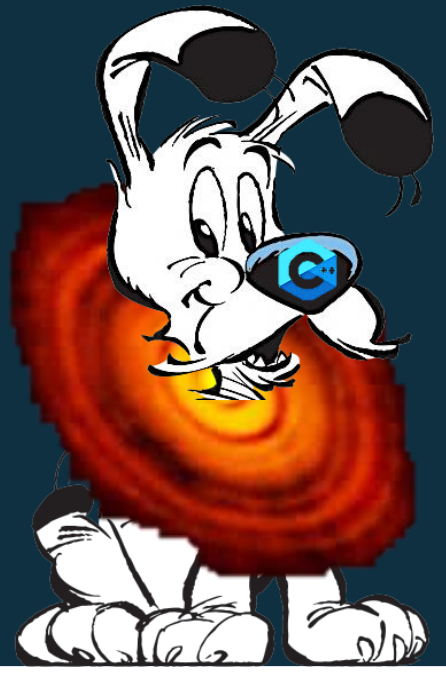


Blowin' in the wind : dust transport in protoplanetary discs

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Protoplanetary discs form around young stars and are the sites where planetary systems emerge. Observations show that these discs contain dust grains spanning a wide range of sizes, from a few tenths of a micron to a few millimeters. We present numerical simulations of protoplanetary discs with outer truncation performed using the IDEFIX code. These are global magnetohydrodynamic (MHD) models in which we simultaneously evolve dust populations spanning 11 different grains sizes, from nanometers to millimeters. We observe the settling and the radial drift of large dust grains in gaseous ring structures, as well as the lift of small dust grains by magnetically launched winds. [Zjawiony & Lesur, in prep]

IDEFIX simulations

- 11 bins of dust from 10 nm to 1 mm

Drag uploaded with the 1st order implicit scheme



try it!

$$\mathbf{v}_g^{(n+1)} = \left(\mathbf{v}_g^{(n)} + \sum_k \frac{\rho_k \gamma_k dt}{1 + \rho_k \gamma_k dt} \mathbf{v}_k^{(n)} \right) / \left(1 + \sum_k \frac{\rho_k \gamma_k dt}{1 + \rho_k \gamma_k dt} \right)$$

$$\mathbf{v}_k^{(n+1)} = \left(\mathbf{v}_k^{(n)} + \rho \gamma_k \mathbf{v}_g^{(n+1)} dt \right) / (1 + \rho \gamma_k dt)$$

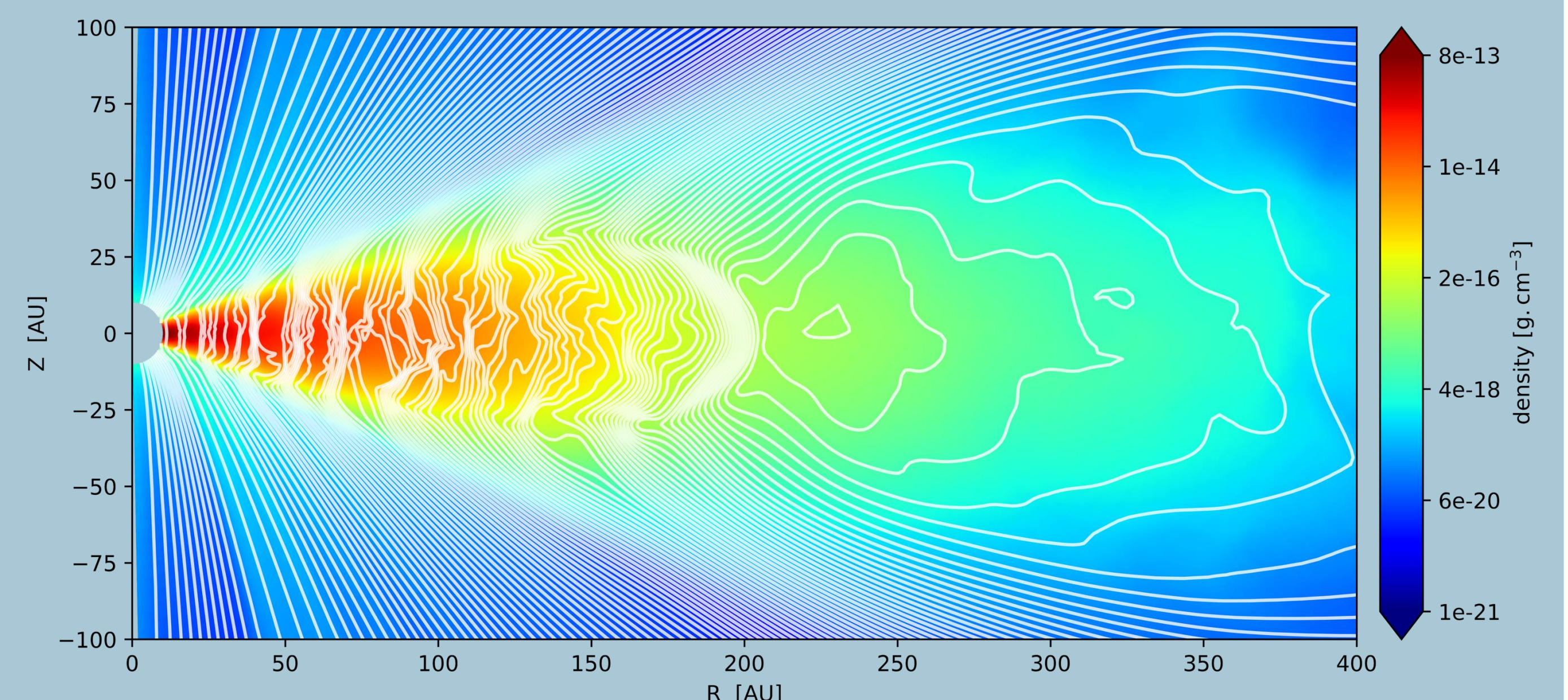
- 2D Axisymmetric
- Outer edge truncation [1]
- Non-ideal MHD

Explore different magnetisation and diffusivity parameters [2]

$$Am = v_A^2 / \eta_A \Omega_K$$

$$\beta = 8\pi P_{mid} / B_{z,mid}^2$$

Results

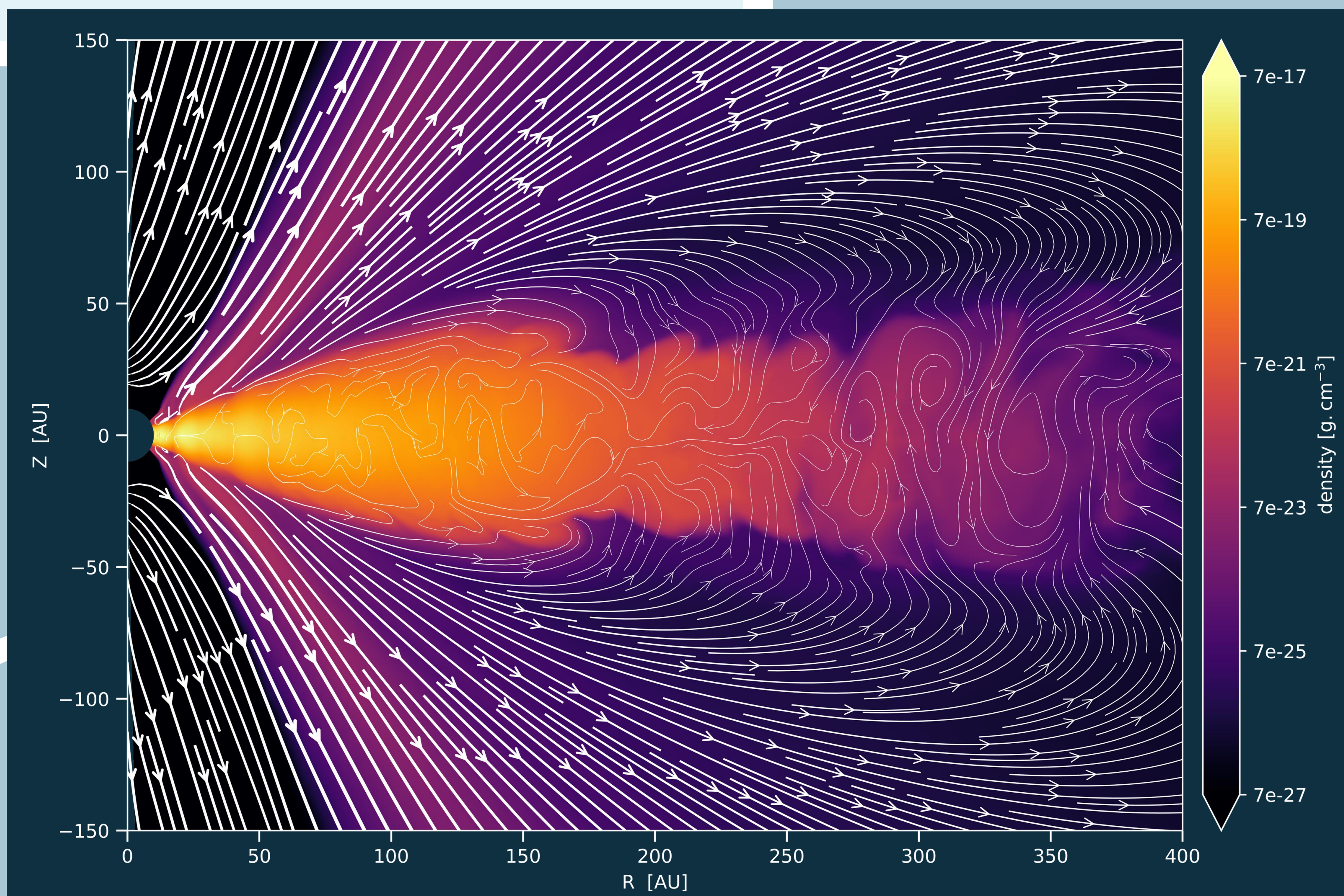


Gas density, magnetic field lines and outer edge

- Self-organisation of \vec{B} and ring formation [3] [4]

Density and streamlines of 0.3 μm size grains

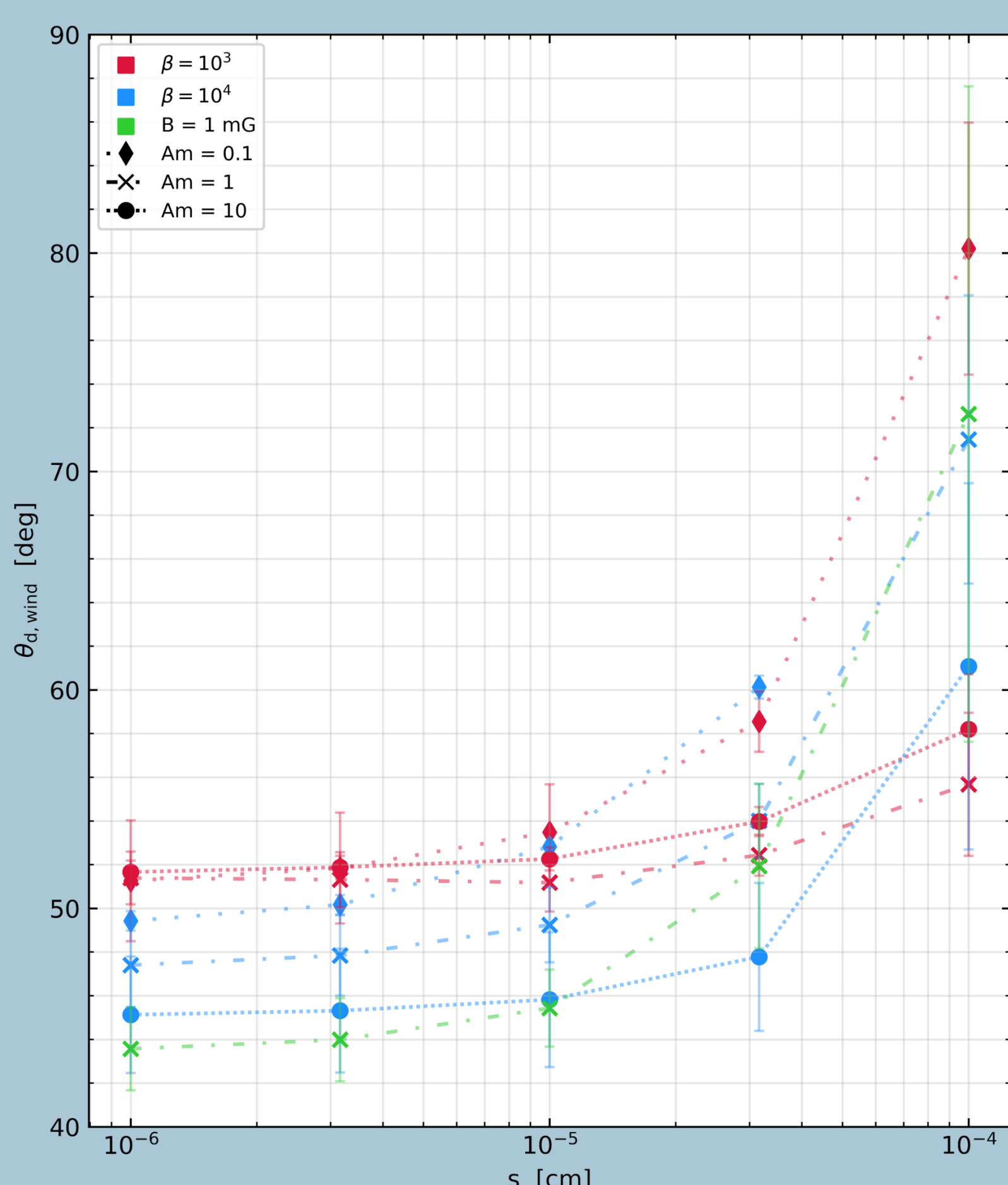
- The inner winds blow away the grains [5]
- Grains fall back in the outer regions



- The largest grains form dusty rings in gaseous structures
- The number of rings, their spacing, their width and contrast depend on β and Am

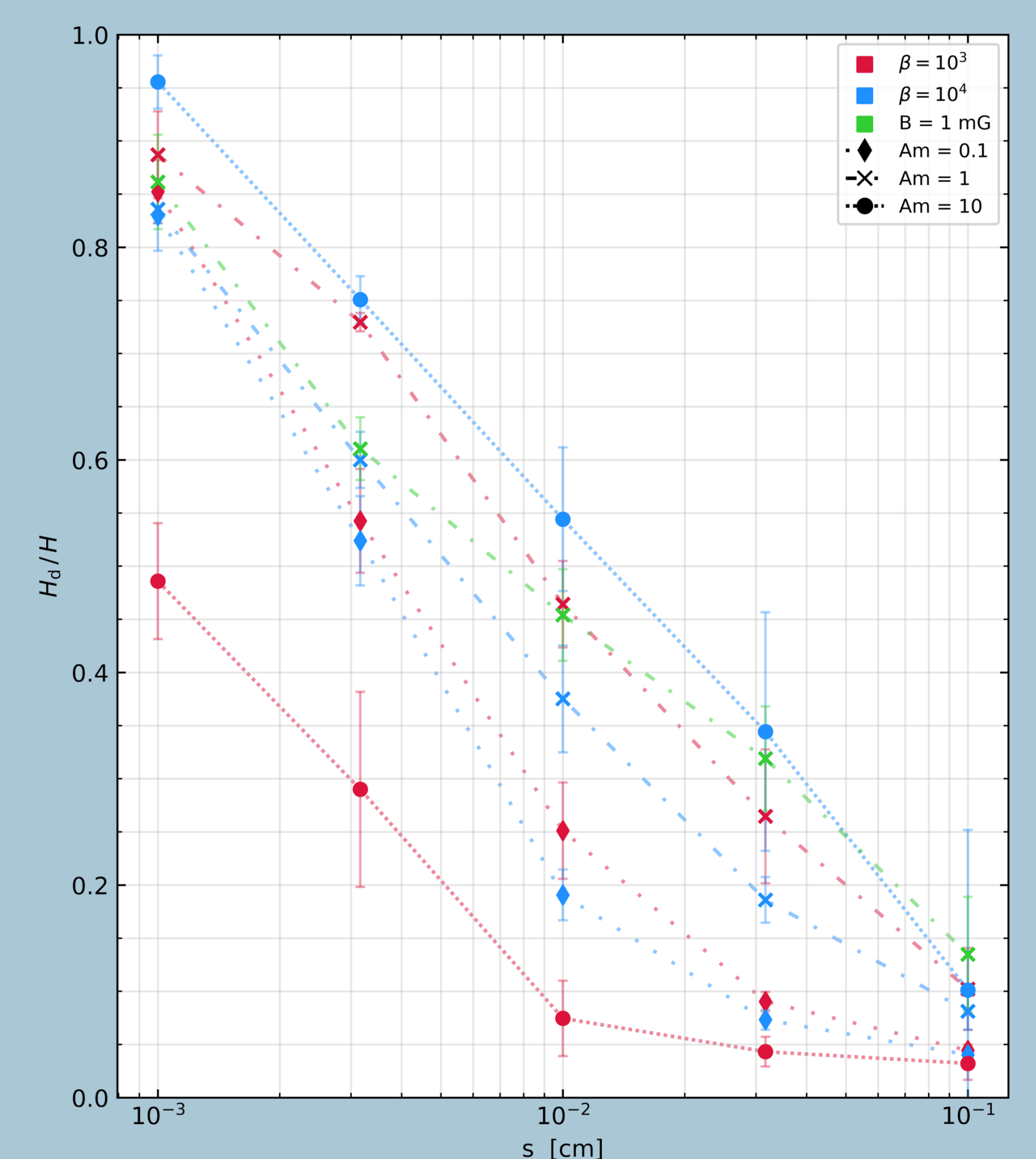
What about the larger grains ?

Ejection angle of grains as a function of their size



- The winds lift grains from nanometers to microns sizes
- Angle increases with grain size [5]
- Larger angles for larger β
- The increase is stiffer for low Am
- North/south asymmetry as for the gas wind

- Grains from 10 μm to 1 mm settle in the midplane [6]
- H_d/H decreases exponentially with size
- H_d/H tends to increase with Am and β



Dust to gas scale height ratio as a function of grain size

[1] Yang & Bai, 2021, ApJ 922, 201

[3] Riols & al., 2020, A&A 639, A95

[5] Rodenkirch & Dullemond, 2021, A&A 659, A42

[2] Lesur, 2021, A&A 650, A35

[4] Cui & Bai, 2021, MNRAS 507, 1106-1126

[6] Birnstiel, 2016, Space Sci Rev 205, 41-75