Do non-linear effects disrupt tidal dissipation estimates in convective envelopes?

In close star/star or star/planet systems, tidal interactions are known to shape the orbital architecture of the system, and modify the star and planet spins. Most stars around which planets have been discovered are low-mass stars and thus feature a (differentially-rotating) convective envelope, as is also expected in giant gaseous planets like Hot-Jupiter. The dissipation of tidal flows, and more specifically the dissipation of inertial waves (restored by the Coriolis acceleration, and recently observed in the Sun) is of particular importance in the convective envelopes, especially in the early stages of the life of a star. In parallel, the nonlinear self-interactions of inertial waves can affect the rotation of the body in which they propagate. Indeed, they can trigger differential rotation in convective shells in the form of axisymmetric zonal flows, as shown in numerical and experimental hydrodynamical simulations. In turn, the propagation and dissipation of inertial waves are also modified by differential rotation. From the observational side, important efforts (started with the data analysis of Kepler and now of Tess) have been undertaken to constrain possible orbital decay of really close planets like Hot-Jupiter. In that sense, the nonlinear dissipation of tidal waves is one promising avenue to explain inward migration of the planet toward its host star.

In this context, I will present our recent results of hydrodynamical direct numerical simulations of tidally-forced inertial waves, in 3D spherical convective shells. In these non-linear simulations, the onset of tidally-driven zonal flows, along with wave/zonal flow interactions, can deeply modify tidal dissipation rates from prior linear predictions. Therefore, I will discuss to what extent these various nonlinear effects disrupt the linear predictions we have for tidal interactions. All permissible forcing frequencies for inertial waves have been explored, along with different viscosities, and various tidal amplitudes and size of the convective shells which are representative of the diversity of convective envelopes of low-mass stars and giant gaseous planets. The new estimates for tidal dissipation are of particular interest for both stars and planets in compact systems in which tidal inertial waves can be excited and subsequently damped.