Experimental study of the penetrative convection in gases

Valentin Dorel[1], Michael Le Bars[1], Patrice Le Gal[1]

Aix–Marseille University, CNRS, Centrale Marseille, IRPHE, UMR 7342, 49 rue F. Joliot-Curie, 13013 Marseille, France
valentin.dorel@univ-amu.fr

Long-time evolution of stars is only accessible through parameterised models that rely on correct physical modelling of small-scale, rapid processes. In particular, their lifetimes depend on the mixing of their nuclear fuel that can happen at the interface between a convective and a stratified radiative zone. Stellar convection zones are strongly turbulent and their interaction with a stratified layer, called penetrative convection, is still hard to model properly. Experimental investigation of this interaction is thus needed. Most experimental studies used liquids, specifically heated (resp. salty) water [1] [2] [3], where the Prandtl (resp. Schmidt) number Pr is equal to 7 (resp. 700), when in stars $\mathrm{Pr} \ll 1$. On the contrary, our setup takes the advantage of using gases and reaches $\mathrm{Pr} = 0.7$.

A heavy gas (SF_6) fills the bottom of a rectangular tank with dimensions 85 x 85 x 150 cm. Diffusion of SF_6 in air quickly establishes a stratified region in the upper part (Fig.1 **a**). Electric resistors heat the bottom plate of the tank up to a chosen temperature while water circulation fixes the top one at room temperature. The SF_6 lower layer rapidly convects. Mist-makers placed at the top and at the bottom produce droplets used for PIV measurements (Fig.1 **b**). A density and temperature probe regularly moves up and down during a run (Fig.1 **a.**).

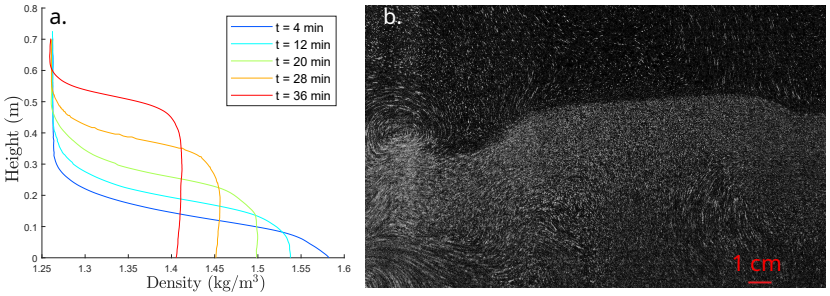

Figure 1. a. Density profiles measured during an experiment **b.** Superimposition of 5 images from a movie of an experiment, performed at 25 fps. The interface between the lower convective region and the upper stratified one is clear.

When most models use eddy diffusivity mechanisms for the interface growth, we found that it is parabolic in time, which contradicts a turbulent diffusive process. The analysis of the spectra in the stratified domain confirms the presence of propagating internal gravity waves. Running PIV in both layers simultaneously allows us to compute the energy transfer from the convective zone to the radiative one, as well as to investigate scaling laws for the erosion rate.

Références

1. J.W Deardoff & G.E. Willis & D.K. Lilly, Laboratory investigation of non-steady penetrative convection, *Journal Of Fluids Mechanics.*, **35**, 7–31 (1969).
2. J. Herault & F. Duval & M. Le Bars, Mass transport induced by a jet impinging on a density interface : The role of interfacial wave breaking, *EPL (Europhysics Letters)*, **117**, 64003 (2017).
3. P. Leard & B. Favier & P. Le Gal & M. Le Bars, Coupled convection and internal gravity waves excited in water around its density maximum at 4°C, *Physical Review Fluids*, **5**, 024801 (2020).