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DIFFUSIVE MCINTYRE INSTABILITY OF GAUSSIAN LENSES

Oleg Kirillov*[1] and Joris Labarbe[2]

[1]Department of Mathematics, Physics, and Electrical Engineering, Northumbria University
[2]Institut de Recherche sur les Phénomènes Hors Équilibre, UMR 7342, CNRS-Aix-Marseille Université

*contact: oleg.kirillov@northumbria.ac.uk

An intriguing class of dynamical systems of geophysics and astrophysics resides in the so-called lenticular vortices that serve to model mesoscale oceanic or atmospheric cyclones and anticyclones, such as the Great Red Spot (GRS) of Jupiter. These compact but intense three-dimensional baroclinic vortices are strongly influenced by planetary rotation and thus are governed by geostrophic and hydrostatic balances between pressure gradients and Coriolis and buoyancy forces, from where they get their ellipsoidal shape varying from flat "pancakes" to nearly round, see Fig. 1 (Orozco Estrada *et al.*, 2020; Le Bars, 2021; Lahaye *et al.*, 2021).

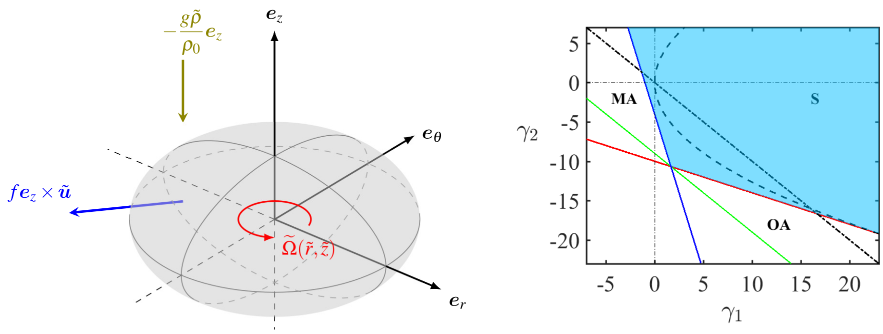

Figure 1: (Left) Sketch of a differentially rotating lenticular vortex in a cyclogeostrophic balance between centrifugal, hydrostatic, and Coriolis forces; (right) its stability map with a codimension-2 point (Labarbe et Kirillov, 2021).

The lenticular vortices observed in nature are notoriously persistent (like the GRS). Nevertheless, even the GRS is subject to variations in its size. Therefore, natural and timely questions arise on how stable such lenticular vortices are, what are their basic destabilization mechanisms, and what are their origins?

In this talk based on the work (Labarbe et Kirillov, 2021) we consider a circular lenticular vortex immersed into a deep and vertically stratified viscous fluid in the presence of gravity and rotation. The vortex is baroclinic with a Gaussian profile of angular velocity both in the radial and axial directions (a *Gaussian lens*). Assuming the base state to be in cyclogeostrophic balance, we linearize the system and seek for its solution in a geometric optics approximation (Labarbe et Kirillov, 2021; Singh et Mathur, 2021) to find a comprehensive dispersion relation. Applying the algebraic Bilharz criterion to the latter, we establish that the main destabilization mechanism is either monotonic or oscillatory axisymmetric instability (the McIntyre instability (Le Bars, 2021)) meeting at a codimension-2 point, Fig. 1. Although we demonstrate that the centrifugally stable (unstable) Gaussian lens can be destabilized (stabilized) by the differential diffusion of mass and momentum and that destabilization can happen even in the limit of vanishing diffusion, we also describe explicitly a set of parameters in which the Gaussian lens is stable for all Schmidt numbers.

References

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