Thermal waves and heat transfer efficiency enhancement in harmonically modulated turbulent thermal convection

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Turbulent Rayleigh-Bénard convection (RBC) serves as the paradigmatic system for studies of various forms of turbulent thermal convection.[1] We observe and discuss (i) significant heat transfer enhancement and (ii) thermal waves propagating through a turbulent fluid layer when the top or bottom boundary temperature harmonically oscillates (Figure 1)[2]. Such experimental observations, enabled by our unique, thermally fast cryogenic apparatus[2], help to better understand Sun-driven atmospheric and ocean natural flows forming planetary weather and climate or to design more efficient heat exchangers for various technical applications.

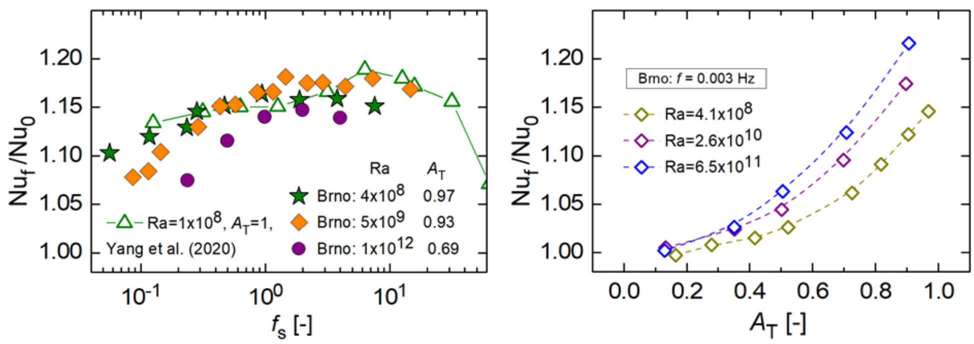

Figure 1: Harmonic modulation of boundary temperatures significantly increases the heat transport efficiency by turbulent thermal convection by up to 20%: (a) Relative heat transport efficiency Nu_f/Nu_0 plotted versus dimensionless modulation frequency f_s for different values of the turbulent convection intensity represented by the Rayleigh number, Ra, where Nu_0 represents the heat transport efficiency at constant temperatures of the top and bottom boundaries. (b) Dependence of Nu_f/Nu_0 on the dimensionless amplitude of modulation $A_T=T_{mod}/\Delta T$, where T_{mod} is the harmonic modulation amplitude of the top plate and ΔT denotes the mean temperature difference between the plates. Dimensionless quantities allow direct comparison of our experimental data with numerical prediction[3].

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