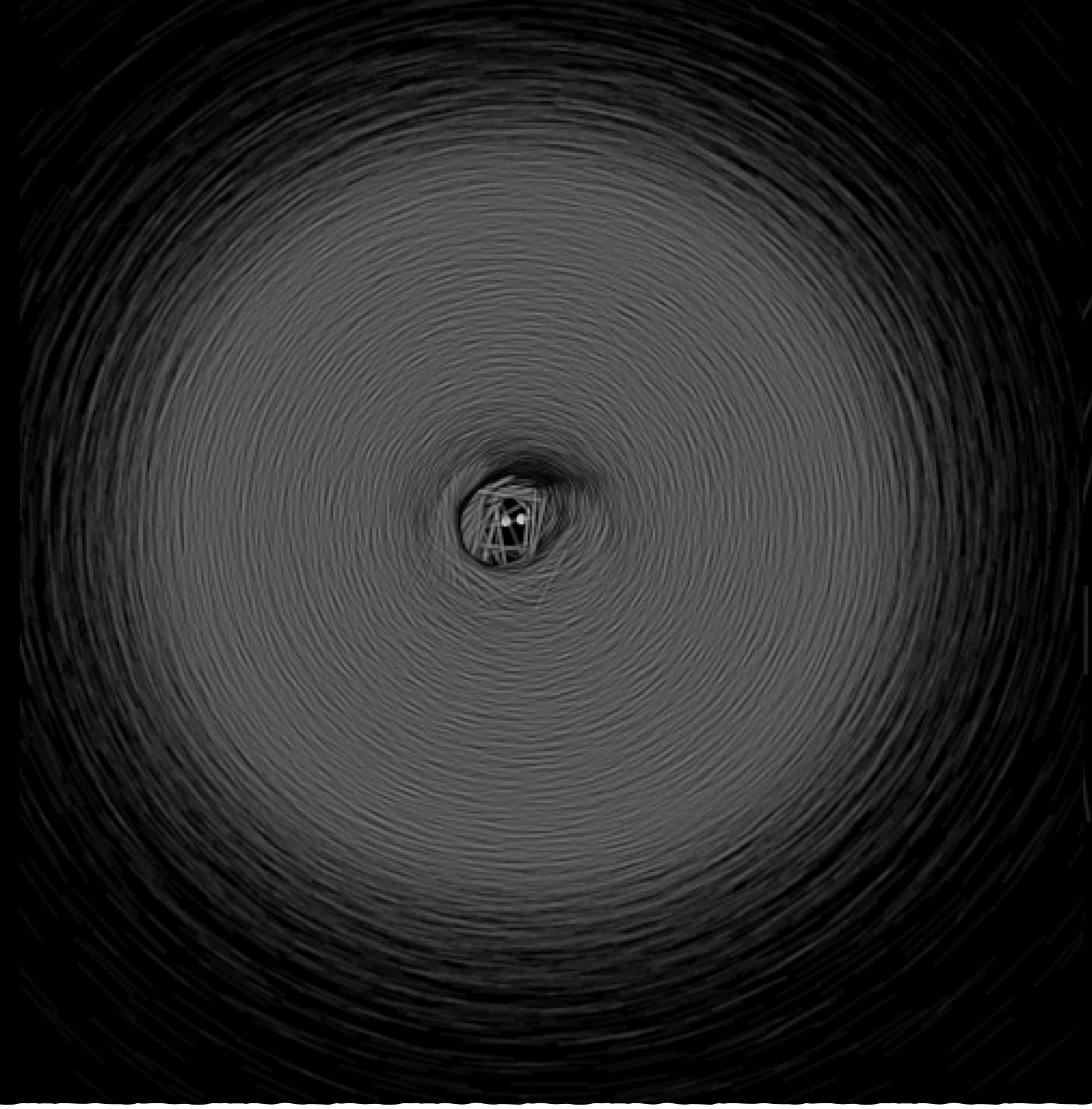
Why collisions and large-scale motions are important?

crossing trajectories => collisions

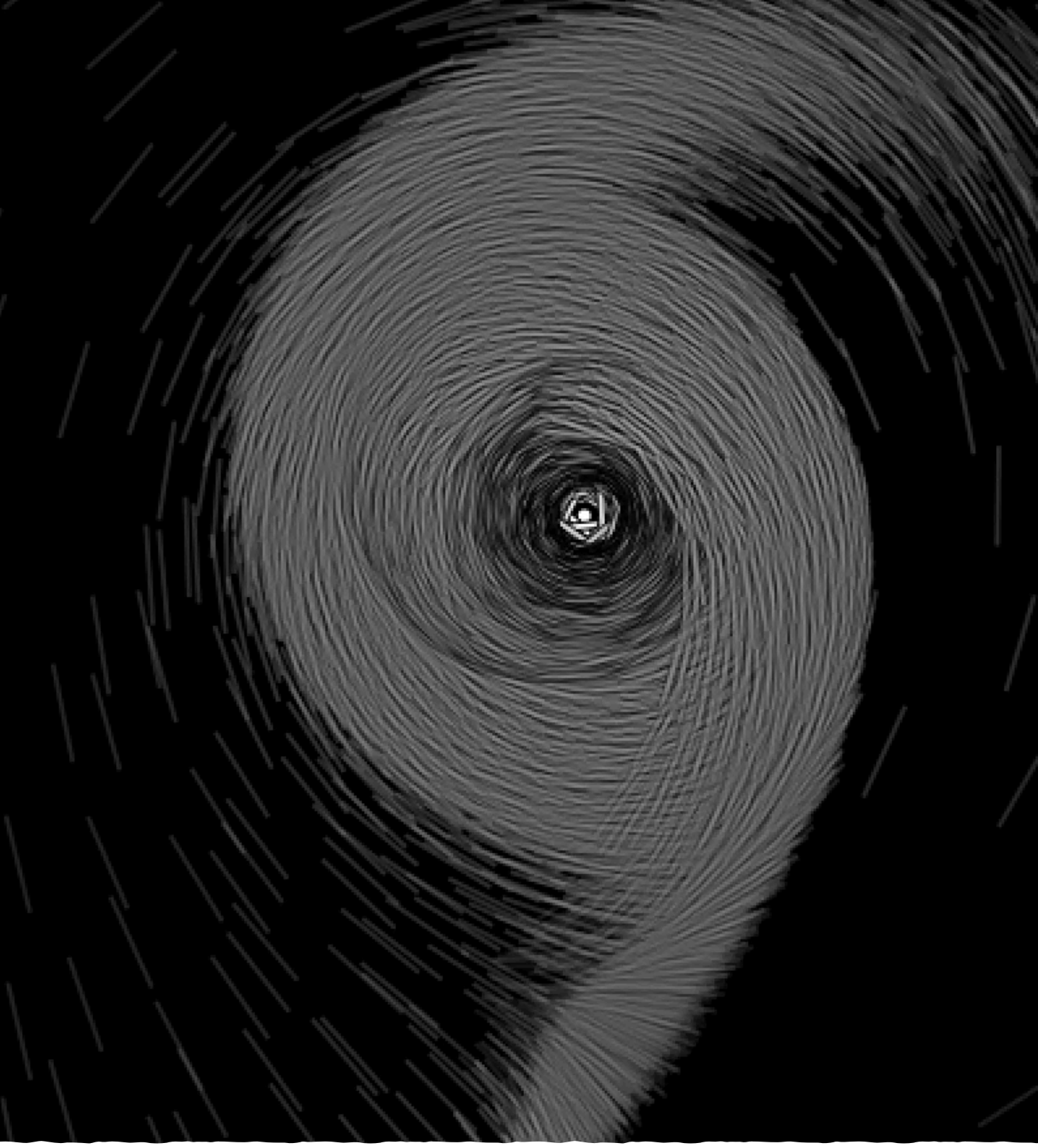
Isolated disc



Circumbinary disc

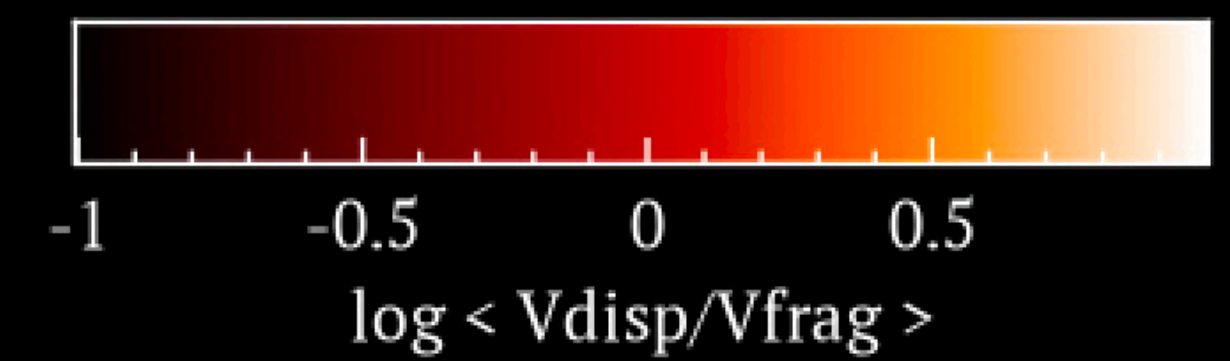
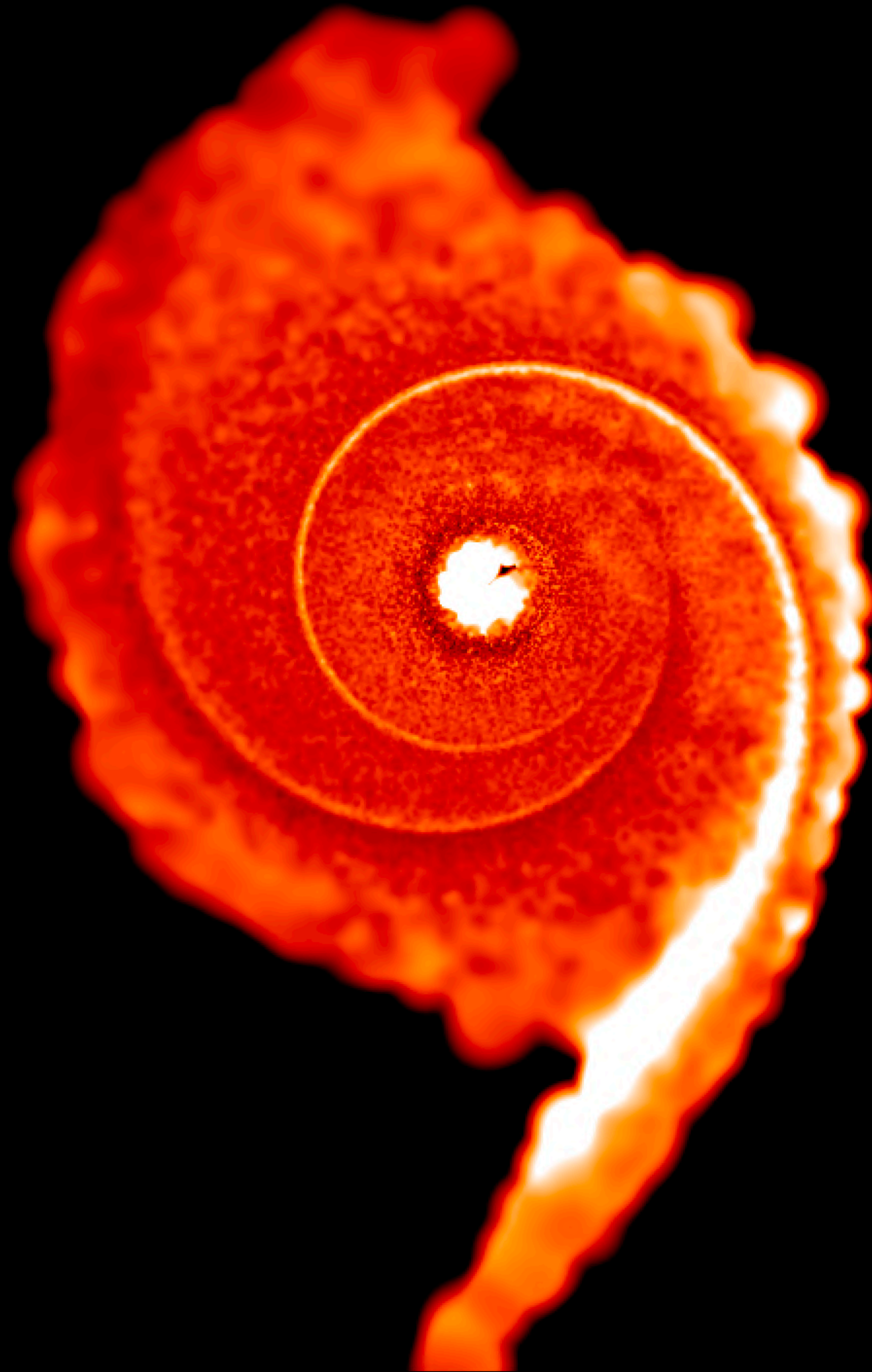
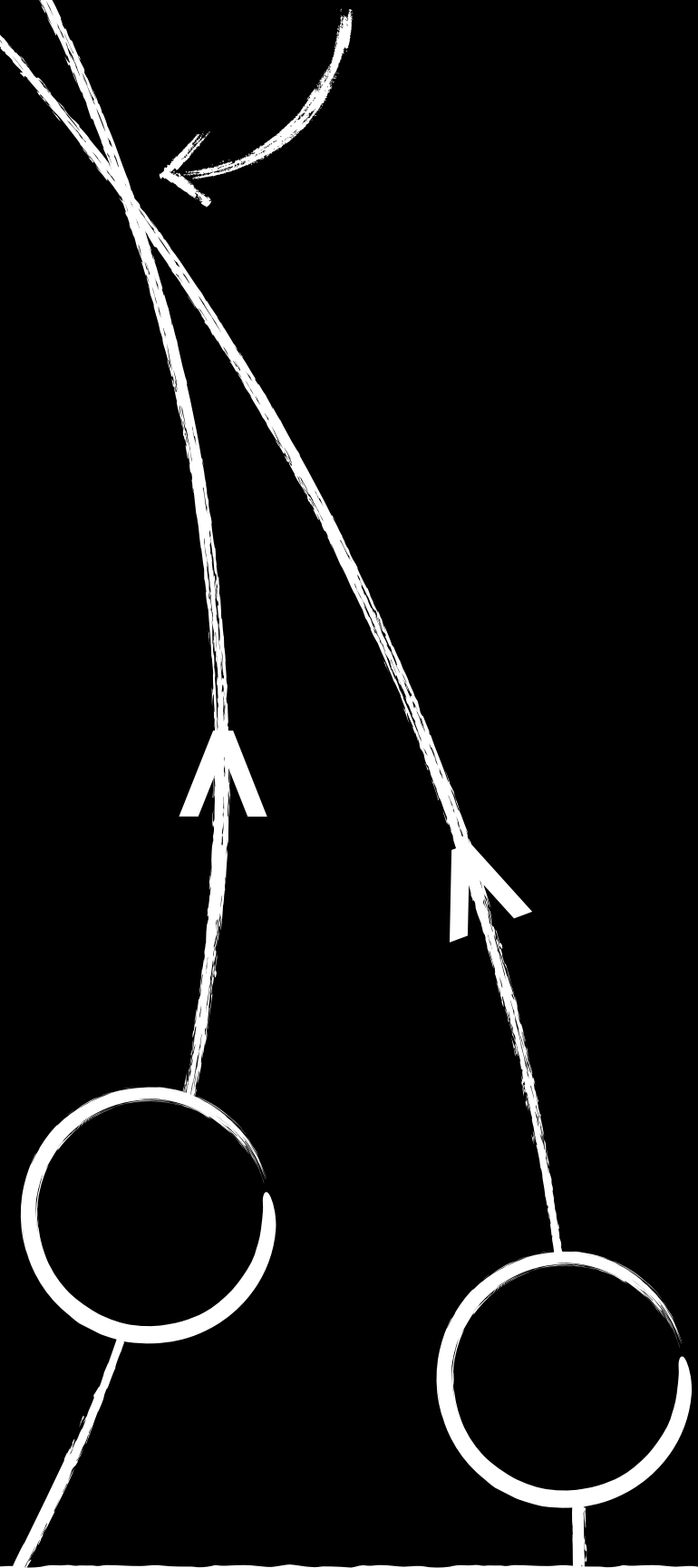


Circumstellar disc in a binary

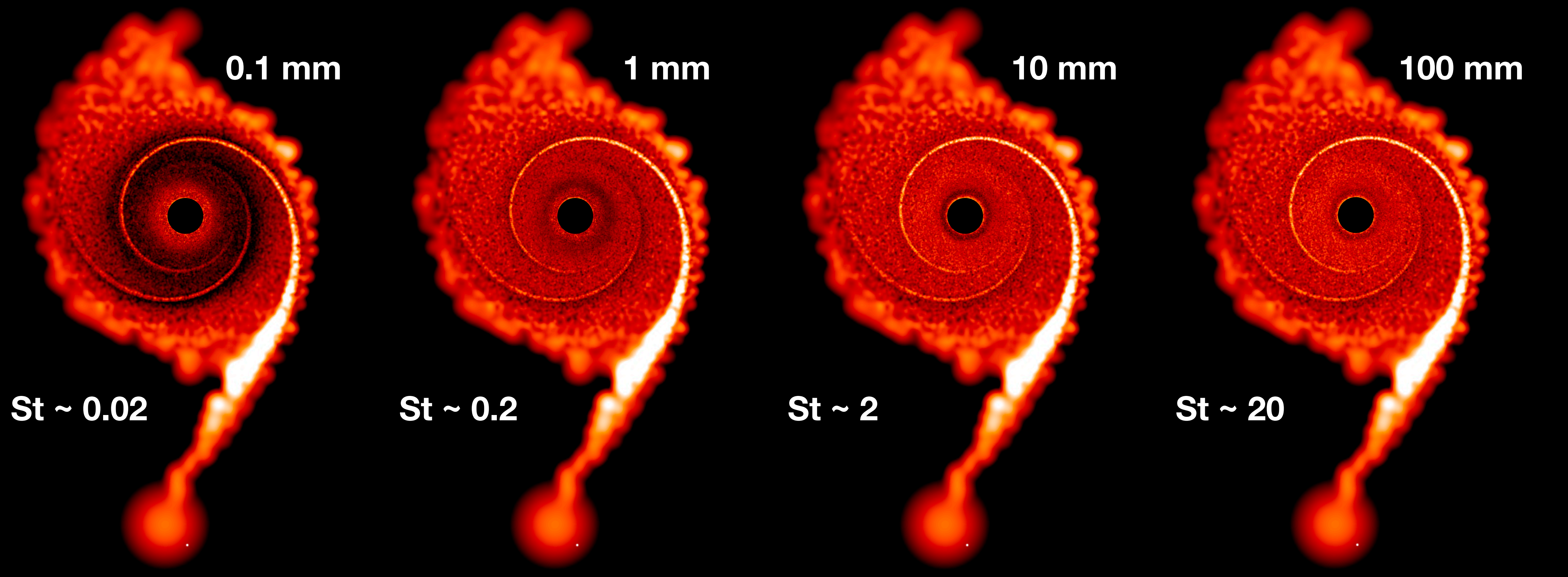
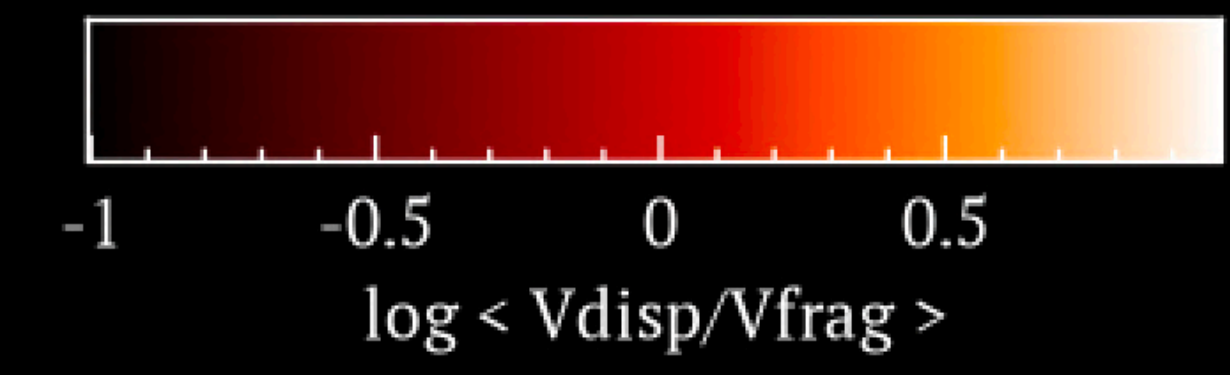
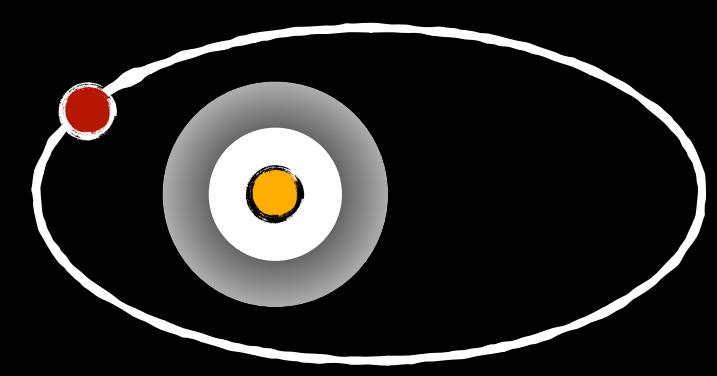


Collisional motions

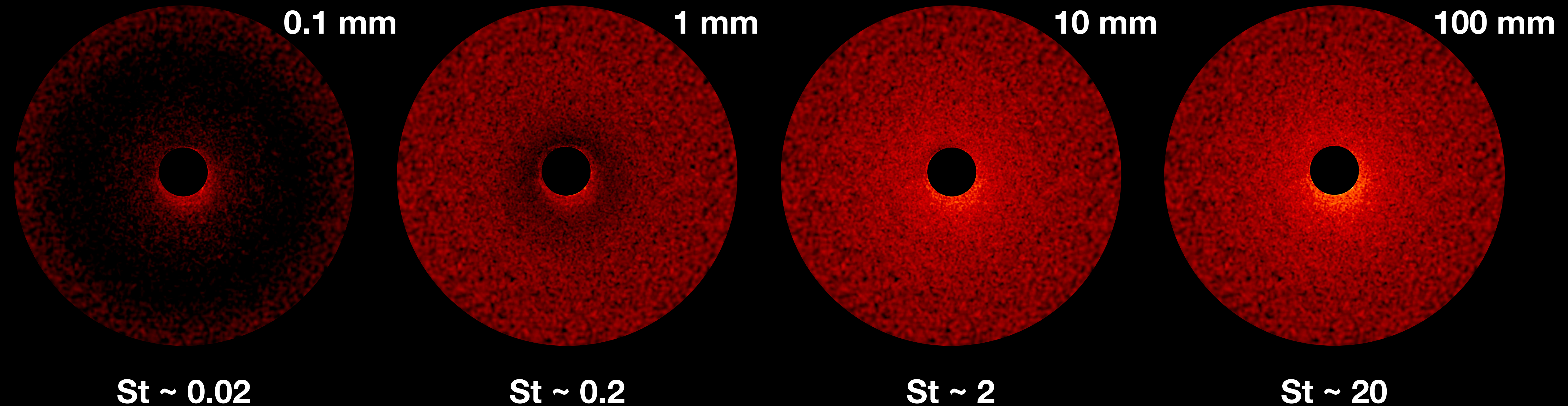
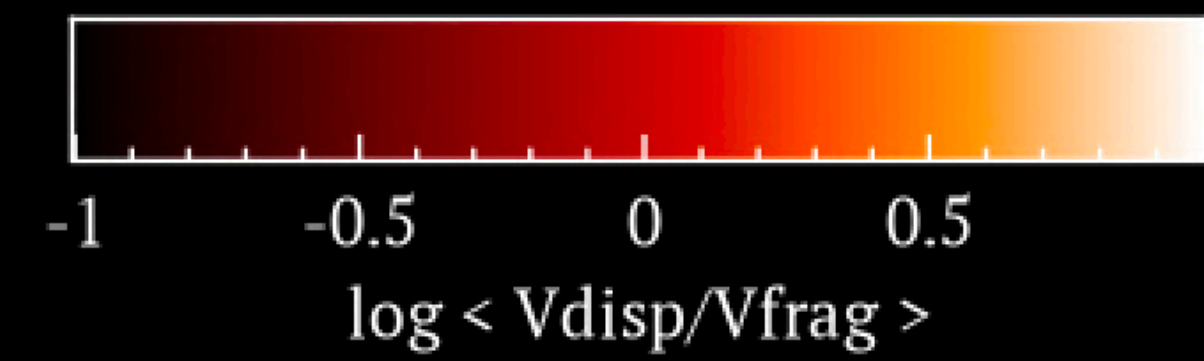
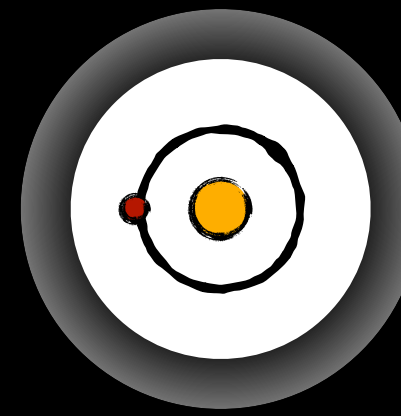
get the collisional speed at the impact point

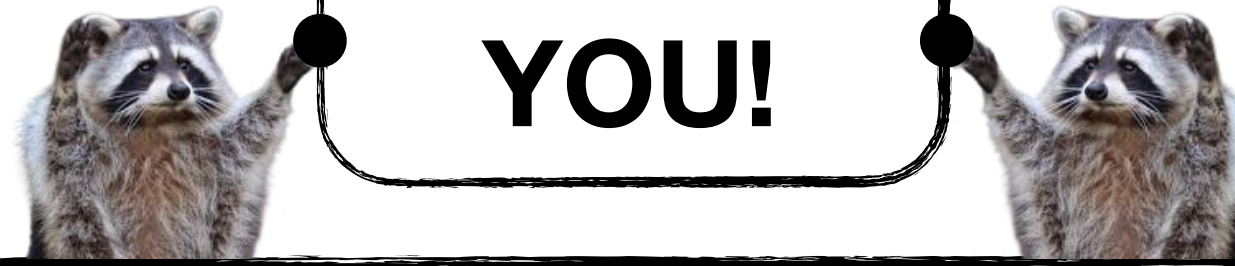


Dependence on grain size



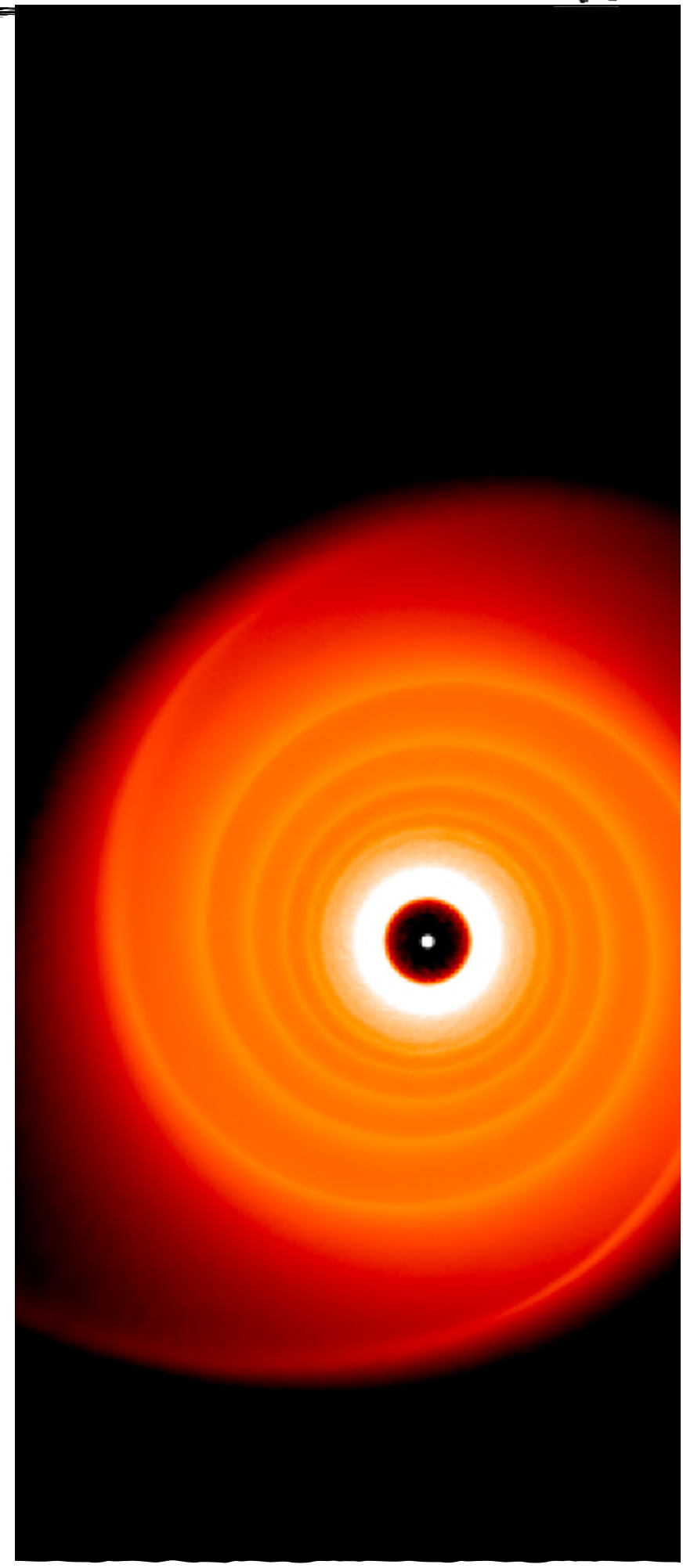
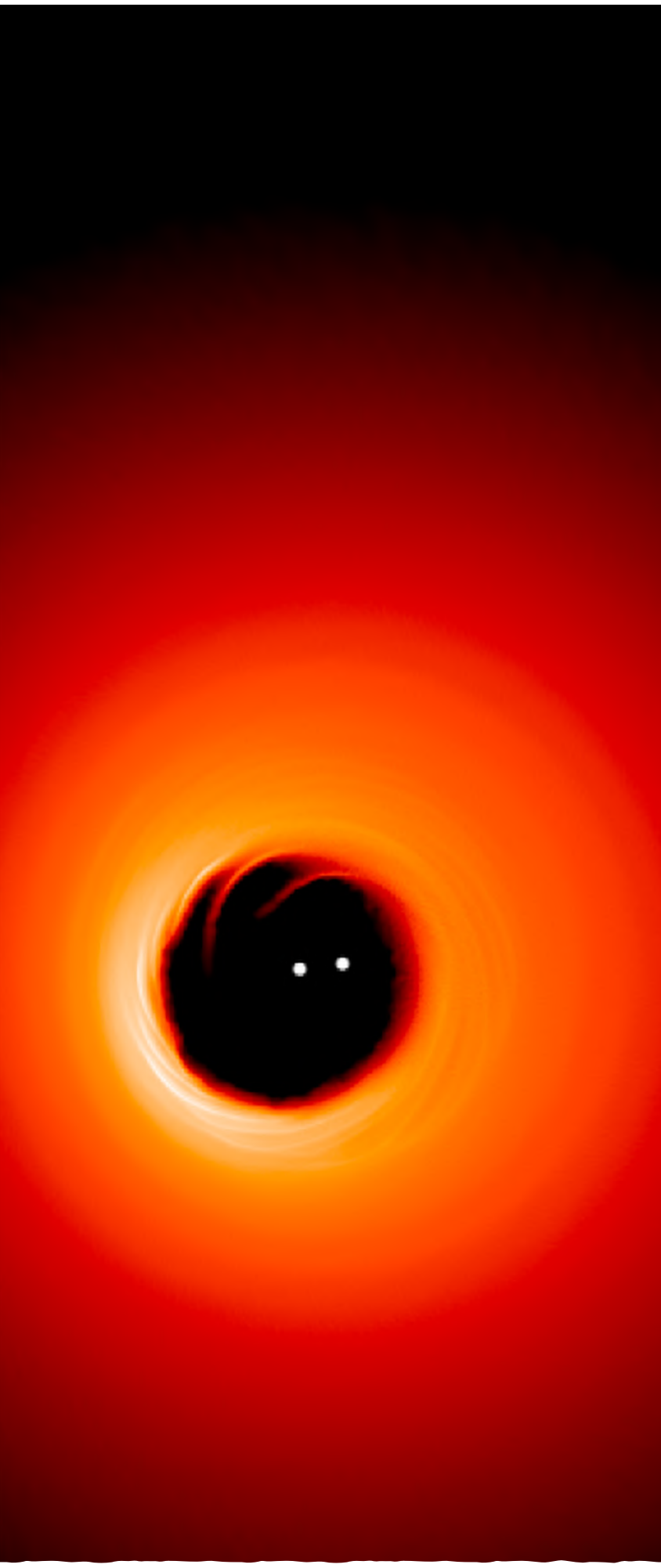
Dependence on grain size





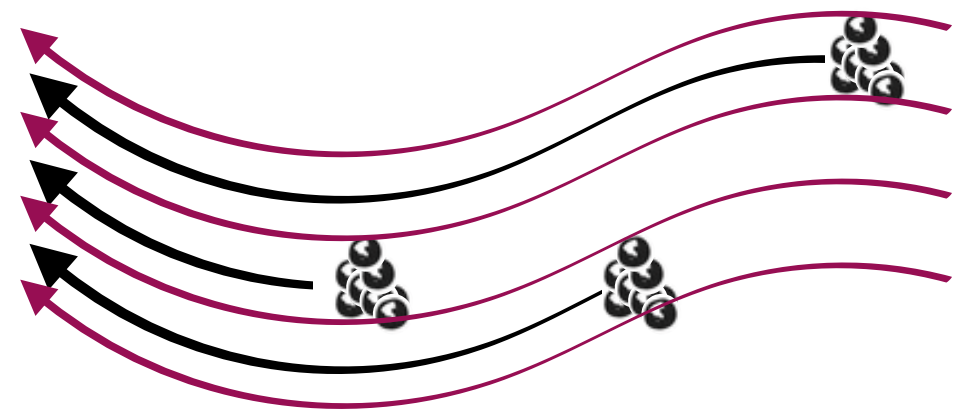
TAKE-AWAY

- ★ **Stellar multiplicity perturbs both the density and kinematics of discs.**
- ★ **Stellar companion does not help to grain growth.**
 - ★ *Then, where can dust growth proceed in discs of multiples?*
- ★ **Large-scale turbulence significantly contributes to collisions between dust grains.**
 - ★ *What is the dust size distribution resulting from these collisions?*

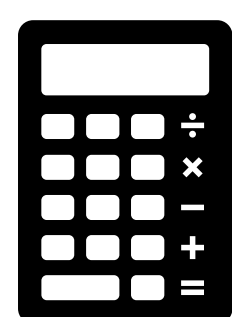


Numerical setup

Price+2018
 Vericel+2021
 Michoulier+2024 + **1 500 000 GAS-DUST PARTICLES**
 + **DUST GROWTH**



$St < 1$
 Small grains
 < mm-cm

 1 population of particles
 (coupled density, 1-fluid)

- + Fast for small particles
- Wrong if $St \gtrsim 1$

$$St = \Omega t_s$$

Dust growth equations

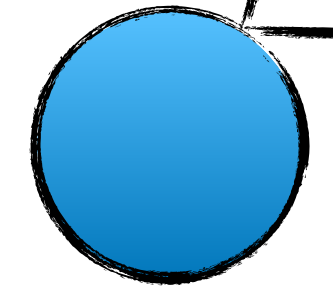
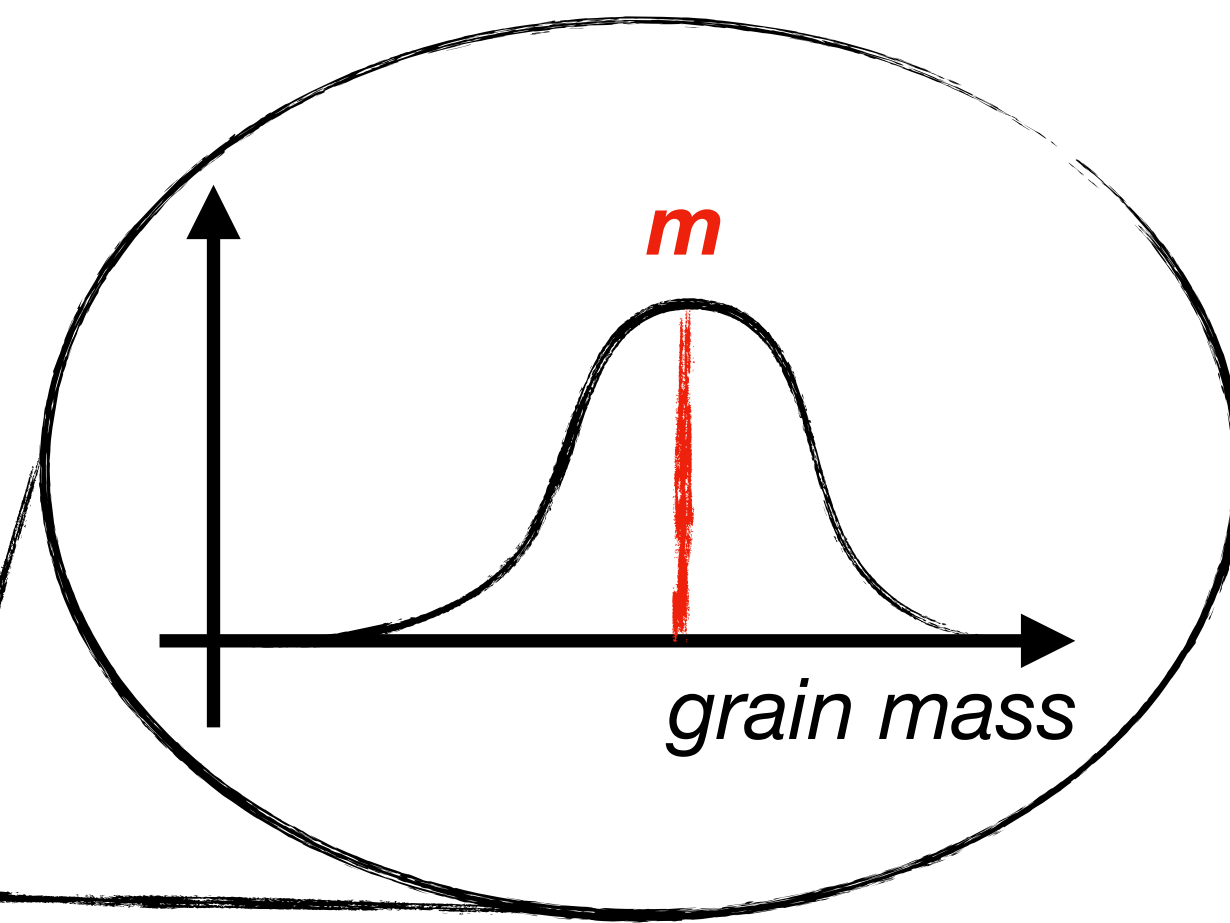
$$V_{rel} = f(v_t, St)$$

VS

$$V_{frag} = 15 \text{ m/s}$$

Stepinski&Valageas 1997
 ↓
 Michoulier+2024

$$\dot{m} = \pm 4\pi s^2 V_{rel} \rho_d \delta$$



SPH particle

Gas turbulence drives collisions

Equal-size collisions

No particle-particle collisions

Dust growth equations



Price+2018

Vericel+2021

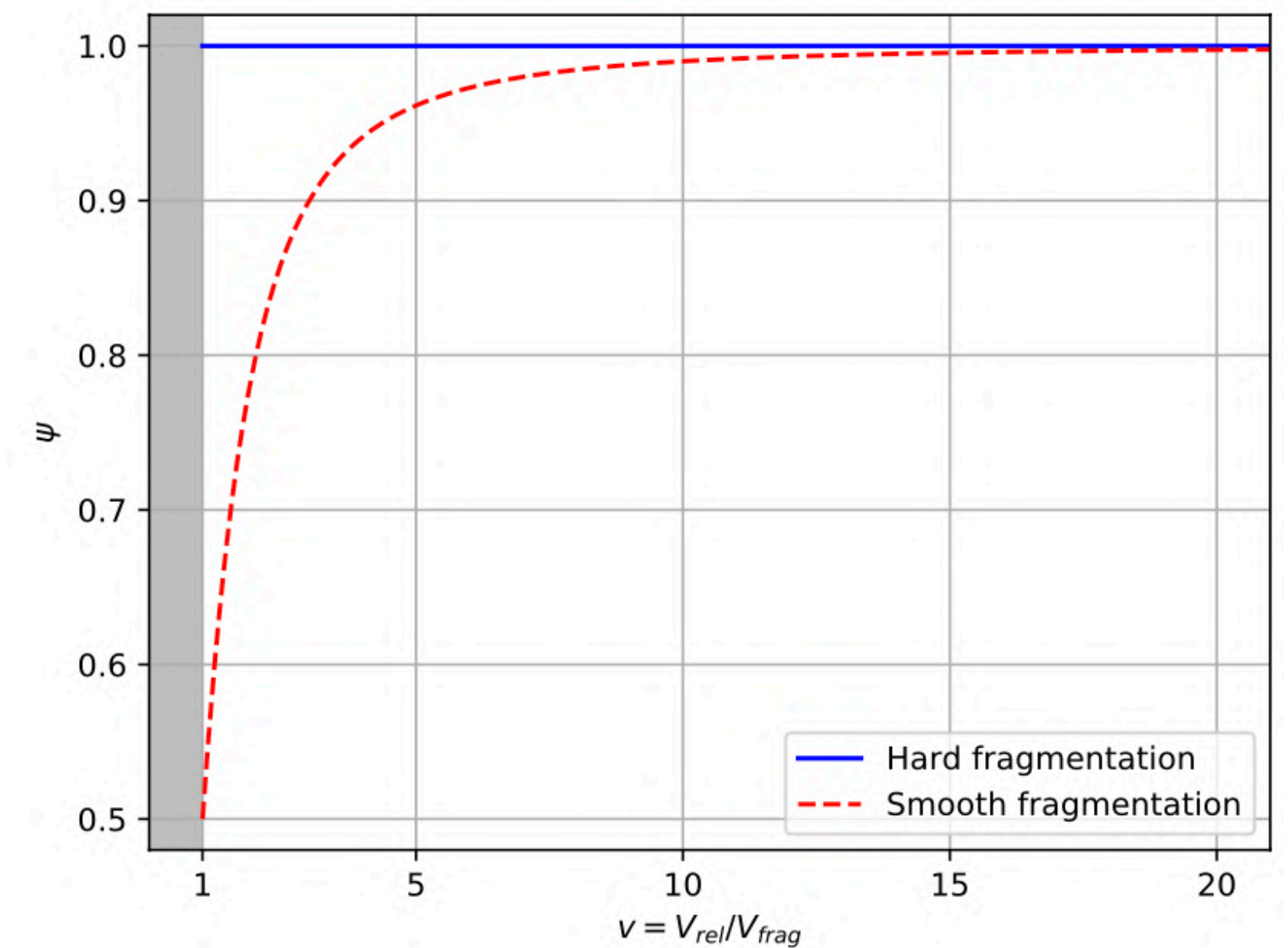
Michoulier+2024

$$St = \Omega t_s$$

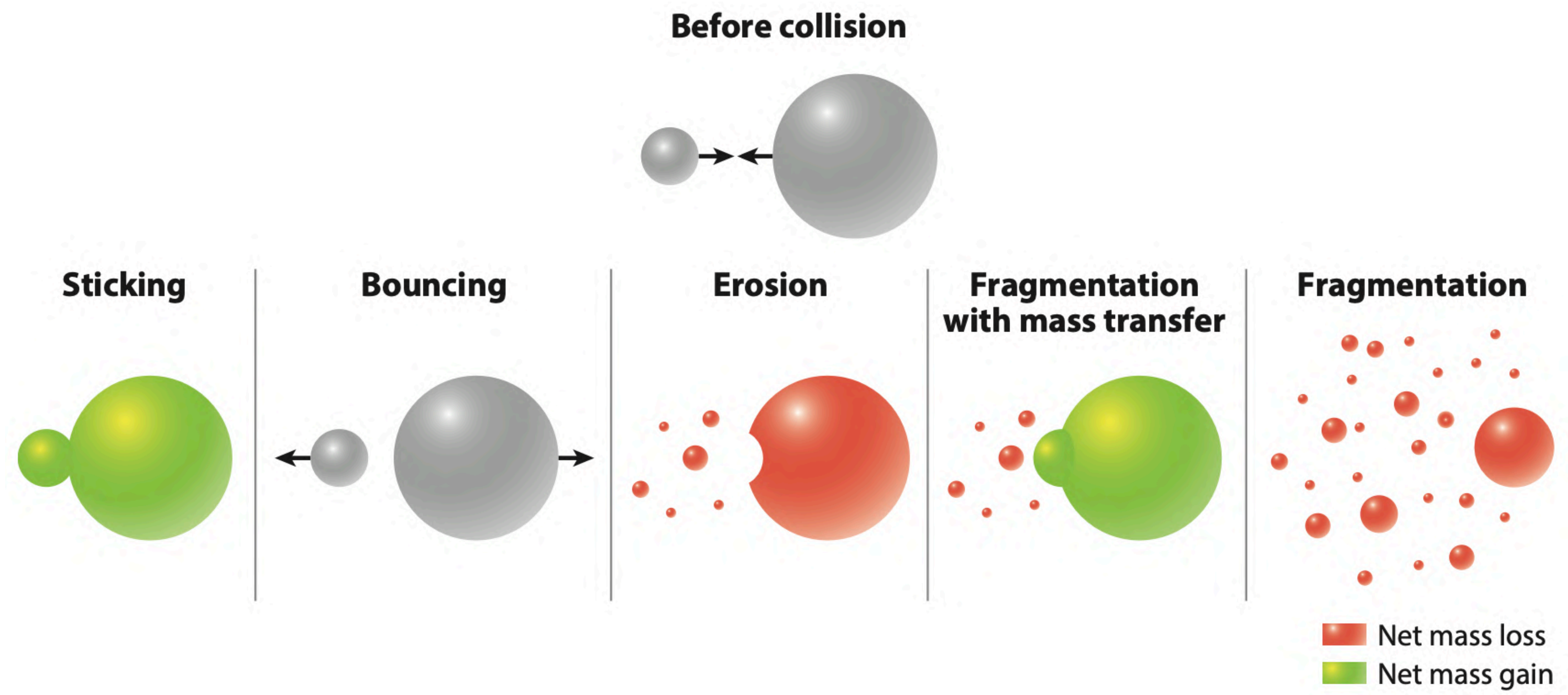
$$Sc = (1 + St) \sqrt{1 + \left(\frac{dv}{v_t}\right)^2} \quad \text{with } dv = t_s \frac{\nabla P}{\rho_g}$$

$$V_{rel} = \sqrt{2} v_t \sqrt{1 - \frac{1}{Sc}} \quad \text{with } v_t = c_s \sqrt{8R_o \alpha_{SS}}$$

$$\dot{m} = \pm 4\pi s^2 \rho_d V_{rel} \delta \quad \text{with } \delta = \frac{(V_{rel}/V_{frag})^2}{1 + (V_{rel}/V_{frag})^2}$$



Collision outcomes



Birnstiel+2024

SPH implementation

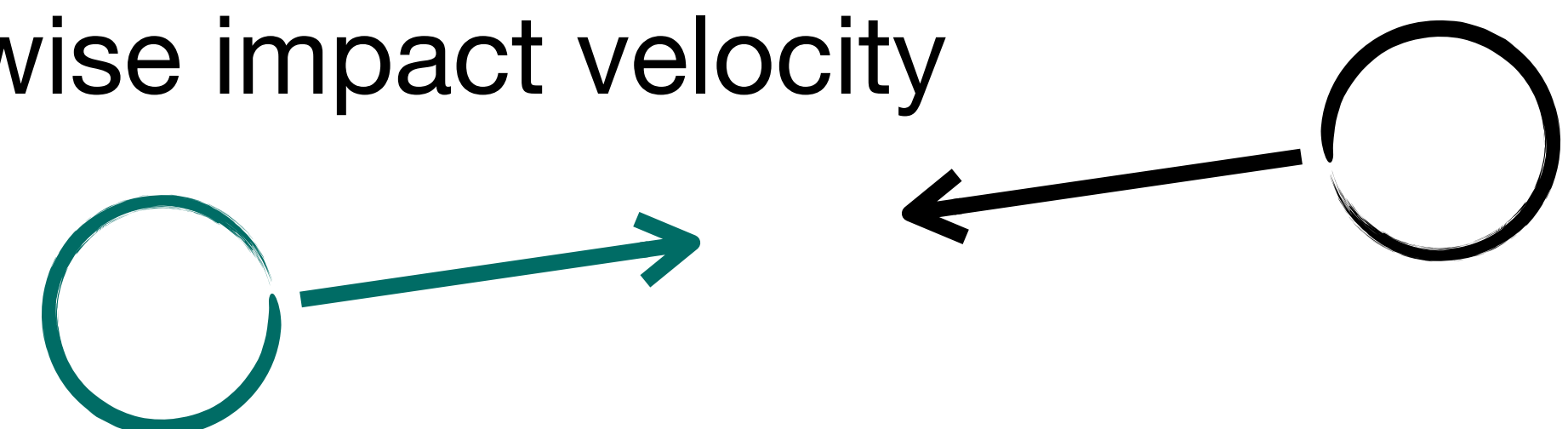
You want to know the impact velocity of



this still is a dust grain (SPH particle)

1. Rule out non-colliding particles

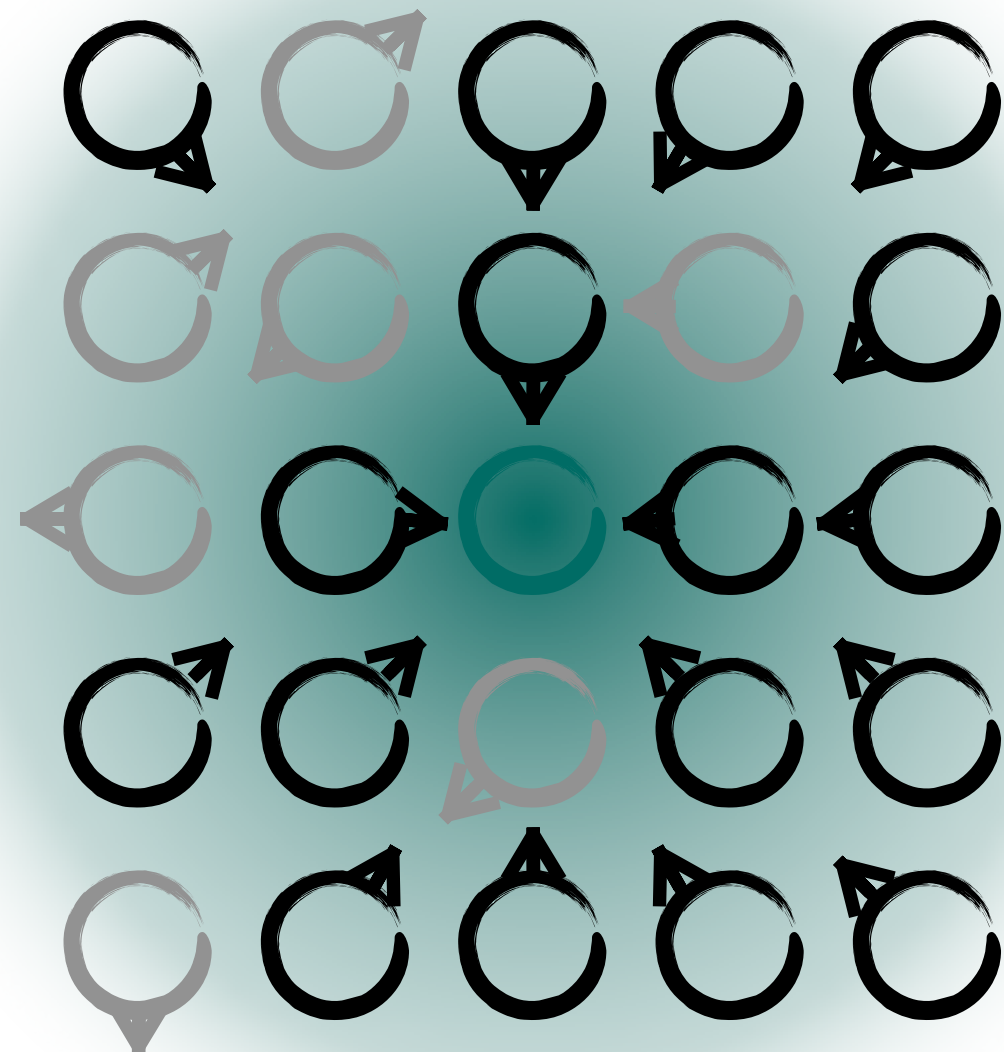
2. Calculate the pair-wise impact velocity at the impact point



Price&Laibe2020

3. Average over the SPH kernel and take the norm

4. Repeat for all the particles

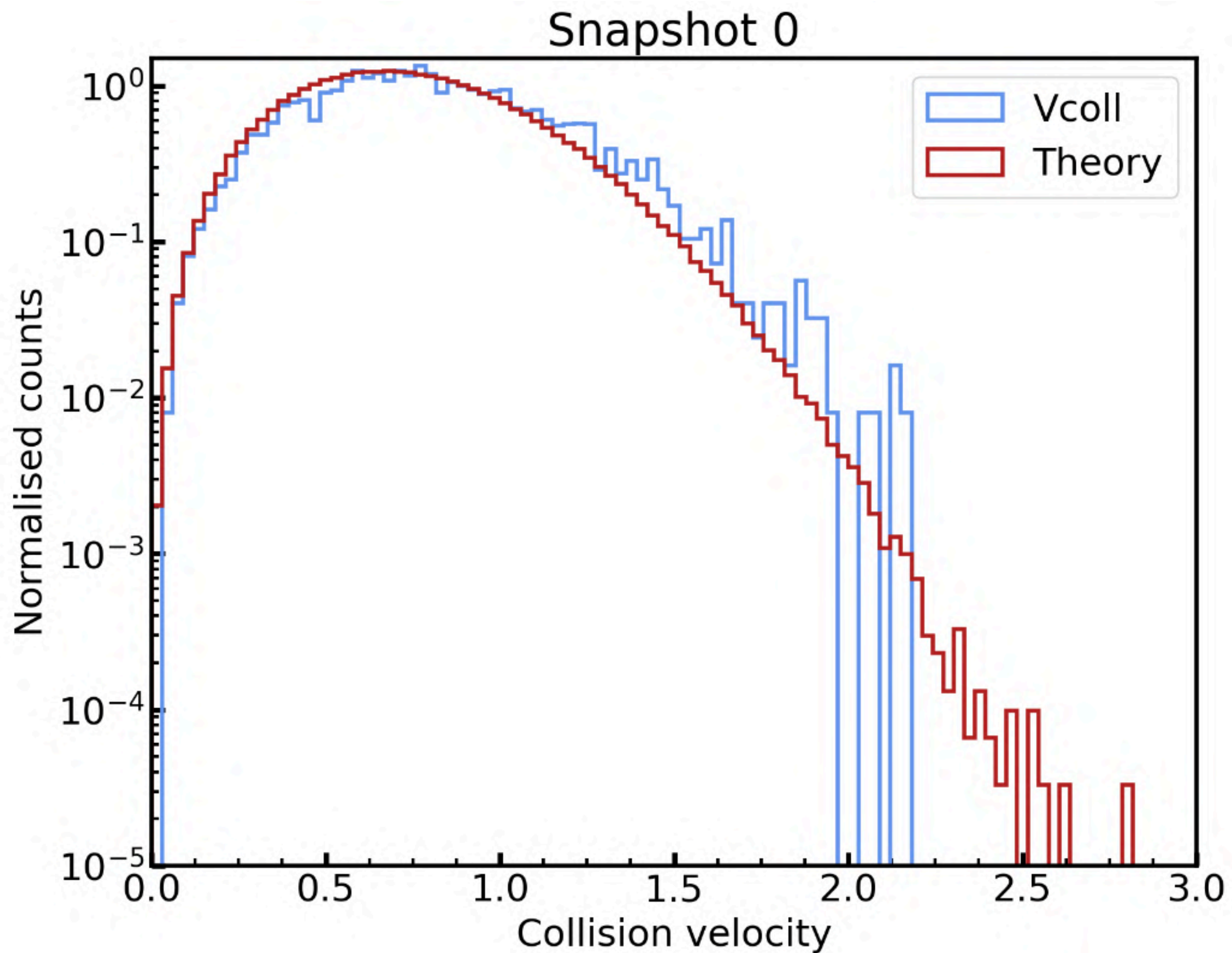
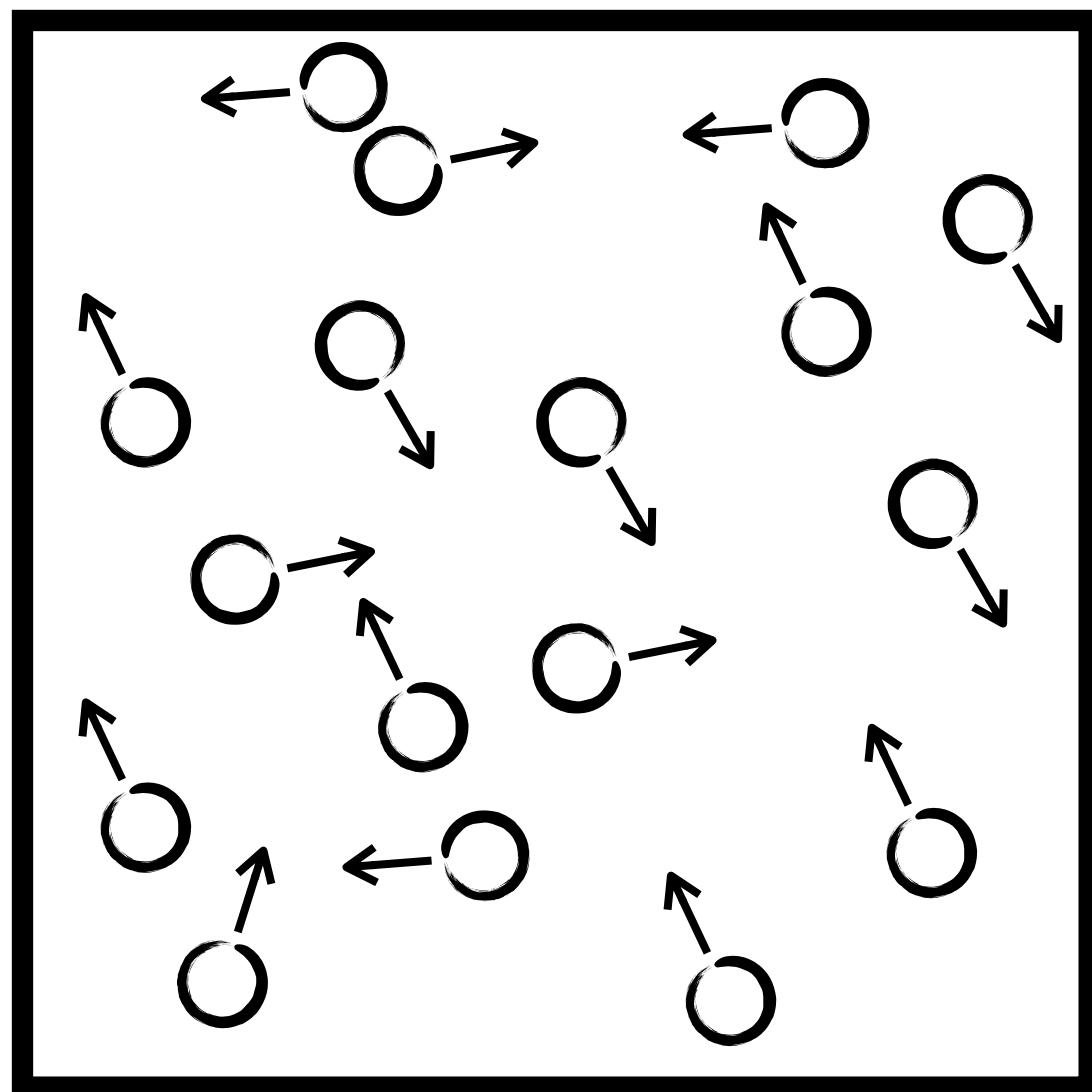


Numerical tests

Gaussian box

Theoretically, $\vec{v}_1 - \vec{v}_2 \rightarrow \mathcal{N}(0,2)^3$
 So:
 Draw N positions in $\mathcal{U}(box)$
 Draw their relative velocity in $\mathcal{N}(0,2)$
 Compute distribution for approaching particles

$\vec{r} \rightarrow \mathcal{U}(box)$
 $\vec{v} \rightarrow \mathcal{N}(0,1)^3$



Numerical tests

Keplerian disc

Theoretically, no crossing trajectories.
So, $V_{rel} = 0$ for all particles.

