Transition to the Ultimate Regime in Boussinesq and Non-Boussinesq conditions

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Thermal convection at very high Rayleigh numbers remains elusive, as published experimental results show apparent contradictions. The transition to the ultimate regime has been reported in several Grenoble convection cells, in experimental conditions satisfying extremely strict Boussinesq conditions. In particular, the ultimate state is observed even when the key properties of the fluid (density, thermal expansion, conductivity, viscosity, heat capacity) are bound to stay within a 1 % window of variation, as reported by Roche et al[1].

The transition to the ultimate regime is evidenced in gaseous and supercritical cryogenic Helium in Grenoble[2] beyond a Rayleigh number within 10^{11} — 10^{13}, depending on the cell aspect ratio[3].

Other convection cell show no heat transfer enhancement[4], or only in Non-Boussinesq conditions[5], or at much larger Rayleigh numbers[6]. This raises the question whether Non-Boussinesq effects in these cells might hinder the transition, and cause the transition to the ultimate state to be differed or damped. To explore this possibility, we present unpublished heat transfer measurements obtained in Non-Boussinesq conditions, and show the impact of these deviations on the strength of the transition.

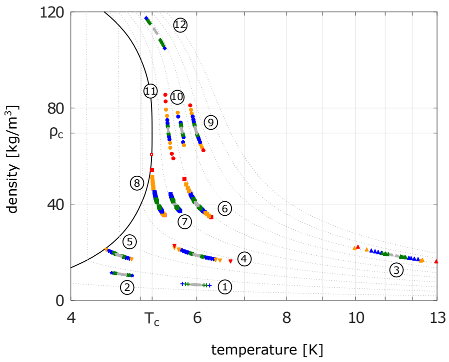

Figure 1: Experimental conditions near each plates for heat transfer measurements series at several mean densities and temperatures. Colors: grey ($\alpha\Delta T < 5$ %) green ($\alpha\Delta T < 10$ %), blue ($\alpha\Delta T < 20$ %), orange ($\alpha\Delta T < 30$ %) and red ($\alpha\Delta T > 30$ %). Dotted line: isochores from 0.5 to 5 bars. Continuous line: frontier of the liquid-vapour coexistence.

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