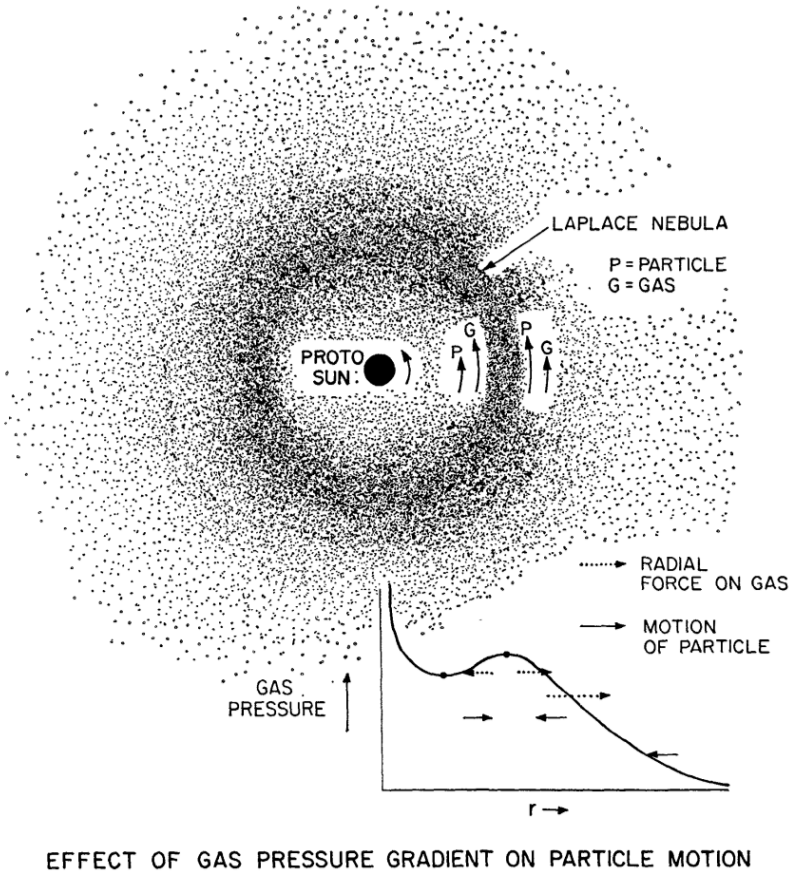
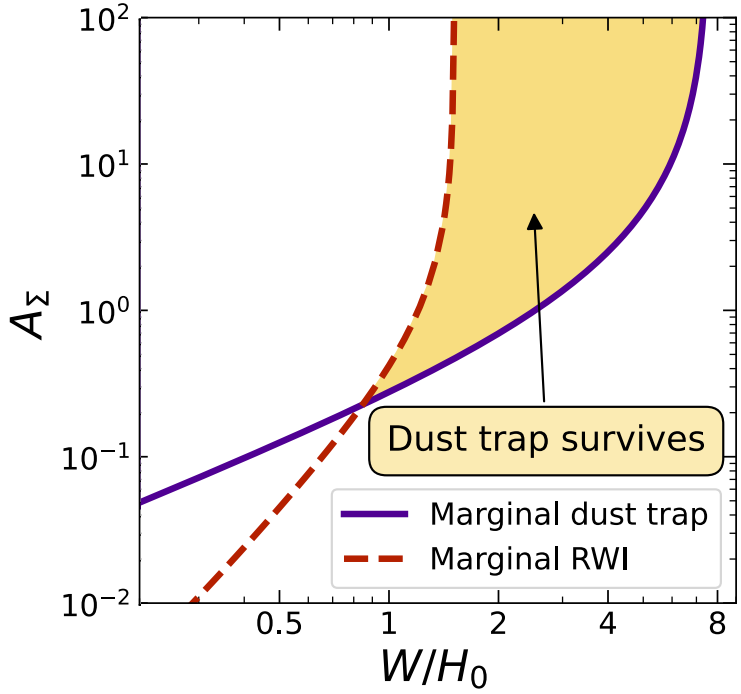
The Nature of ALMAs Dust Rings: Are they Rossby Wave Stable?

Andrew Youdin



EFFECT OF GAS PRESSURE GRADIENT ON PARTICLE MOTION

Whipple (1972)



Chang, Youdin & Krapp (2023)

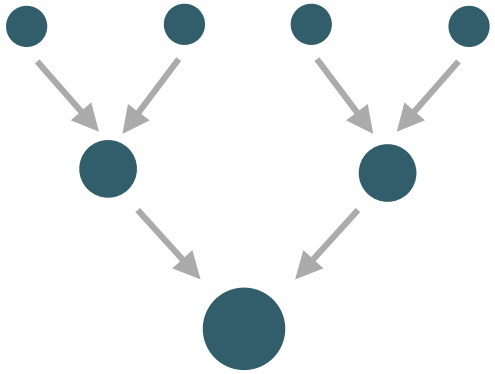
Thank You!

To the Organizers

Unsolved Problem 1:
How Do Planetesimals Form?

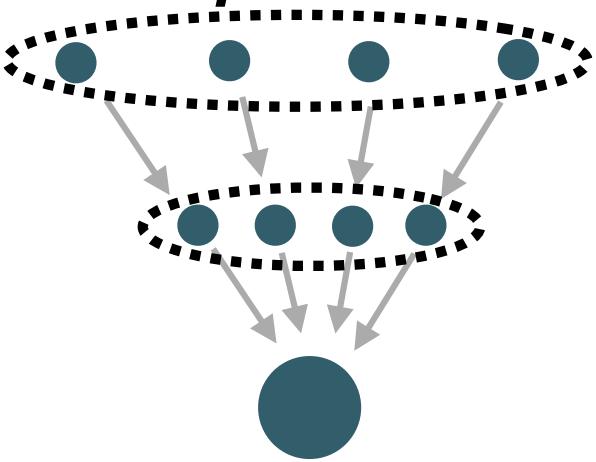
"collisions"

Bottom up



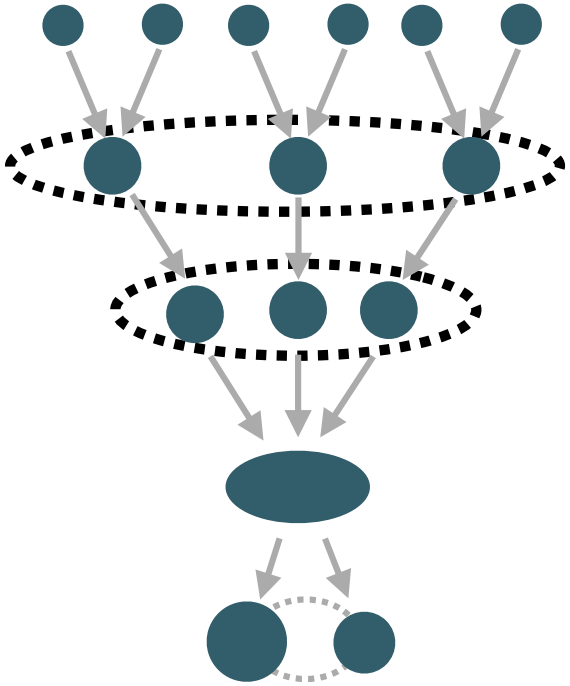
"gravitational collapse (of solids)"

Top Down



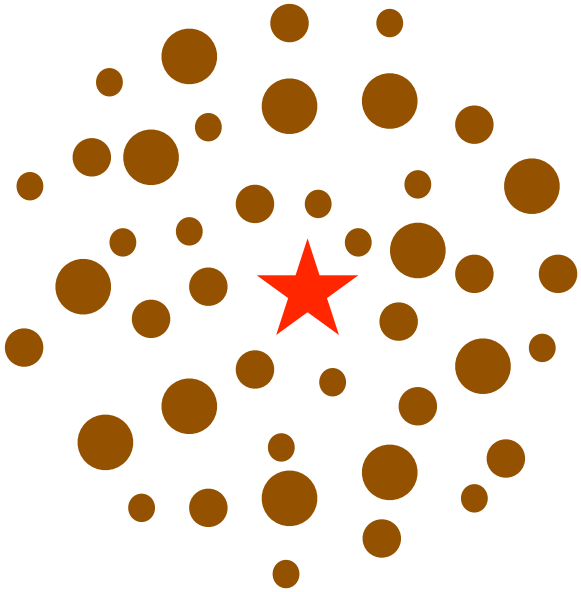
"growth to pebbles, concentration & collapse"

Hybrid

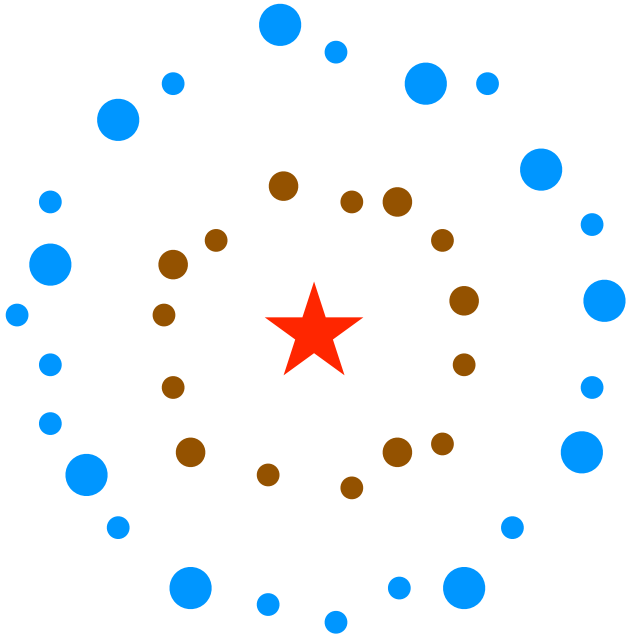


Unsolved Problem 2:
Where Do Planetesimals Form?

Smoothly ~Everywhere



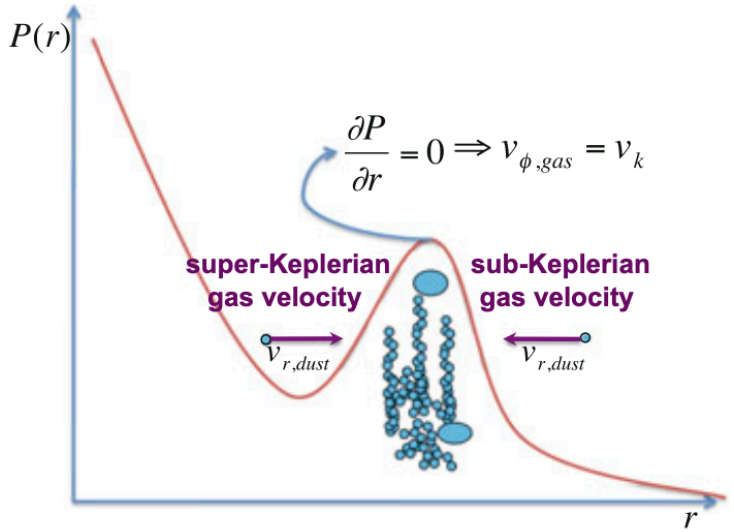
Special Locations: Dust/Pebble Traps



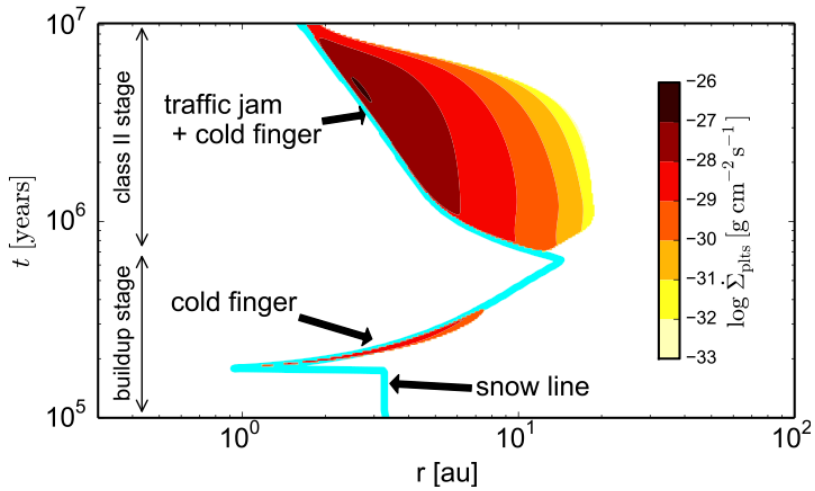
Hybrid

Why might planetesimals form in special locations?

- Particle Traps: larger pebble/gas ratio, Z_p
  - **Pressure bumps**, e.g. planet gap edges (2nd generation planetesimals)
  - **Snowlines** *(Kretke & Lin 2007, Ida & Guillot 2016, Drazkowska & Dullemond 2018)* and silicate sublimation fronts *(Aguichine+ 2020)*
- Planetesimals seem to be everywhere: **migration** or everyone is special?



Pinilla & Youdin (2017)

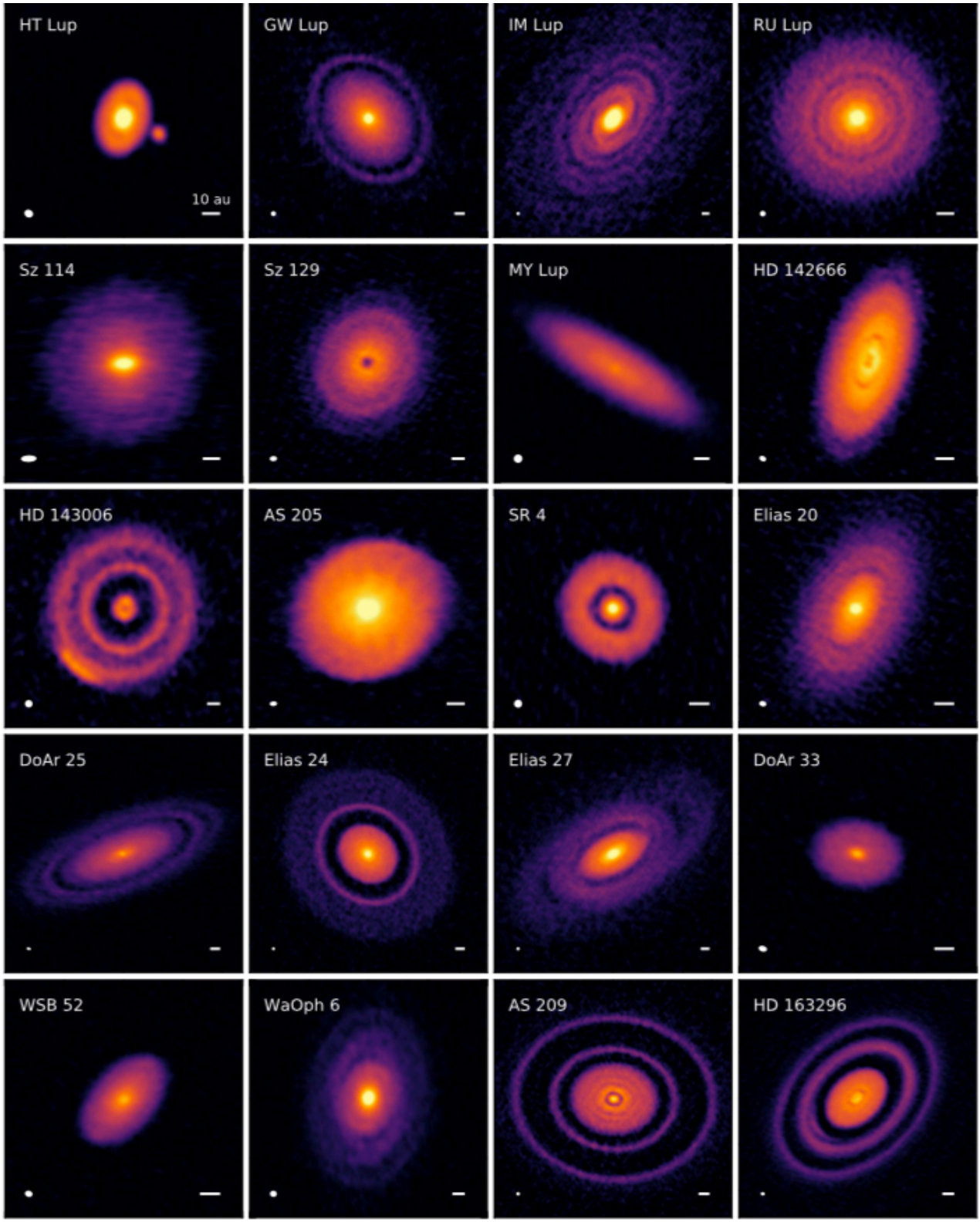


Drazkowska & Dullemond (2018)

Planetesimals forming in special locations?

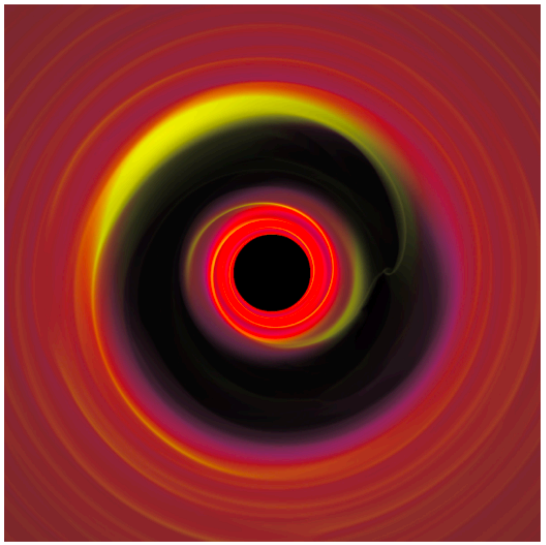
- **Dust rings** in PPDs
  - Sites of (primordial) planetesimal formation?
  - Carved by already formed planets?

Andrews & DSHARP team (2018)

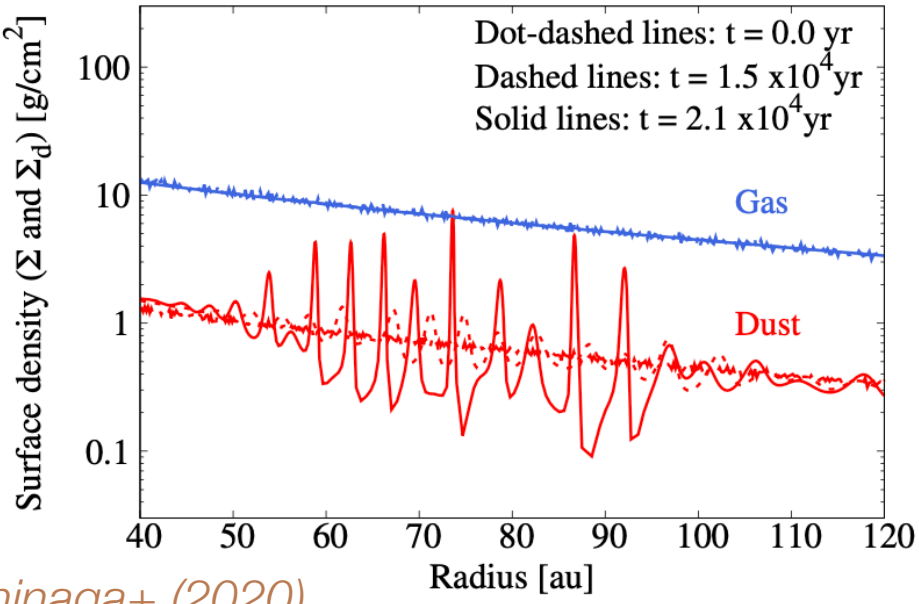


Unsolved Problem:
What is the nature of ALMAs dust rings?

- **Gas Pressure** Bumps
  - (Magneto)-**hydrodynamic** *(Johansen, Youdin & Klahr 2009)*
  - **Planet**-carved gaps
- **Particle Self-Gravity**
  - Gas-mediated "Secular Grav. Inst." *(Ward 1976, Youdin 2011)*



Armitage (2015)

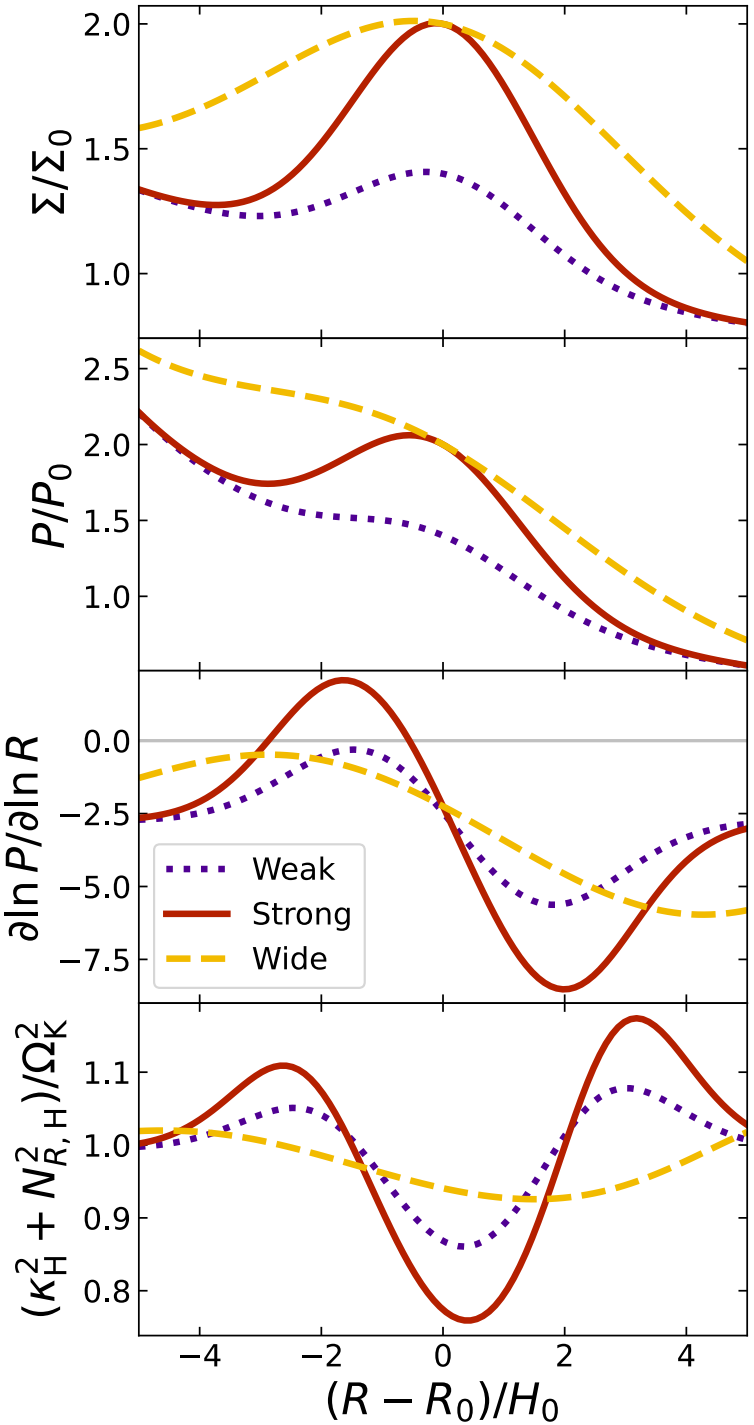


Tominaga+ (2020)

Our Problem To Solve: What is the nature of ALMAs dust rings?

- Difficult for ALMA to detect narrow gas features *(MAPS: Öberg+21)*
- A **dust trapping** gas ring should
  1. Have a **pressure maximum**
  2. Be **hydro-dynamically stable**
     - To the Rossby Wave instability *(Lovelace+99, Ono+16)*
     - Or else evolve, maybe to vortex

Chang, Youdin & Krapp (in prep)



Conclusions / Implications

- We constrain the amplitudes and widths for **stable dust traps**.
- As **bumps**, similar results expected for (planet-carved) **gaps**
- A guide to the interpretation and planning of **ALMA observations**: velocity/spatial resolution and sensitivity.
- **Test** the theory of gas traps (vs. e.g. SGI) and **vortex** formation.