Stratified shear flows at low Prandtl number : the combined effects of horizontal and vertical shear, and/or rotation
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In the past few years, we have been very interested in understanding the effect of shear on vertical transport in stellar interiors, which are usually modeled as low Prandtl number Boussinesq fluids. The cases of vertically sheared and horizontally sheared stratified flows has been investigated by two former fellows (Tobias Bischoff, 2013, and Laura Cope, 2018), respectively. We have found that the fluid responds in dramatically different ways to horizontal and vertical shear, and have derived a number of scaling laws for transport as a function of input parameters in both cases. In real stars, however, we anticipate that both vertical and horizontal shear should be present, which begs the question of how the fluid will respond in that case. Stars also rotate, but this effect has so far been neglected.

This project would start with an obligatory linear stability analysis of the system, followed by exploratory numerical simulations (the code will be provided, as well as supercomputing access). These will help formulate a few specific questions of interest to the fellow that can be answered in the program timeframe (given the high dimensionality of parameter space, an exhaustive study is out of the question).

For instance, one question of particular interest to astrophysicists is whether the presence of even a tiny amount of horizontal shear can destabilize a vertical shear flow whose Richardson number is very large (which is usually the case in stars). As an alternative possibility (or a follow up to the above) the project could also look at the effect of rotation on the development of the shear instabilities (either vertical shear or horizontal shear, or a combination of the two). Rotation can either stabilize or destabilize shear flows as a result of angular momentum conservation. While the linear problem is reasonably well-understood, the nonlinear development of shear instabilities in rotating fluids at low Prandtl number has not been thoroughly investigated to date.