# Stars and Planets in computers

## Spherical Couette dynamos

***A. Barik, J. Wicht, U.R. Christensen, A. Tilgner***, *Max-Planck Institut für Sonnensystemforschung, Georg-August-Universität Göttingen*

**In Short**

- Interiors of geo- and astrophysical objects can be modelled as spherical shells filled with fluid. Our goal is to study the effect of differential rotation on fluid interiors using the spherical Couette set-up - two concentric rotating spheres with fluid filled in the gap.
- We compare our simulations with experiments performed at BTU Cottbus-Senftenberg [1], reproducing their observations while providing further insight, in terms of observed inertial modes as well as turbulence in the system.
- We scale regime boundaries of different hydrodynamic states to understand interiors of astrophysical objects better.
- We also explore the effect of introducing a density stratification, something never been done before. This yielded surprising results.
- We intend to study dynamo action with density stratification, also something that has not been done before and would be directly applicable to interiors of astrophysical objects.

The interiors of geo- and astrophysical objects can be thought of as rotating spherical shells with fluid filling the gap. This motivates the study of the spherical Couette system (figure 1) to study the hydro- and magnetohydrodynamic (MHD) instabilities that are caused and modified by differential rotation. The system has been studied analytically (e.g. [3]), experimentally (e.g. [1],[2],[4],[5]) as well as using simulations (e.g. [6]). This is also the set-up used by the new generation of MHD experiments (e.g. 3-meter experiment by D. Lathrop, USA and DTS experiment, France).

Despite all the past studies, several open questions remain to be solved. Our aim is to simulate this set up using our code **MagIC**[1,2]. We solve MHD equations (Navier-Stokes, continuity, Maxwell's equations, induction equation) in a spherical shell using pseudo-spectral methods. Thus, we expand the unknowns in terms of orthogonal functions, solve for the coefficients, but solve the non-linear terms on a spherical grid, numerically. Details can be found in [7] and in the manual [8]. It is parallelised in a hybrid manner using MPI between different nodes of a cluster and OpenMP inside each node. The efficiency of the code scales ideally with the number of cores. The spherical harmonic transform library SHTns [9] has made our code a lot faster than before.

[1] https://github.com/magic-sph/magic
[2] https://magic-sph.github.io/

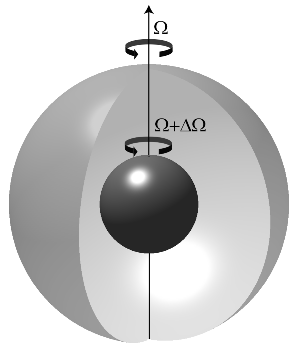


***Figure 1:*** *The numerical set up. Two concentric rotating spheres driving a fluid in between by differential viscous drag.*

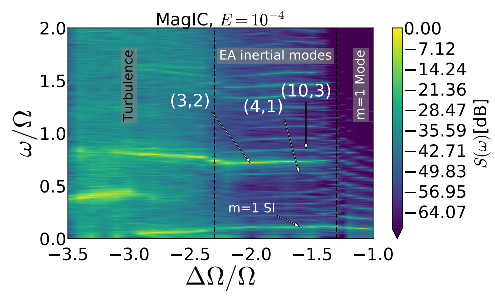


***Figure 2:*** *Velocity spectrogram showing various hydrodynamic regimes.*

We have found that the equatorially antisymmetric wave-like instabilities observed by [1] are possibly due to the instability of the background flow. This and other related exciting results have been published in [10]. Right now we are looking at the transition to turbulence which shows that the background flow has a sudden increase right after the transition and that the turbulent regime is dominated by inertial waves. We scale the various hydrodynamic regimes we observe to astrophysical parameters, as shown in figure 3

We have also started exploring the effect of density stratification on the flow. We find that as density stratification increases (given by the number of density scale heights $N_\rho$), the background flow becomes stronger and spreads outside the tangent cylinder.