Dust dynamics in the inner regions of protoplanetary discs: global MHD simulations

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I Active-dead zone interface

In the inner regions of protoplanetary discs, when $T \sim 1000K$ (i.e. radii of 0.1 to 1 au) the ionisation fraction drops and non-ideal MHD effects come into play. We run simulations in which the temperature and the ionisation fraction are effectively fixed in space and time.

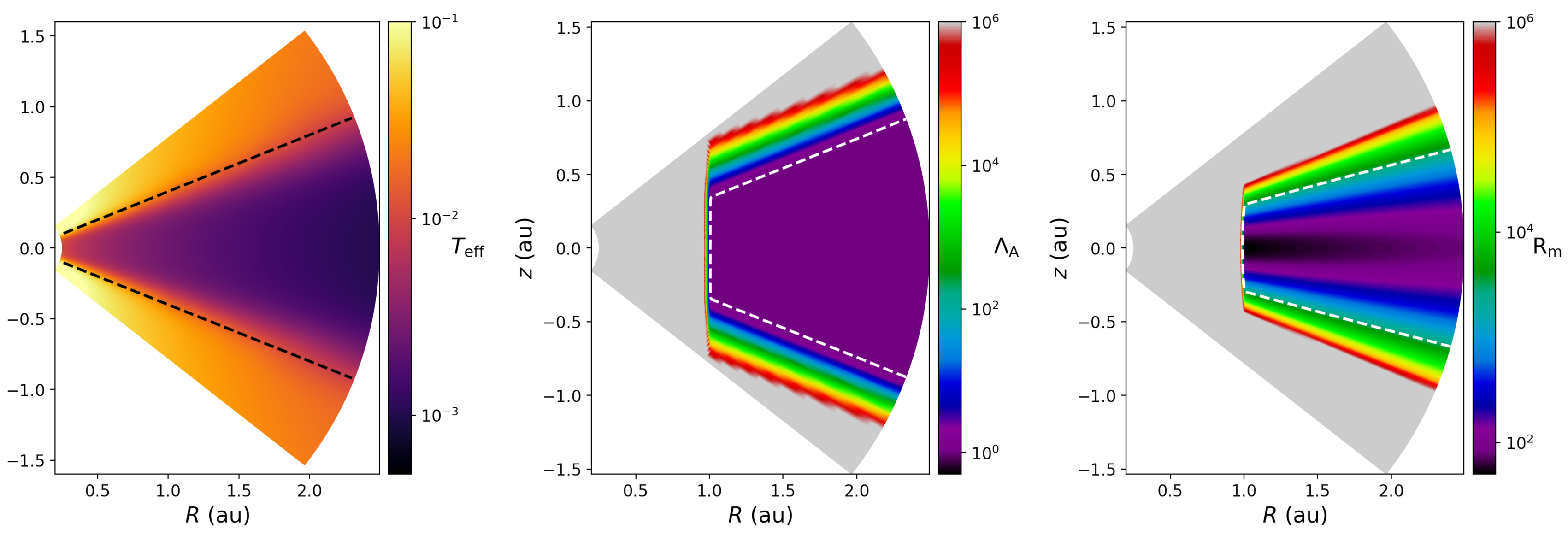

Fig. 1: Temperature, Ambipolar Elsässer number and initial magnetic Reynolds number [1].

II Turbulent torque and pressure bump

This sharp drop in ionisation limits the onset of the MRI. This leads to a swift decrease in turbulence, quantified by the *turbulent* α. In turn, this drop in turbulence forms a zone of decretion and thus a pressure (or density) bump, as the accretion rate is:

$$\dot{M}_{\rm acc} = \frac{4\pi}{R\Omega_K}\frac{\partial}{\partial R}\left(R^2\alpha c_s^2\Sigma\right). \quad (1)$$

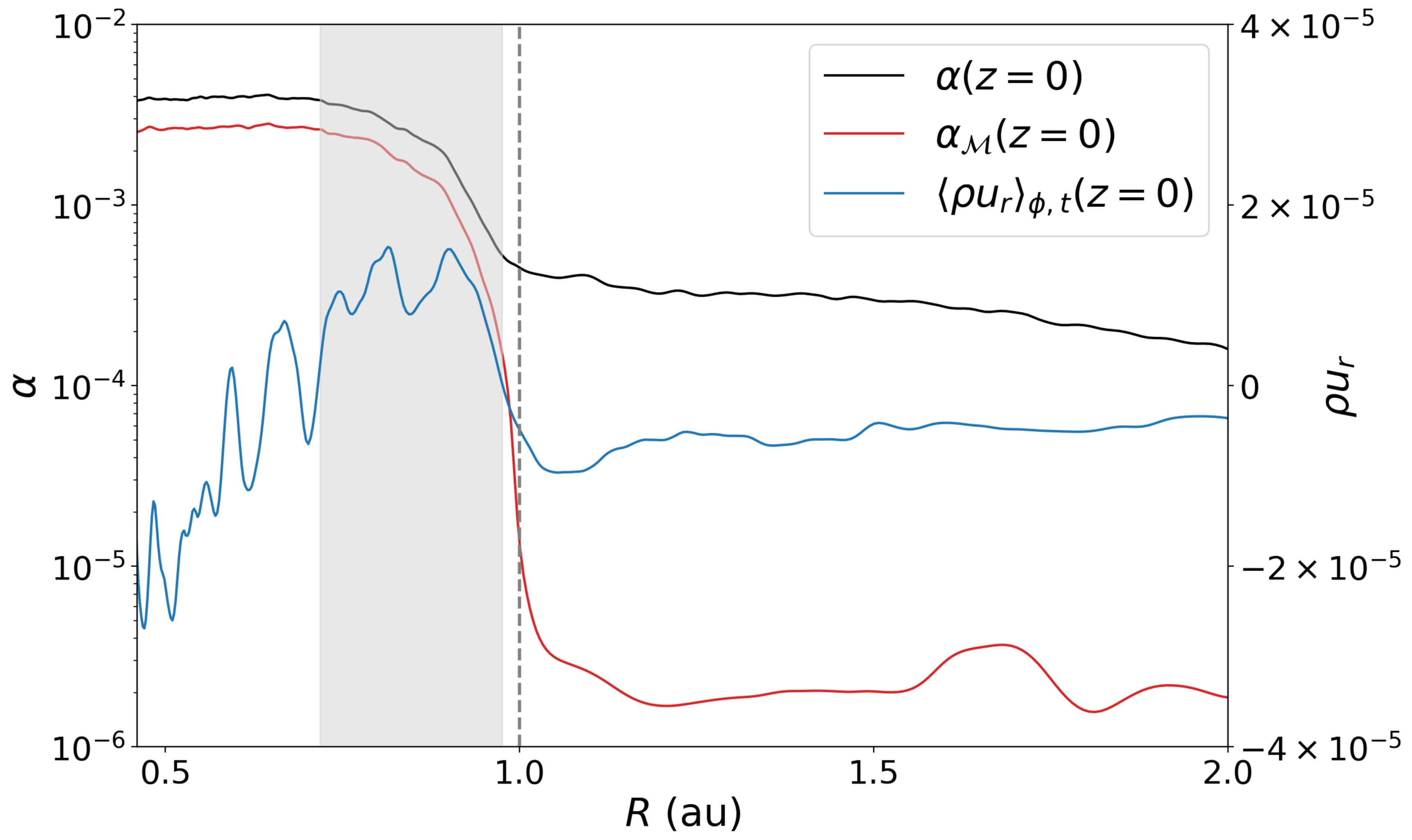

Fig. 4: Radial profiles of the turbulent alphas and the accretion rate [1].

III Axisymmetric pressure bumps and dust rings

We model the presence of solid dust with several pressureless fluids. The axisymmetric pressure bump acts as an efficient trap to the dust incoming from the outer disc.

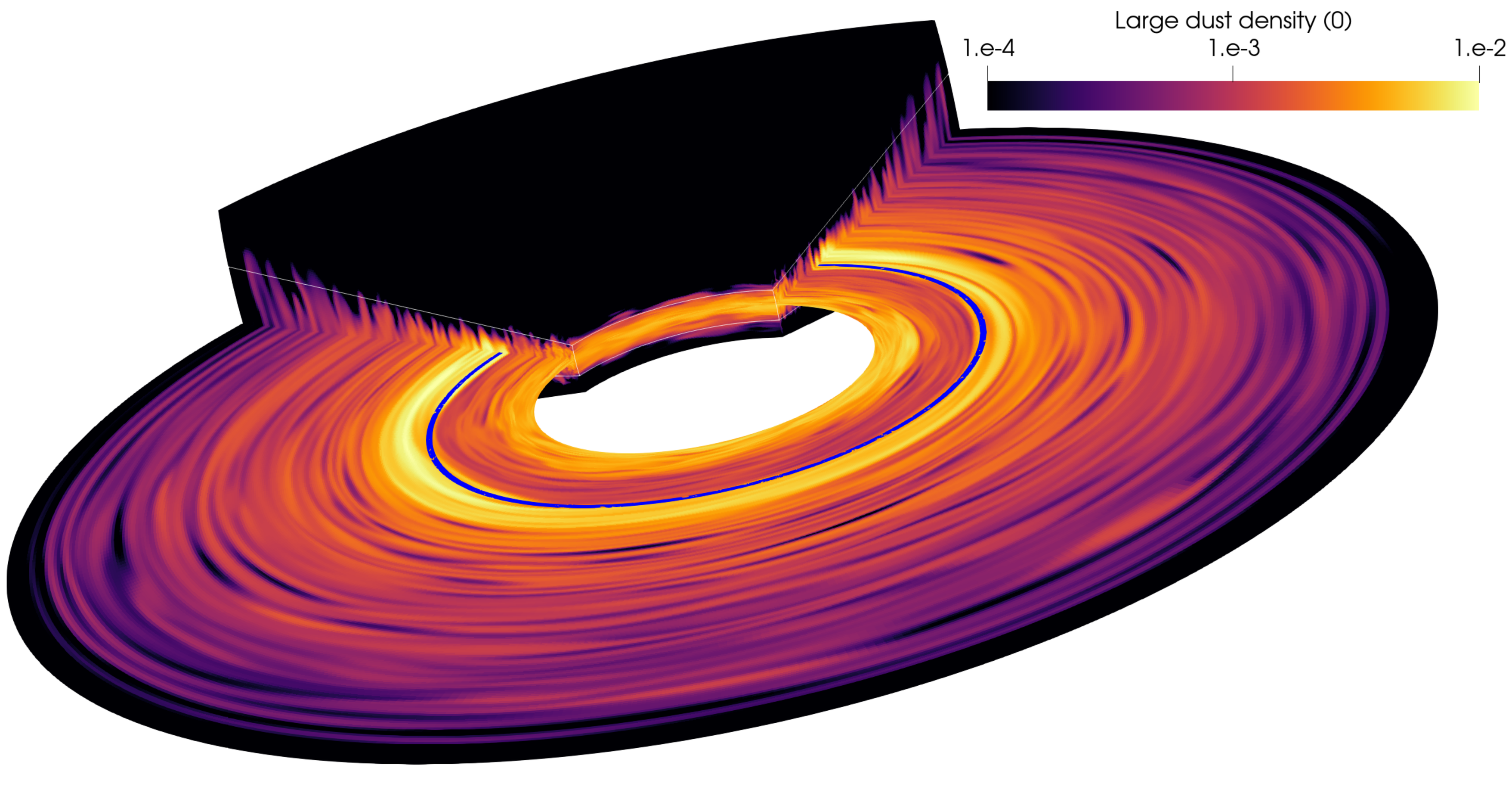

Fig. 2: 3D rendering of the dust density for the larger dust species (cm grains) [2].

IV Rossby-wave vortices trapping and stirring dust

- The presence of an interface (pressure bump) and a Keplerian shear leads to the creation of vortices at the interface through the Rossby wave instability.
- Vortices can efficiently trap dust, especially larger grains. But they can also mix dust between the outer active zone and the inner dead zone, replenishing the dead zone.

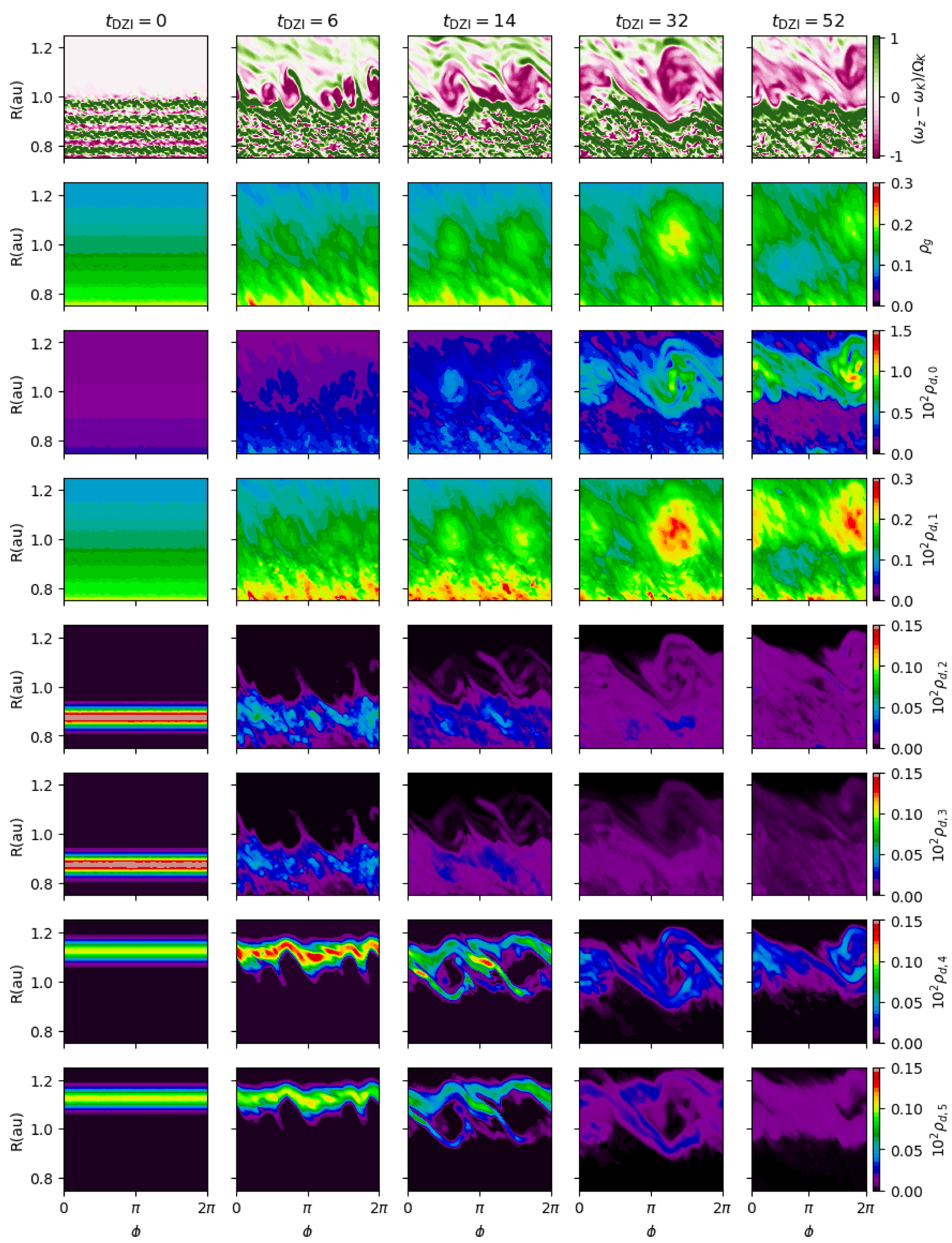

Fig. 5: Midplane vorticity (row 1), gas density (row 2) and dust densities (rows 3 to 8) [2].

V Net vertical flux and dust-laden MHD winds

We study the impact of a net vertical magnetic flux, and the impending MHD wind.
The presence of a net vertical flux leads to faster accumulation of dust at the interface.

- The presence of a wind leads to an additional accreting torque in the surface layers.
- Moreover, the flux tends to accumulate at the interface, eroding the minimum of the pressure bump and thus strengthening its dust-trapping capability.

While larger (cm sized) dust grains are only infalling onto the disc, smaller (mm sized) grains can be entrained in the wind. This particularly prominent in the inner active zone, that launches a fast turbulent wind. This could have strong consequences:

- For the direct observations of elevated small dust in scattered light.
- For the measures of crystallinity and the presence of high-temperature condensates (CAIs and AOAs) in the outer solar system.

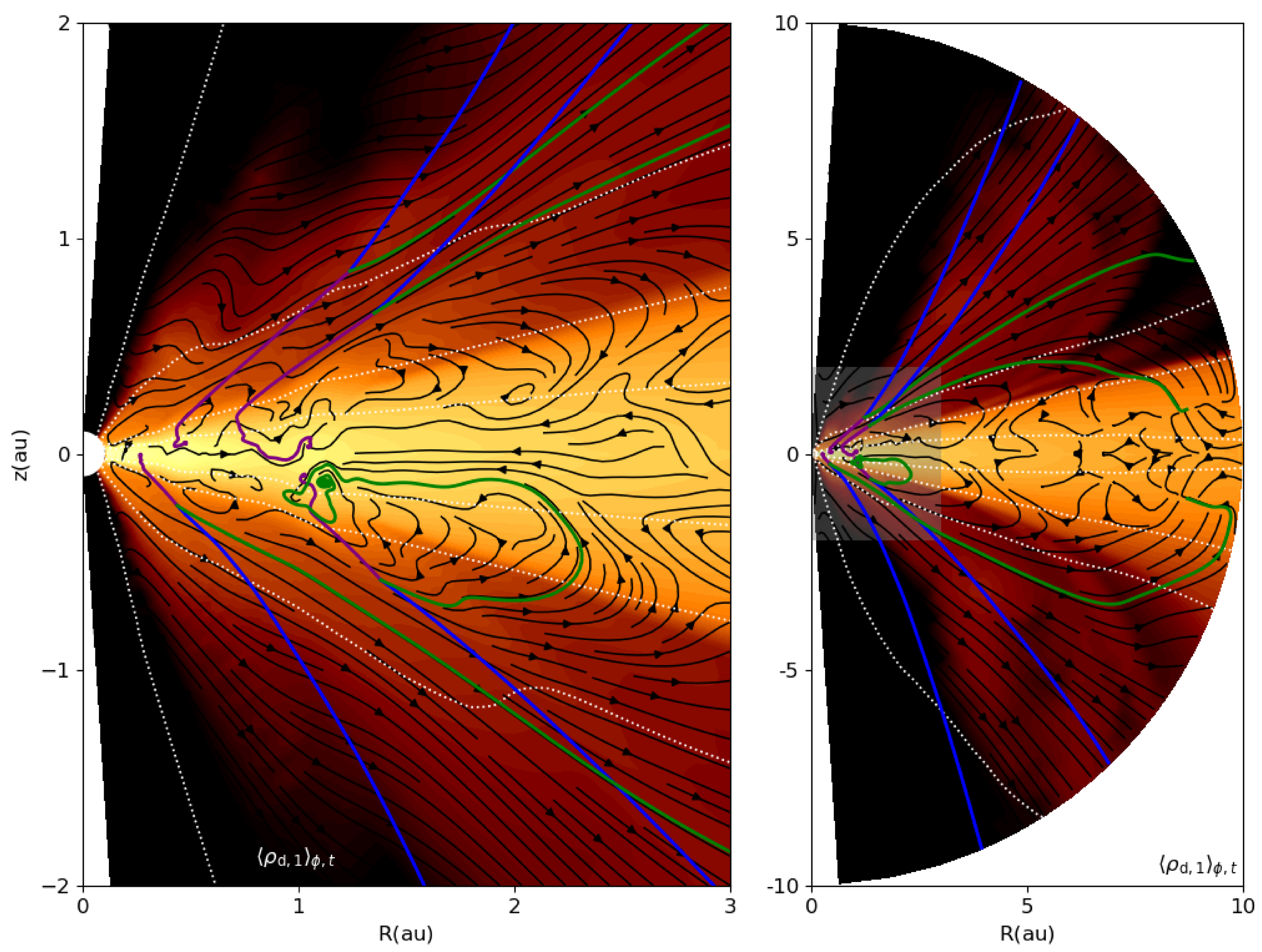

Fig. 3: Map of the smaller dust (mm grains) [2]. Smaller dust streamlines are shown in green and black, larger dust streamlines are shown in purple, and gas streamlines are shown in blue.

References

[1] Roberts M. J. O., Latter H. N., Lesur G. (2025): *Global magnetohydrodynamic simulations of the inner regions of protoplanetary discs. I. Zero-net flux regime*, MNRAS, 544, 1284

[2] Jannaud T., Latter H. N.(2026b): *Dust dynamics in the inner regions of protoplanetary discs - Global magnetohydrodynamic simulations*, submitted to MNRAS