Formation of Dust Rings and Gaps in Non-ideal MHD Disks Through Meridional Gas Flows

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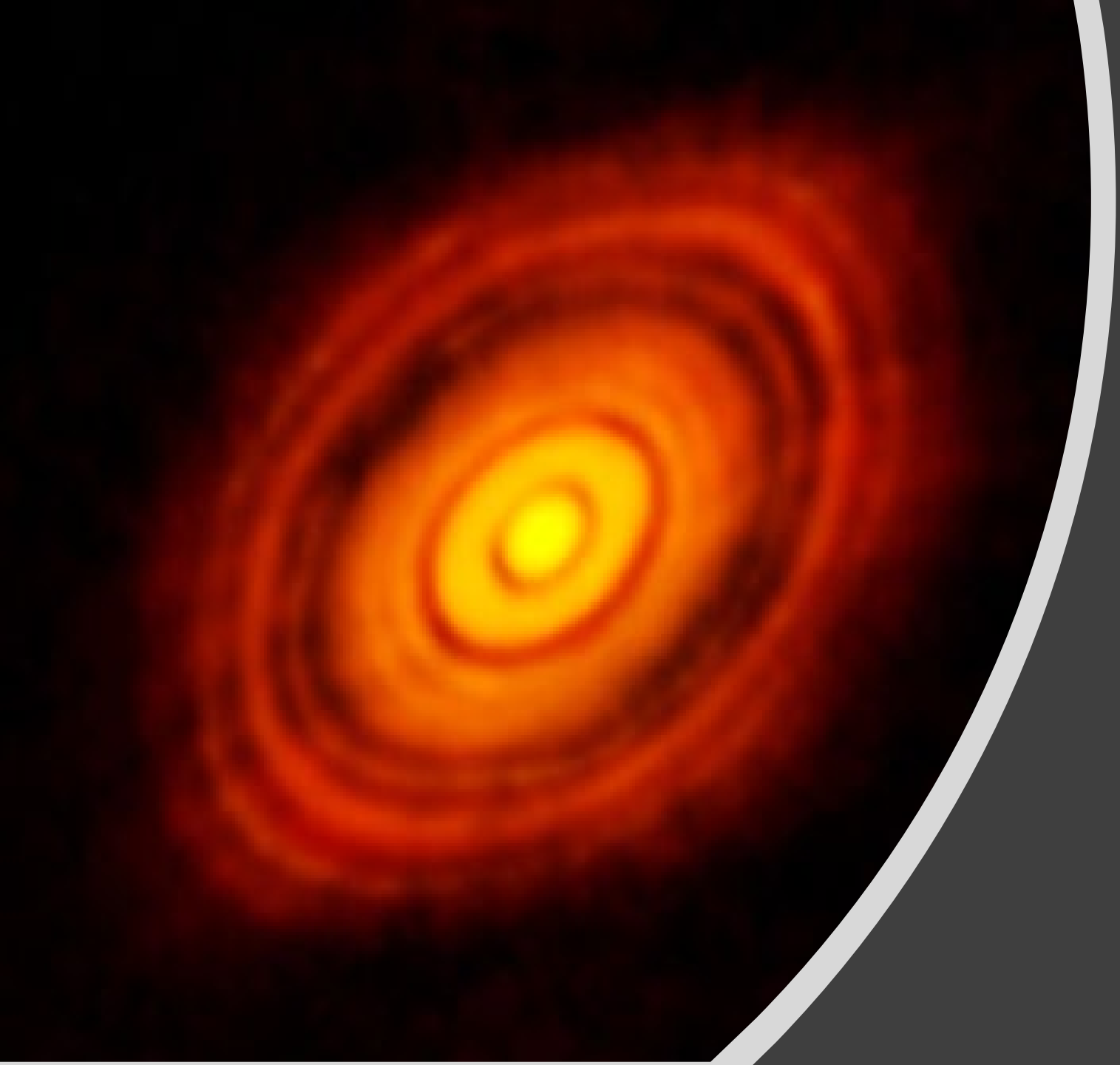
Presentation by Shengtang Wang, IASTU



Gaps in Protoplanetary disks(PPDs)

ALMA Image of the protoplanetary disk around the young star HL Tauri

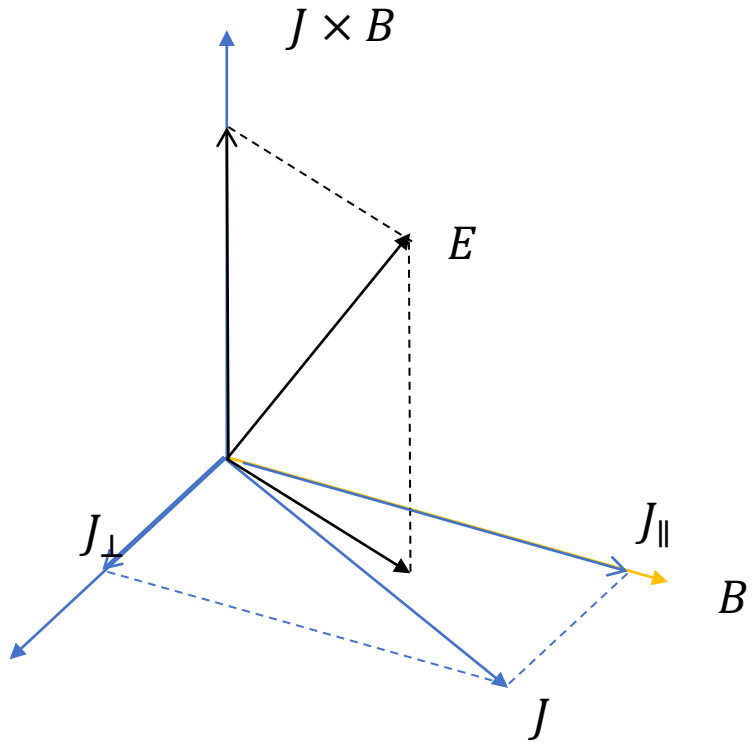
(Figure from aasnova.org)

How to Explain the Formation of Gaps?

- Multi planets with one in each gap?
- Jupiter-mass planets embedded in the gas disk and resonance?
- Grain growth?
- Dust radial transport?

What is Ambipolar Diffusion? (AD)

- Because of collision with gas, current density, magnetic field and electric field are linear independent in the gas comoving frame
- $E = \eta_O J + \eta_H \left(J \times \hat{B} \right) + \eta_A J_\perp$

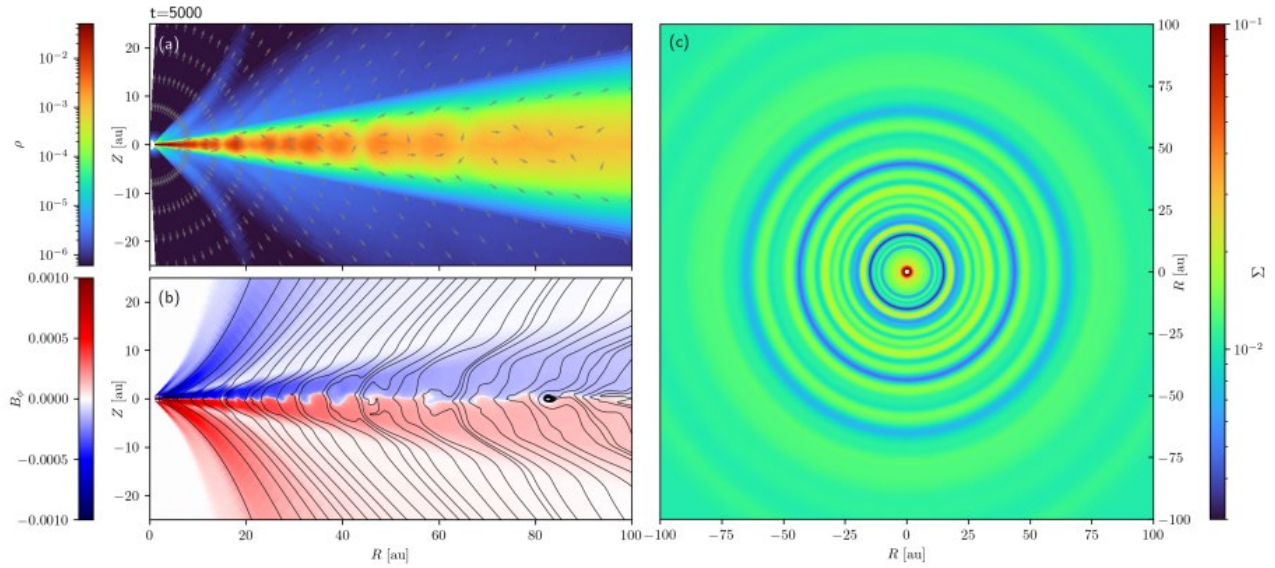


Method

- Global MHD equations by Athena++
- Power law density and temperature profile with r
- Smooth vertical temperature profile
- Only AD

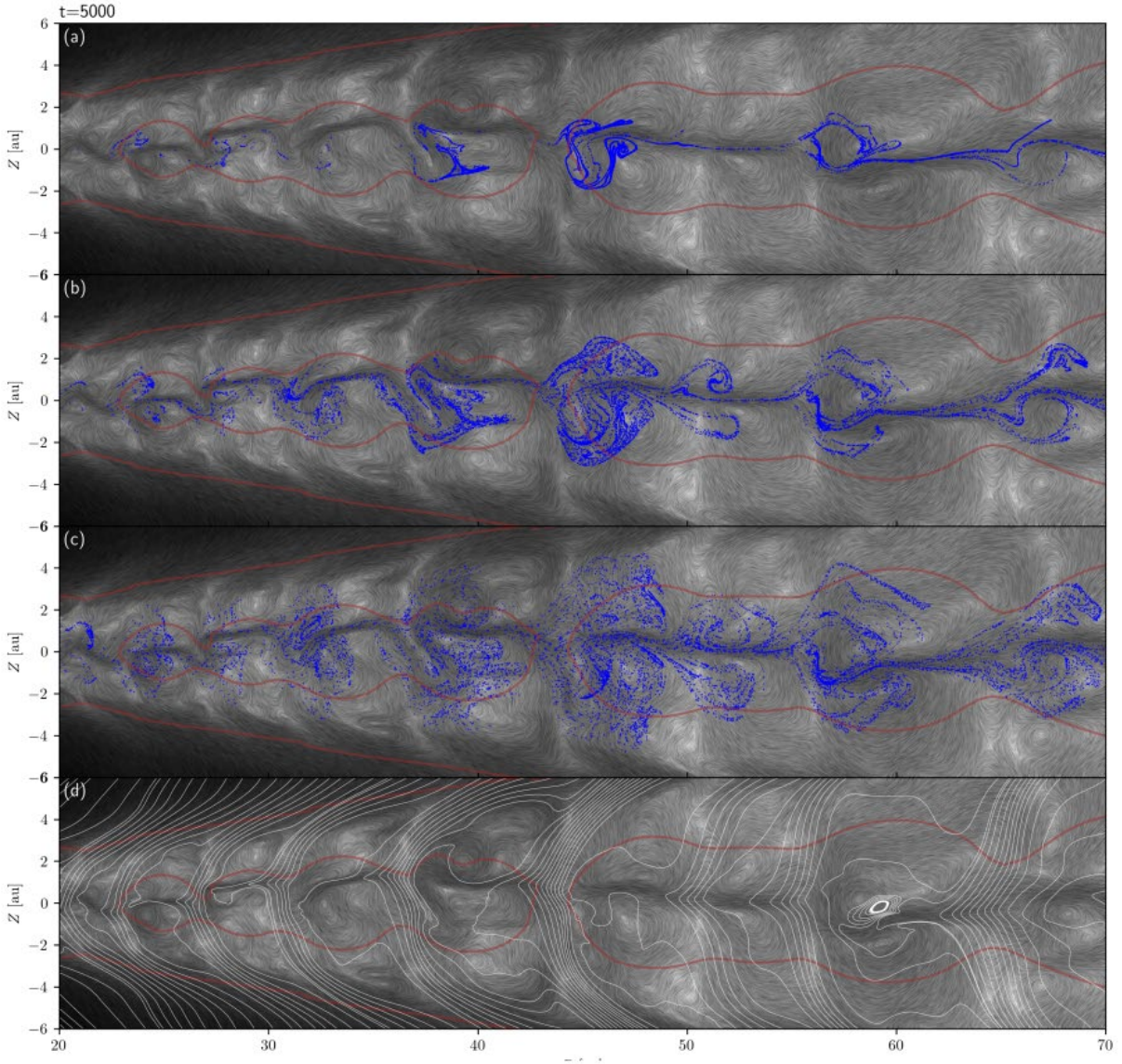
Results

Fig 1 of the paper



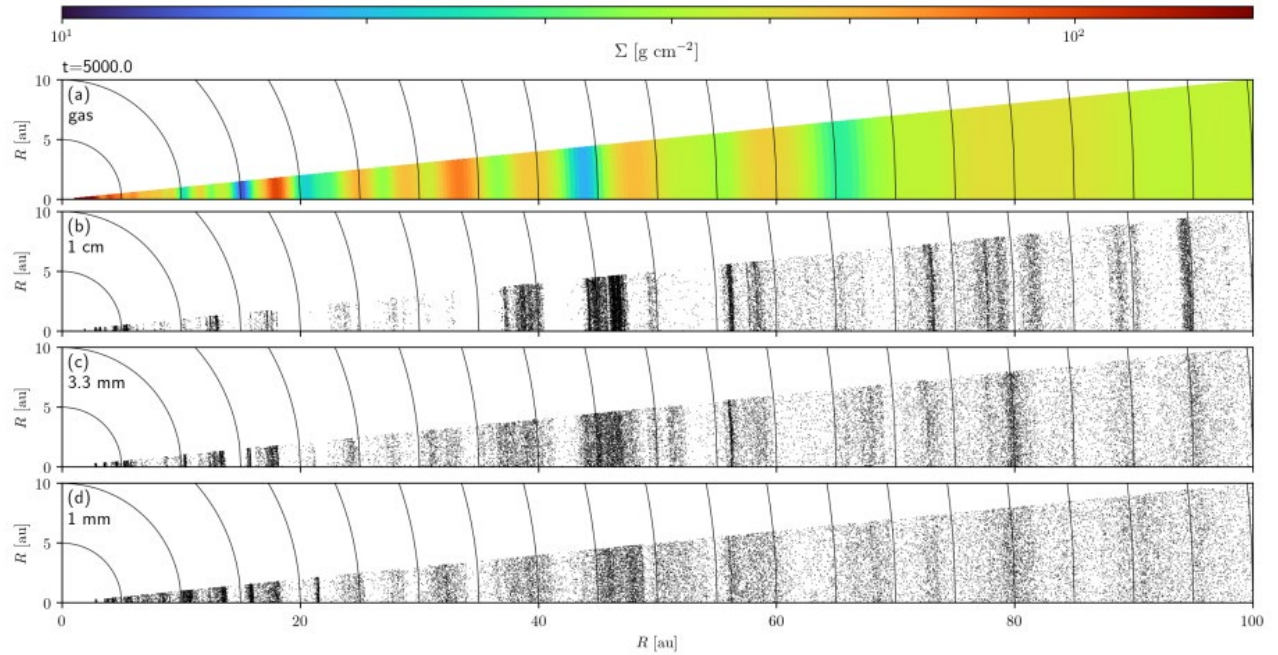
Meridional Flow

Fig 8 of the paper



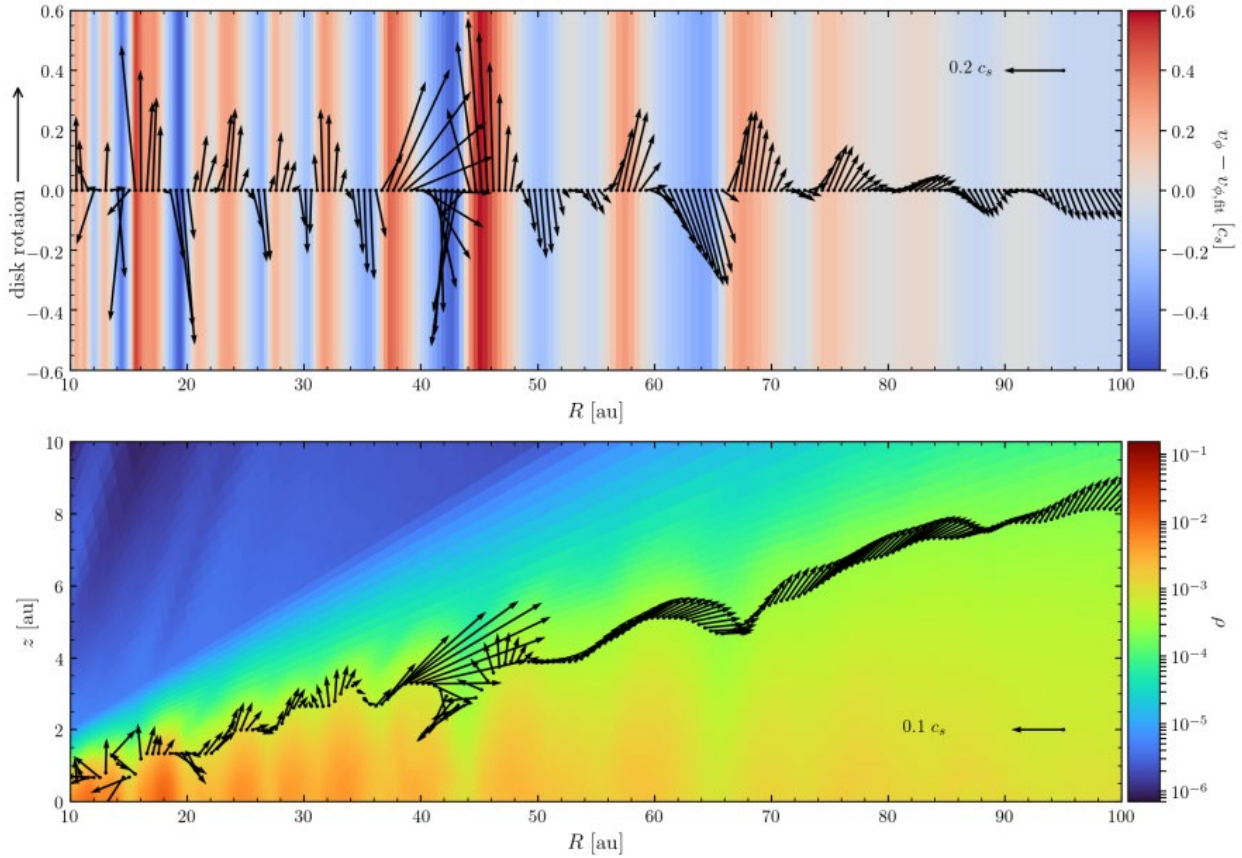
Meridional Gas flow pattern and dust concentration

Fig 3 of the paper



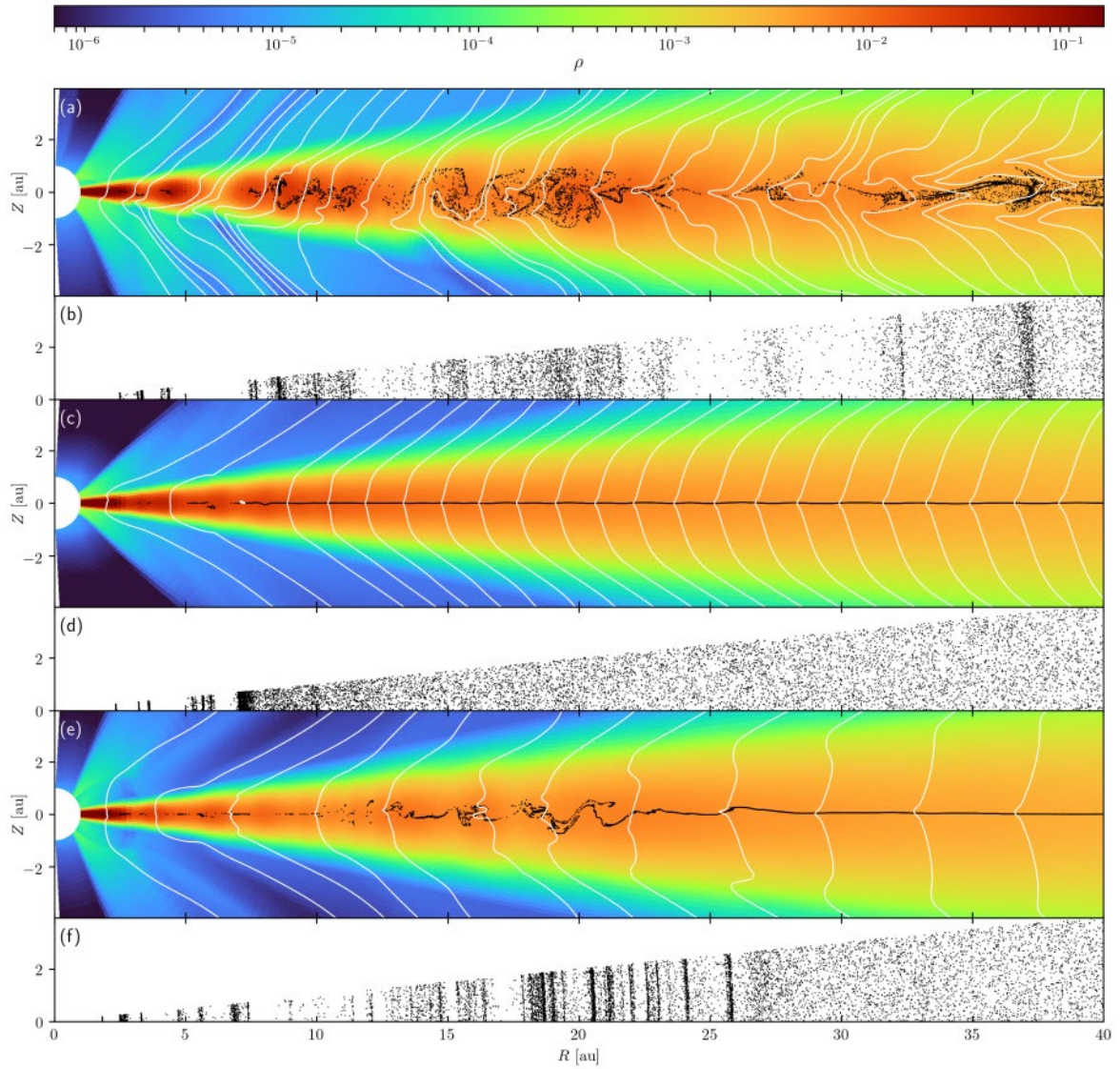
“Collapsing” Regions

Fig 16 of the paper



Better magnetic coupling enables an earlier development of the rings and gaps

Fig 12 of the paper



Take Home Messages

- Authors found a characteristic meridional flow pattern that is driven by a fast accretion stream near the midplane due to rapid angular momentum loss from efficient magnetic braking
- The meridional gas flow pattern is the key to the dust concentration in their simulation
- Authors found several “collapsing” regions in their fiducial simulation where the gas near the disk surface converges towards the midplane
- The substructure formation in both the gas and dust in a non-ideal MHD disk depends on the degree of magnetic coupling and the strength of the magnetic field