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Two prevailing features of Jupiter's fluid mechanics studied in laboratory experiments: the stability of the Great Red Spot and the zonal winds generation by tides

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The origin of Jupiter's stripes and the stability of the Great Red Spot (GRS) are among the most puzzling features that challenge researchers in planetary atmospheres for decades. With the view to participate in the full understanding of these phenomena, we present here the main results of two laboratory experiments designed for understanding some of their basic hydrodynamic mechanisms.

In the first experiment, we describe a new phenomenon of zonal wind generation in a rotating fluid sphere by tidal forcing. Following the recent theoretical and numerical analysis by Tilgner [Phys. Rev. Lett. 99, 194501 (2007)], we present the first experimental evidence that the nonlinear self-interaction of a tidally forced inertial wave can drive an intense axisymmetric flow, seen at the surface of the sphere as a shear band. Systematic measurements are carried out by an embarked system of particle image velocimetry (PIV), allowing the determination of general scaling laws. These results illustrate a generic mechanism of geostrophic flow generation by any external periodic forcing. At the surface of Jupiter's atmosphere, tides from the various Galilean moons would thus generate zonal winds, in complement to the already suggested models based on convection.

In the second experiment, we investigate the stability of the GRS, which constitutes one of the most famous example of long-lived pancake-like anticyclones taking place in rotating and stably stratified medium. In Jupiter's atmosphere, diffusive processes are very fast, but thermal-dynamical effects must also be taken into account. The rapid radiation of heat at the surface of the GRS is compensated by a strong recirculation inside the GRS, which is thus fully mixed. To reproduce and study the GRS dynamics in the laboratory, we inject a volume of isodensity dyed fluid in a rotating linearly stratified layer of salty water. After a rather fast geostrophic adjustment, we observe the formation of a pancake vortex with a fully mixed interior, whose anticyclonic motion slowly decreases while preserving its self-similar shape. This behavior 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.

Reference: Experimental determination of zonal winds driven by tides, Morize C, Le Bars M, Le Gal P, Tilgner A. Phys Rev Lett. 2010,104(21):214501.