The interplay between magnetism and tidal flows in convective envelopes

Tidal interactions play a crucial role in shaping the orbital architecture and rotational evolution of close stellar and planetary systems. The dissipation of the tidal flow energy within the fluid convective envelopes of stars and planets is an efficient way of exchanging angular momentum in these compact systems. Furthermore, when the tidal forcing is strong, namely in compact systems such as hot Jupiter systems, tidal flows are sensitive to non-linear effects. Although magnetism and differential rotation are likely to be ubiquitous in the convective region(s) of host solar-like stars and giant gaseous planets, most studies give tidal interaction predictions based on linear 2D hydrodynamic models using uniform rotation.

We have performed the first 3D nonlinear numerical analysis of tidal flows and their dissipation in a magnetised convective shell. Differential rotation, in the form of axisymmetric zonal flows, arises spontaneously in 3D shellular and hydrodynamical simulations due to the nonlinear self-interactions of tidal inertial waves in shear layers, which strongly affect tidal dissipation from prior linear predictions. When an initial dipolar magnetic field is added, we characterise different regimes depending on the relative strength of the magnetic field and tidal forcing, as well as Ohmic versus viscous damping. The magnetic field can either destroy tidally driven zonal flows, in which case linear tidal dissipation estimates may still hold, or the magnetic field can be altered in both amplitude and topology. In the latter case, tidal (zonal) flows are able to stretch the dipolar magnetic field to produce azimuthal magnetic field lines and enhanced poloidal components, which could indicate the occurrence of a tidal dynamo.