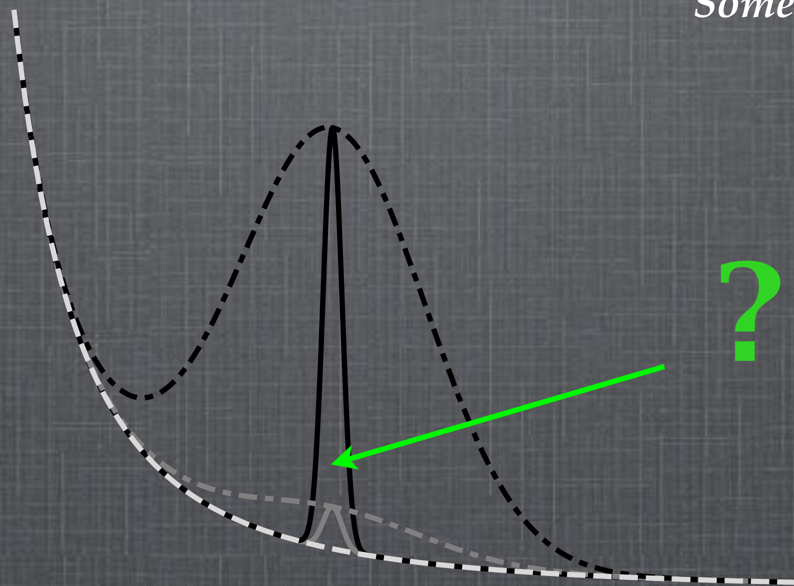
On linear growth of streaming instability in pressure bumps

"Somehow, a planet forms…"

Jonathan T.



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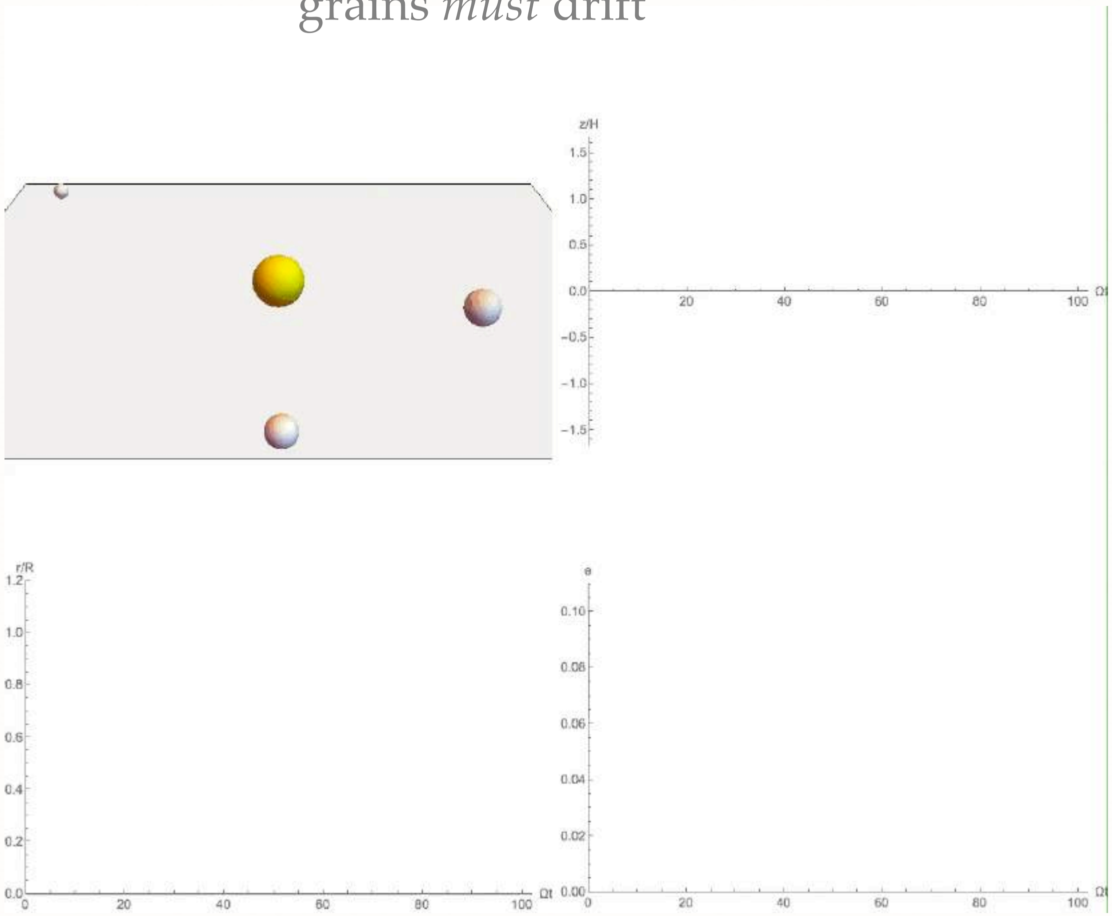
Auffinger et Laibe (2018), MNRAS

Radial drift

discs warmer and denser in the inner regions:
grains *must* drift

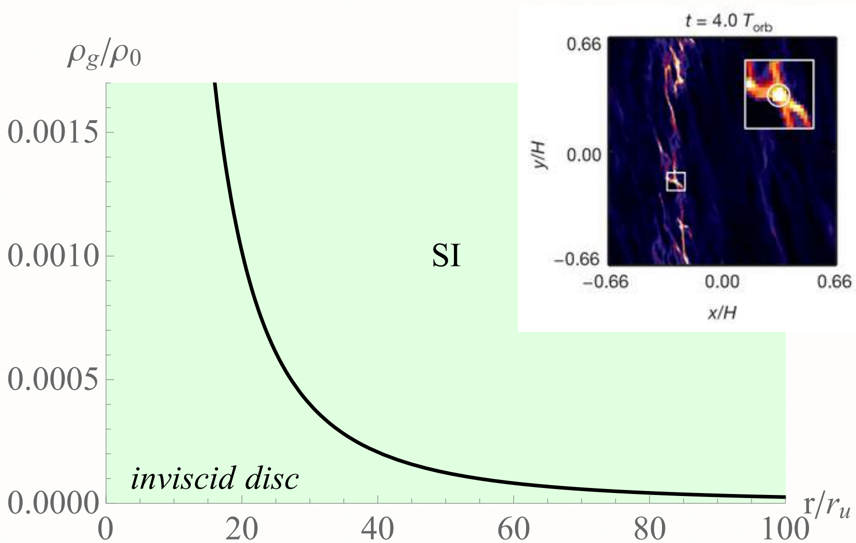


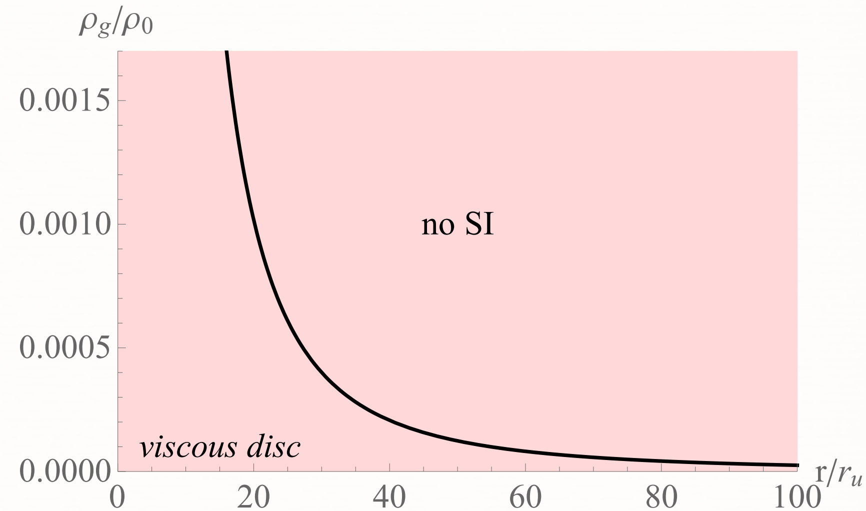
Drift most efficient for t_{drag} / t_{kepler} $= S_t =$ one

Safronov (1969), Hadashi (1976), Weidenschillling (1977), Nakagawa et al (1986)…

Streaming instability

But : radial drift is **unstable** (*SI*)





SI very efficient
second stage towards planetesimals…

…in discs of low viscosity ($\alpha > 10^{-5}$ - 10^{-4})

Youdin and Goodman (2005)
Johansen et al. (2007)
Bai and Stone (2010)
Yang and Johansen (2014)…

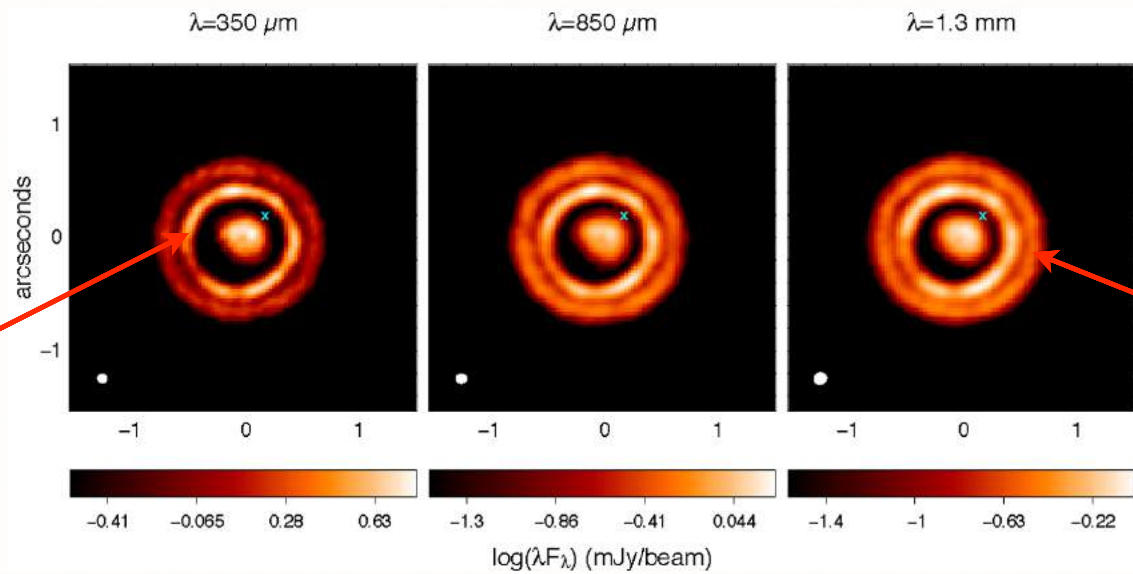
HL Tau: planets + grains ?

ALMA Partnership et al. (2015)

What happens in pressure bumps ?

Dust drifts towards pressure maxima

Paardekooper and Mellema (2005)
Pinilla et al. (2012)
…



Gonzalez et al. (2015)

planet's outer edge

Self-Induced Dust Trap

does only partially help…

How to form planetesimals at specific locations in discs ?

Goal : can SI grow in pressure maxima and how ?

Revisiting *SI* theory in a pressure bump

SI in shearing box:

$$\left(\frac{\partial}{\partial t} + \mathbf{V}_\mathrm{g}\cdot\boldsymbol{\nabla}\right)\mathbf{V}_\mathrm{g} = -\, r_0 x \left.\frac{\mathrm{d}\Omega_\mathrm{K}^2}{\mathrm{d}r}\right|_{r_0} \mathbf{u}_x - 2\Omega_0 \mathbf{u}_z \times \mathbf{V}_\mathrm{g}$$
$$+\, 2 r_0 \Omega_0^2 \left(\eta + \frac{\Gamma}{2 r_0} x\right) \mathbf{u}_x + \nu \Delta \mathbf{V}_\mathrm{g}$$
$$+\, \frac{\rho_\mathrm{p}}{\rho_\mathrm{g}} \frac{\mathbf{V}_\mathrm{p} - \mathbf{V}_\mathrm{g}}{t_\mathrm{stop}}\,, \qquad (10)$$

pressure gradient (YG05)

pressure curvature (this work)

$$\left(\frac{\partial}{\partial t} + \mathbf{V}_\mathrm{p}\cdot\boldsymbol{\nabla}\right)\mathbf{V}_\mathrm{p} = -\, r_0 x \left.\frac{\mathrm{d}\Omega_\mathrm{K}^2}{\mathrm{d}r}\right|_{r_0} \mathbf{u}_x - 2\Omega_0 \mathbf{u}_z \times \mathbf{V}_\mathrm{p}$$
$$-\, \frac{\mathbf{V}_\mathrm{p} - \mathbf{V}_\mathrm{g}}{t_\mathrm{stop}}\,.$$

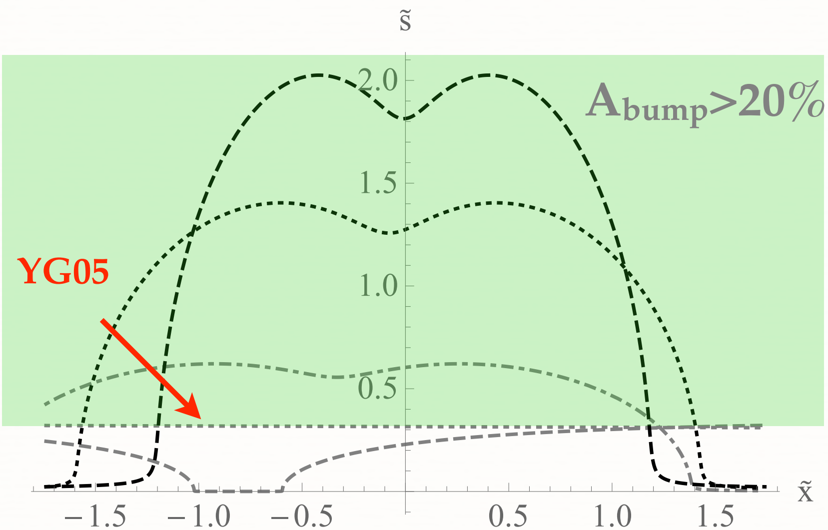
Non-standard $v_{r,\theta}(\eta,\Gamma,x)$ solution (radial advection)

Then:

- Linear analysis with local WKB approach
- Short times
- Get the YG05 results with $\Gamma = 0$

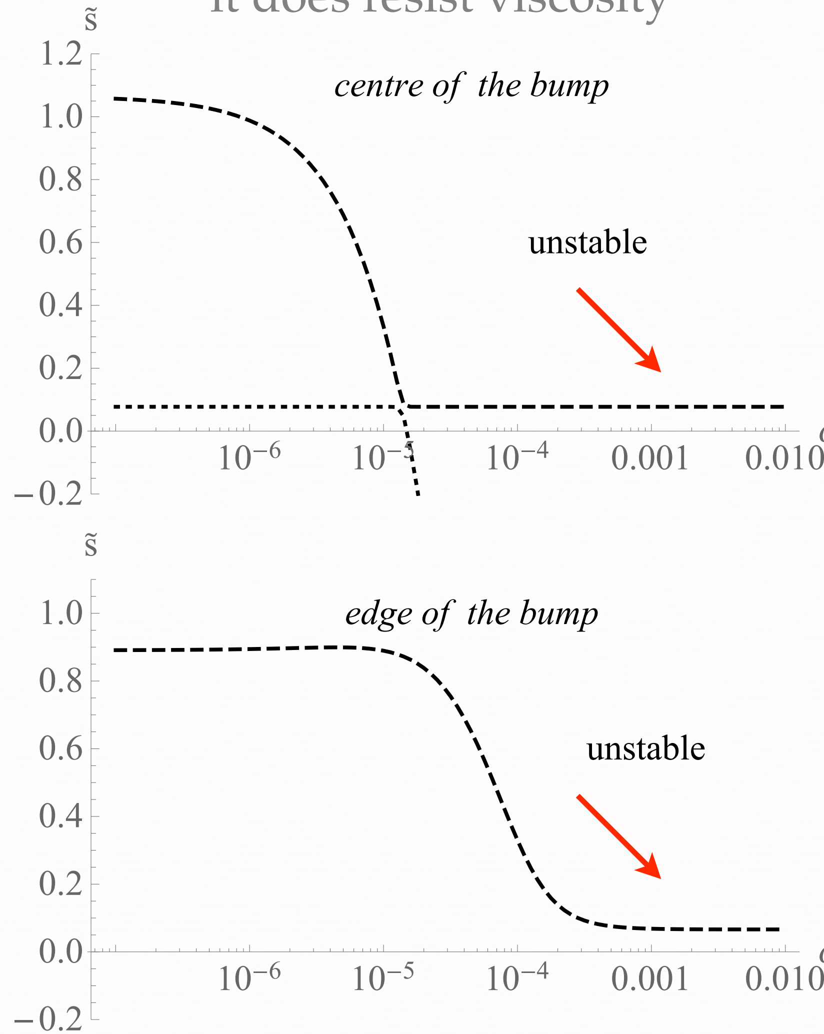
Results

An unstable mode grows



Stones, $\rho_d / \rho_g \sim 1$

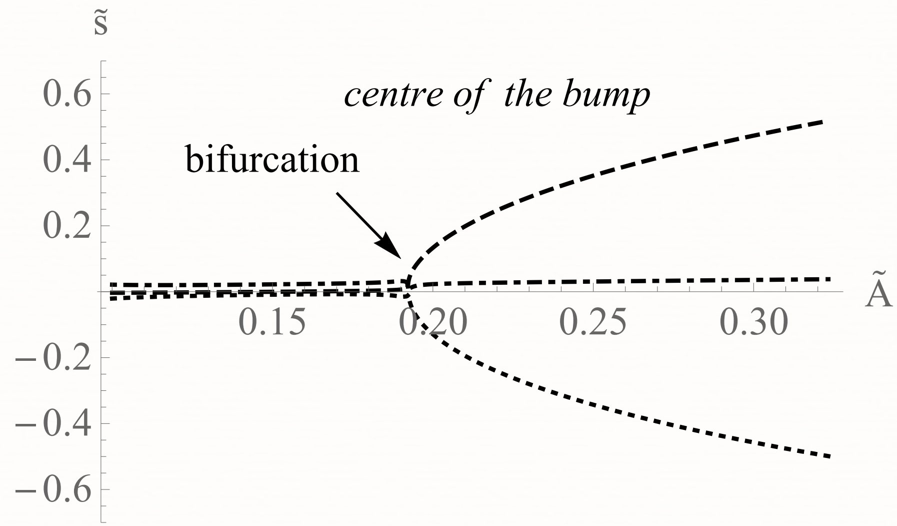
it does resist viscosity



Physical interpretation

Q: What is the physical mechanism ?

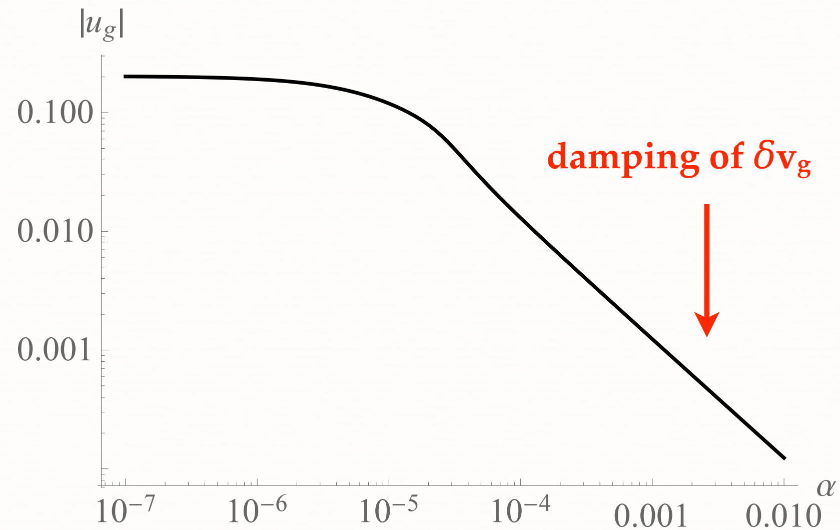
A: $$\frac{\mathrm{d}\Delta\mathbf{v}}{\mathrm{d}t} = -\frac{\Delta\mathbf{v}}{t_\mathrm{s}} + \frac{\nabla P}{\rho_\mathrm{g}} + \frac{1}{2}\nabla\left[(2\epsilon - 1)\,\Delta\mathbf{v}\Delta\mathbf{v}\right] - (\Delta\mathbf{v})\cdot\mathbf{v}$$



bifurcation for $A_{\mathbf{bump}} > 20\%$

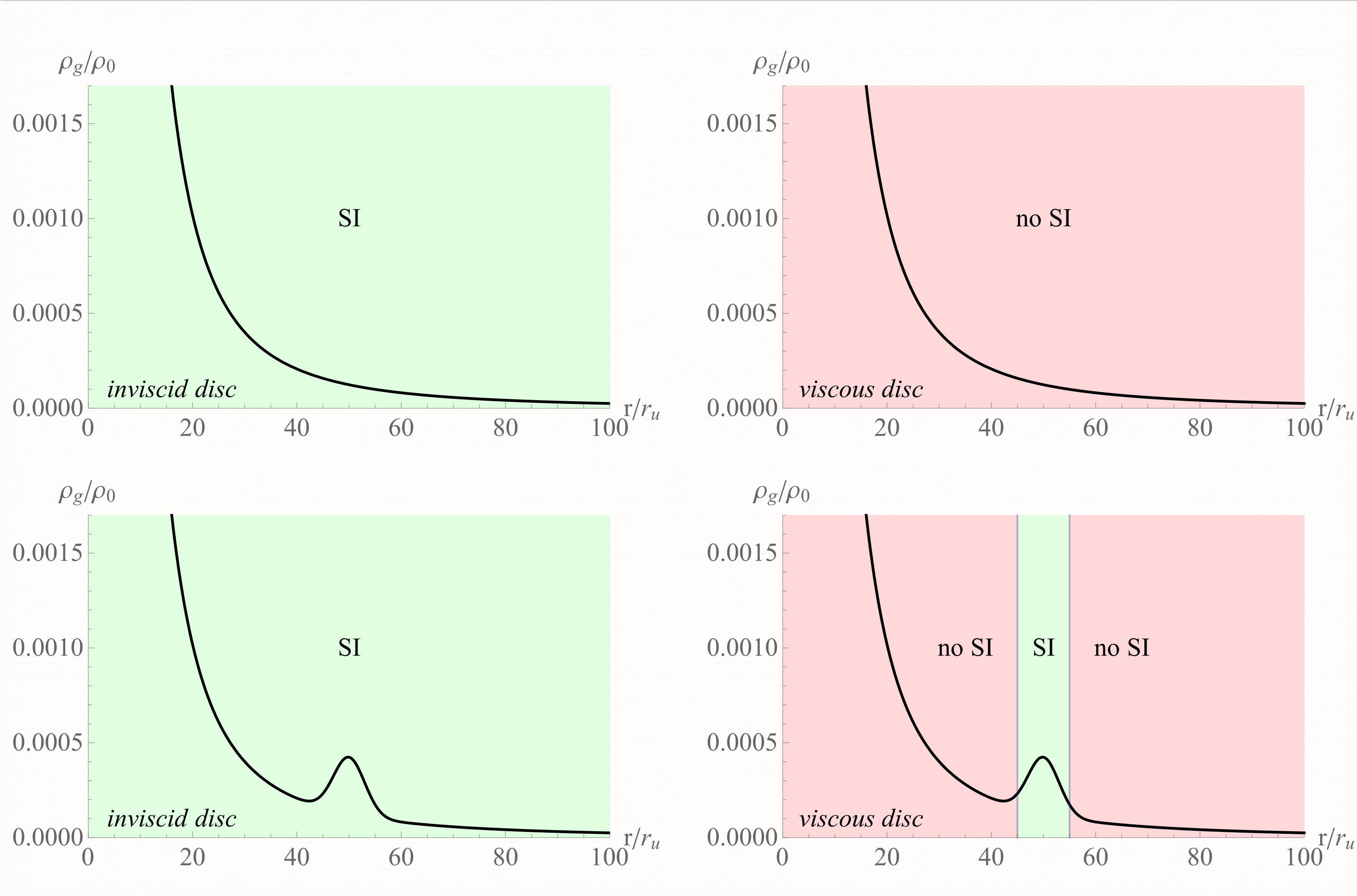
Laibe and Price (2014) a,b
Lin and Youdin (2017)

Q: Why does it resists viscosity ?



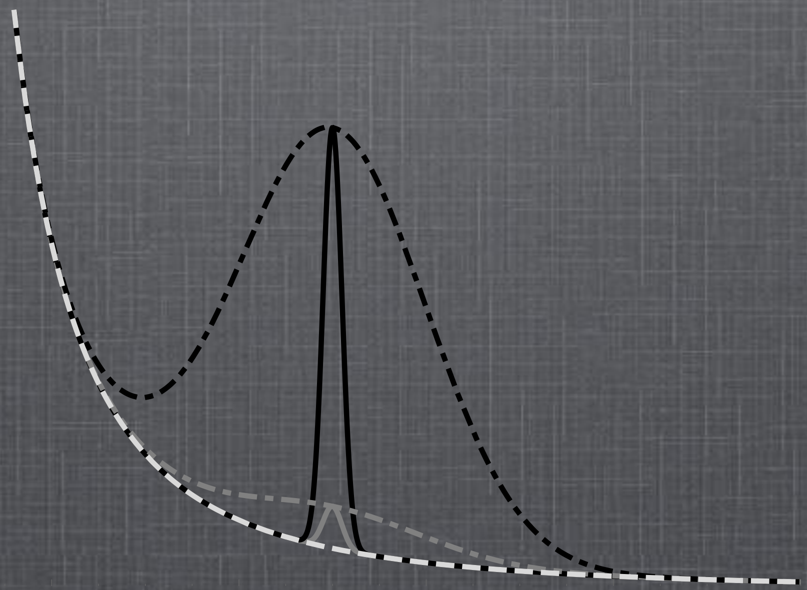
A: **Strong gradient of differential velocity provided by the background**
(not the perturbation)

Consequences for planet formation



Conclusions

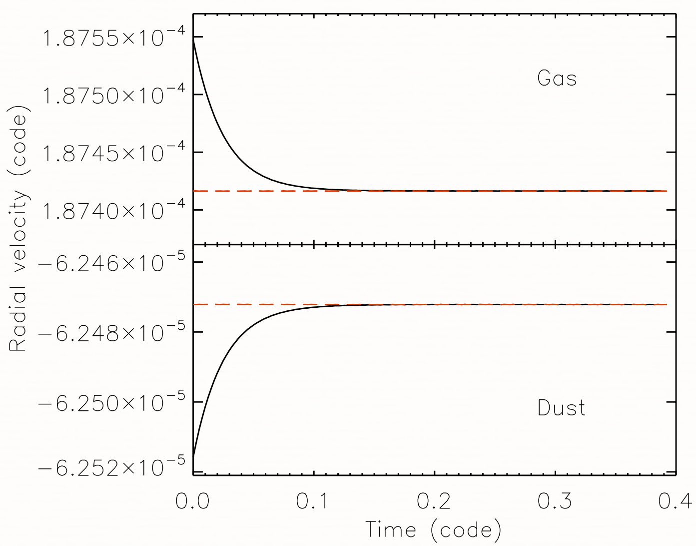
PROBABLY, YES



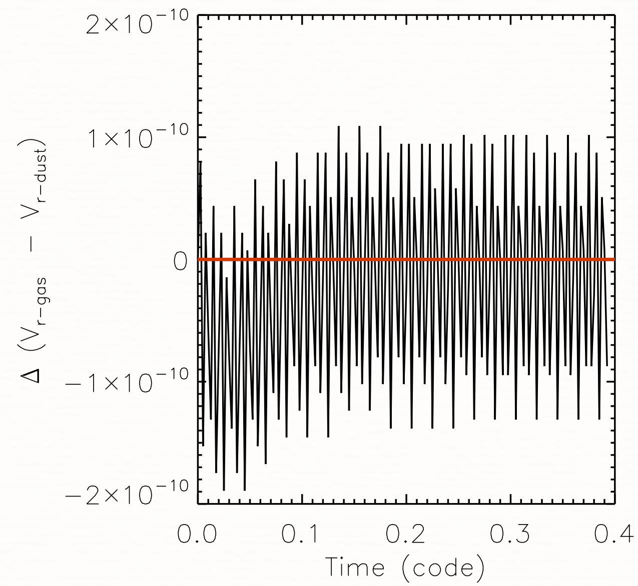
Auffinger et Laibe (2018), MNRAS

Numerical simulations needed for NL regime

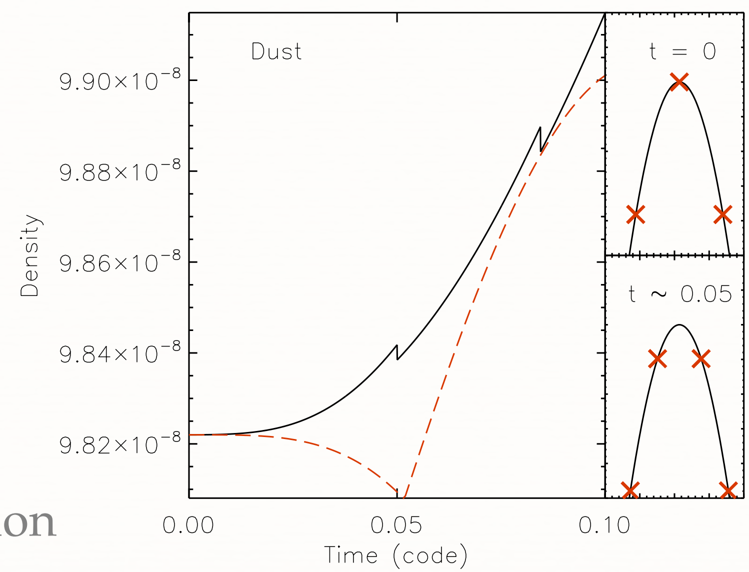
Streaming instability with SPH (an old trauma)?



NSH86 solution



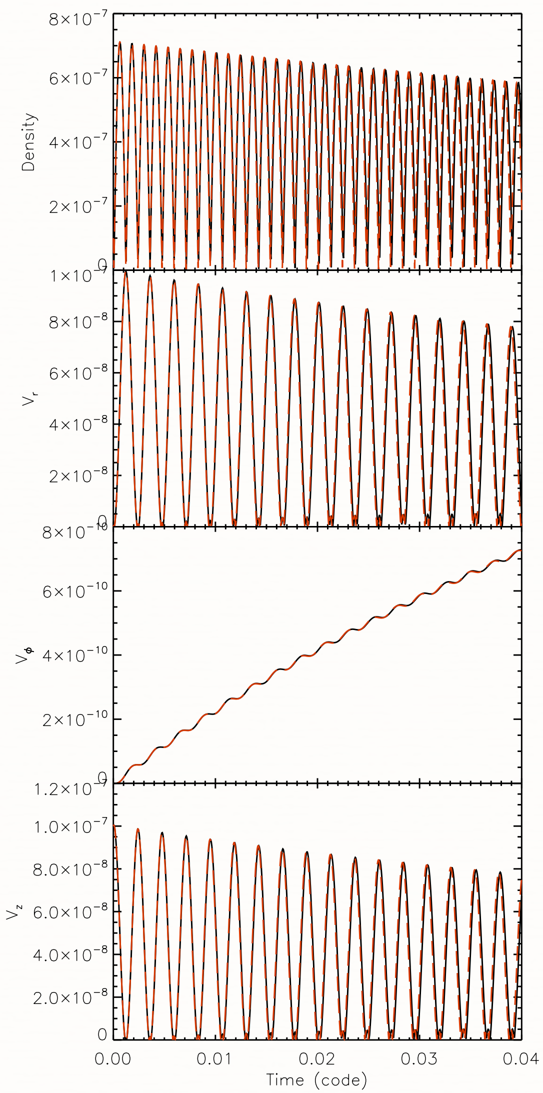
fluctuations…



Max detection

with B. Ayliffe, D. Price

Streaming instability with SPH?



this test ~ perfect…

but…