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THREE-DIMENSIONAL FLOW TOPOLOGY EVOLUTION IN TURBULENT RAYLEIGH-BÉNARD CONVECTION

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Small-scale dynamics is the spirit of turbulence physics. It delivers complex mechanisms when turbulence is purely sustained by buoyancy. This takes place in Rayleigh-Bénard convection (RBC). Most of the existing RBC dynamics is ruled by hard turbulent regime and a deep understanding of small scale dynamics with its relevant nonlinearities, is still unsatisfied. To do so, the 2D evolution of $Q_\mathsf{G} = -1/2tr(\mathsf{G}^2)$ and $R_\mathsf{G} = -1/3tr(\mathsf{G}^3)$, invariants of the velocity gradient tensor, $\mathsf{G} = \nabla u$, are studied and reported in Dabbagh *et al.* [1] using DNS of RBC. In the present work, we expand the 2D $\{Q_\mathsf{G}, R_\mathsf{G}\}$ evolution to three dimensions by decomposing R_G into its strain production $R_\mathsf{S} = -1/3tr(\mathsf{S}^3)$ and enstrophy production $tr(\Omega^2\mathsf{S}) = R_\mathsf{S} - R_\mathsf{G}$ terms, where S and Ω are the rate-of-strain and rate-of-rotation tensors, respectively. In the $\{Q_\mathsf{G}, R_\mathsf{S}, R_\mathsf{S} - R_\mathsf{G}\}$ space, the flow topology in a Lagrangian evolution is changing by the conditional mean trajectories (CMTs) $\{DQ_\mathsf{G}/Dt, DR_\mathsf{S}/Dt, D(R_\mathsf{S} - R_\mathsf{G})/Dt\}$. Using the dataset in [1], and from Figure 1: An identified cyclical start of trajectories is distinguished in areas of vortex-stretching $R_\mathsf{S} - R_\mathsf{G} > 0$ and $R_\mathsf{S} > 0$ in the strain dominated slots ($Q_\mathsf{G} < 0$), which becomes stronger and longer expanded at Rayleigh number $Ra = 10^{10}$. Afterwards, the trajectories move downwards ($Q_\mathsf{G} << 0$) in areas of vortex-compression $R_\mathsf{S} - R_\mathsf{G} < 0$ and $R_\mathsf{S} > 0$, that also become more diverging at $Ra = 10^{10}$ as a result of the self-amplified straining [1]. This is followed by rising trajectories upwards ($Q_\mathsf{G} > 0$) to continue performing the typical planner $\{Q_\mathsf{G}, R_\mathsf{G}\}$ cyclical behaviour [1], next to $R_\mathsf{S} = 0$, and decaying towards the origin. DNS at $Ra = 10^{11}$ is currently being computed on the MareNostrum supercomputer [2]. Results will be presented during the conference.

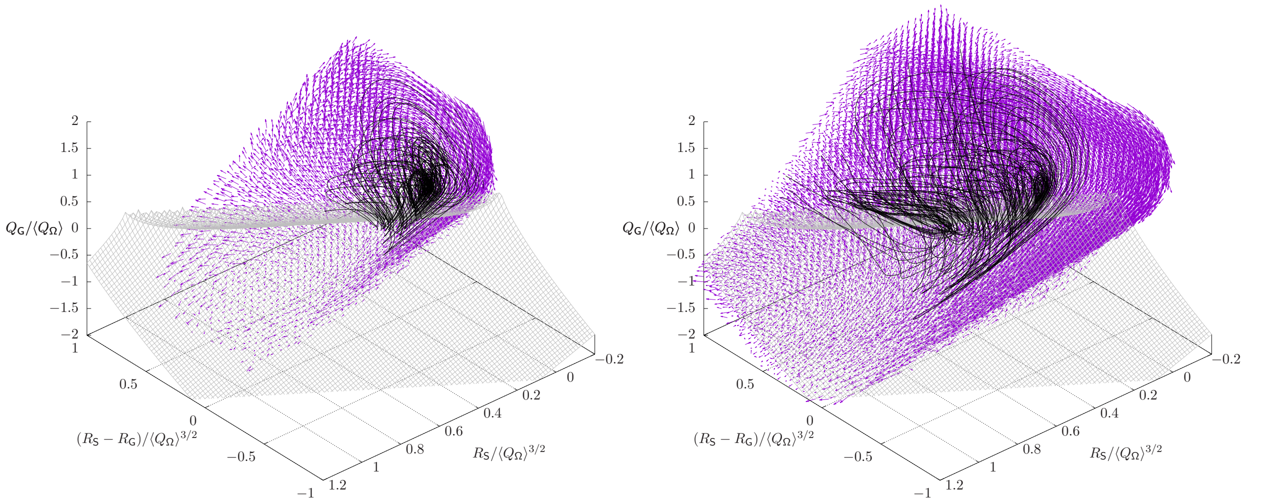

Figure 1: CMTs of the evolution of G in $\{Q_\mathsf{G}, R_\mathsf{S}, R_\mathsf{S} - R_\mathsf{G}\}$ space through the bulk region of turbulent RBC at $Ra = 10^8$(left) and 10^{10} (right). The surface $D_\mathsf{G} = (27/4)R_\mathsf{G}^2 + Q_\mathsf{G}^3 = 0$ is shown as a gray wire mesh.

References

[1] F. Dabbagh, F. X. Trias, A. Gorobets, and A. Oliva, *Physics of Fluids*, **28**, 115105, 2016.
[2] F. X. Trias, F. Dabbagh, A. Gorobets and C. D. Pérez-Segarra, *(Ref. 2016163972), PRACE 15th Call.*

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