Physical mechanism behind the early onset of the ultimate state in supergravitational centrifugal thermal convection

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Abstract

We present a combined experimental and numerical investigation of the transition from the classical to the ultimate regime of thermal turbulence in a supergravitational centrifugal convection system. The transition is found to be robust, with the critical Rayleigh number decreasing systematically as the Froude number, defined as the ratio of centrifugal to Earth's gravity, decreases, highlighting the effect of residual gravity. Once the Rayleigh number reaches the transition threshold, the Stewartson layer induced by residual Earth gravity becomes comparable in thickness to the viscous boundary layer, and their interaction results in a coupled flow that distorts the viscous boundary layer, triggering its transition from laminar to turbulent flow and leading to a sharp increase in heat transport. These findings demonstrate the key role of the Stewartson layer induced by residual gravity in facilitating the transition to the ultimate regime in supergravitational centrifugal thermal convection.

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