Streaming instabilities in modern protoplanetary disks

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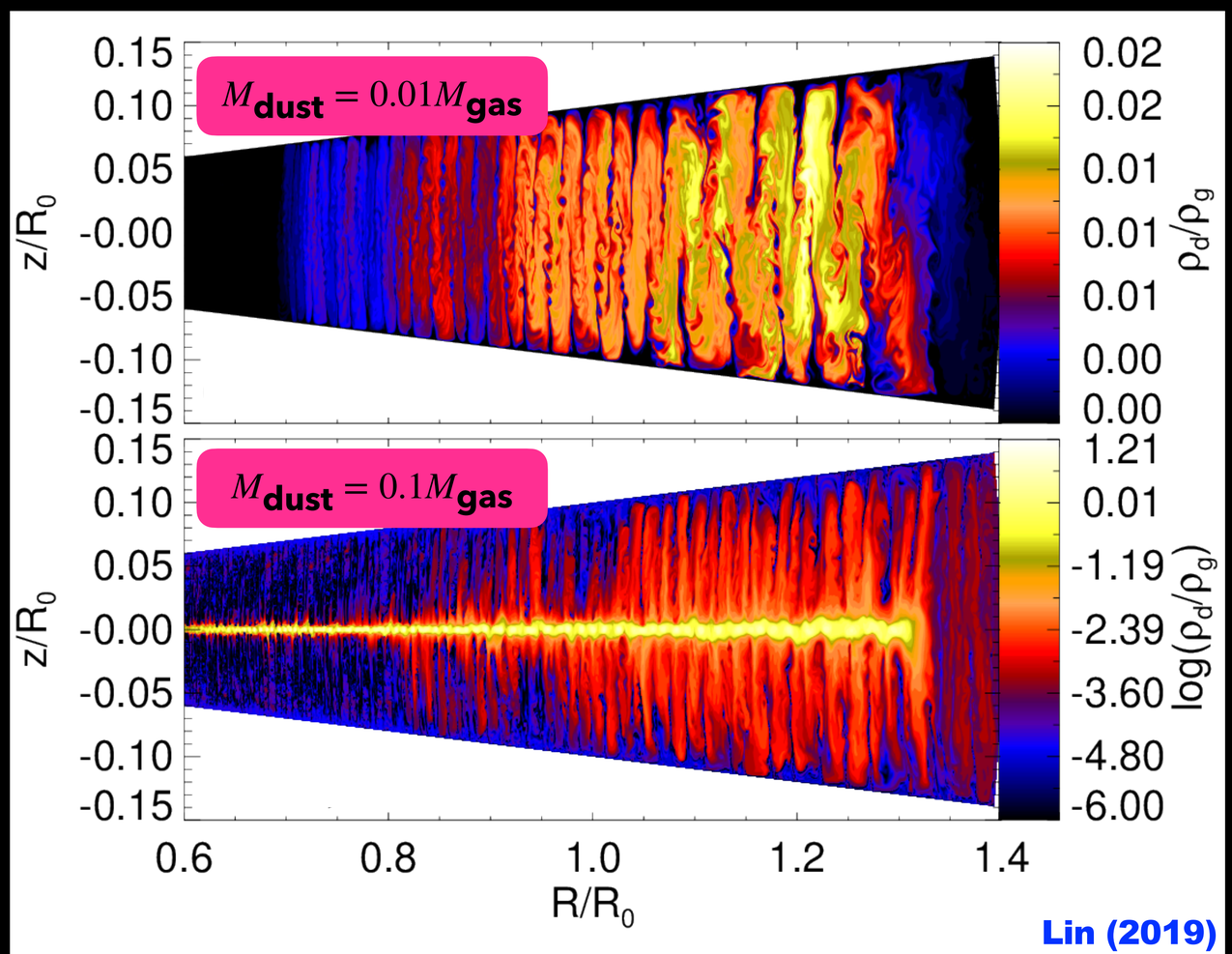
Introduction

Planets are built from planetesimals, themselves formed from dust grains or pebbles. The streaming instability (SI) is a promising mechanism to concentrate pebbles to the point of self-gravitational collapse. We present several extensions to the standard SI by accounting for turbulence, vertical structure, and accretion flows in protoplanetary disks (PPDs). We find new challenges, but also potentially new pathways for the SI under these conditions.

Dust settling in turbulent disks

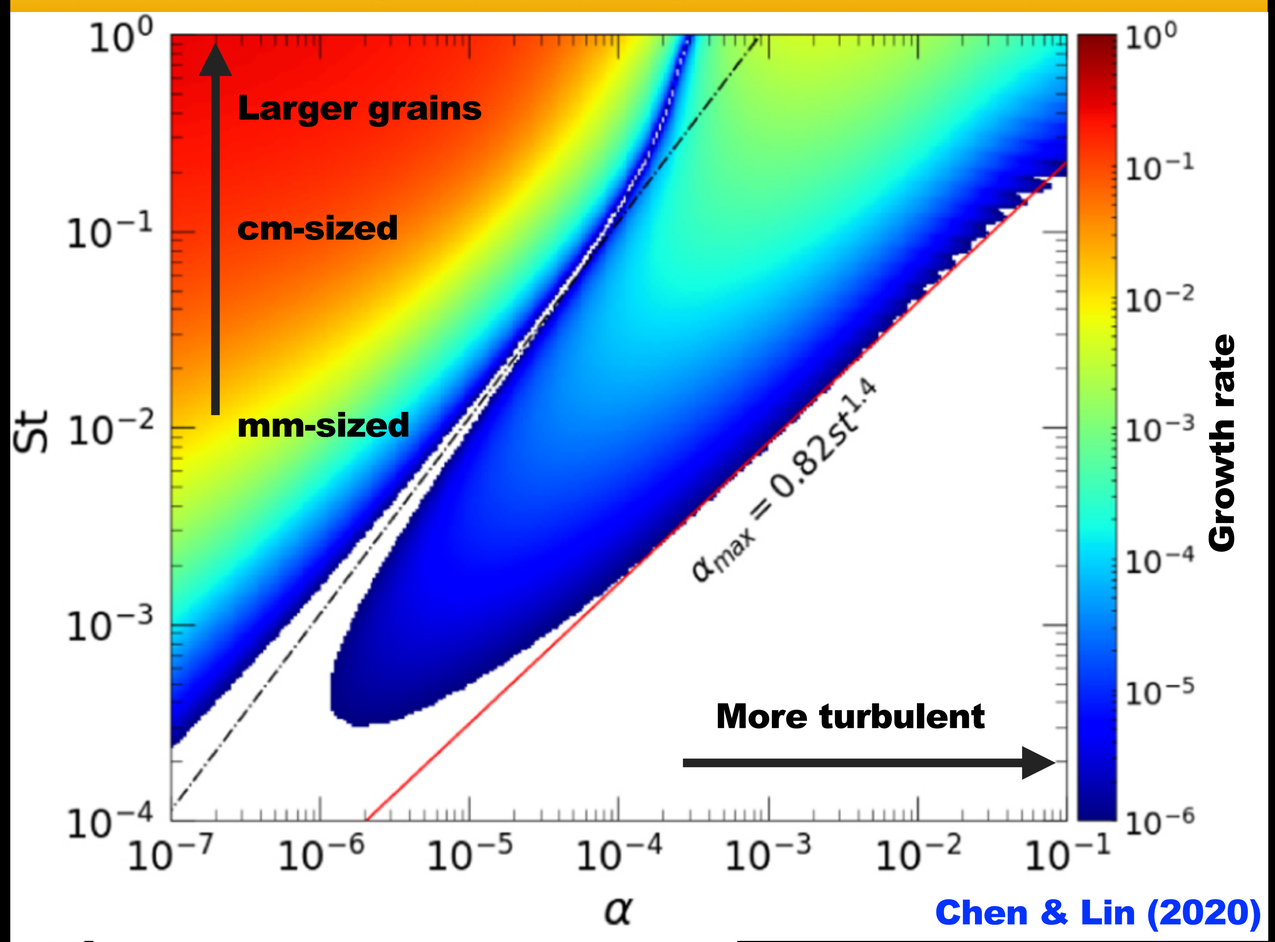
Simulations of PPDs undergoing the "vertical shear instability"



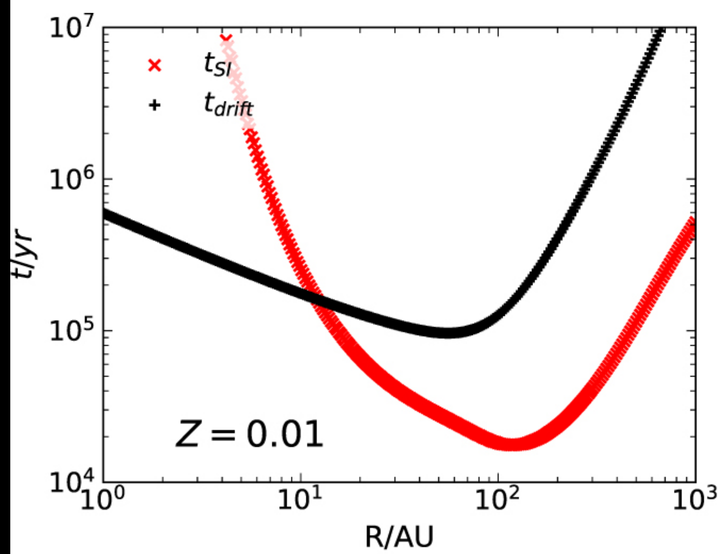
Lin (2019)

- **Nominal dust-to-gas mass ratio → dust is vertically mixed**
- **Enhanced dust-to-gas mass ratio → dust settles to the midplane**

Streaming instability with turbulence



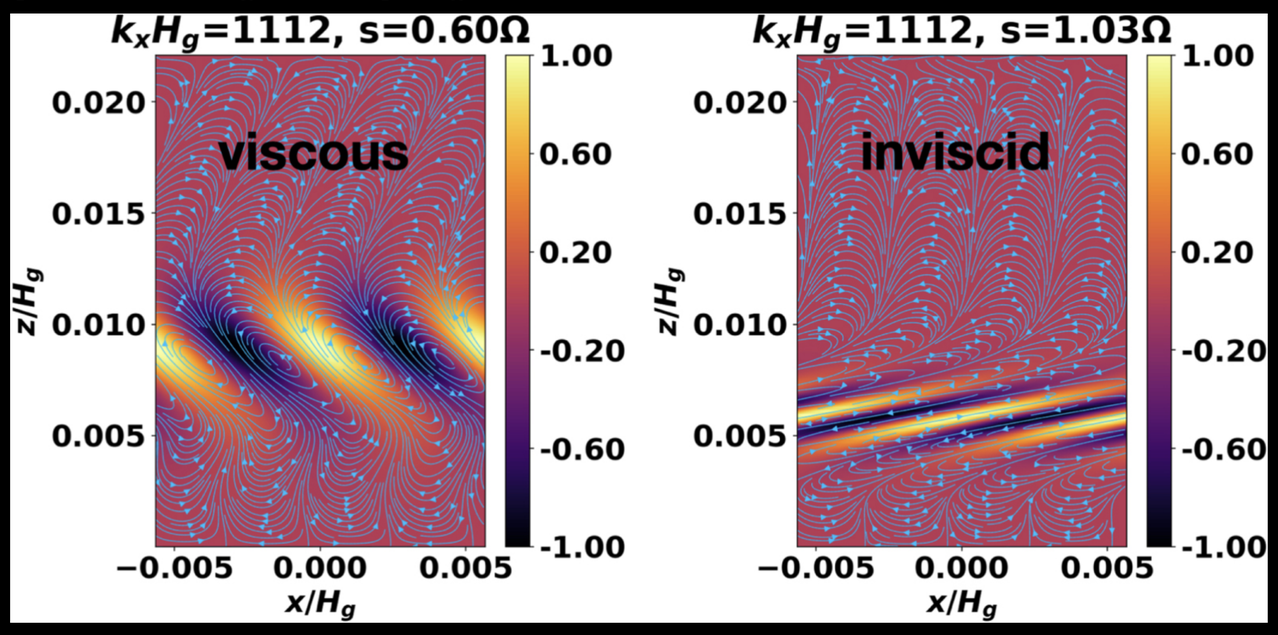
Chen & Lin (2020)



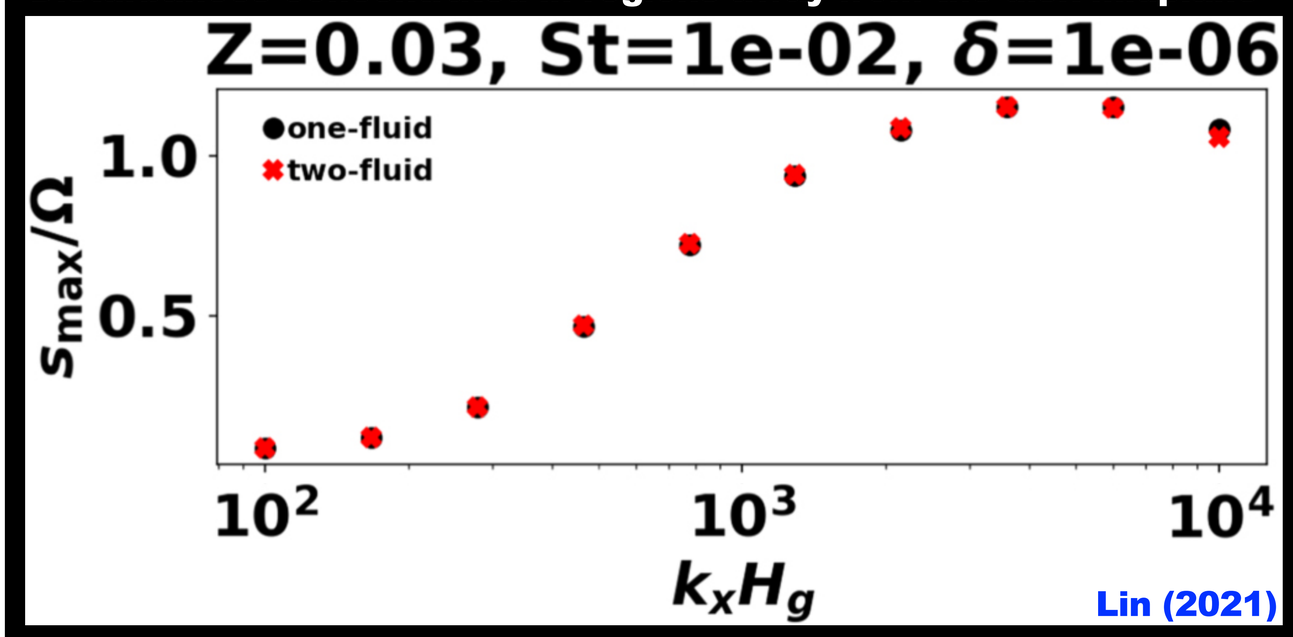
- **SI easily weakened by turbulent viscosity**
- $\lesssim 10$ **au: dust drifts inwards before SI can grow**
- $\gtrsim 10$ **au: SI can grow before dust is lost**

Vertically-shearing streaming instabilities

A new family of SIs powered by the vertical gradient of the dusty gas' rotation velocity in the midplane dust layer, combined with partial dust-gas coupling.



Disturbances concentrated in regions away from the disk midplane

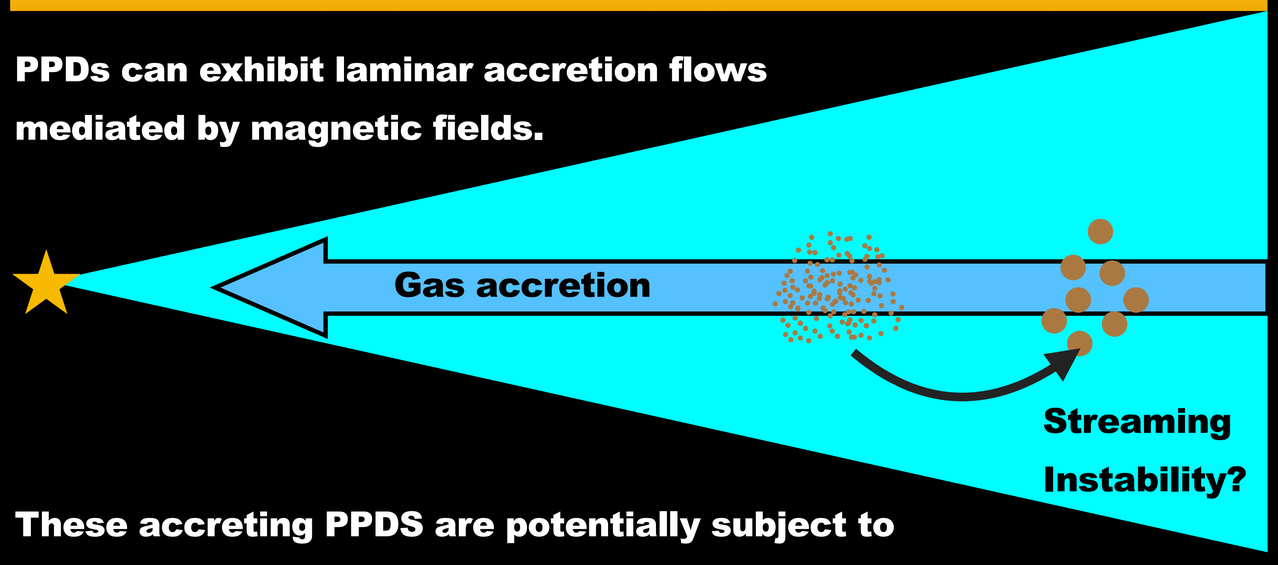


Lin (2021)

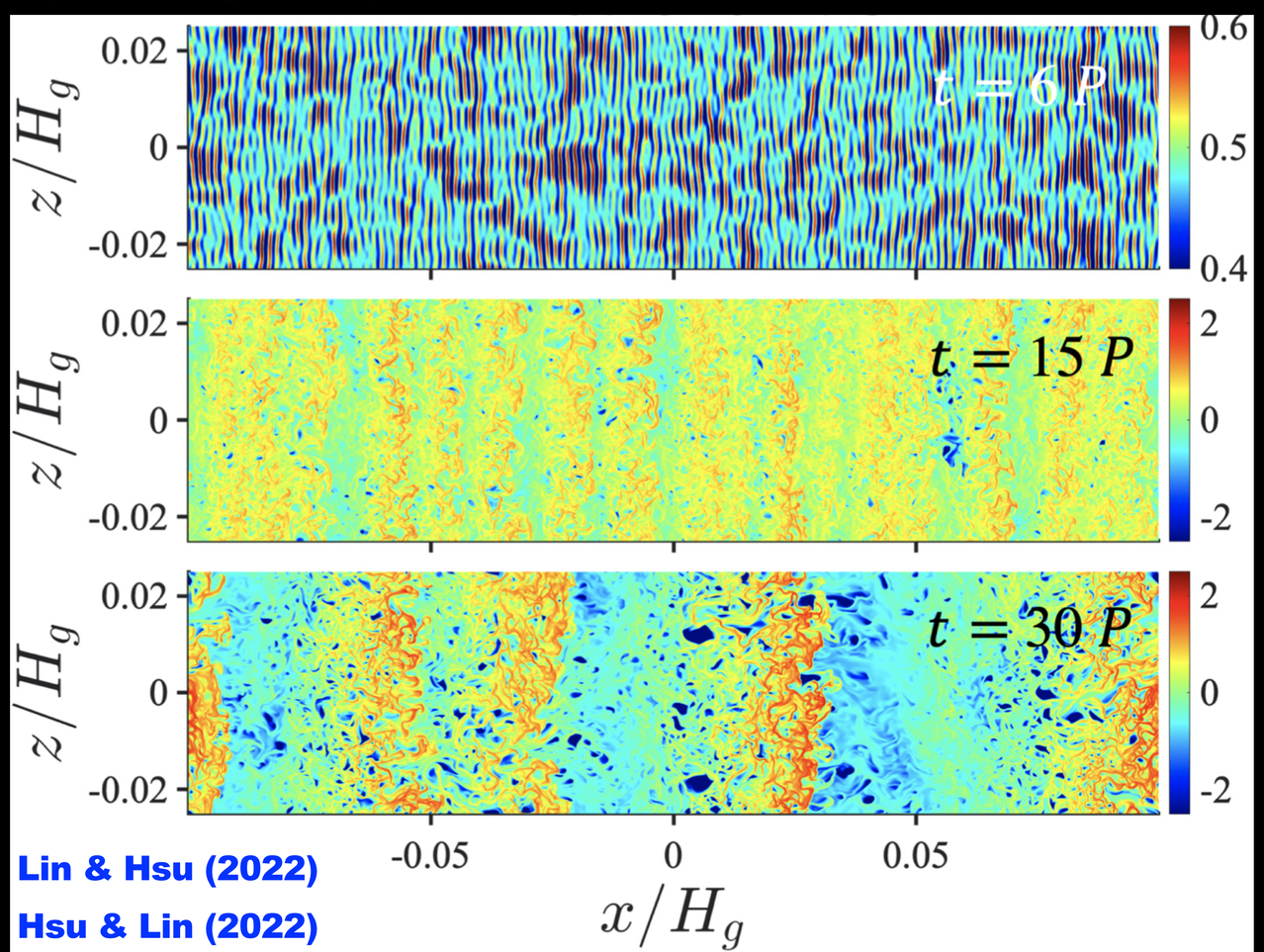
Rapidly growing on small scales of order $10^{-3} H_{\rm gas}$

Streaming instabilities in accreting disks

PPDs can exhibit laminar accretion flows mediated by magnetic fields.



These accreting PPDS are potentially subject to a new "azimuthal-drift" SI, which does not require a pressure gradient, unlike the classic SI.



Lin & Hsu (2022)

Hsu & Lin (2022)