Pebbles to Planetesimals
The Role of Pressure Bumps

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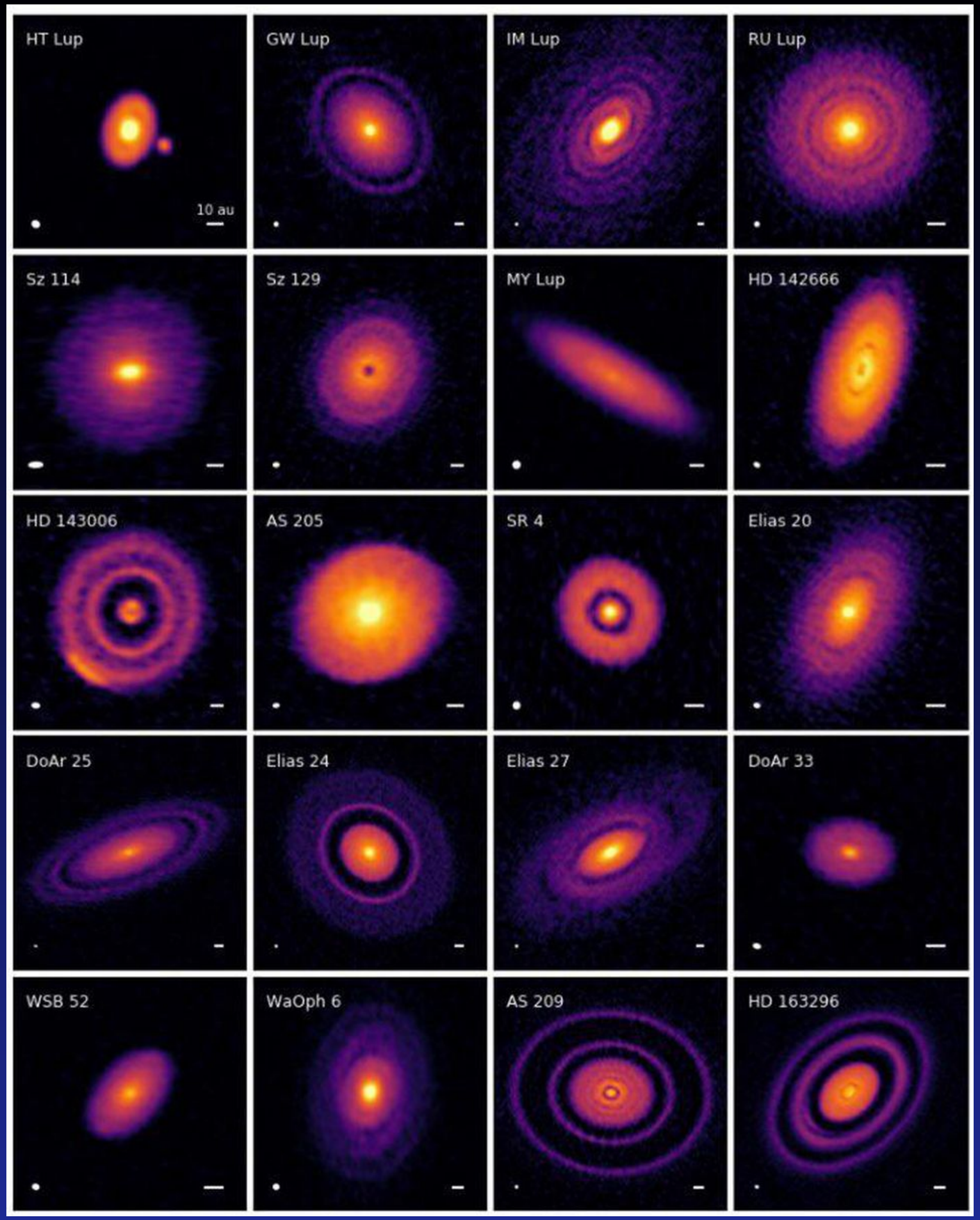
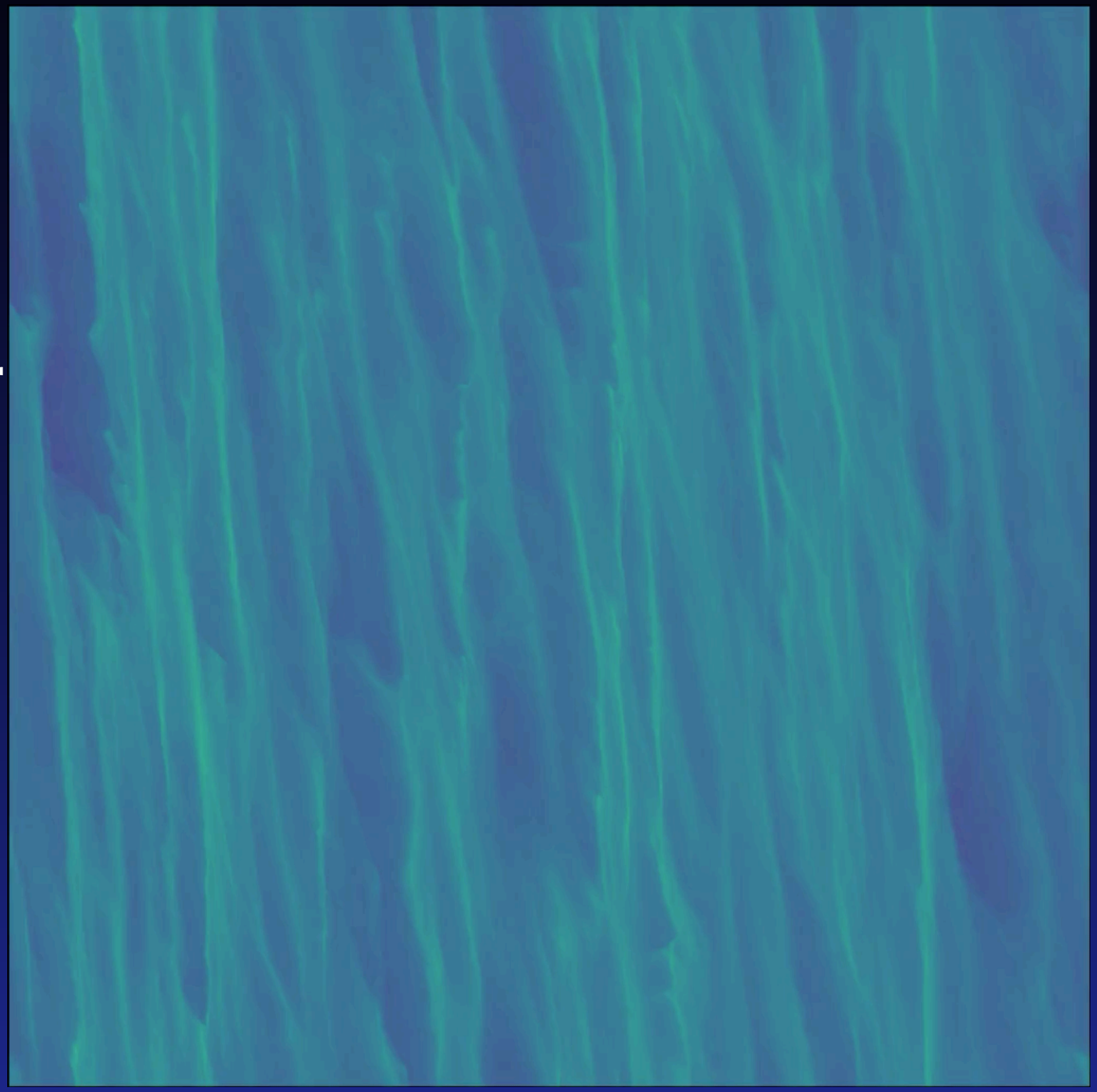
Great Barriers in Planet Formation

CALIFORNIA ACADEMY OF SCIENCES



Andrews et al. and the DSHARP collaboration

Streaming instability can produce planetesimals



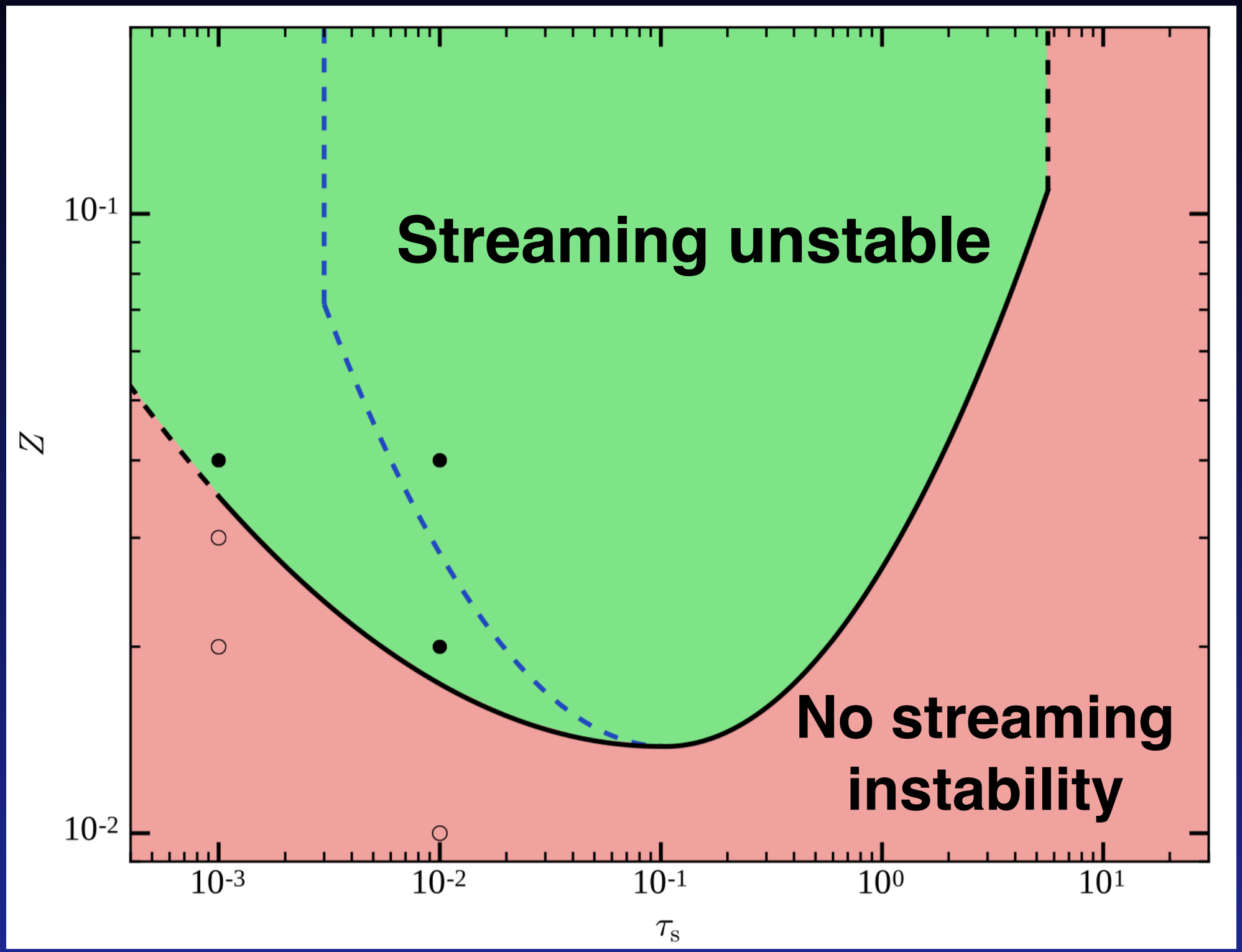
Towards star

Azimuthal

Radial

Nesvorny…Simon… (2019), accepted to Nature Astronomy

Streaming instability requires enhanced solid concentration

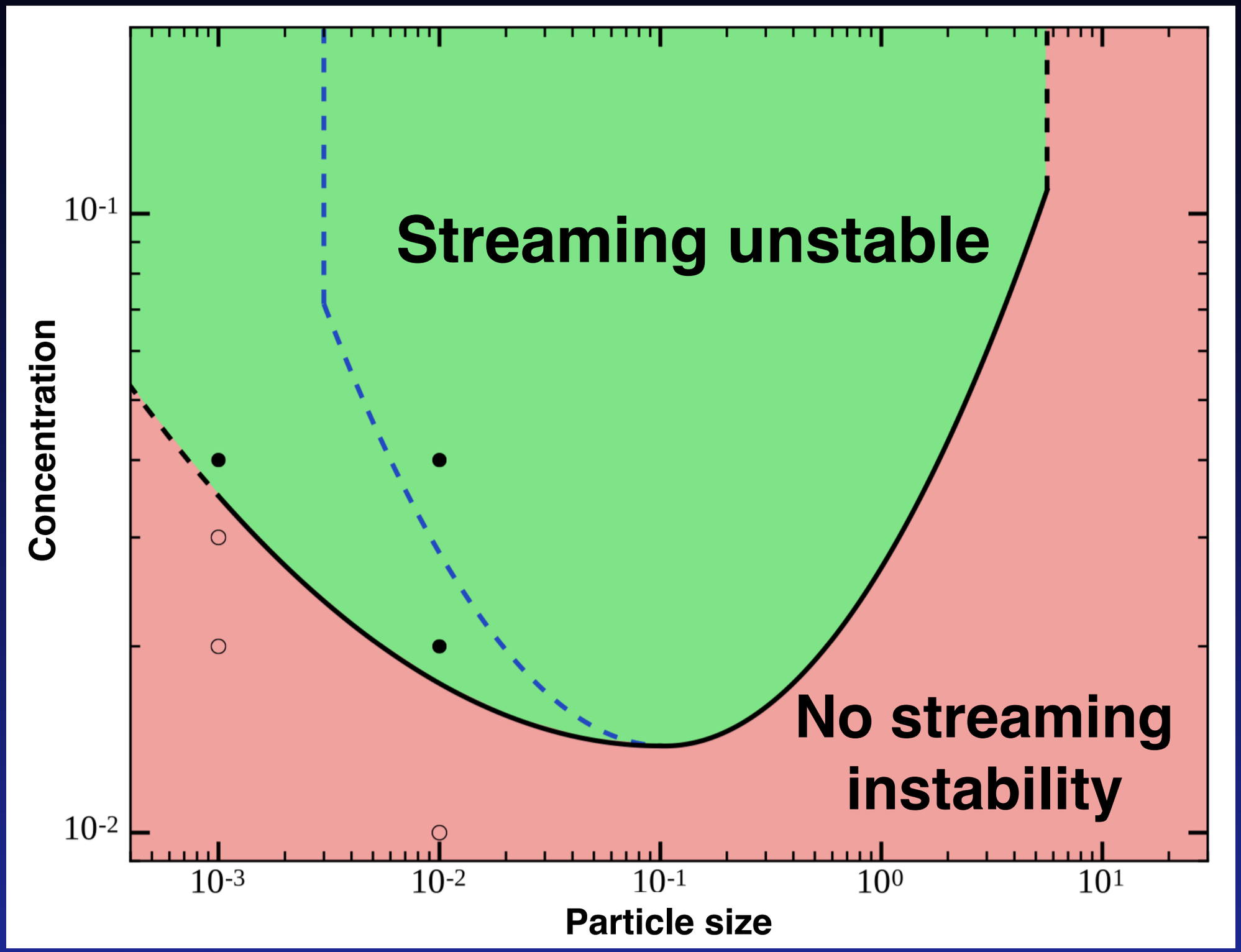


$$\tau \equiv t_{\rm stop}\Omega^{-1}$$

$$Z = \frac{\Sigma_p}{\Sigma_g}$$

Yang et al. (2017)

Streaming instability requires enhanced solid concentration



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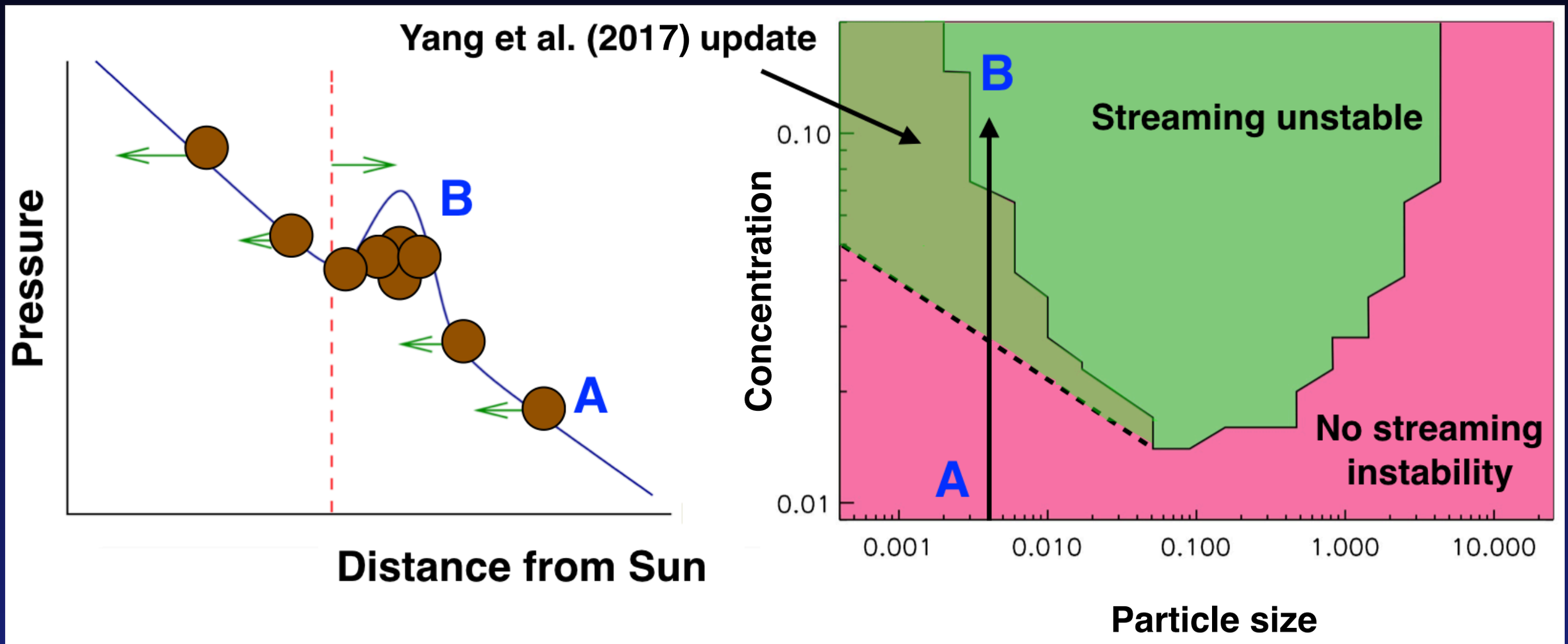
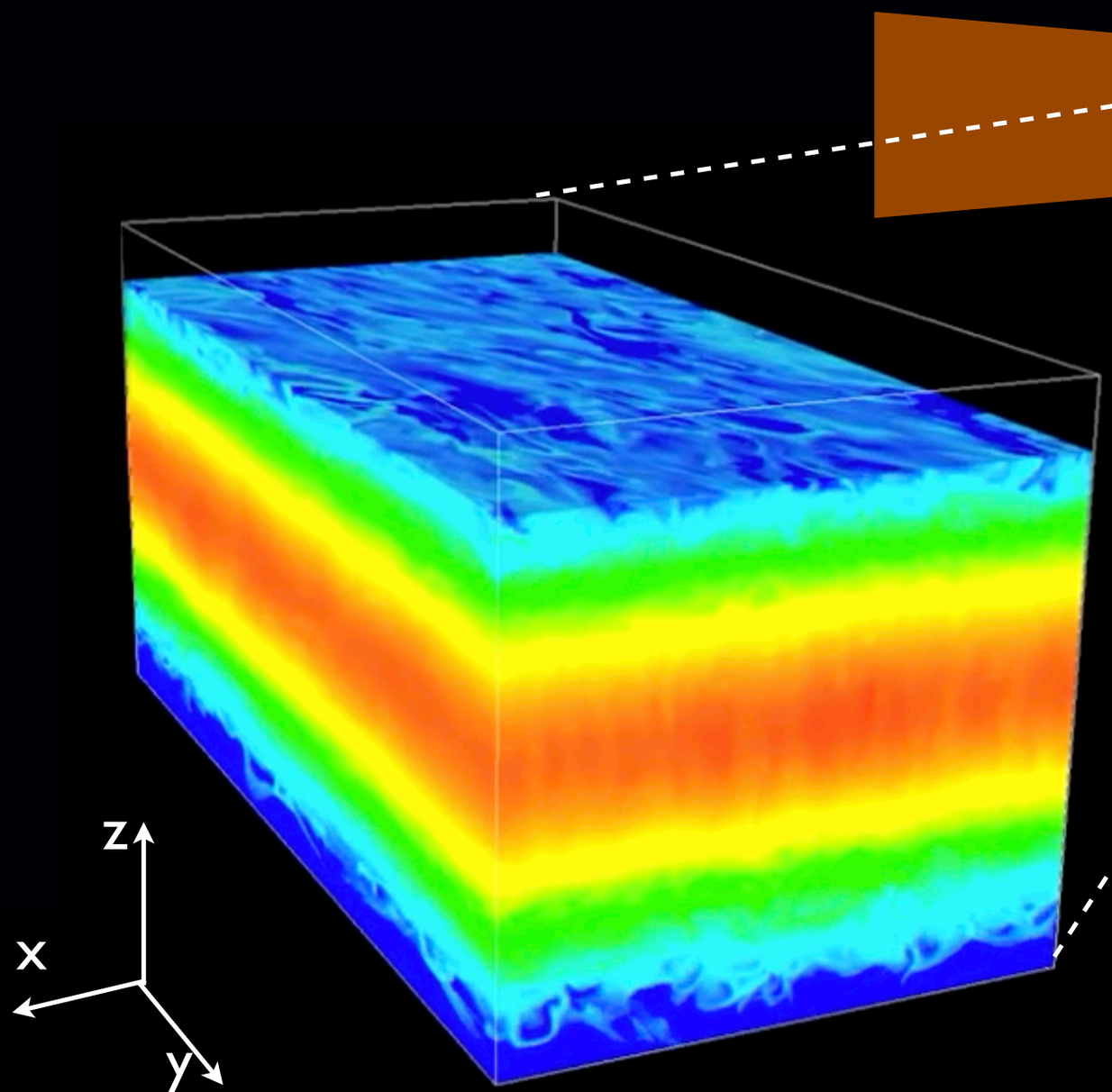
Yang et al. (2017)

Pressure traps can provide that enhanced concentration



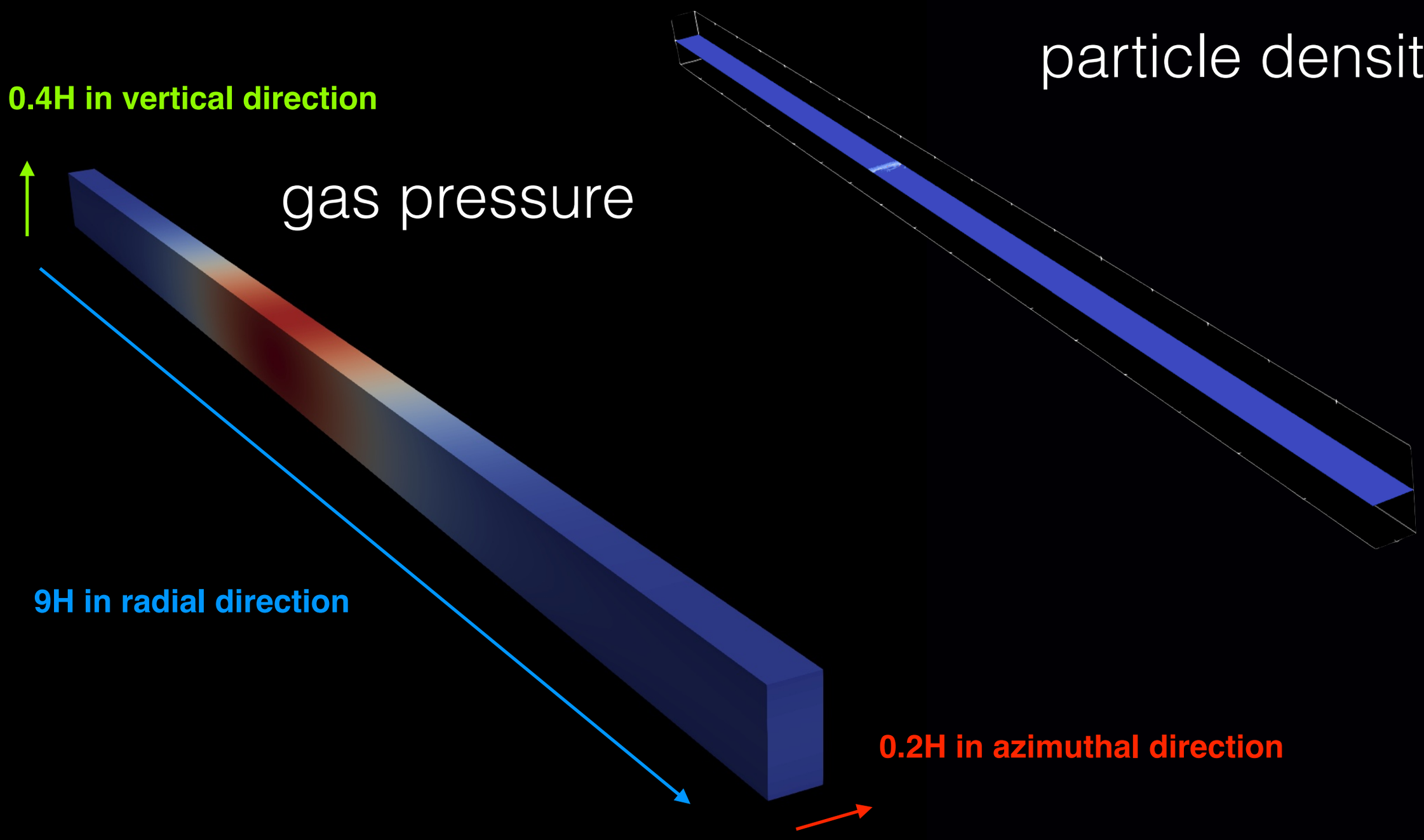
Carrera et al. (2015), Yang et al. (2017)

Local simulations of a small, co-rotating disk patch



- Assume Cartesian geometry
- Add appropriate source terms
- Solve equations of hydro + particles
- Shearing periodic boundaries
- Valid if H/R << 1
- Assume gas is isothermal

Use large aspect ratio to properly capture pressure bump



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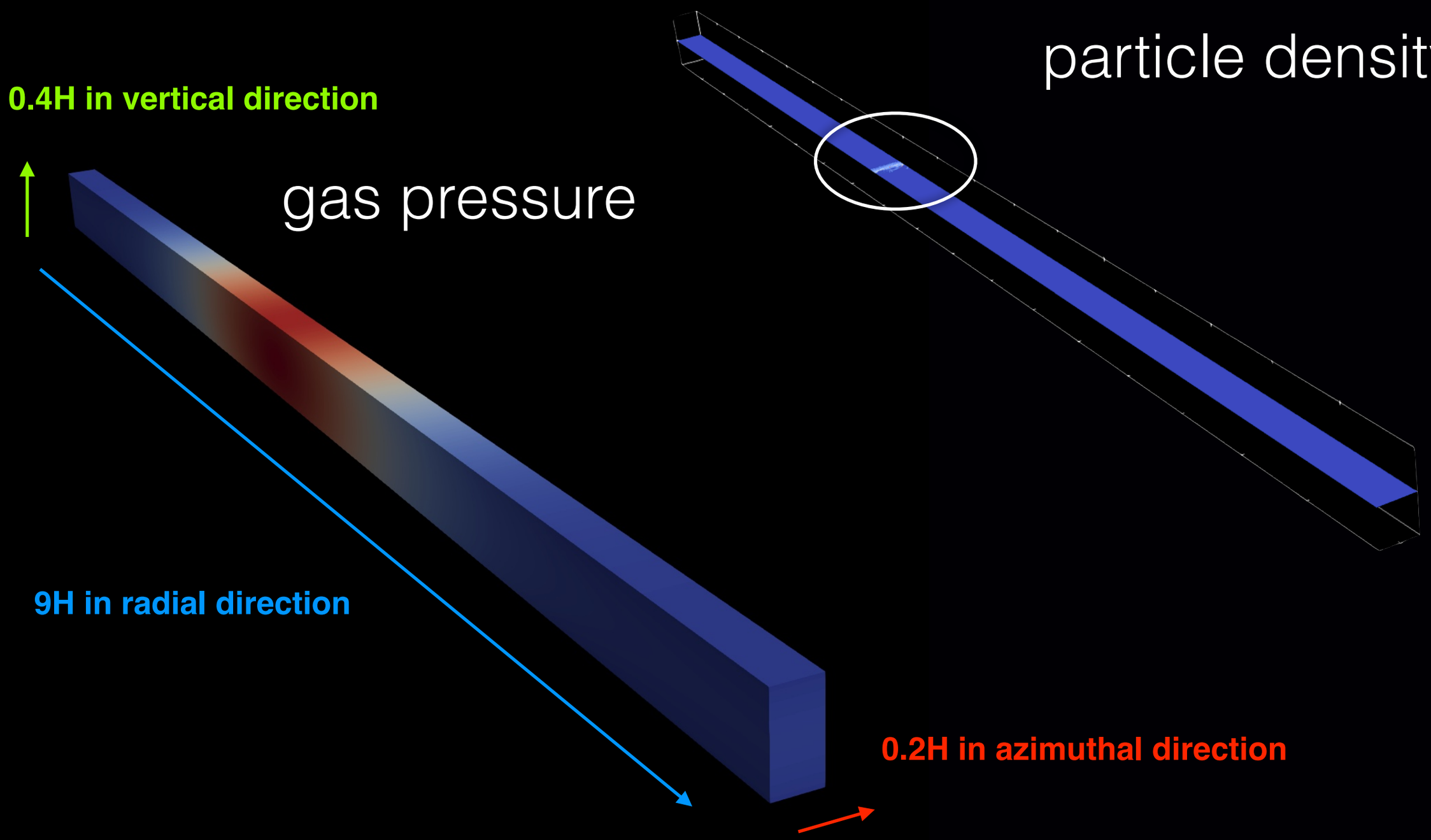

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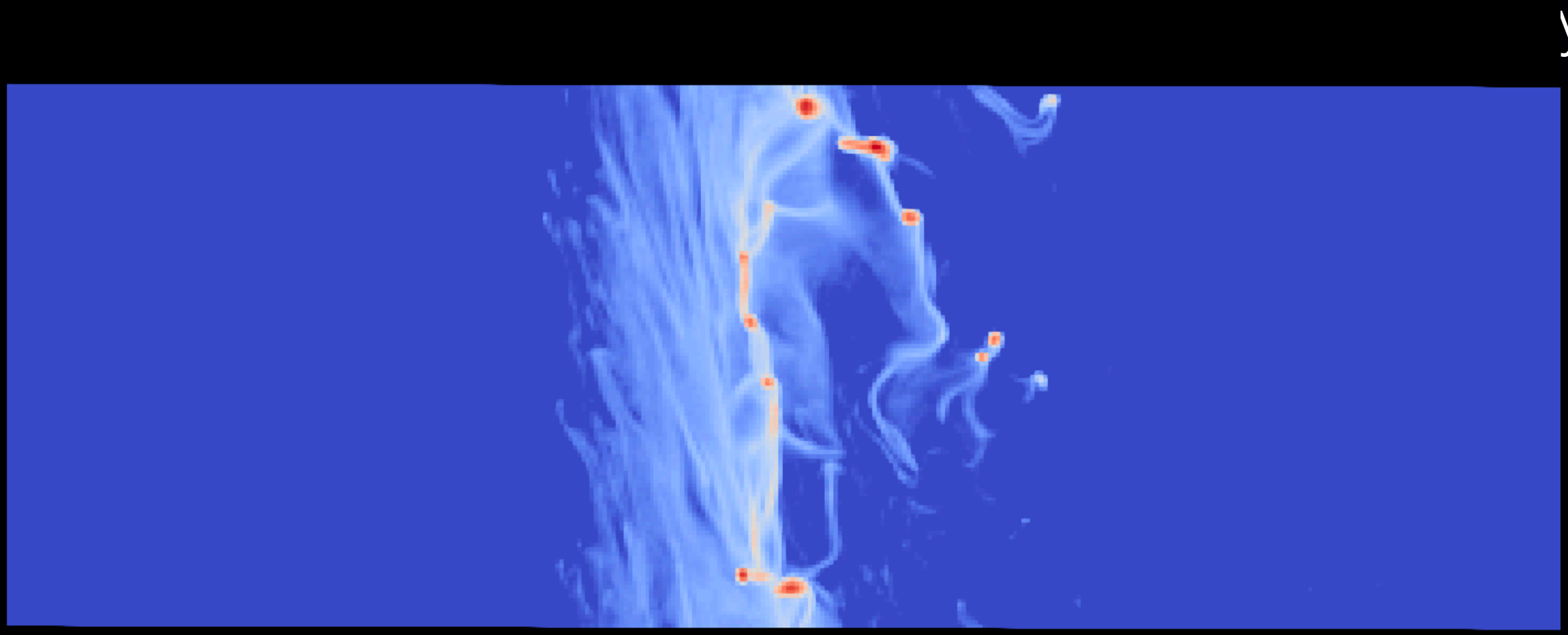
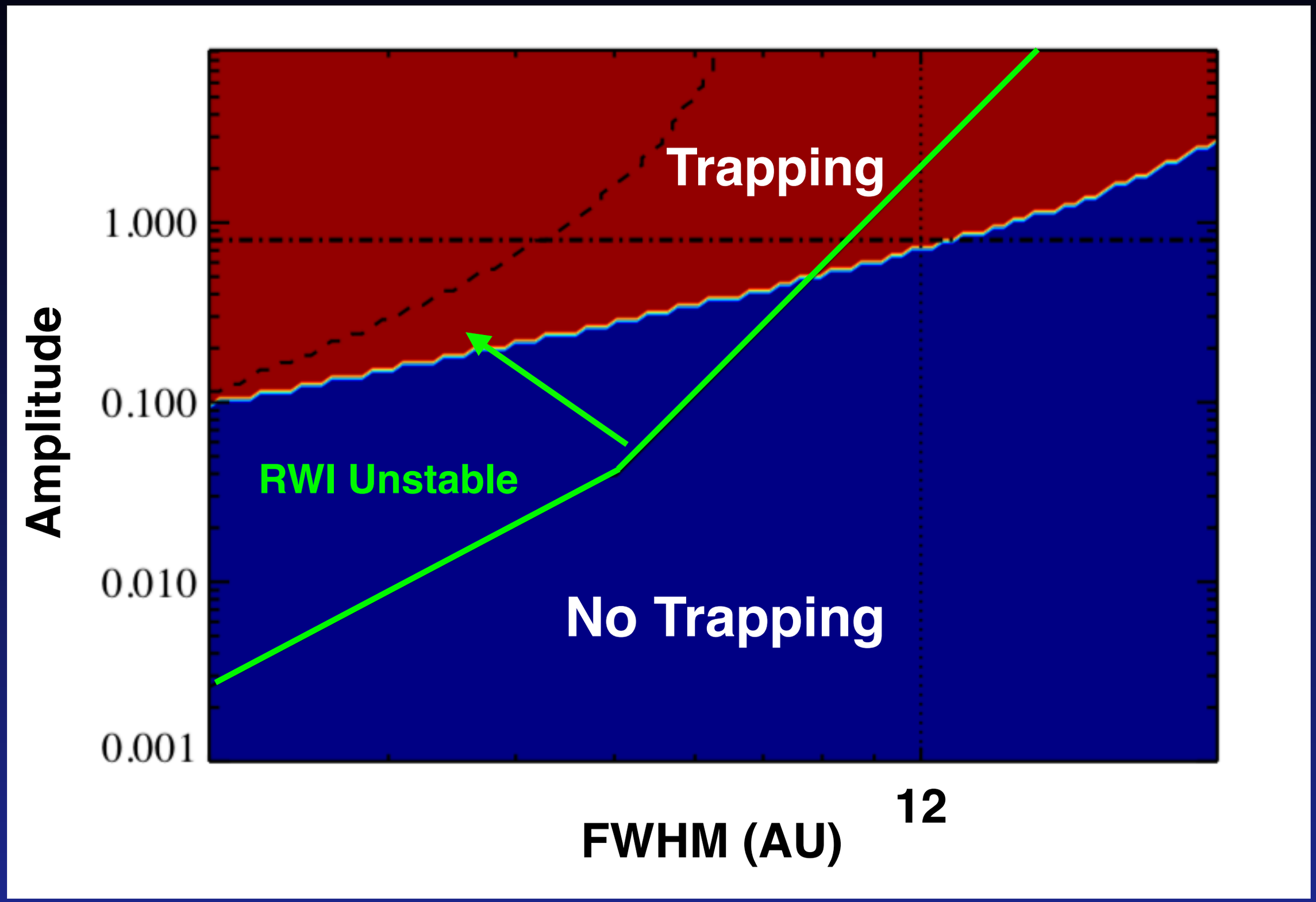


But it must be stable to RI and RWI



Adopted from Ono et al. (2016)

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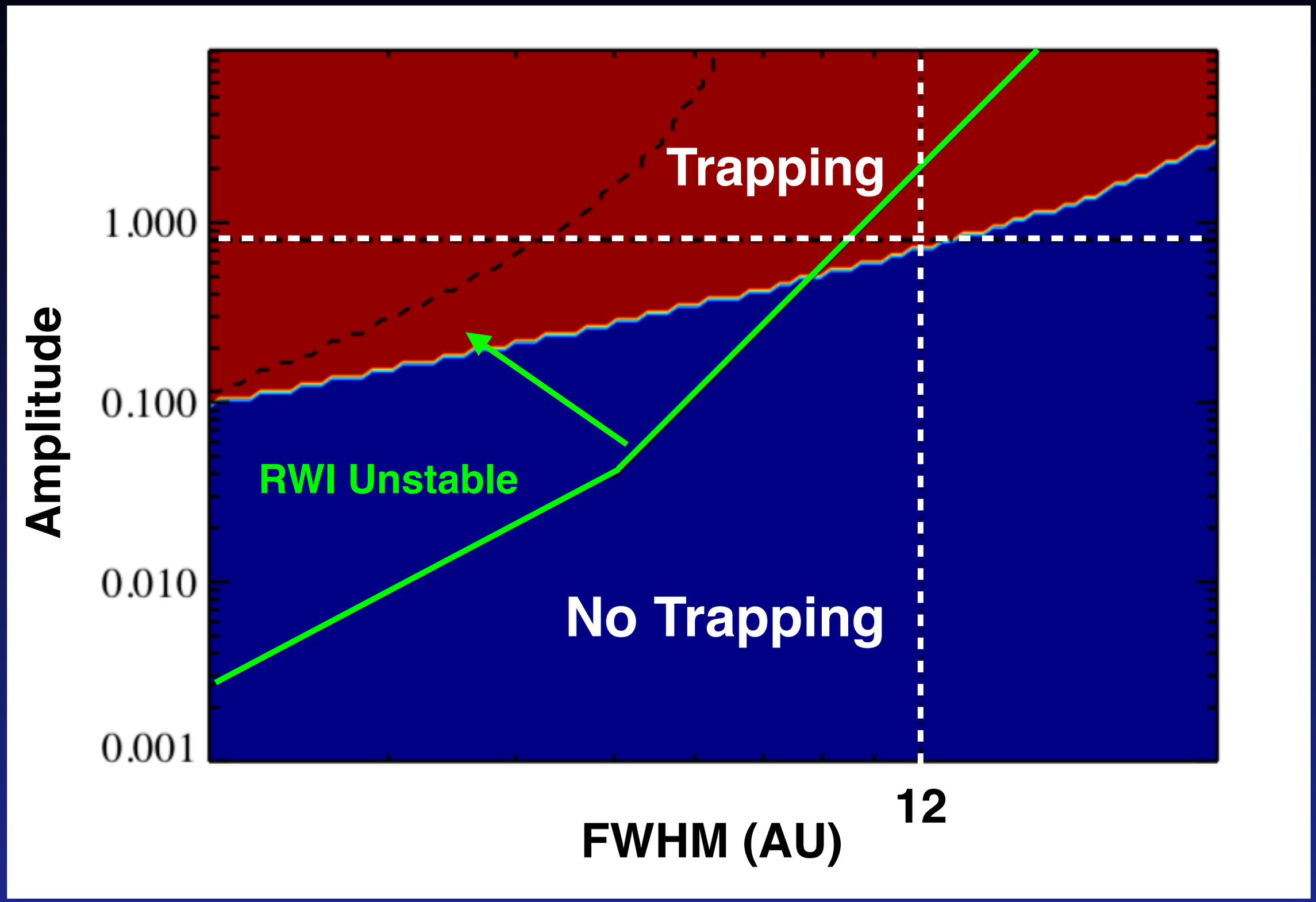
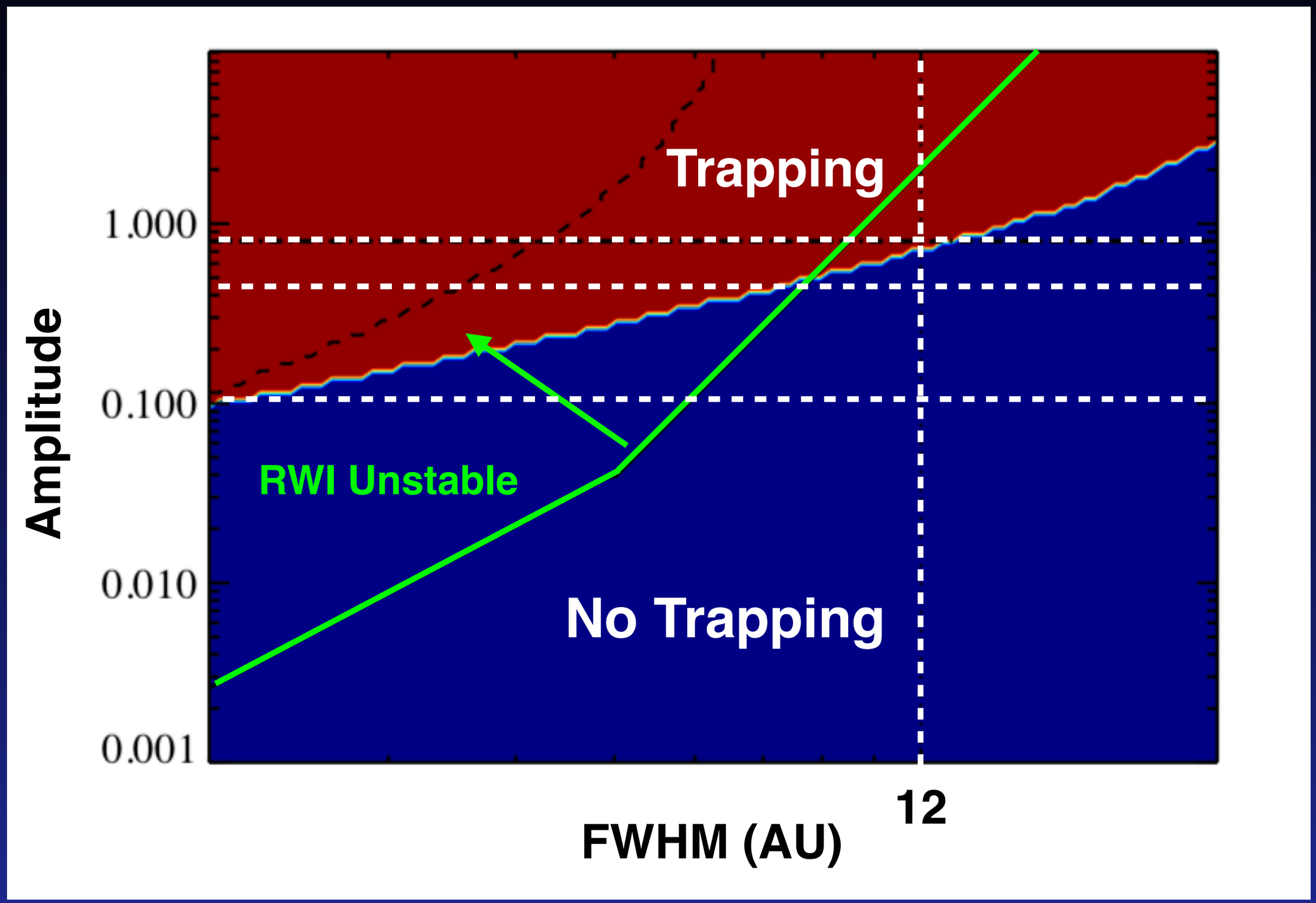


Adopted from Ono et al. (2016)

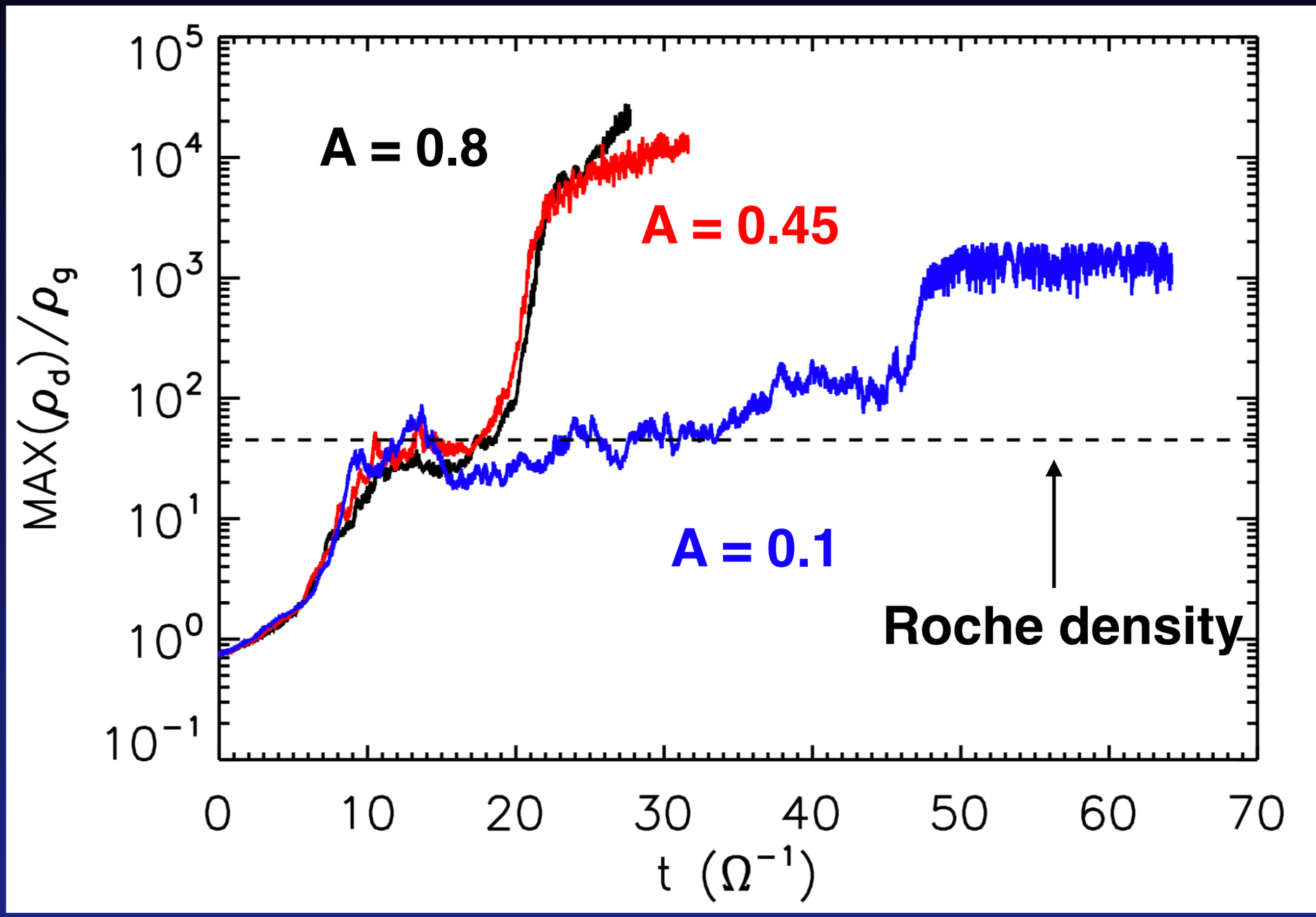
Different amplitudes



Adopted from Ono et al. (2016)

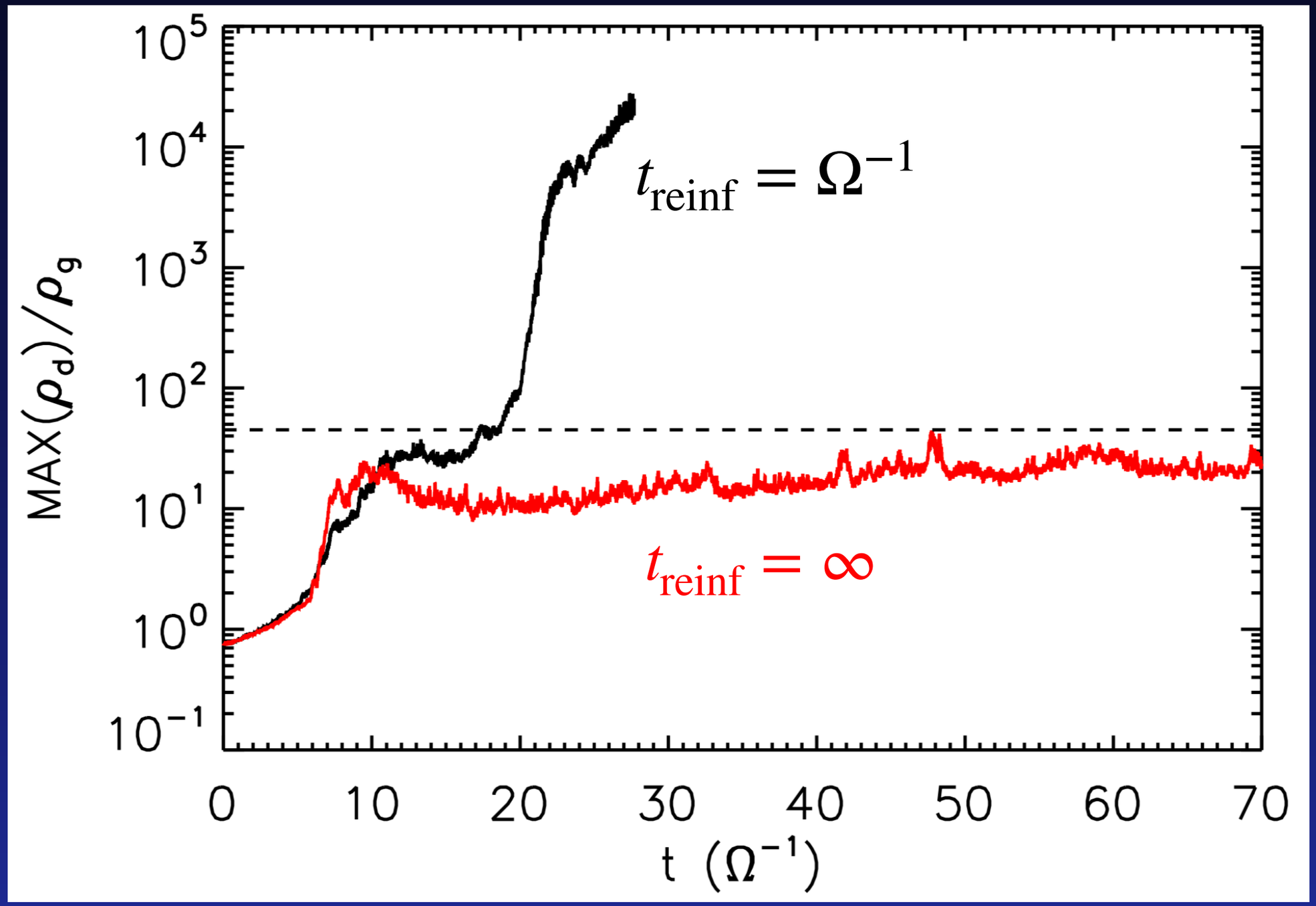
Warning: all results are preliminary

All amplitudes show planetesimal formation



Pebbles don’t need to be trapped to form planetesimals

Particles destroy pressure trap before planetesimal formation (with no reinforcement)

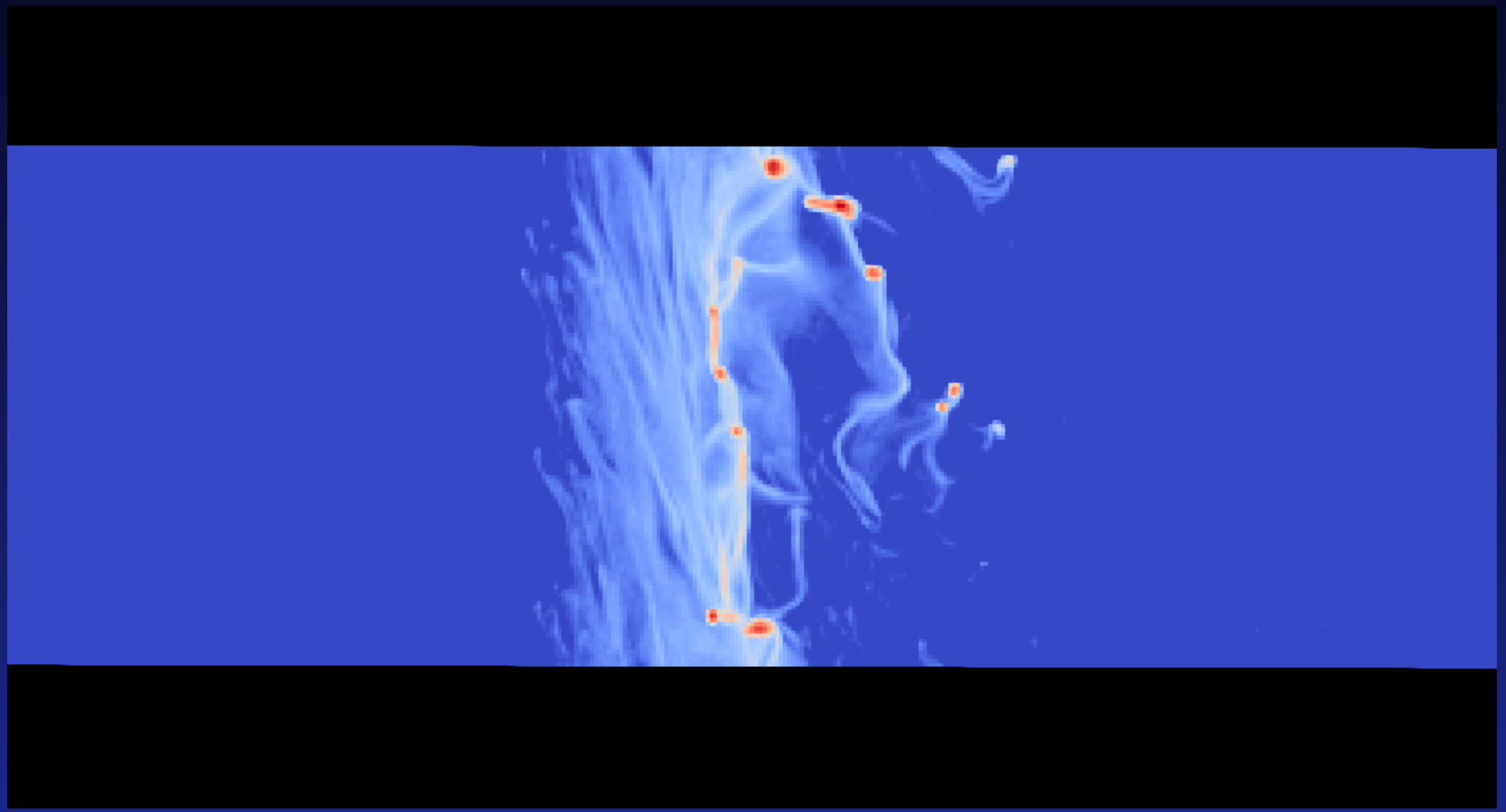


Some reinforcement is necessary to form planetesimals

Some reinforcement is necessary to form planetesimals

At least on a dynamical timescale…

Surprising result:
Flat planetesimals



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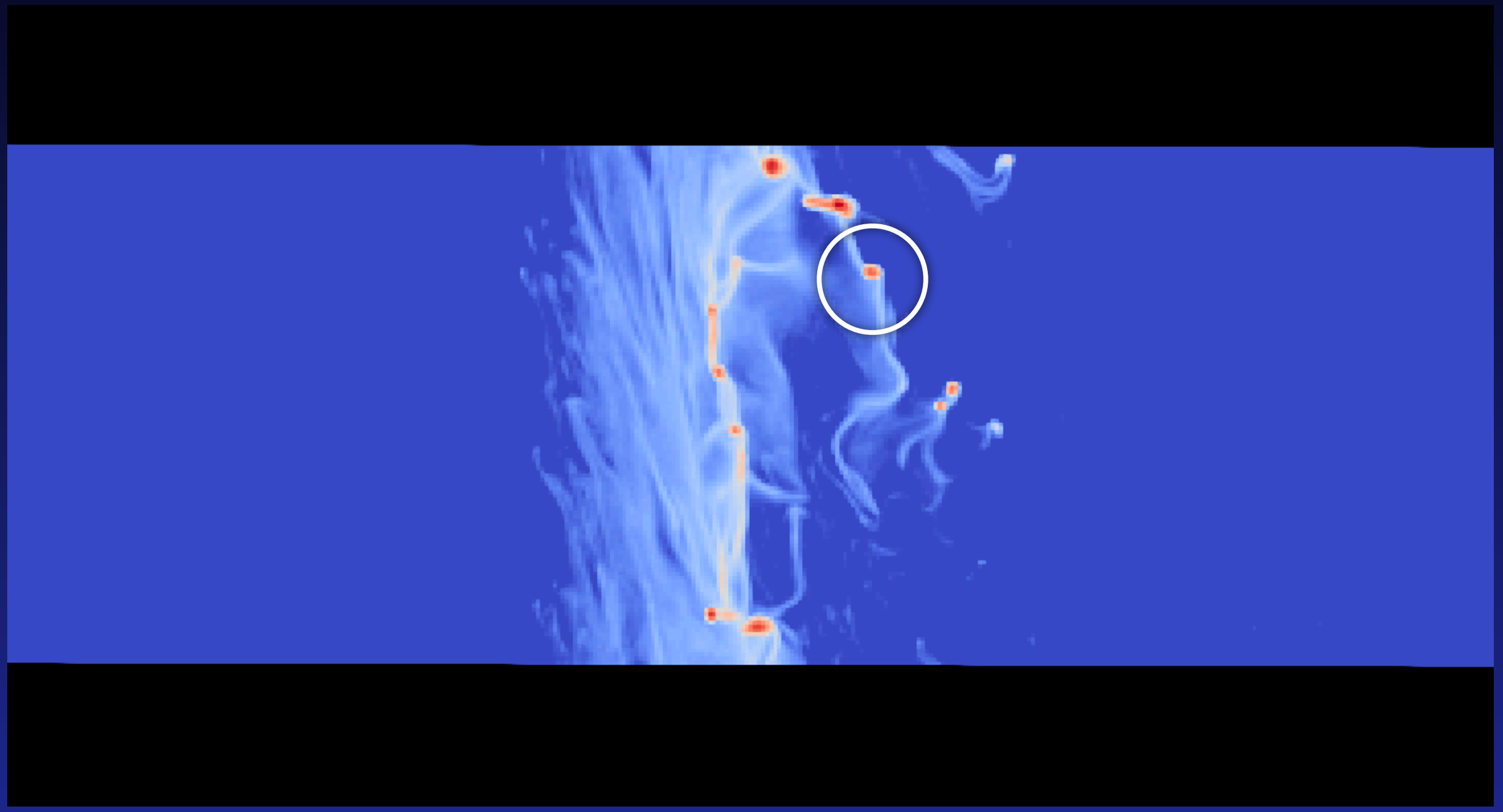
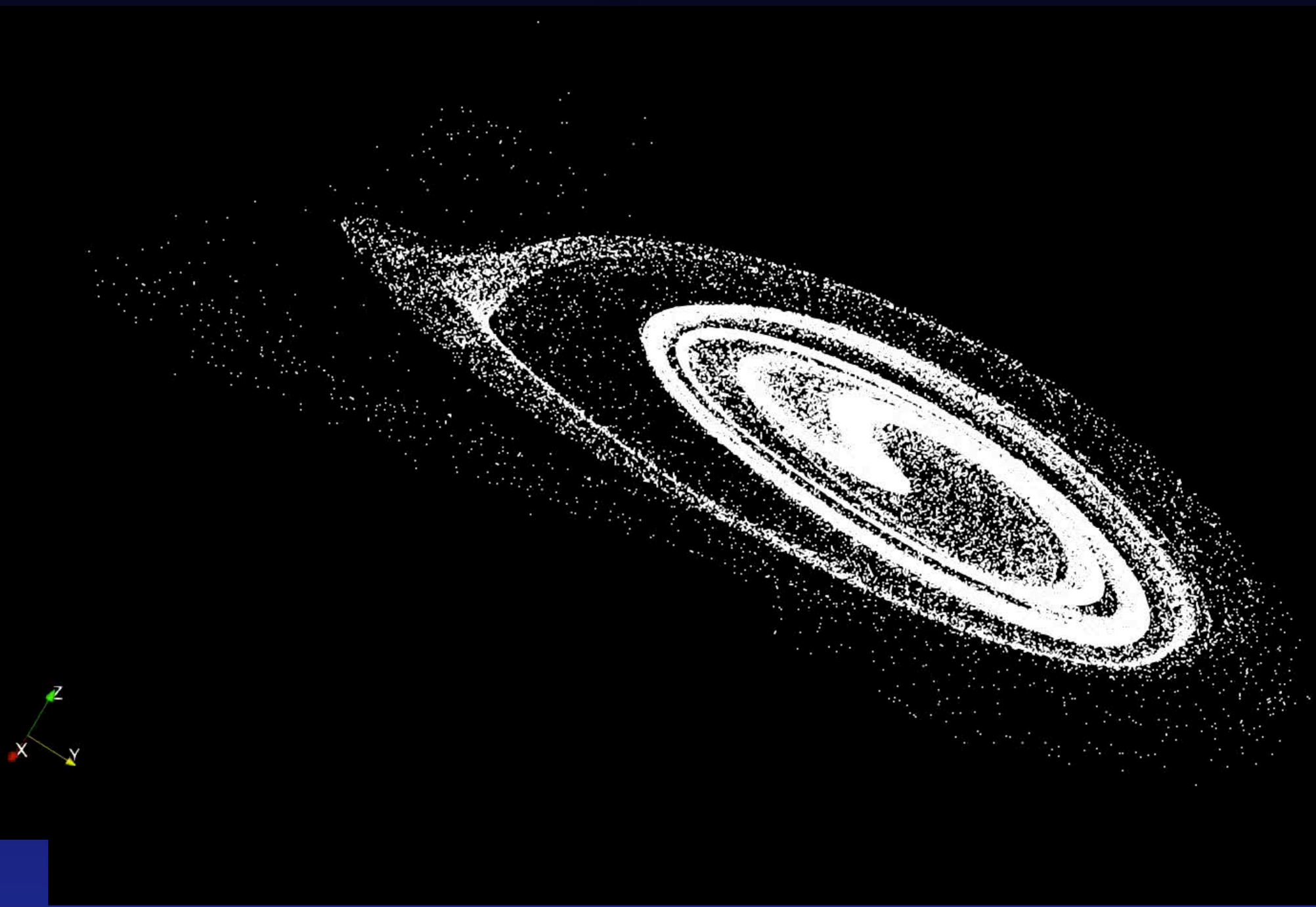
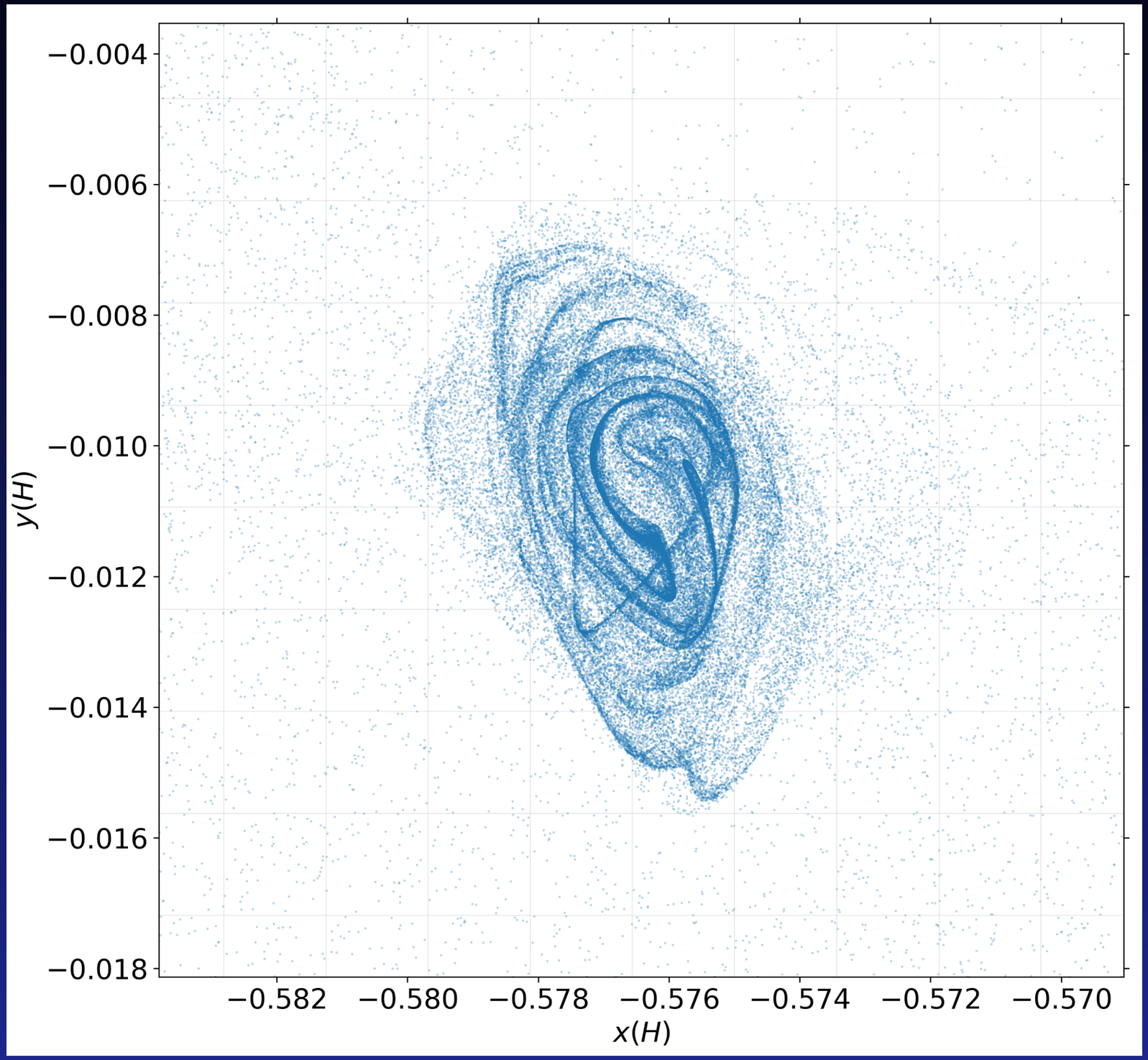


Surprising result: Flat planetesimals



But collapse is halted at the grid scale



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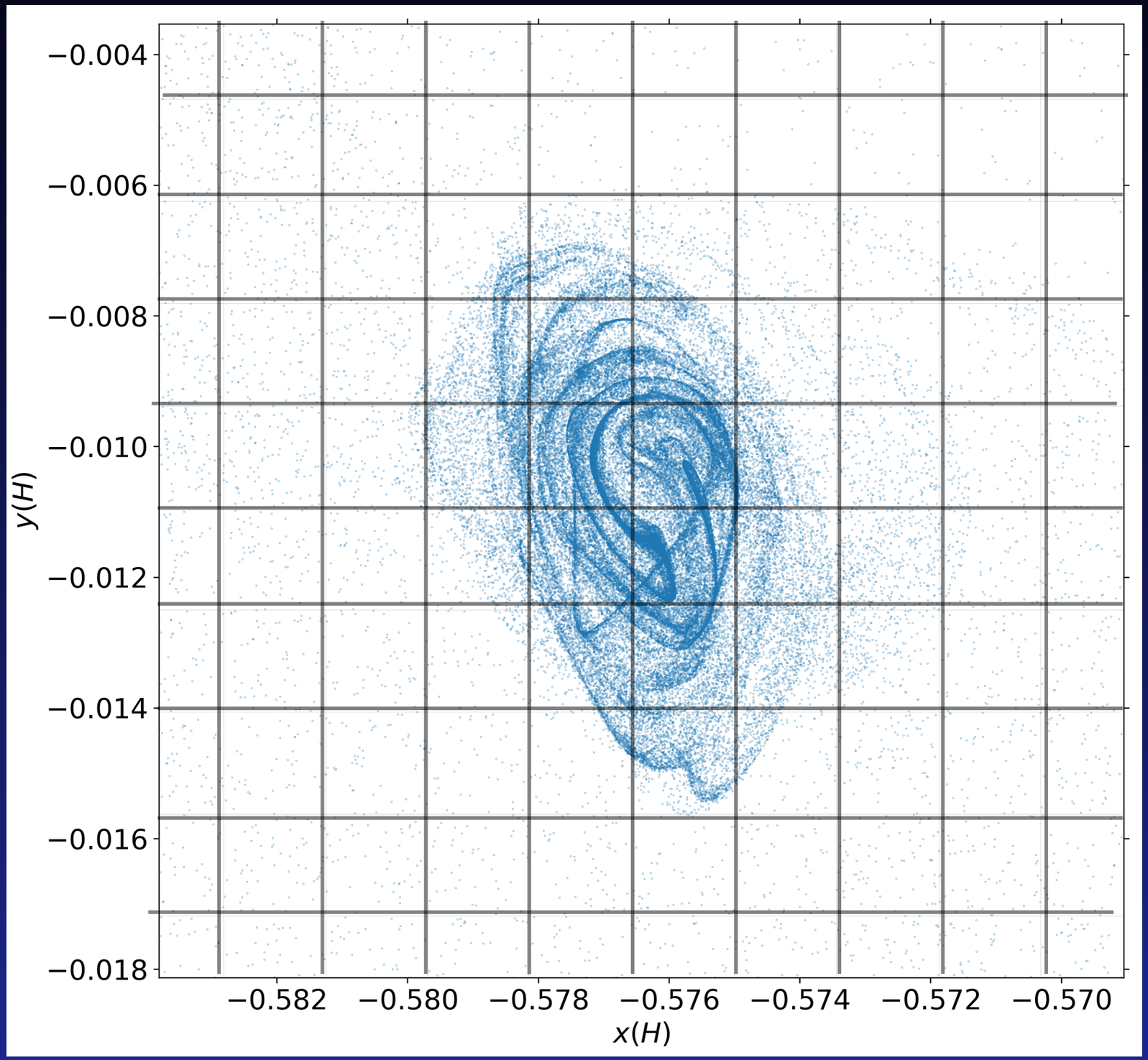
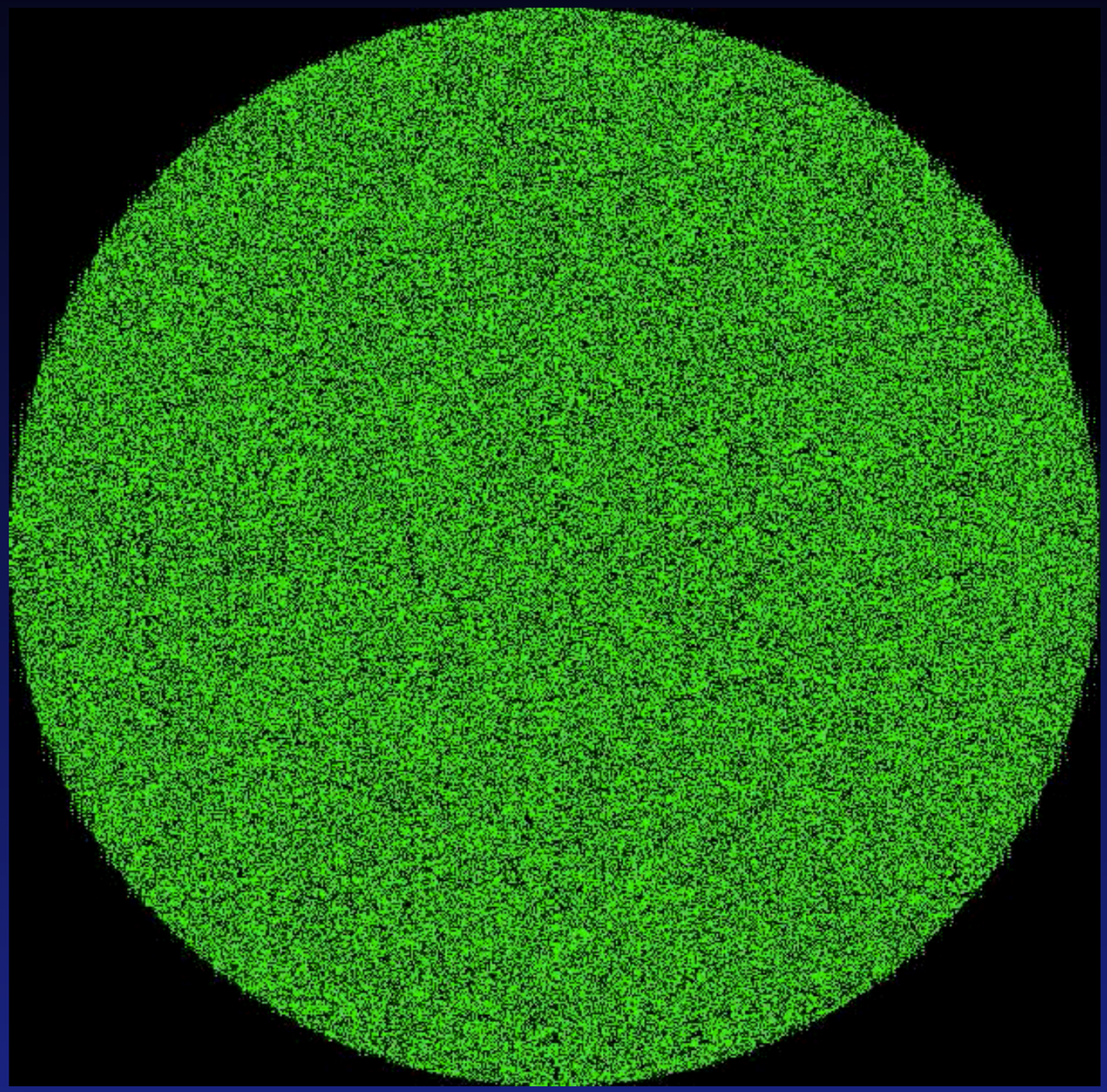
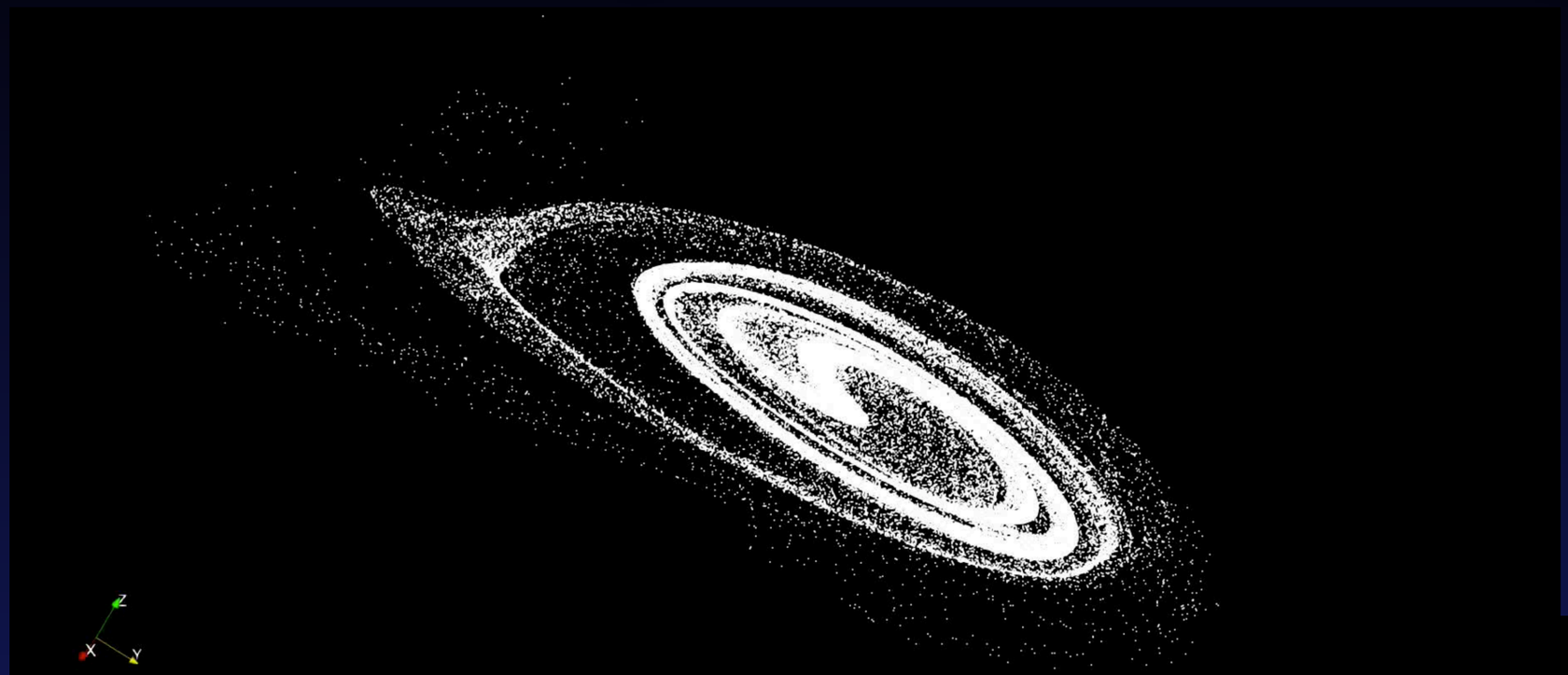


Following up with PKDGRAV simulations

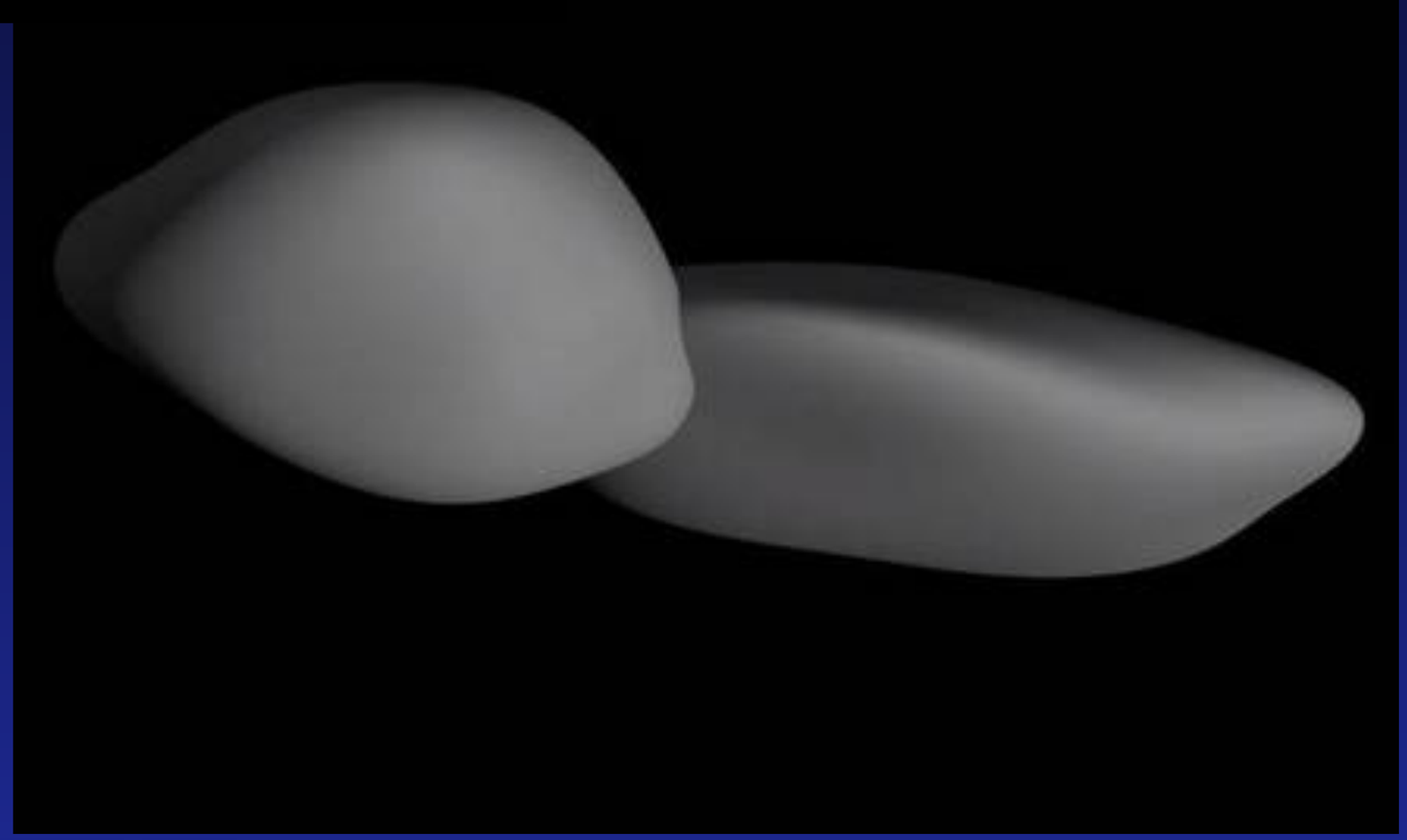


Nesvorny et al. (2010)

Obviously, an interesting connection



MU69
(aka Ultima Thule)



NASA, JHU APL, SwRI

Take home points

(subject to further investigation)

1. Even low amplitude bumps can produce planetesimals

2. But pressure bump must be reinforced (likely not a problem, but needs to be worked out)

3. Flat planetesimals

4. Possible explanation for the formation of MU69!