Turning planet formation inside-out

Assembling the building blocks for planet formation

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In Short

- Systems of tightly-spaced inner planets (TIPs) may form *in-situ* via an"inside-out" mechanism
- "Dust traps" in protoplanetary discs can accumulate solid building blocks for planet formation
- A promising candidate for a dust trap is the inner "dead-zone" interface, which we aim to study

In their role as planet nurseries, protoplanetary discs (PPDs) are of key interest to planet formation theory. Their dynamical, radiative and thermodynamic properties critically define the environment for embedded solids: dust grains, pebbles and planetesimals. In short, the building blocks of planet formation. The discs' dynamics and structure in turn depend critically on the influence of magnetic fields [1], which we aim to study from first principles.

The Kepler Space mission has identified a class of planetary systems characterised by tightly-spaced inner planets (TIPs). A contending theory for explaining these *in situ* is built around the idea of "inside-out planet formation": The paradigm starts from the observation that solids that have grown to macroscopic sizes gradually become aerodynamically decoupled and experience a head-wind in the radially pressure-supported gas disc around the protostar. In a featureless disc, this head-wind would make their orbit decay towards the star, and the material would be lost for planet-formation. Once a planet of sufficient mass has formed, it naturally creates a barrier to dust [2] via opening a gap in the gas (see Fig. 1 on the right). Together With the inward drift of the solids, this intuitively explains the inside-out mode of forming the system — but how then do you create the first planet to begin with?

The interface between the thermally ionized, turbulent (via the magnetorotational instability, MRI) innermost region of a PPD and the so-called *dead-zone*, where Ohmic dissipation suppresses the MRI, offers a natural mechanism for creating a so-called *dust-trap* [3,4]. We aim to test this scenario by combining state-of-the-art non-ideal MHD simulations with passively advected dust fluids. This way, we can test from first principles, whether, at this location, solid materials can be collected in sufficient amounts for planetesimal formation to ensue.

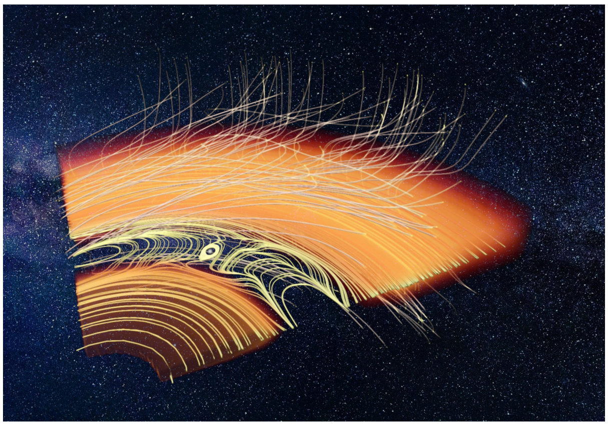

Figure 1: *MHD simulation of a PPD with a planetary gap.*

The proposed project will create the most realistic computer simulations of the inner reaches of PPDs containing gas and dust, thus defining the environment that shapes the early development of compact planetary systems (TIPs). It is unique in that it combines the PIs expertise in non-ideal MHD and realistic ionization chemistry with passively evolved dust components. The latter are treated in a dual scheme, i) via aerodynamically coupled fluids (to obtain enhancement factors) as well as ii) via complementary finite Stokes-number tracer particles (to illustrate typical trajectories highlighting the pathways of dust segregation).

Our results will provide an important foundation in the context of the "inside-out planet formation" scenario. They will directly support the central assumption of the presence of a *dust-trap* in the inner regions of a PPD by means of direct simulations of the *dead-zone* transition region. Quantifying dust enhancement factors from simulations [5] will be useful in gauging the overall efficiency and timescales in the derived phenomenological models.

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ERC StG "New-PPD-Environments"
`https://pages.aip.de/ogressel/erc.html`

More Information

[1] Gressel, Turner, Nelson & McNally, *ApJ* **801**, 84 (2015). doi:10.1088/0004-637X/801/2/84

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[3] Dzyurkevich, Flock, Turner, Klahr & Henning, *A&A* **515**, A70 (2010). doi:10.1051/0004-6361/200912834

[4] Mohanty, Jankovic, Tan & Owen, *ApJ* **861**, 144 (2018). doi:10.3847/1538-4357/aabcd0

[5] Krapp, Gressel, Benítez-Llambay, Downes, Mohandas & Pessah, *ApJ* **865**, 105 (2018). doi:10.3847/1538-4357/aadcf0

Project Partners

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