Diffusive behavior of columnar vortices in rotating thermal convection

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Rotation effect on thermal convections in a fluid layer driven between two parallel plates with temperature difference, i.e., Rayleigh-Bénard convection (RBC) is a ubiquitous to explain large scale fluid motions observed on the Earth, such as typhoon, tornadoes, and liquid metal convection inside outer core. Various approaches so far have revealed its interesting features, e.g. heat transfer enhancement at moderate rotation rate, rotation dependent flow morphologies, and so on. Especially in them, formation of vertically aligned columnar vortices is one of the most curious phenomenon. Early experimental works mentioned those chaotic behavior like vortex-vortex interactions, however, little is known about this complicated vortex dynamics.

The present study is paying attention to such vortex dynamics observable in rotating RBC. With using encapsulated thermochromic liquid crystals, long-time $O(10^3$ s) experimental visualizations of the vortices on time variations of a temperature field were conducted, and we reached two novel insights. One is horizontal diffusive motion like Brownian motion of the columnar vortices. Statistical analyses on motions of the columnar vortices elucidated various kinds of diffusive motion. Such diffusive motions strongly depend on observation timescale (vortex lifetime) and columnar vortices present anomalous diffusive motion. Another is the effect of centrifugal force even under conditions for empirically negligible small effects of centrifugal force. This is the first found thanks to our long-time observations and might give a new caution to rotating RBC studies.

Keywords: Natural convection, Rotating field, Diffusive motion, Vortex dynamics

