PhD Research Proposal Form
China Scholarship Council (CSC) - ENS Group

FIELD: Physics

Thesis subject title: Local heat transfer mechanism in Rayleigh-Bénard convection in the high Rayleigh number limit

Name of the French doctoral school : ED 52 (PHAST)

Name of the Research team : Thermal Convection
Website : https://www.ens-lyon.fr/PHYSIQUE/teams/non-lineaire-hydrodynamique/research-topics/hydro_turb

Name of the Supervisor : Francesca CHILLÀ and Julien SALORT
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Lab Language : French and English

Research Proposal Abstract :

Turbulent thermal convection is a pervasive problem in many natural situations. It can be modelled in the laboratory by the Rayleigh-Bénard cell. It is a toy model simple to use, that allows to mimic thermal transfer when the temperature is responsible for the fluid motion. As a paradigm for experimental studies, it can give information on thermal exchange in rooms, atmospheric boundary layers and other systems. The Rayleigh-Bénard system is a layer of fluid confined between two horizontal plates. The fluid is heated from below and cooled from above. Thermal boundary layers form in the vicinity of the plates. Buoyancy instability leads to the formation of coherent structures, called thermal plumes. These plumes and their interaction give rise to a global motion (the large-scale circulation). When the forcing is strong enough, the flow can become turbulent, and the global behavior is determined by the competition between purely inertial effects, local thermal forcing and the interaction between plumes. Moreover, a transition of the boundary layer can be expected [1], which induces an enhancement of the heat transport, and the so called “Ultimate regime of Rayleigh Bénard convection” can settle.

The recent developments of new quantitative experimental method, based on Thermochromic Liquid Crystals [2], and Quantitative Shadowgraph [3], allow to investigate the local heat flux map. In particular, we have well developed both the techniques and we are contributing to quantitively characterize the local heat flux at Rayleigh number as high as 10^{10} thanks to very refined calibration [4]. We can also wery well identify thermal plumes as reported in figure (1). The aim of this project is to tackle the the ultimate regime, which allows for a greatly augmented heat flux transport and which possibly observed at larger than Ra 10^{11}. The critical Ra value can change as function of the shape of the container and the kind of fluid. We propose to use several methods to reach this highest turbulent regime: (i) we can use exotic fluids such as cryogenic helium, or fluorocarbon, to reach higher Rayleigh numbers; (ii) we can use plate roughness to trigger higher turbulence regimes. In those situations, we want to measure quantitatively the heat flux.

The main work of the Ph.D. student will be to operate Rayleigh-Bénard cells in these various configurations, using different working fluids (water, fluorocarbon and cryogenic liquid helium) and to further improve the methods of TLC and measurements of velocity to analyze the experimental data to gain new insights in the physics of turbulent thermal convection.

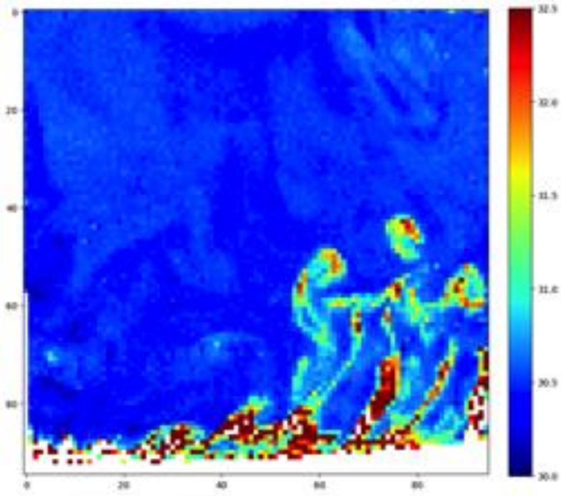

Figure (1): thermal plume near the bottom boundary layer.
The color represent the local temperature.

References :

[1] Lohse, Shiskina, Physics Today **76**:11 (2023) 26
[2] Moller, König, Resagk and Cierpka, “Influence of the illumination spectrum and observation angle on temperature measurements using thermochromic liquid crystals”, Meas. Sci. Technol. **30** (2019) 084006
[3] Méthivier, Braun, Chillà and Salort, “Turbulent transition in Rayleigh-Bénard convection with fluorocarbon”, EPL **136** (2021) 10003
[4] Bernard, Barret, Salort and Chillà, in preparation for JFM.

Type of PhD :

1.Full PhD

- Joint PhD/cotutelle (leading to a double diploma) : NO
- Regular PhD (leading to a single French diploma) : YES

2. Visiting PhD (for students enrolled at a Chinese institution who will be invited to a French institution to carry out a mobility period) : NO