Exploring waves properties with multi-dimensional fully compressible hydrodynamical simulations: from solar type stars to intermediate-mass stars

Internal gravity waves (IGWs) that propagate in stellar interiors have become essential in stellar physics. These waves are well known for transporting angular momentum (AM), energy and chemical elements in stably stratified media, i.e. in radiative zones of stars. For instance, they could explain the solid rotation of the solar core inferred from helioseismology. However, despite observations of very high precisions, detection of IGWs is still challenging and their properties in stellar interiors remain poorly understood and/or constrained. This is mostly because IGWs are inherently 3D, non-linear and anisotropic phenomena. Consequently, multi-dimensional modelling is a great tool to study their properties but also their excitation mechanism, i.e. convection, and their interaction with the mean flow, i.e. rotation. However, to overcome some of the challenges inherent to stellar hydrodynamics, simulations are often run with artefacts. Two of the most important challenges are numerical stability and thermal relaxation. To face them, an artificial increase of the stellar luminosity and of the thermal diffusivity by several orders of magnitudes is a commonly used tactic. This technique is known as *boosting* a numerical model.

In this talk, I will present a study of IGWs properties in solar-like stars based on 2D stellar structure models preformed with a fully compressible hydrodynamics time implicit code, the MUSIC code (Pratt et al. 2017, Baraffe et al. 2021). I will show how boosting a numerical model impact the waves properties. Our results suggest that this technique affect the excitation of IGWs, because of an impact on convective motions and overshooting, but also their damping. This is of particular importance when studying stellar rotation. Indeed, the AM flux in stellar interiors depends strongly on the wave energy flux and on the radiative damping of IGWs, both quantities being impacted by this boosting technique.

In a recent study, I have analysed IGWs propagating in the radiative envelope of intermediate mass stars. Excited at the convective core boundary, it is still debated if these waves should be able to propagate up to the surface. Our results suggest that low frequency waves excited by core convection could be damped before. Indeed, I show that these low frequency waves are impacted by radiative and nonlinear effects as they propagate. However, these effects are affected by the artificial enhancement of the luminosity and radiative diffusivity. Thus, comparison between numerical simulations and observations is not straightforward and should be done with great caution.