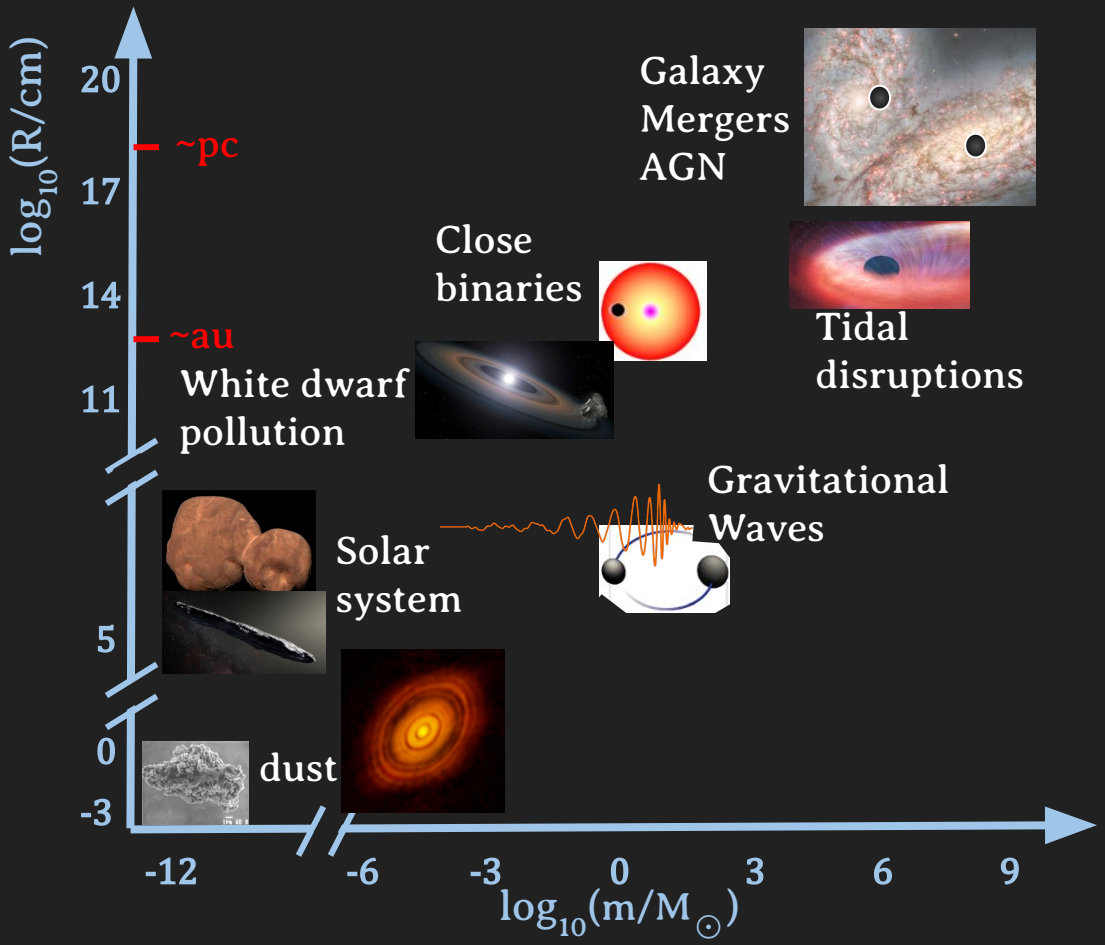
Phantom impostor II

Evgeni Grishin (Monash)

Phantom workshop, 16.02.2023
Melbourne, VIC, Australia

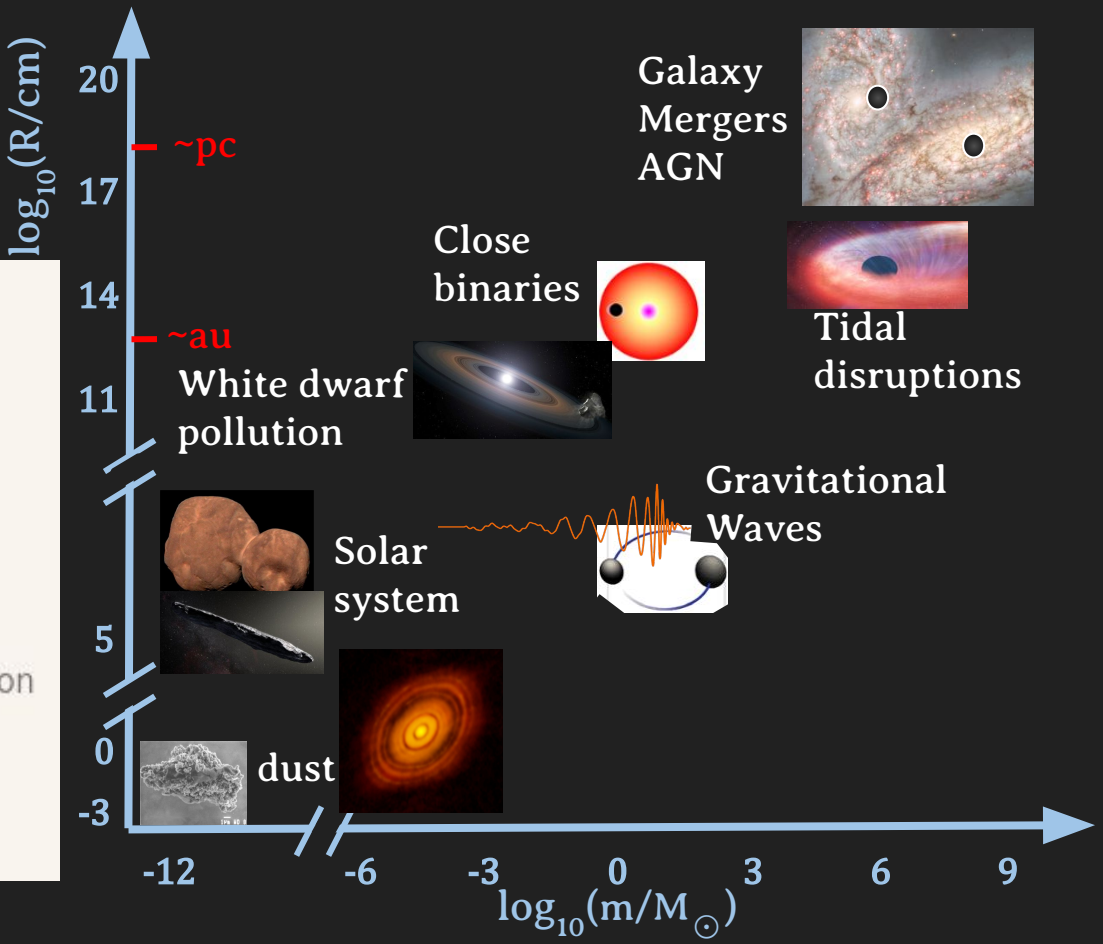
Binary / multiple interactions with gas occur on many scales



Binary / multiple interactions with gas occur on many scales

List of topics

- Protoplanetary discs
- Planet formation
- Star formation
- Stellar flybys
- Black hole accretion
- Common envelope interaction
- Binary and triple stars
- Tidal disruption events
- Software development



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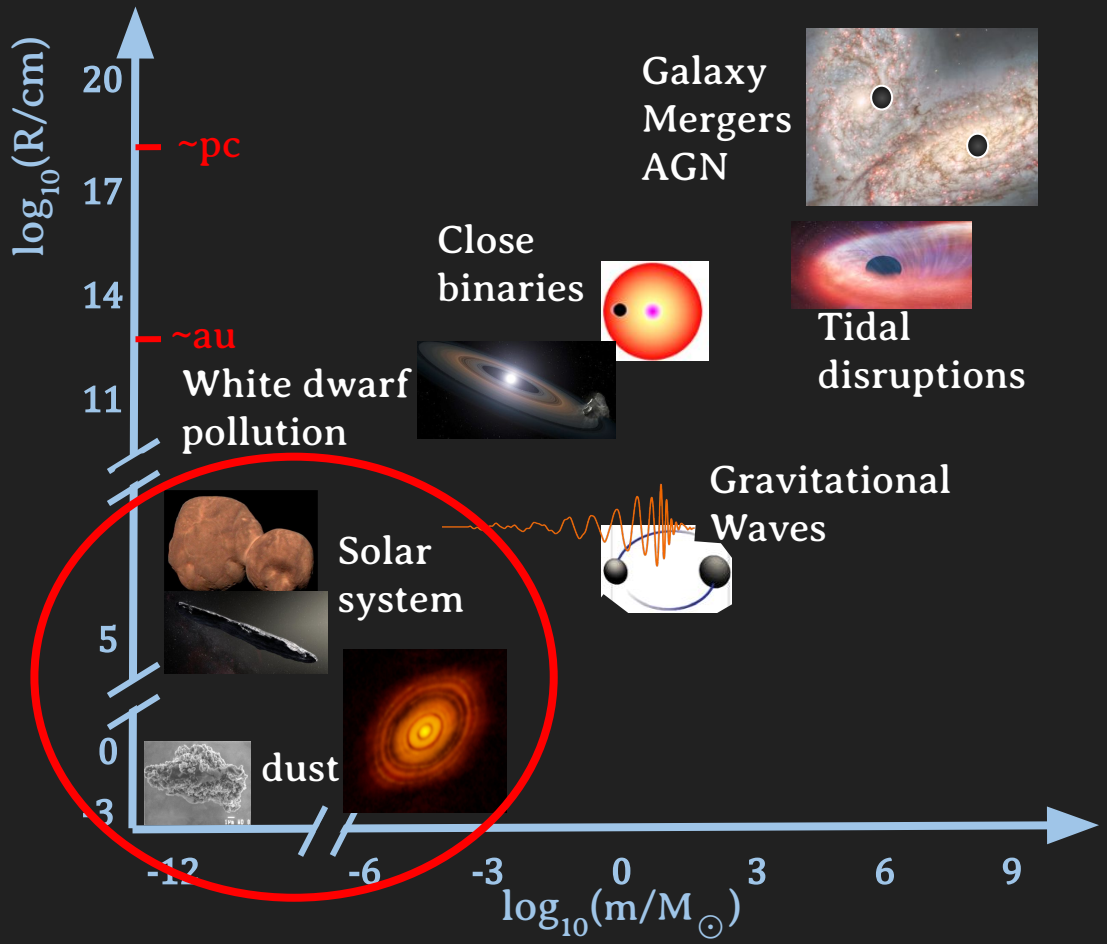
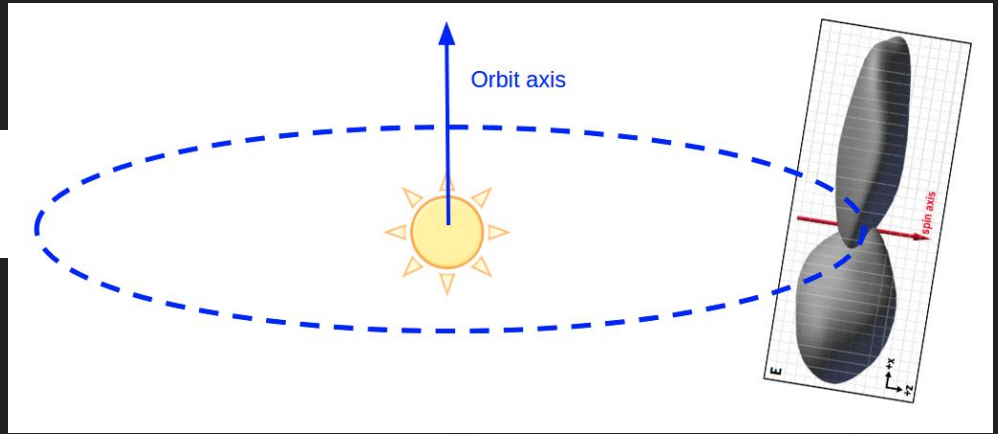


We have used SPH to model a collision between Kuiper Belt Objects (KBOs)

muliphCUDA (Schäfer+2016)

A smooth particle hydrodynamics code to model collisions between solid, self-gravitating objects★

C. Schäfer[1], S. Riecker[1], T. I. Maindl[2], R. Speith[3], S. Scherrer[1], and W. Kley[1]

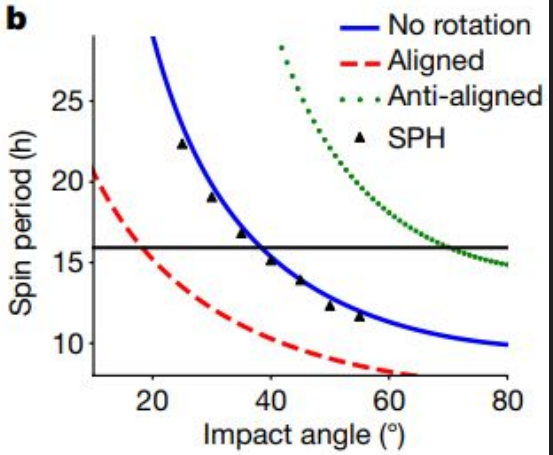


The wide-binary origin of (2014) MU_{69}-like Kuiper belt contact binaries

Evgeni Grishin ✉, Uri Malamud, Hagai B. Perets, Oliver Wandel & Christoph M. Schäfer

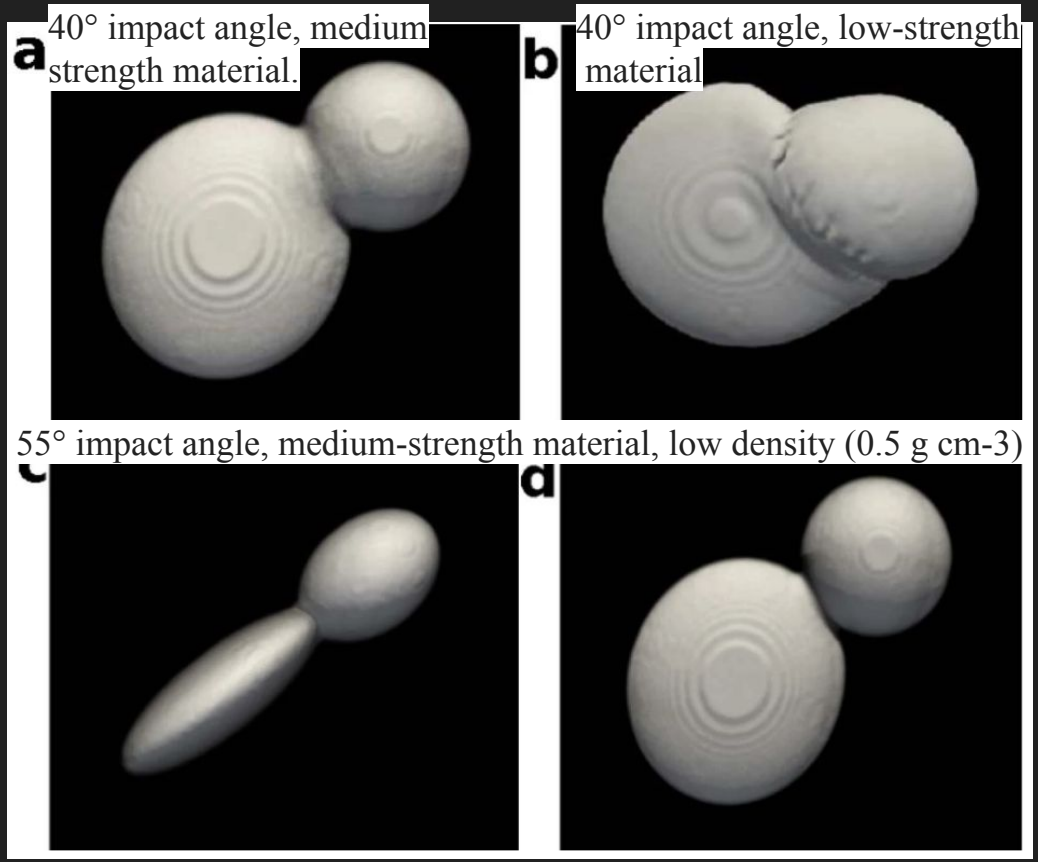
Nature **580**, 463–466 (2020) | Cite this article

Stern+19, Science



Three body dynamics (wide binary + Sun) provide the initial conditions for the SPH simulations

High V impact



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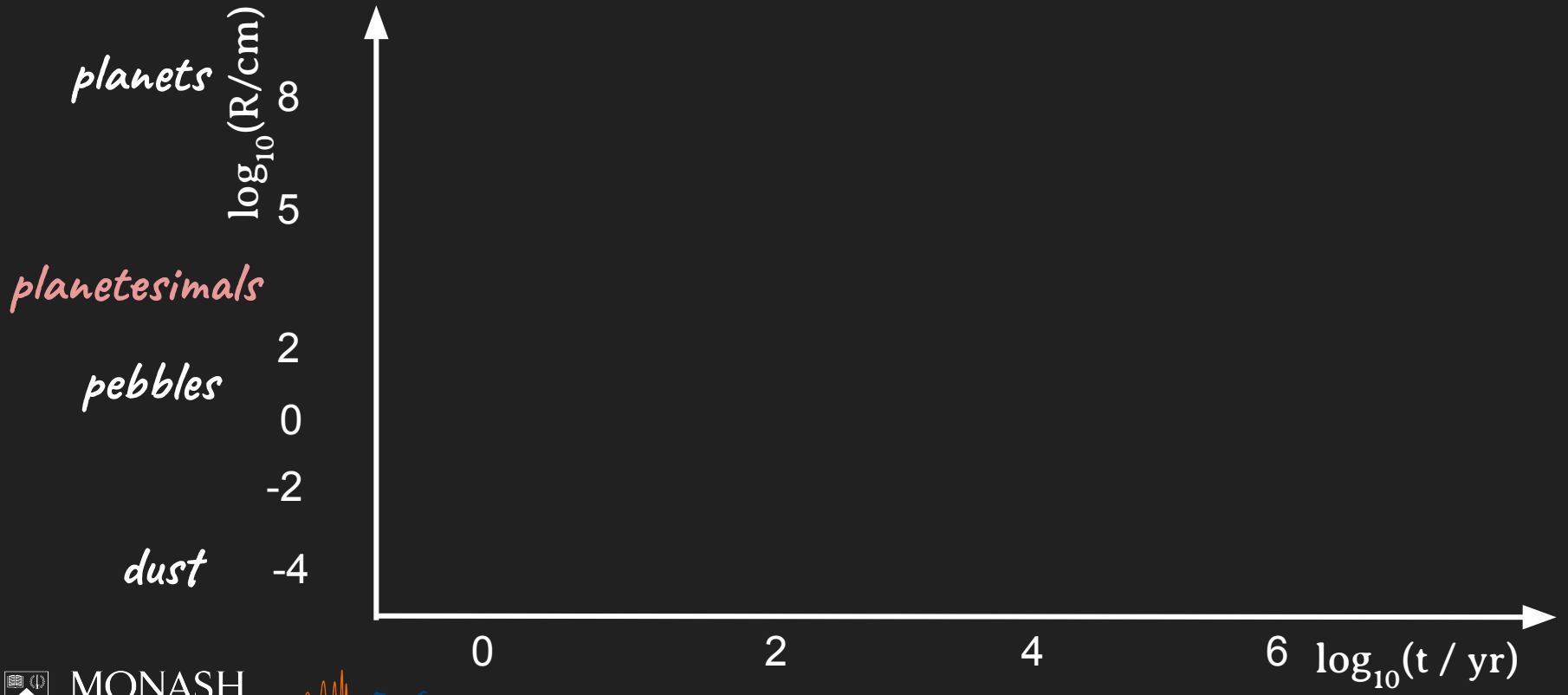
Planet formation relies on successful formation of planetesimals



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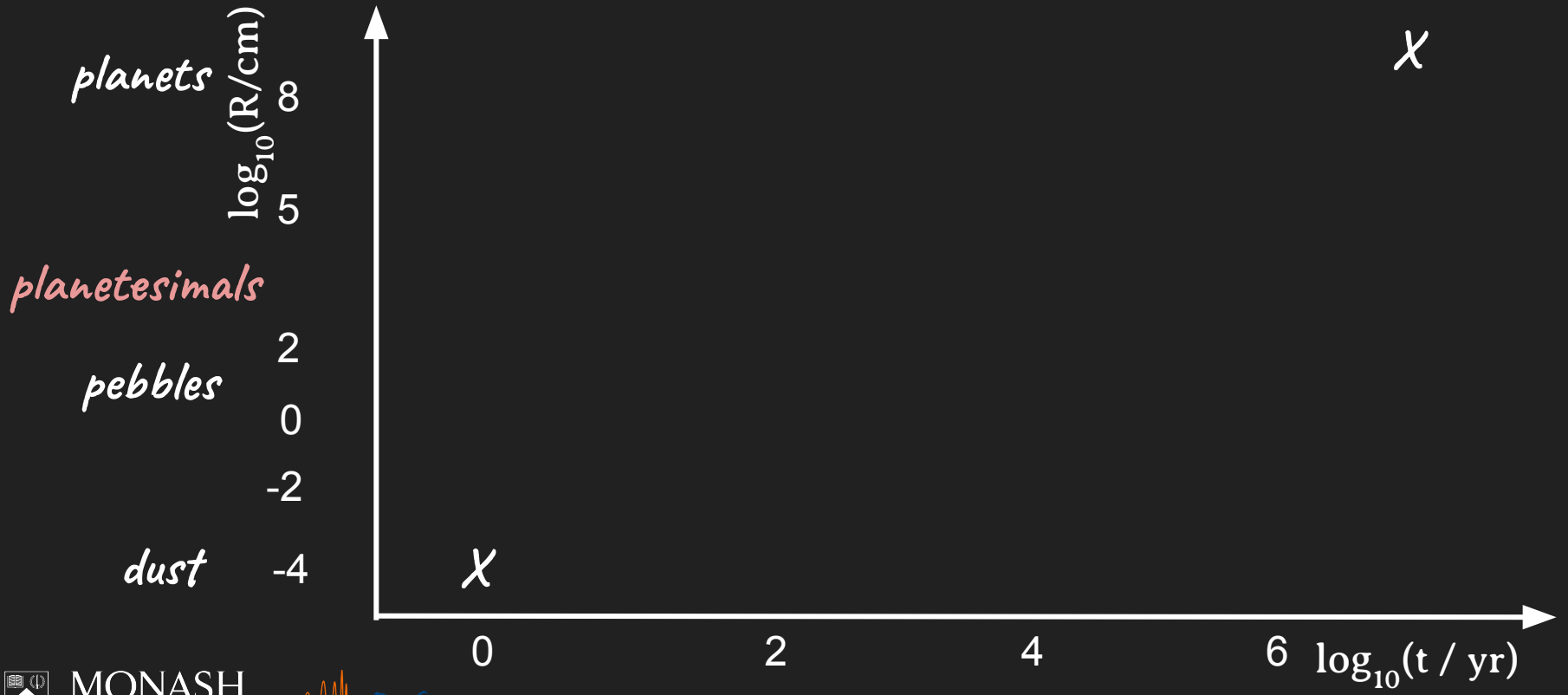

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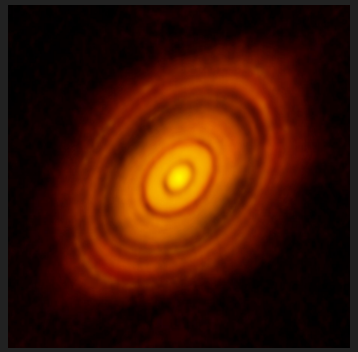
Giant planets could form early



planets

planetesimals

pebbles

dust

$\log_{10}$(R/cm)

8

5

2

0

-2

-4

0

2

4

6

$\log_{10}$(t / yr)

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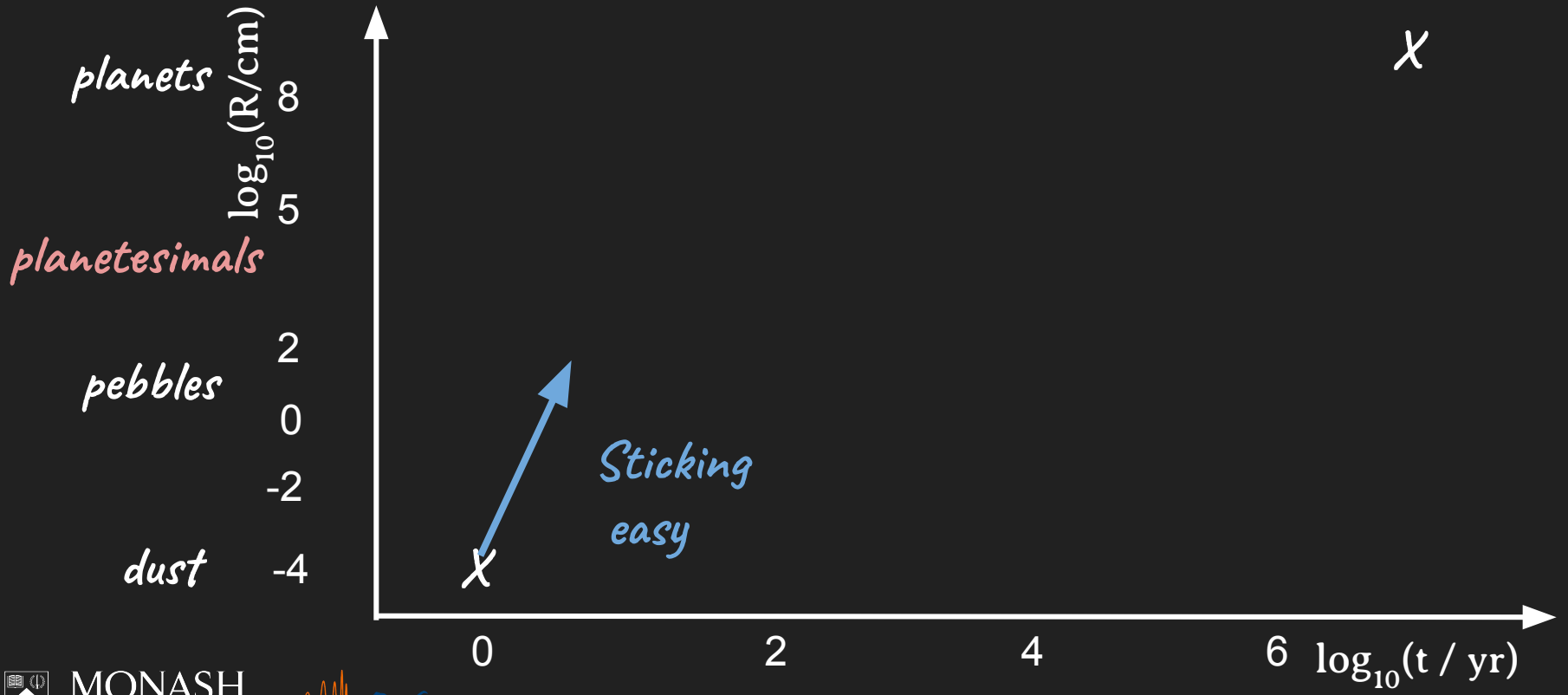

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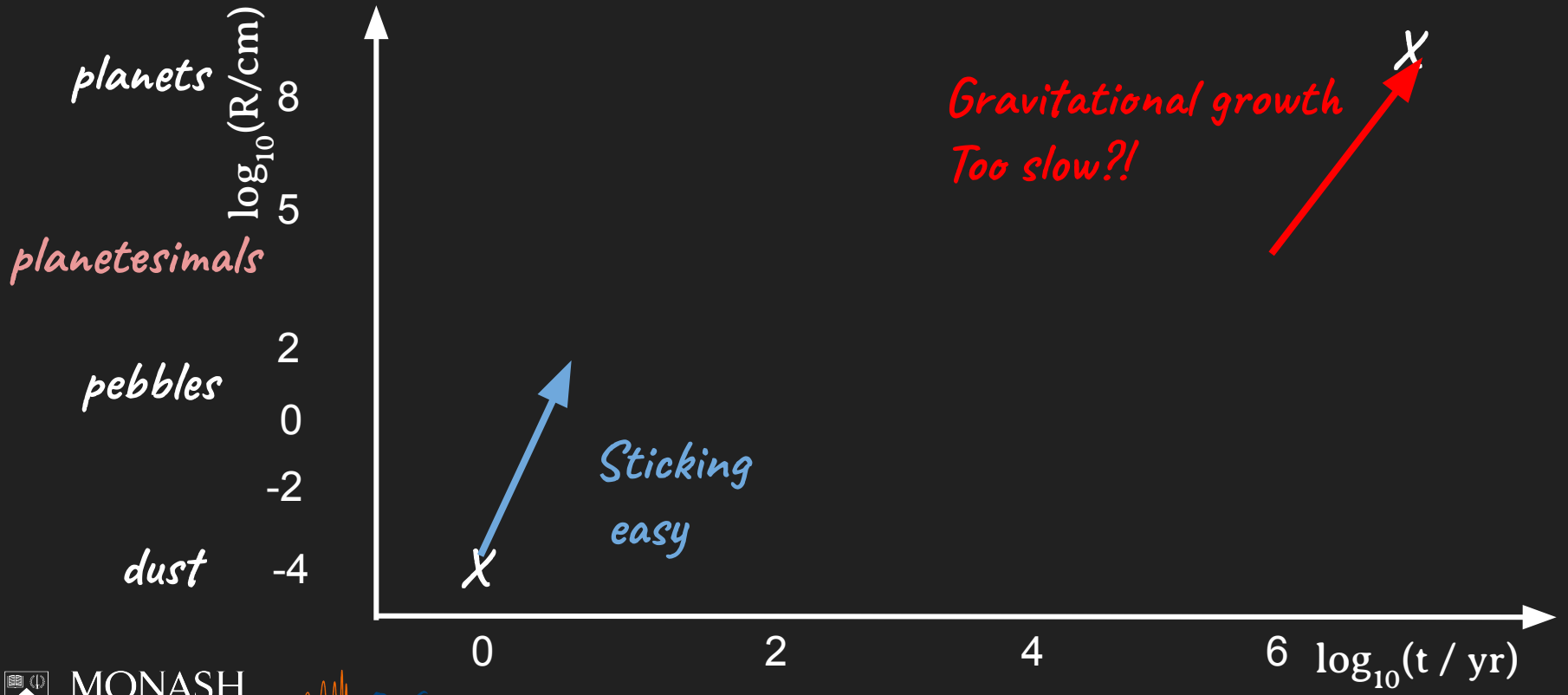

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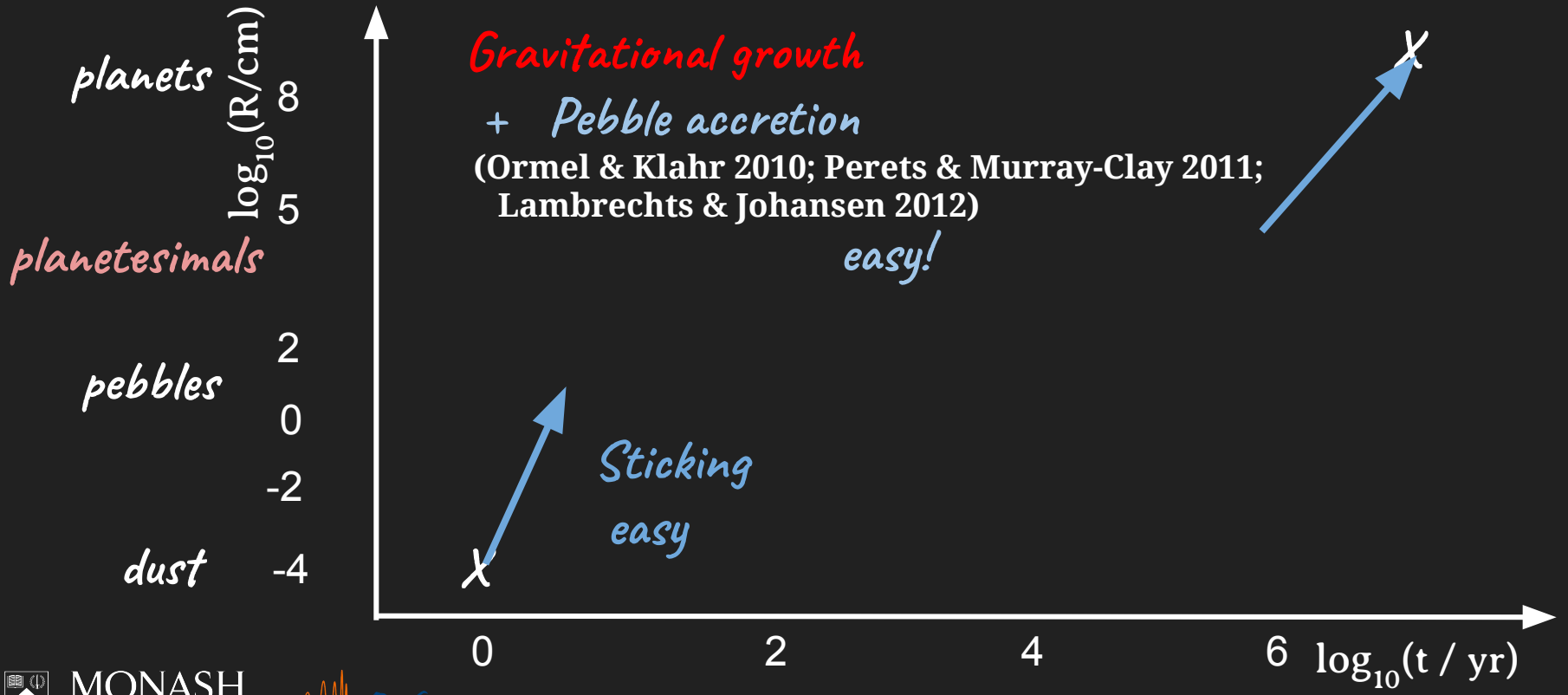

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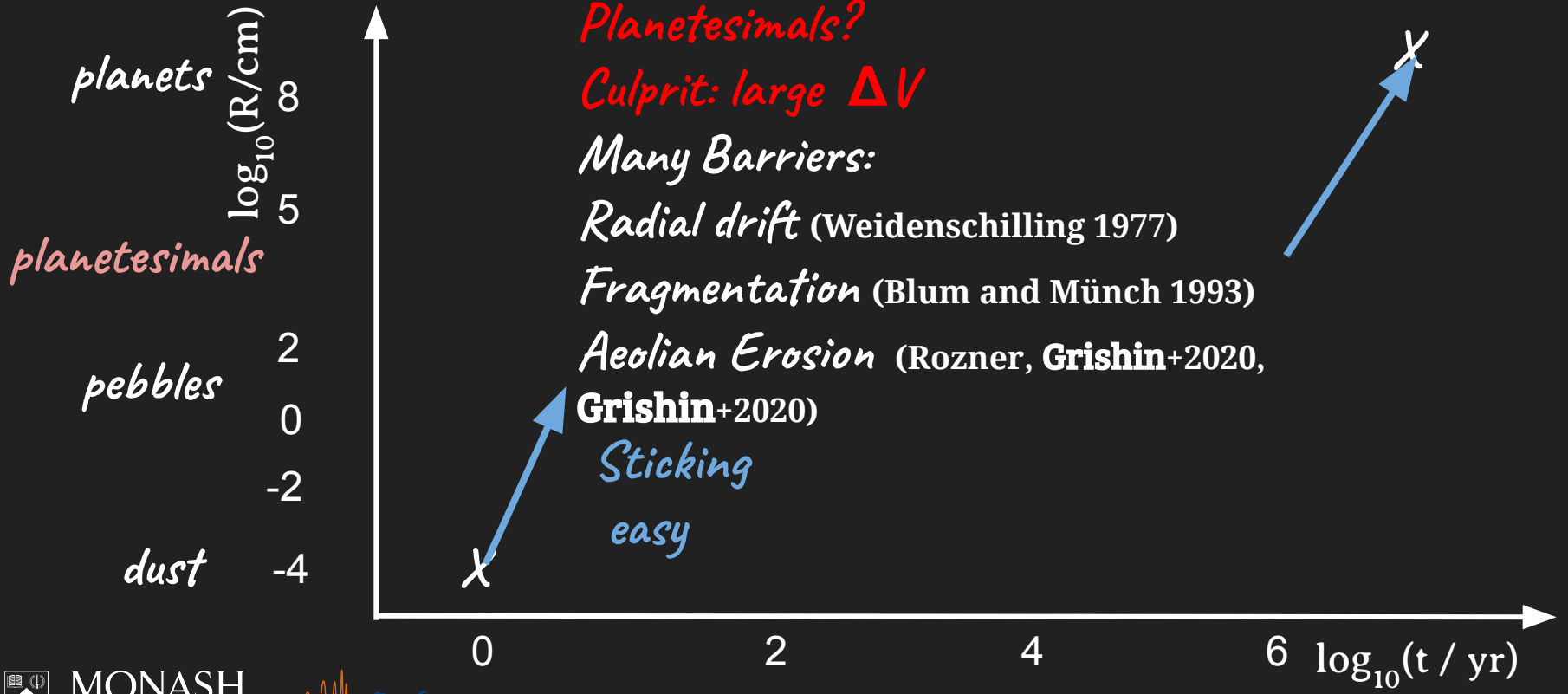

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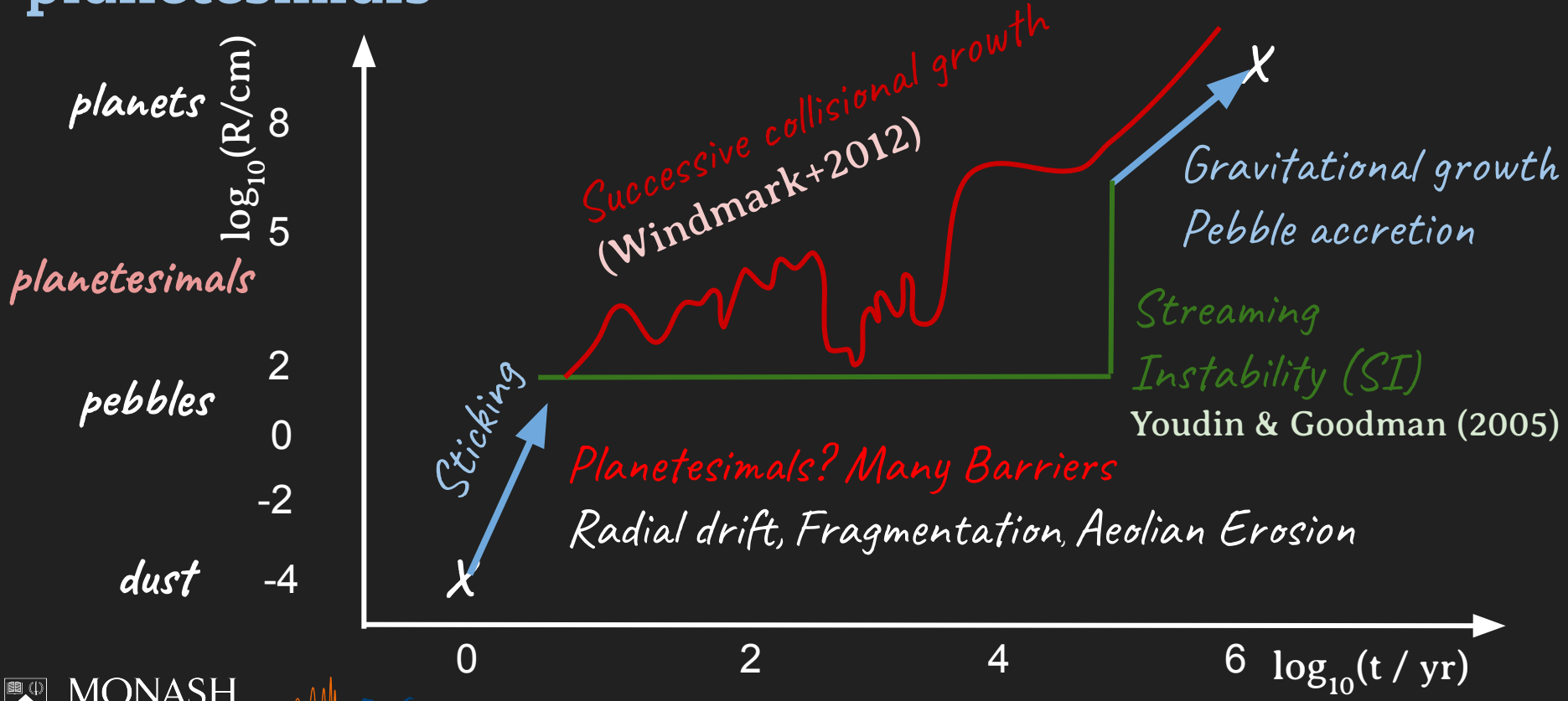

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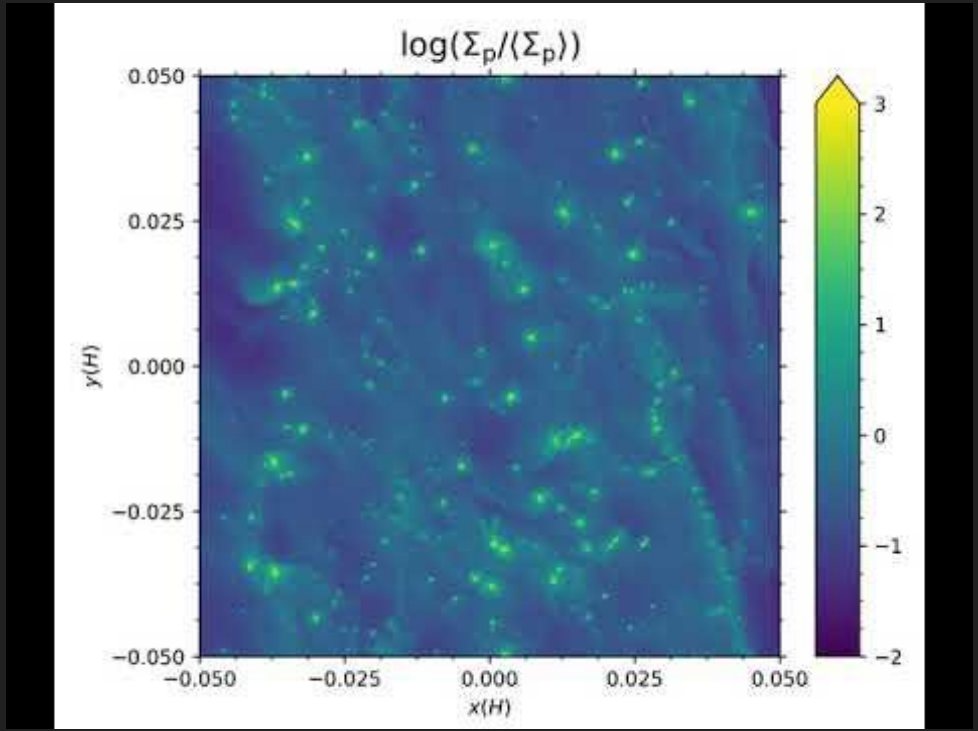
Streaming instability is a promising channel for planet formation

- Two fluid approximation: Feedback on the gas makes dust grains to accumulate
- For local dust-to-gas ratio > 1 gravitational collapse occurs (Youdin and Goodman, 2005; Johansen+2007, Nat)
- Successful in reproducing Kuiper belt binary orientations (Nesvorny+2019, NatAs)



Video: David Nesvorny

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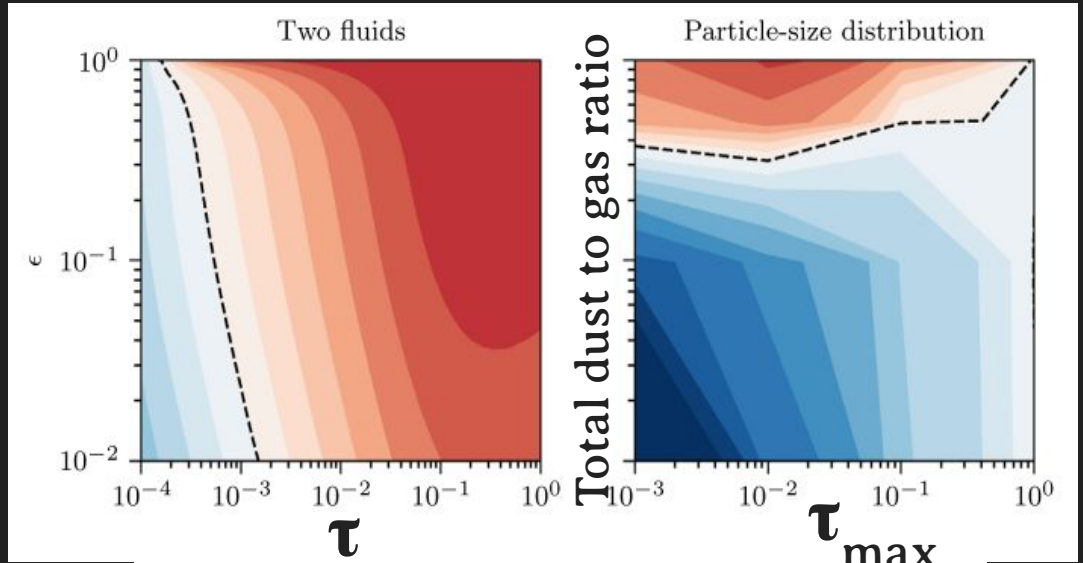
Streaming instability is not converging for large number

Previous SI simulations work well with Stokes number $\tau \sim 0.1$

$$\tau = \Omega \, m|v| / F_D = \Omega \, t_s$$

- Convergence with multiple dust sizes is poor (Krapp+2019)



Growth of fastest eigenmode

> *Planetesimal formation*. We anticipate that the multi-species streaming instability could still be an efficient mechanism to enable planetesimal formation if dust particles are filtered/segregated according to their size and accumulated somewhere in the disk. This will naturally produce regions with large

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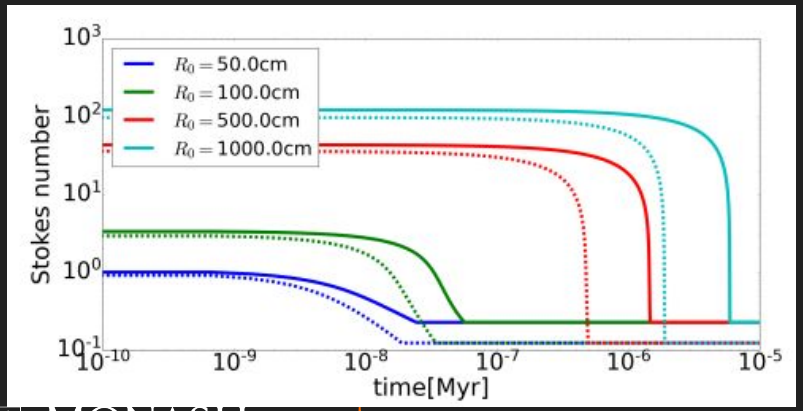
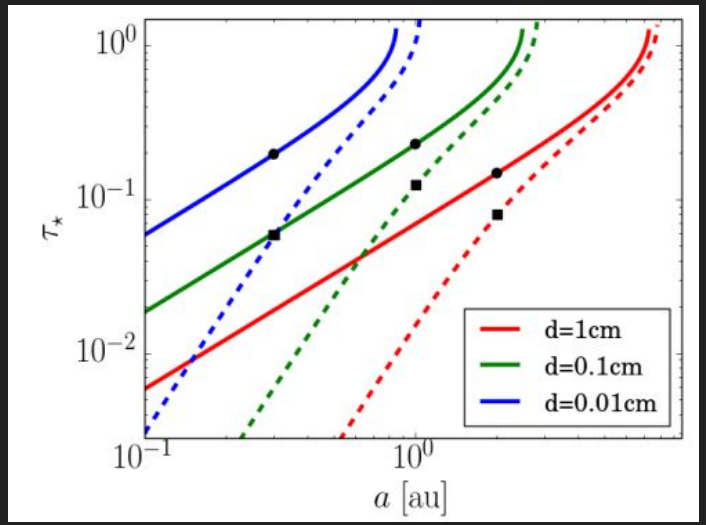
Aeolian erosion is fast and could be the size segregation mechanism

- Aeolian erosion was observed in wind tunnel experiments
- Aeolian erosion naturally segregates dust grains (Rozner, **Grishin**+2020; **Grishin**+2020)





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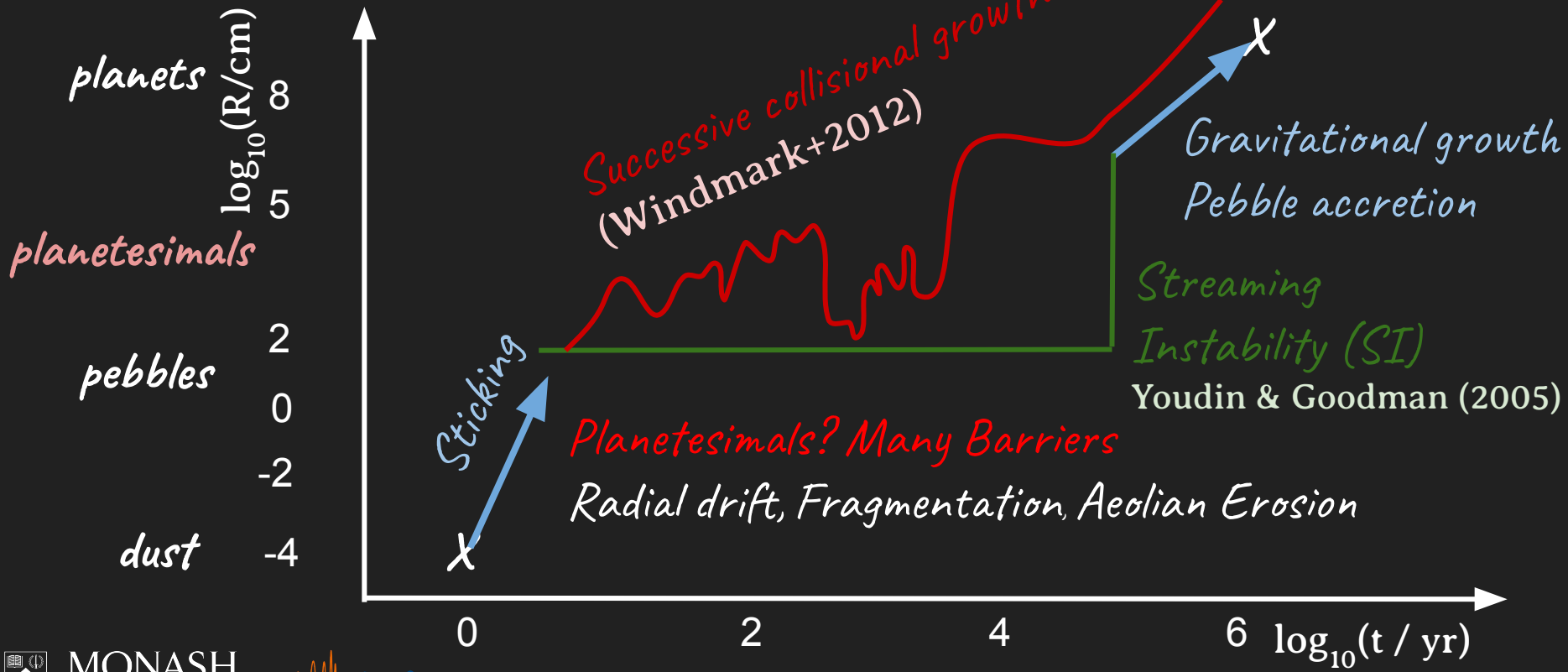
Capture of interstellar planetesimals can be the missing source for planetesimals



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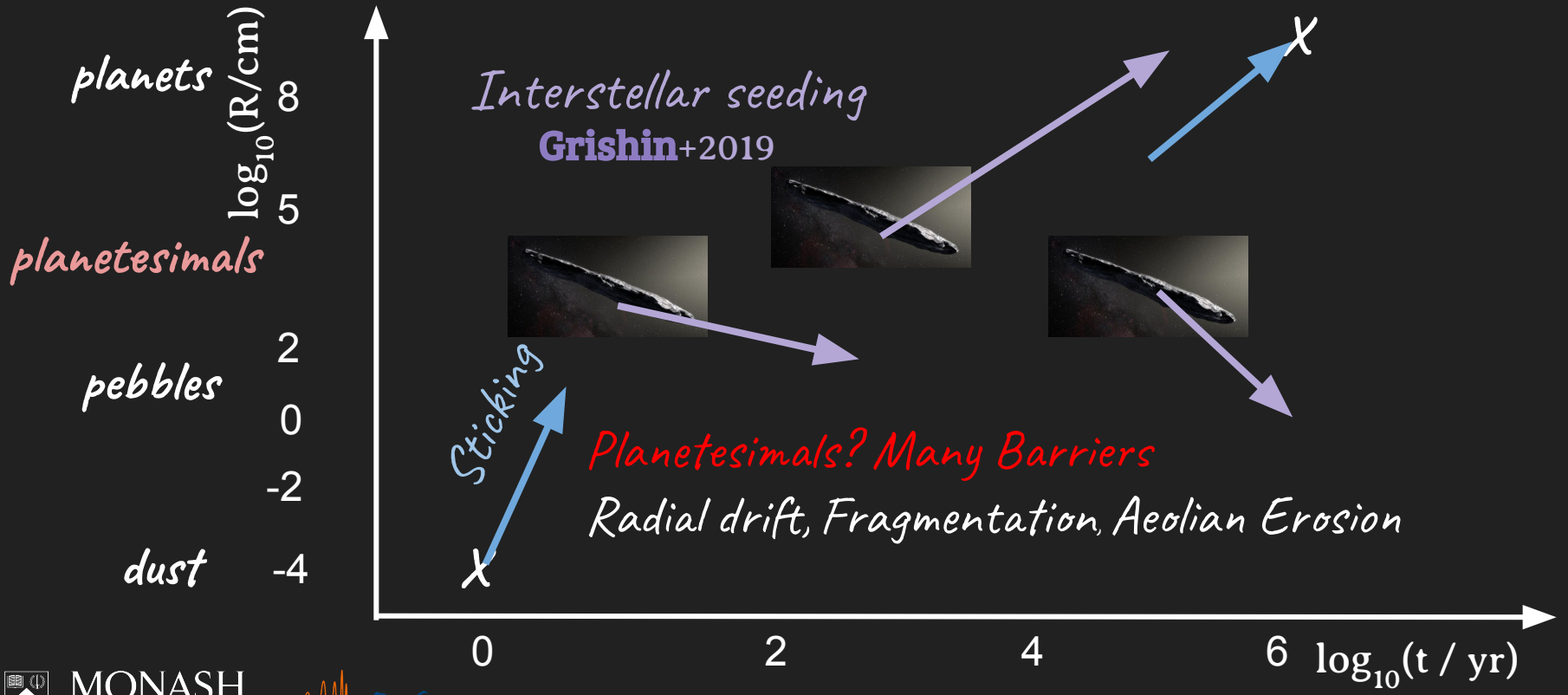

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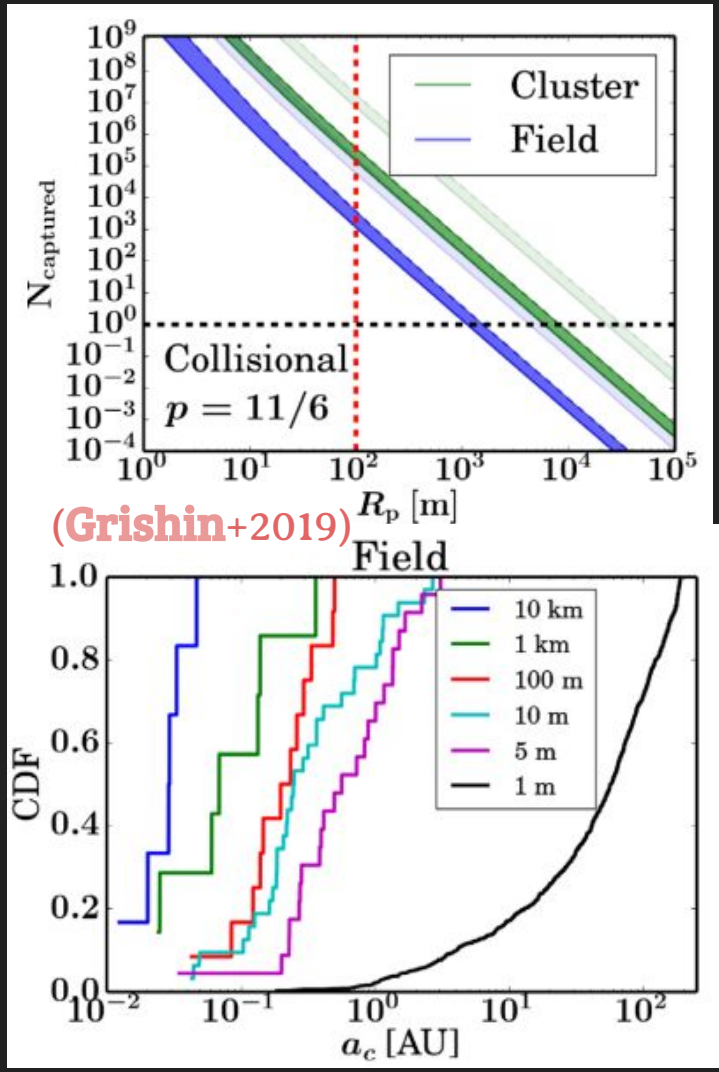
Can Phantom simulate feedback on the disc?

- Protoplanetary discs can capture many planetesimals
- Good for CAI's planet formation in clusters, lithopanspermia?
- Feedback from ablation?! (Pinhas+2016)



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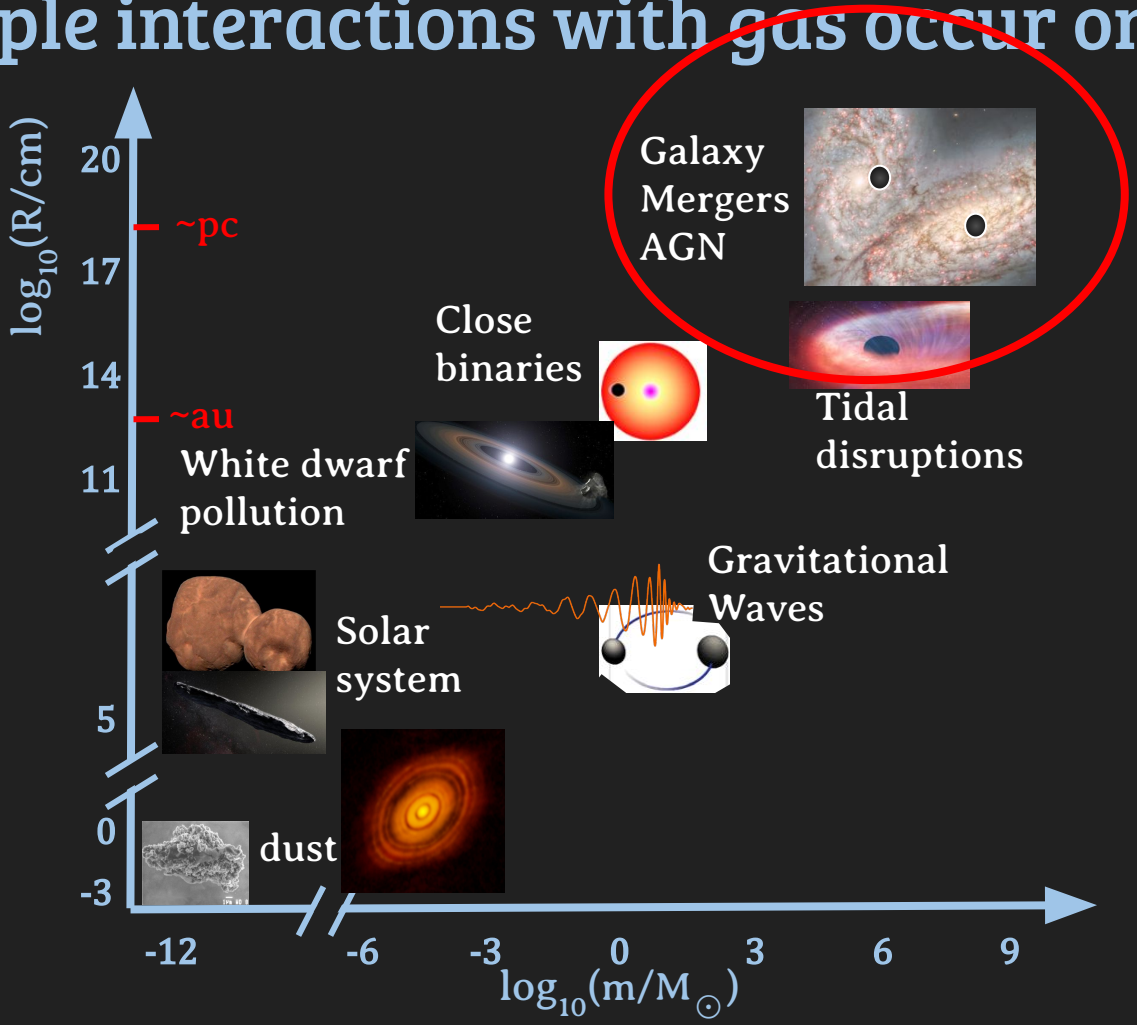
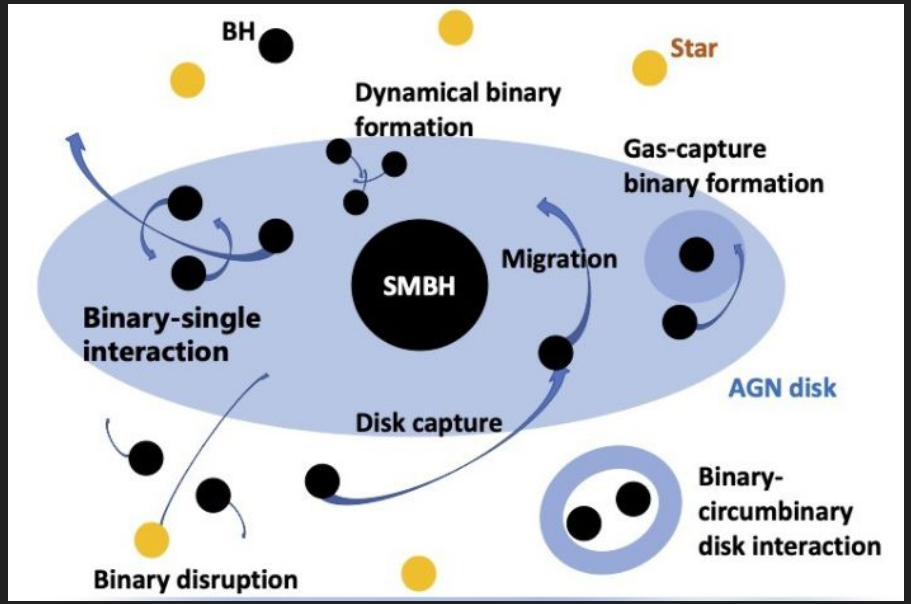


Merger of black holes (and other several object) has several avenues for formation

Various formation channels
(Mandel & Broekgaarden 2022)

- Isolated binaries
- Dynamical formation: field triples, open/globular clusters
- Galactic nuclei
  - Nuclear stellar cluster
  - Active galactic nuclear (AGN) disc

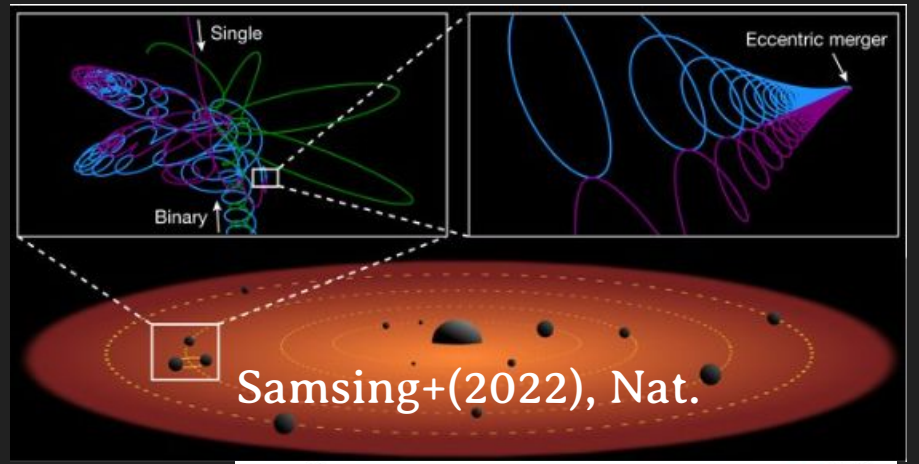


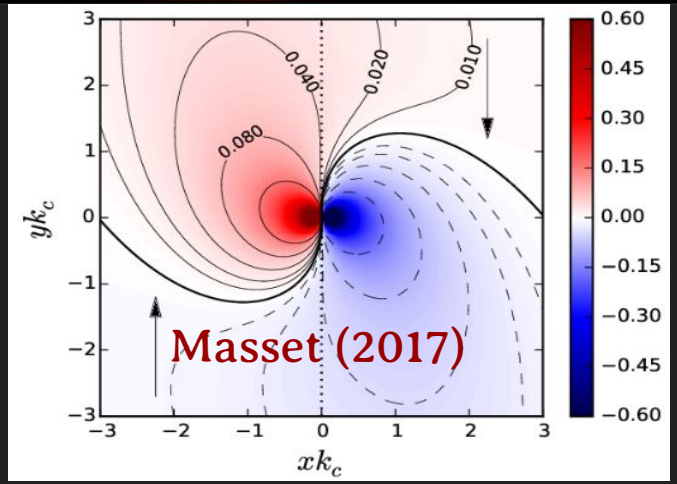
Tagawa+(2020), Nat.

AGN discs have uncertain physics

- The AGN channel relies on migration + pile up (Bellovary+2016; Tagawa+2020)
- Analogous to planetary migration

- Luminous planets in optically thick medium tend to add extra "thermal torque" (Lega+2014; Benitez-Llambay+2015)
- BHs in AGN dics should radiate close to L_{Edd}





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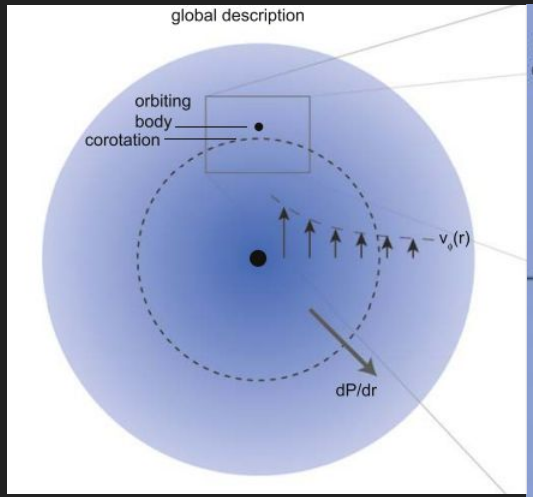
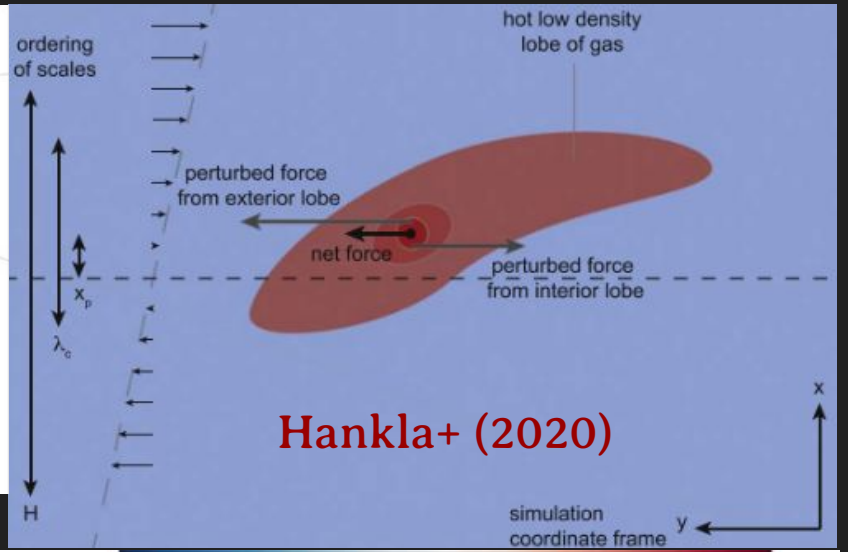
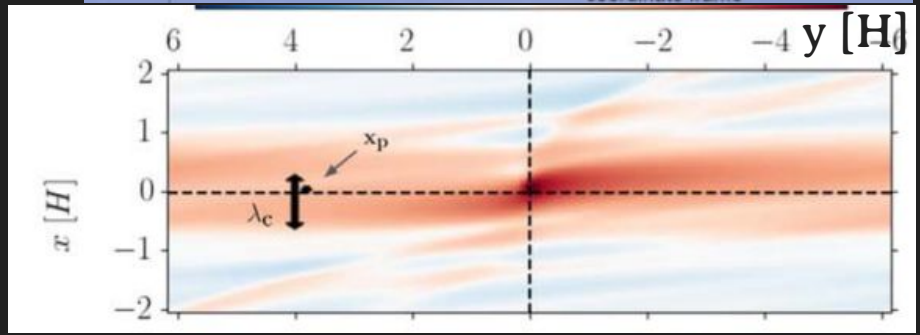
Exploration of thermal AGN torques is in its infancy





- Preliminary exploration of luminous BH in accretion discs with grid codes (Athena++, Hankla+2020)



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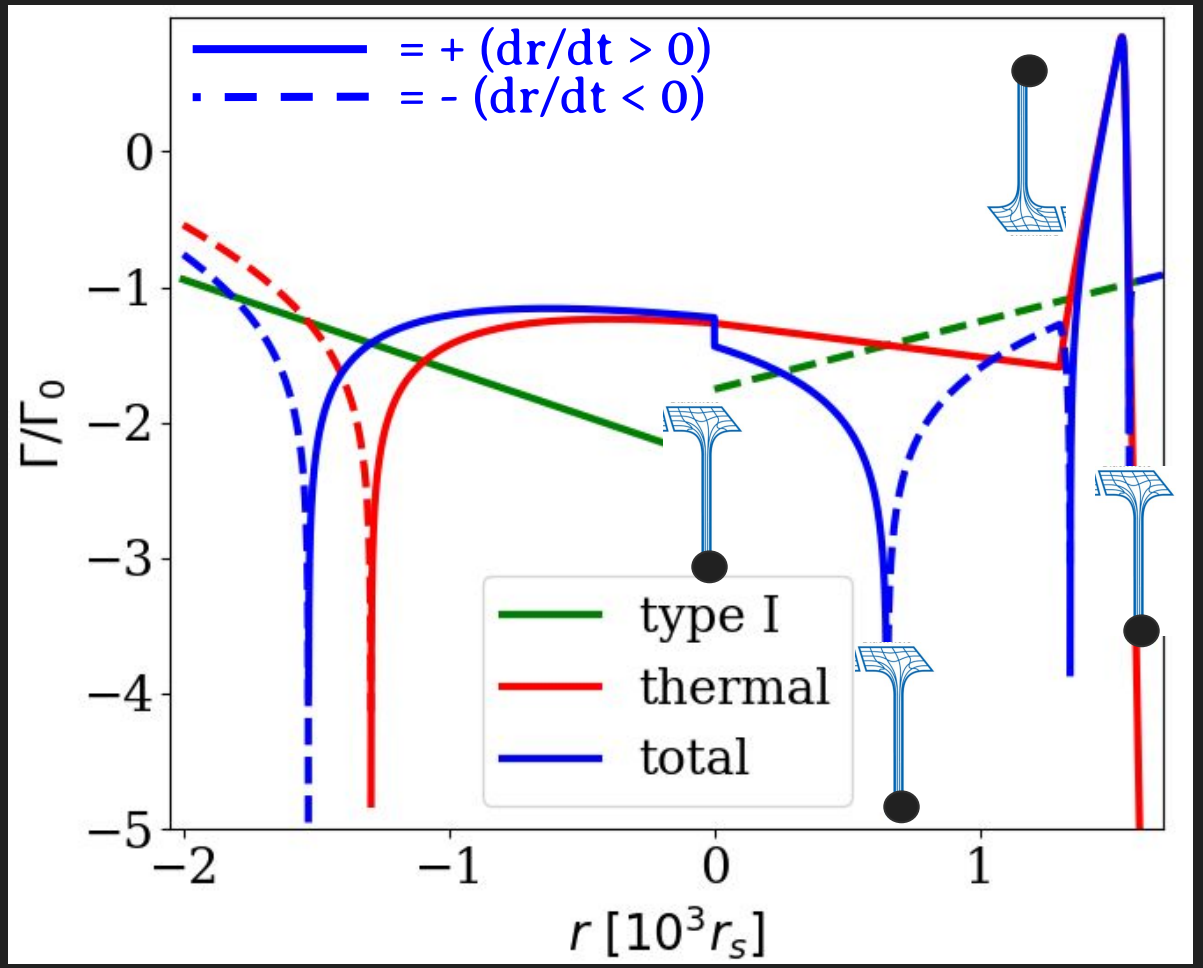
Exploration of thermal AGN torques is in its infancy

- The total torque is altered (**Grishin**+23, in prep.)
- Thermal conductivity is very large (non-linear)



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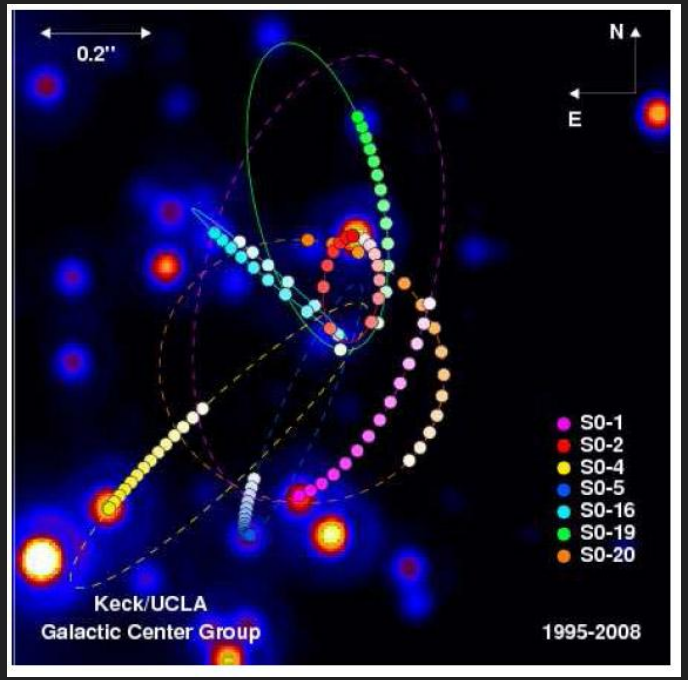
Star formation can occur in explosive environments, including tidal disruption near a SMBH

- Stars form in weird environments (Maiolino+2016)
- TDE can trigger star formation (Zubovas, 2019; Perna & **Grishin**, 2022)
- Expanding cocoon from a TDE can compress clouds
- What happens to a shocked cloud near an SMBH?



Star formation inside a galactic outflow

R. Maiolino[1,2], H. R. Russell[3], A. C. Fabian[3], S. Carniani[1,2], R. Gallagher[1,2], S. Cazzoli[4], S. Arribas[4], F. Belfiore[1,2], E. Bellocchi[4], L. Colina[4], G. Cresci[5], W. Ishibashi[6], A. Marconi[5,7], F. Mannucci[5], E. Oliva[5] & E. Sturm[8]

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