Tidally-driven dynamo action in convective envelopes

Binary systems are ubiquitous among stars, and most of (current) detected exoplanets orbit their host stars within distances comparable to or smaller than Mercury's orbit in the Solar System. Beyond their architectural and rotational influences, tidal interactions can profoundly affect the internal physical processes of tidally perturbed bodies. Using 3D magnetohydrodynamic (MHD) simulations in a spherical shell, we have recently shown that tidal flows can significantly alter both the amplitude and topology of magnetic fields in the convective envelopes of stars and giant gaseous planets. Our simulations reveal that tidal (inertial) waves non-linearly interact to generate cylindrical differential rotation (also called zonal flows)—a key ingredient for dynamo action.

This raises a critical question: what is the role of tidal flows in modifying or driving dynamo action within close stellar binaries and exoplanetary systems? While this topic remains largely unexplored, Cebron & Hollerbach (2014) showed that a tidally driven dynamo effect can possibly emerge in fully convective spheres, triggered by the elliptical instability. In this talk, we investigate how tidal flows can amplify and possibly sustain magnetic fields in a convective shell, guided by the magneto-rotational instability that we have observed and characterized in our 3D MHD tidal flow model.

We highlight that the strength of the tidal forcing, and thus of the tidally driven zonal flow, is decisive in sustaining or not the magnetic energy. Finally, we discuss the potential occurrence of tidally driven dynamos in observed close binary stars and Hot-Jupiter systems, offering new insights into the magnetic evolution of these objects.