Two-years Post-Doctoral project
on experimental and numerical geophysical fluid dynamics

Mixing by topographically-forced stratified turbulence with application to icy moons

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Context. Water rich planetary bodies are ubiquitous in the outer solar system (Nimmo and Pappalardo, 2016). Various observations hint at the presence of liquid/conducting layers beneath the ice crust. Some constitute at present the most promising of potentially habitable extraterrestrial environments (Europa, Enceladus) and two of the most ambitious planetary missions to come are devoted to the characterization of such ice-covered ocean worlds: ESA's JUICE, scrutinizing Ganymede, and NASA's Europa Clipper.

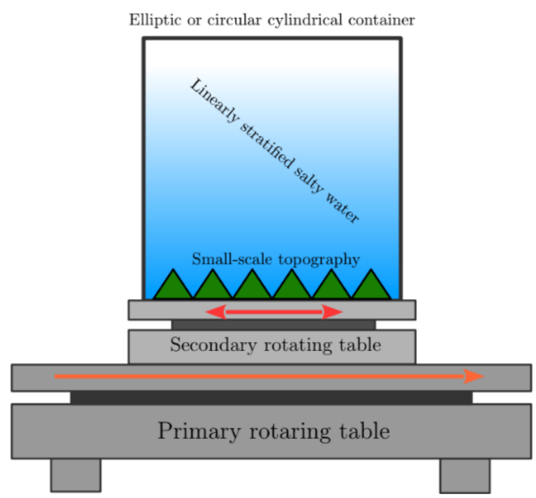

Figure 1: Schematic of the experimental device

Available observations primarily constrain the state of the surface ice shell, and to a lesser extent the deep rocky core. The internal ocean dynamics remains comparatively unconstrained. Although different in nature, tidal heating of deep rocky cores in both Enceladus and Europa possibly provides means for complex chemistry and sets a heterogeneous boundary condition at the seafloor (cf. for Enceladus Choblet et al., 2017a). Melting within Titan or Ganymede's high pressure ice mantles might have a comparable effect (Choblet et al., 2017b). But the consequences on ocean dynamics are largely unknown. Surface compositions of ocean worlds reveal a richness of non-water compounds suggesting chemical transport from rocky interiors to icy surfaces, as does the analysis of Enceladus' powerful plume. However the practical means by which the oceans convey this signature are uncertain.

Using a dual experimental and numerical approach and building on an interdisciplinary team at the frontier of planetology and fluid mechanics (ANR COLOSSE with LPG Nantes and IPG Paris), we wish in particular to answer the following main question on buried oceans, essential to prepare the coming space missions, in particular JUICE and Europa Clipper: is stratification a barrier for radial transfer of a deep chemical signal caused by active water-rock interaction at Europa's or Enceladus' seafloor?

Program. We will focus on libration (periodic modulation of the rotation rate, Le Bars 2015), easier to access in the lab and quite promising for objects with ice shells that are deformed by tides. First, we will investigate how turbulence can be generated by the libration of a large elliptic cylinder filled with a stratified (using salty water) fluid (McEwan 1975). Using a similar setup, we will also investigate the flow generated by the libration of a small-scale topography and study how it affects the stratified ocean above. This parametrically forced system can also be studied numerically using spectral elements simulations to work in the same complex geometry as the experiment (see Favier et al., 2015, for an example in a tri-axial ellipsoid). The goal is to quantify the mixing induced by the parametrically-excited instabilities and turbulence of an initially linearly-stratified system, when considering both large-scale and small-scale topographical couplings.

The potential candidate should possess a strong background in experimental fluid dynamics. The initial contract will be signed for one year, with a second year available upon satisfying progress.

References.

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