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Universal scaling law for the aspect ratio of a pancake vortex in a rotating stratified medium

Oriane Aubert (1), Michael Le Bars (1), Patrice Le Gal (1), and Philip S. Marcus (2)

(1) IRPHE, CNRS & Aix-Marseille University, France (lebars@irphe.univ-mrs.fr), (2) Computational Fluid Dynamics Lab, UC Berkeley, USA

Long-lived pancake vortices are typical structures of rotating stratified fluids: the Great Red Spot of Jupiter and the Meddies in the Atlantic Ocean on Earth count among the most famous ones. Although these structures have very different Reynolds numbers, composition and background environments, they exhibit the same characteristics: they are anticyclonic, elongated and long-lived.

To reproduce and study these structures in the laboratory, we inject a volume of isodensity dyed fluid in a rotating linearly stratified layer of salty water. Due to the Coriolis force, the injected fluid rapidly forms a pancake anticyclonic vortex whose long term evolution is quantified using PIV measurements and image processing. After a rather fast geostrophic adjustment, we observe a very slow decrease of the motion while preserving the self-similar shape of the pancake vortex. This regime can be described using a simplified system of equations based on a geostrophic equilibrium, where the energy source maintaining the long-lived vortex is the density anomaly with the outside: the vortex persists as long as the density anomaly remains, maintained by internal recirculations. The non-diffusive version of the equations gives an analytical solution for the self-similar shape of the vortex and the evolution law of the aspect ratio for small Rossby numbers. These theoretical predictions are verified experimentally and agree with published measurements for Jupiter's Great Red Spot.