# Streaming Instability for Particle-size Distributions

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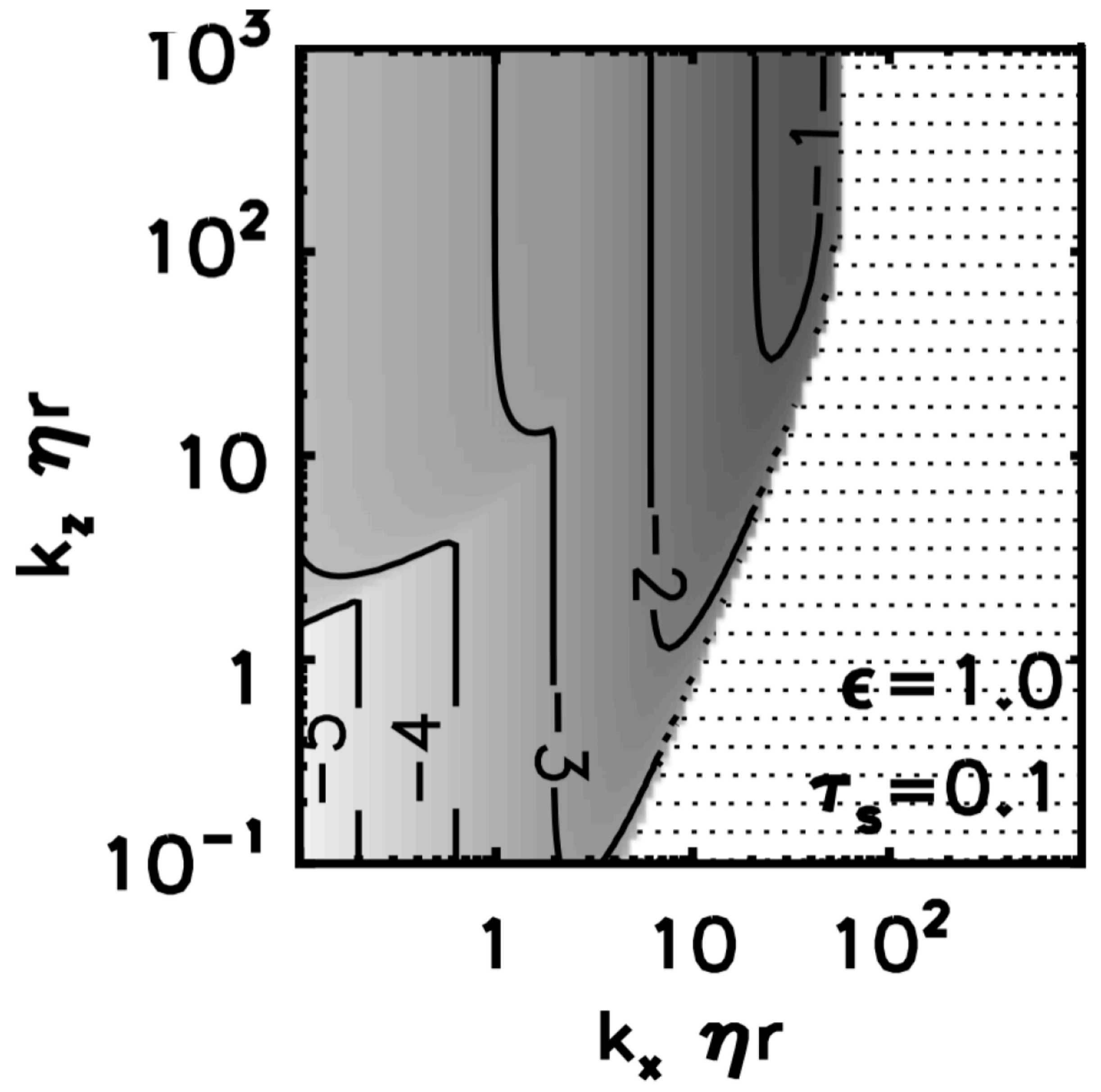
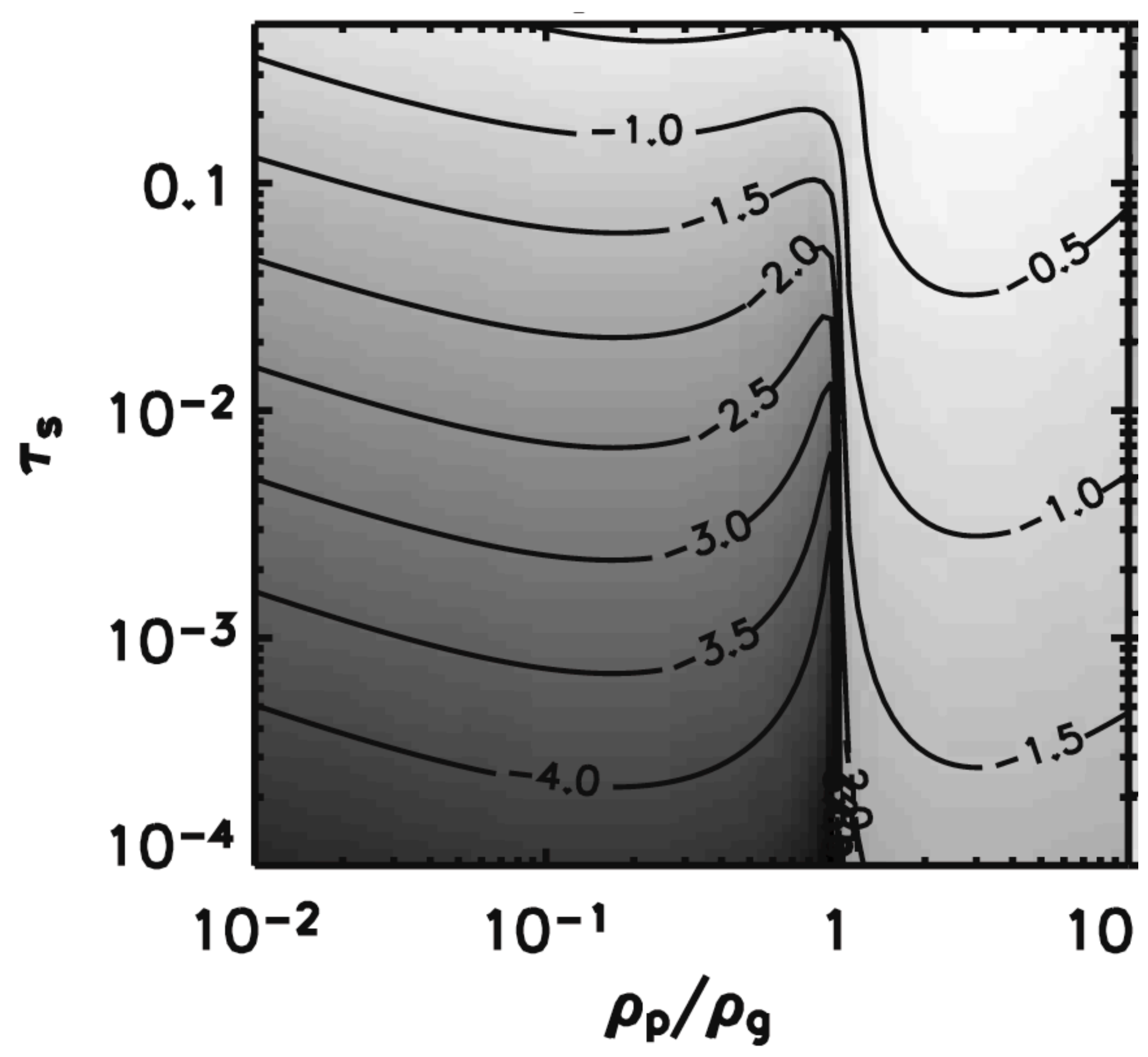
Zooming In on Star Formation - Napflio - June 10-14, 2019

# Streaming Instability - One Dust Species

- Homogeneous shearing box
- Radial pressure gradient
- Dust particles drift wrt gas
- Drift velocity depends on Stokes number $T_s$ and dust-to-gas mass ratio $\epsilon$




Youdin & Goodman 2005

Youdin & Johansen 2007

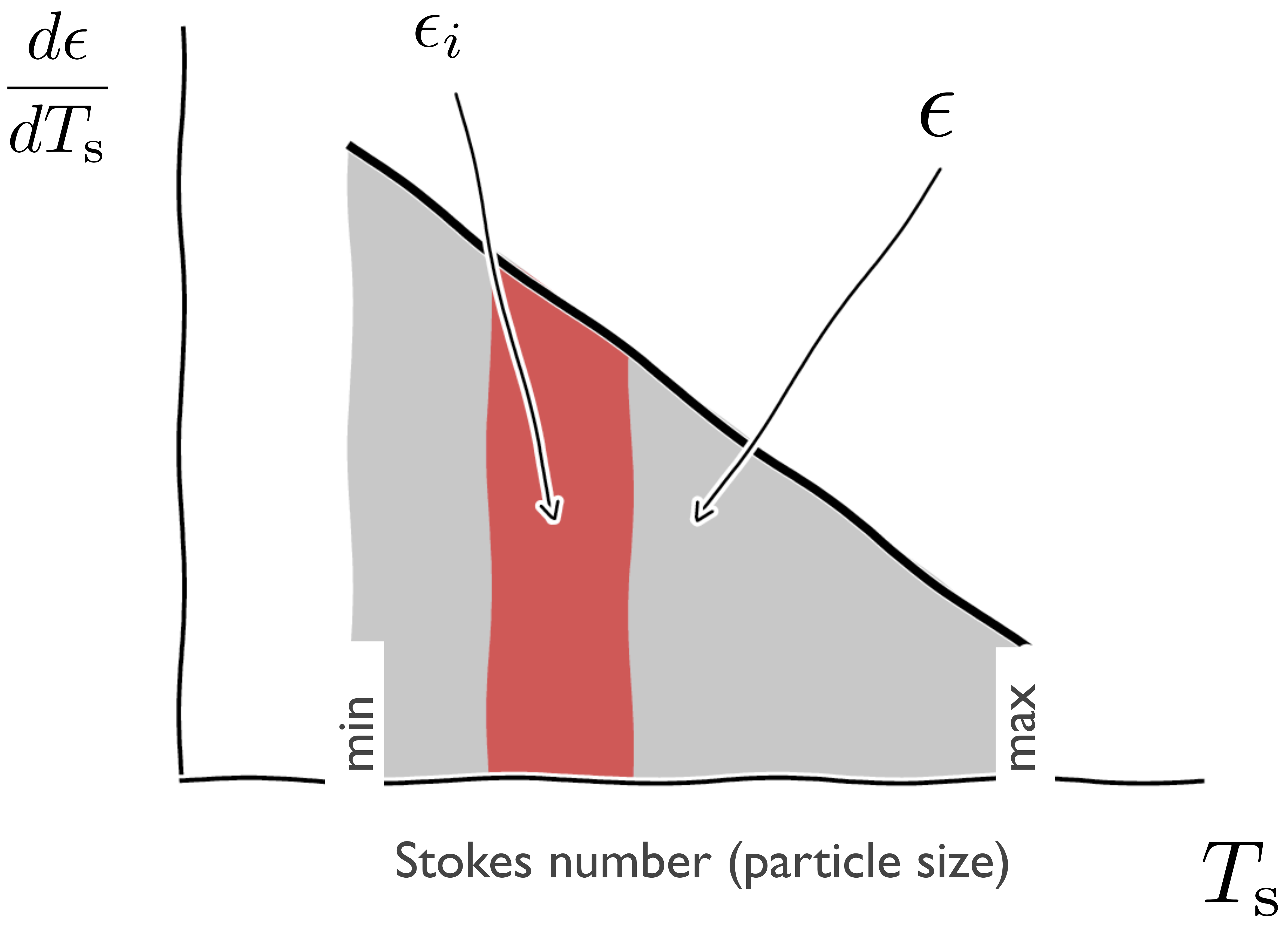
Johansen & Youdin 2007

Jacquet, Balbus, & Latter 2011

Squire & Hopkins 2018

…

# Particle-size Distribution




$$\sum_{i=1}^{N} \epsilon_i = \epsilon$$

- Discrete representation of a continuous distribution with N dust species $\{\epsilon_i, T_{si}\}$

# Multi-Fluid Shearing Box & Steady State

Benitez-Llambay et al. 2019
ApJS, 241, 25

- Multi-fluid shearing box $\{\epsilon_i, T_{si}\}$ for $i = 1, \dots, N$

- Steady state solution

$$\mathbf{v}_g^0 = -q\Omega_0 x\,\hat{y} + \Delta\mathbf{v}_g^0(\mathcal{A}, \mathcal{B})$$
$$\mathbf{v}_i^0 = -q\Omega_0 x\,\hat{y} + \Delta\mathbf{v}_i^0(\mathcal{A}, \mathcal{B})$$

$$\mathcal{A}_N = \sum_{i=1}^{N} \frac{\epsilon_i T_{si}}{1 + T_{si}^2} \qquad \mathcal{B}_N = 1 + \sum_{i=1}^{N} \frac{\epsilon_i}{1 + T_{si}^2}$$

- Small amplitude perturbations lead to a 4(N+1) linear equations

- Assume $\delta f(x, z, t) \sim \mathrm{Re}[\delta\hat{f}(k_x, k_z)\, e^{i(k_x x + k_z z) - \omega t}]$ and find the fastest growing modes

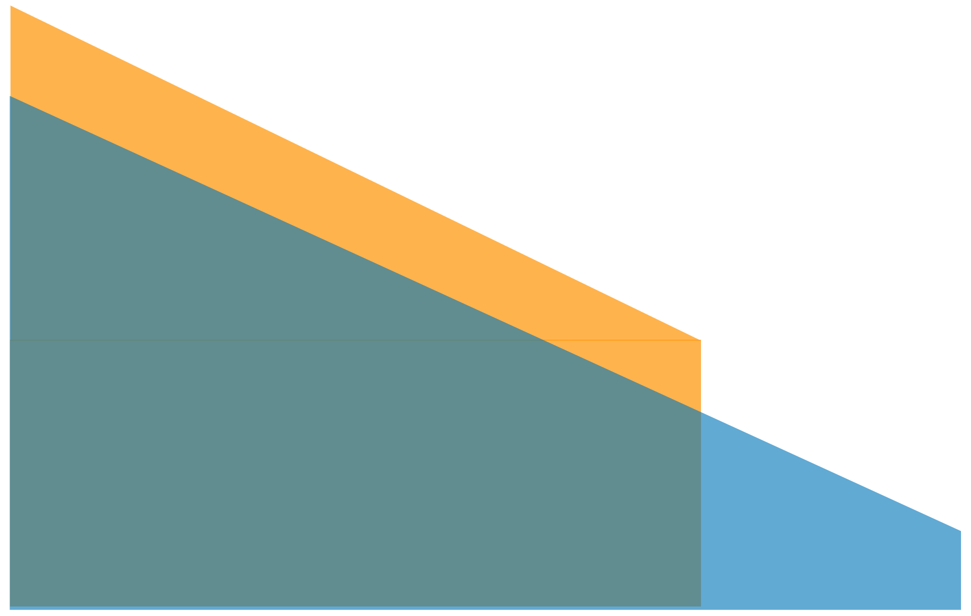
# Exercise

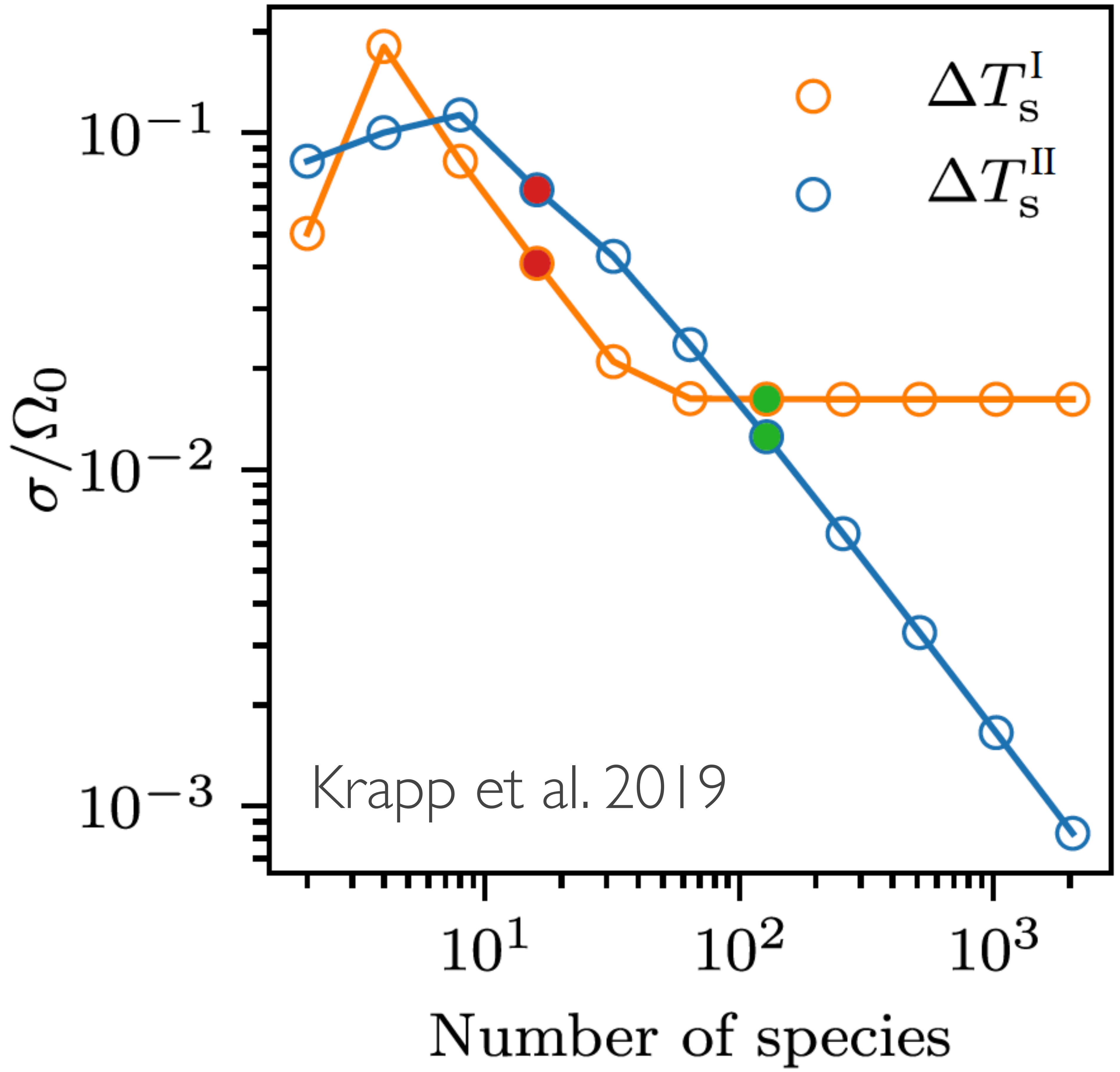
- @ fixed dust-to-gas mass ratio and Stokes number range; increase the number of species

- Two examples (equal gas and dust mass)

$$\Delta T_{\rm s}^{\rm I} = [10^{-4}, 10^{-1}]$$

$$\Delta T_{\rm s}^{\rm II} = [10^{-4}, 1]$$

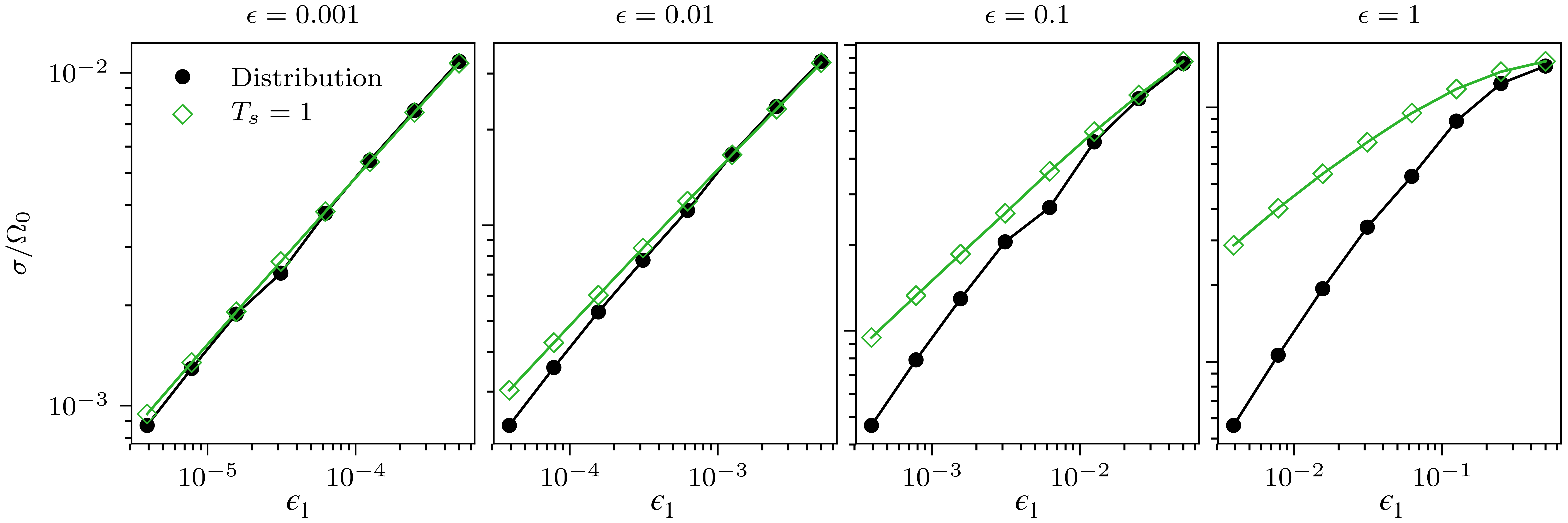





- Maximum growth rate behaves quite differently!

# What Is Going On?

- Fix dust-to-gas-mass ratio and fix range of Stokes numbers
- Consider a distribution with equal mass-per-bin
- Increase the number of species so that the mass-per-species decreases



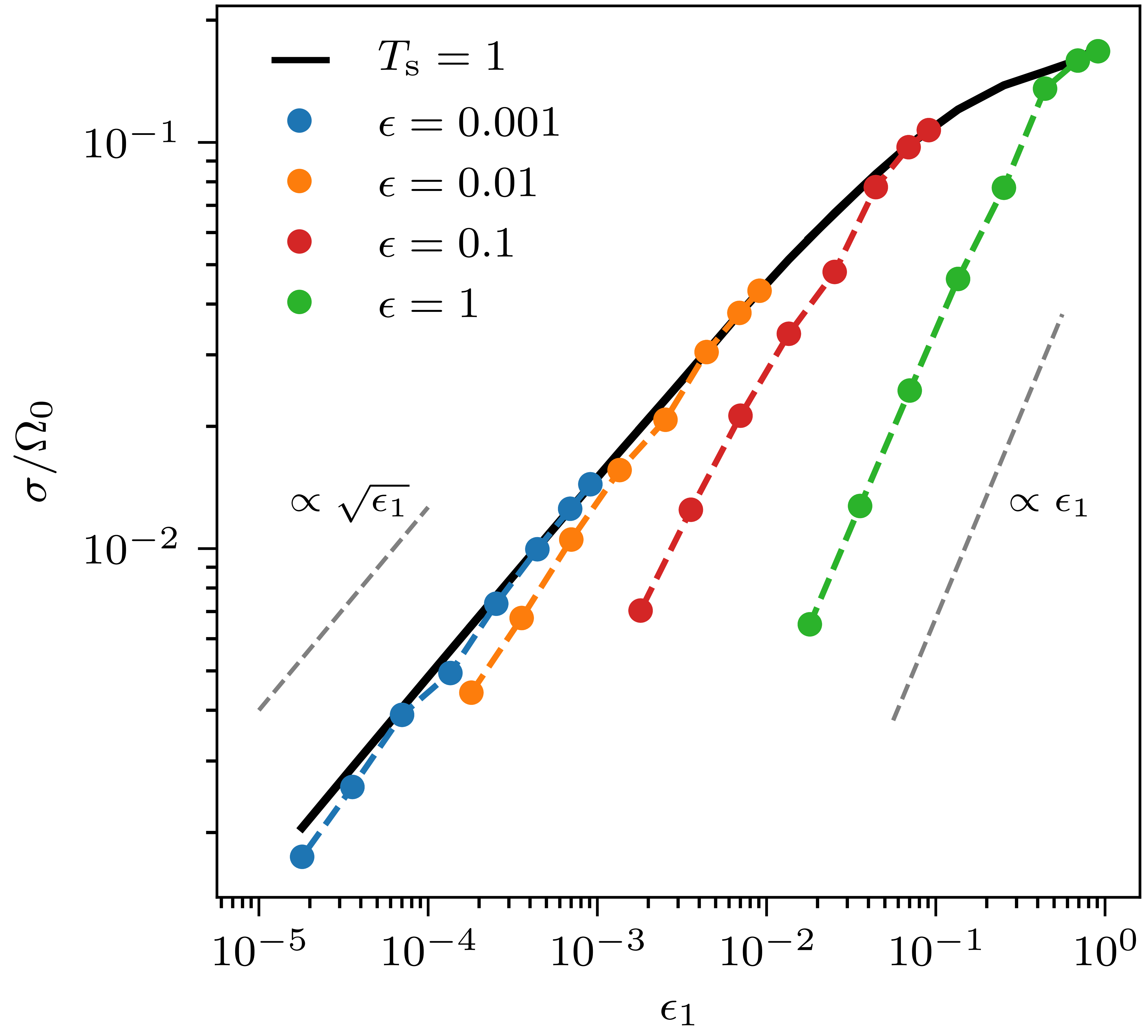
# Some Insights

**At very low dust-to-gas mass ratios:**

- species with largest Stokes number dominates
- problem reduces to one-dust species with decreasing mass
- growth-rate scales with $\sqrt{\epsilon}_1$ (RDI, Squire & Hopkins 2018)

**At higher dust-to-gas mass ratios:**

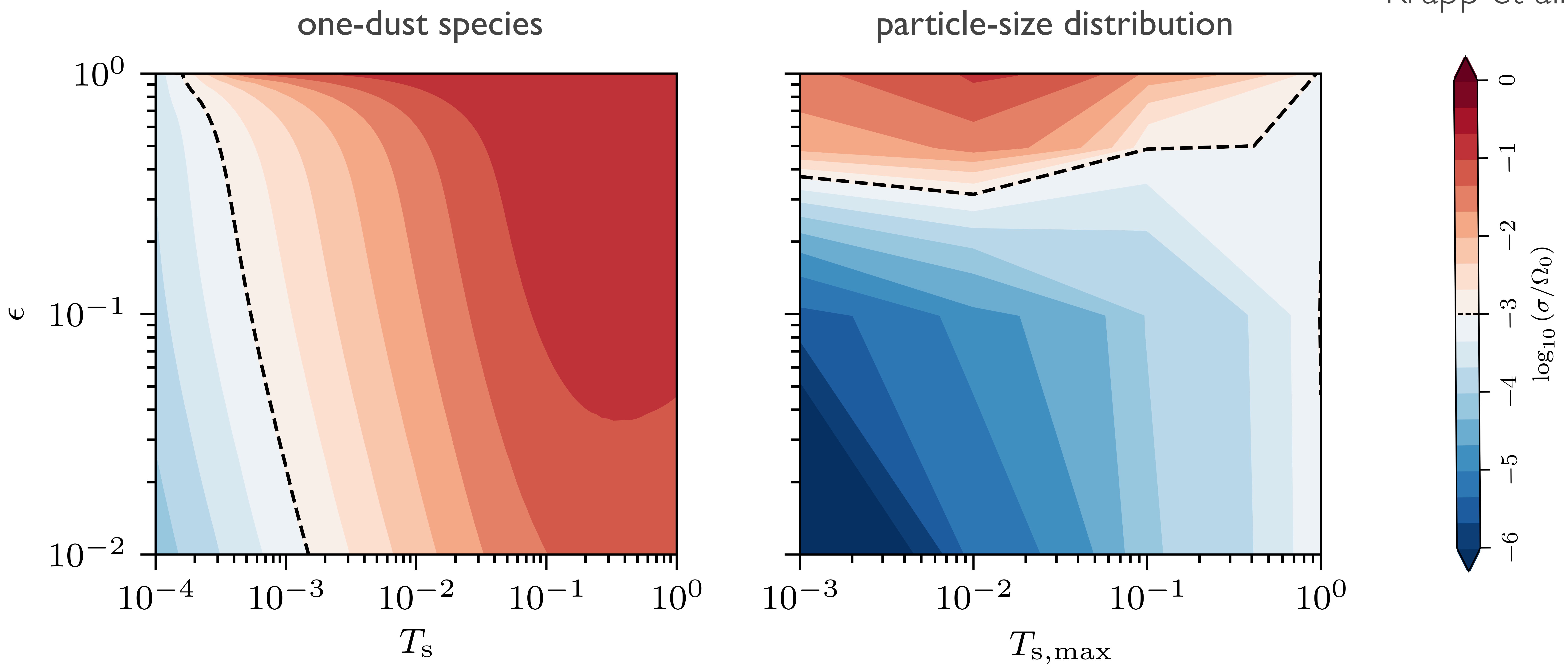
- background flow is determined by the ensemble
- no longer describable as a one-dust problem
- unclear current RDI framework can describe this
- growth-rate scales with $\epsilon_1$




Krapp et al. 2019

# Reduced Growth for Particle-size Distributions

Krapp et al. 2019




Unless we can identify mechanisms to produce mono disperse particle populations efficiently, the scope of the streaming instability may be narrowed down profoundly.