A Persistent Clock in Turbulent Rayleigh-Bénard Convection

Lázaro Martínez-Ortíz*[1], Youri H. Lemm[1], Herman J. H. Clercx[1], and Rudie P. J. Kunnen[1]

[1]Fluids and Flows, Department of Applied Physics, Eindhoven University of Technology – Netherlands

Abstract

The large-scale circulation (LSC) is the hallmark structure of confined Rayleigh-Bénard convection (RBC). It arises from the collective organization of thermal plumes, which tend to cluster and move in a synchronized manner, producing periodic signals in near-wall temperature and velocity. Whether the LSC drives the motion of the plumes or is itself sustained by their buoyancy has remained a longstanding paradox. Using combined experimental and numerical results, we show that the LSC possesses a persistent internal "clock": its pulsating velocity follows a universal relation linking the pulsation frequency to the characteristic system scale. We connect this parameter to the ratio between the imposed shear and the plume-shedding frequency. By introducing a narrow sidewall barrier, we can trip the LSC into a pair of interconnected rolls stacked above and below the barrier, through a transition triggered by viscous boundary layers. Remarkably, each roll independently exhibits the same ratio, even in vertically asymmetric configurations, indicating signatures of synchrony. These findings reveal a direct quantitative link between plume dynamics and the mean flow, shedding new light on the long-standing question of how plume generation relates to LSC organization, and opening avenues to explore the interplay between circulation structure, synchrony, and turbulence in RBC.

*Speaker