Asymptotic Ultimate Regime of Homogeneous Rayleigh-Bénard Convection on Logarithmic Lattices

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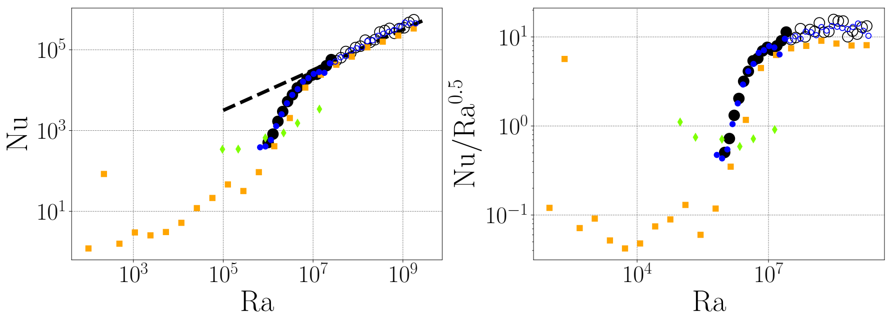
We investigate how the heat flux Nu scales with the imposed temperature gradient Ra in Homogeneous Rayleigh-Bénard convection[1] using 1, 2 and 3D simulations on logarithmic lattices. Logarithmic lattices are a new spectral decimation framework[2] which enables us to span an unprecedented range of parameters (Ra, Re, Pr) and test existing theories using little computational power.

We first show that known diverging solutions can be suppressed with a large-scale friction. In the turbulent regime, for Pr ≈ 1, the heat flux becomes independent of viscous processes ("asymptotic ultimate regime", Nu $\sim$ Ra$^{1/2}$ with no logarithmic correction). We recover[3] scalings coherent with the theory developed by Grossmann & Lohse, for all situations where the large-scale frictions keep a constant magnitude with respect to viscous and diffusive dissipation.

We also identify another turbulent friction dominated regime at Pr $\ll 1$, where deviations from GL prediction are observed. These two friction dominated regimes may be relevant in some geophysical or astrophysical situations, where large scale friction arises due to rotation, stratification or magnetic field. We finally extend some of those results to rotating turbulence.



(a) (b)

Figure 1: Non-dimensional heat transfer Nu vs Rayleigh number Ra in 3D for Pr = 1. (1a) Nu vs Ra. Filled symbols (resp. open) symbols have been used to discriminate between non-universal (resp. universal) friction dominated regimes. The dotted line corresponds to Nu $\sim \sqrt{\text{Ra}}$, corresponding to asymptotic ultimate regime scaling. (1b) Compensated plot Nu $/\sqrt{\text{Ra}}$ vs Ra.

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[1] Calzavarini, E. and Lohse, D. and Toschi, F. and Tripiccione, R., *Physics of fluids* **17**, 055107 (2005).

[2] Campolina, C. and Mailybaev, A., *Nonlinearity* **34**(7), 4684 (2021).

[3] Barral, A. and Dubrulle, B., *t.b.p. in JFM* (2023).