On the existence of radiating waves in vortices

- BIFD2011 -

Luis Parras[*,†]**, Stéphane Le Dizès**[†]

[*] E.T.S.I.I. Industriales
Universidad de Málaga,
C/ Pedro Ortiz Ramos S/N 29071 Málaga, Spain
e-mail: lparras@uma.es, web page: http://www.fluidmal.uma.es/lparras

[†]IRPHE, CNRS & Aix-Marseille University
49, rue F. Joliot Curie, F-13013 Marseille, France.
e-mail: ledizes@irphe.univ-mrs.fr - Web page: https://www.irphe.fr/~ledizes/

ABSTRACT

In an incompressible medium, columnar vortices are generally stable and sustain only neutral or damped waves. In a compressible or stably stratified medium, these waves can become weakly unstable, and a new instability, associated with a mechanism of radiation, is active. Le Dizès and Billant [1,2] analysed this instability in the framework of a stably stratified medium and showed that the instability was always 3D for both Gaussian and Rankine vortices. By contrast, unstable 2D modes were found for a Rankine vortex in a compressible medium [3] or in shallow water [4].

In this work, we want to analyse the effect of the vortex profile on the existence of 2D instability modes. We shall consider columnar vortices in a compressible medium with $\gamma = 2$. This problem is equivalent to the flow in shallow water where the Froude number replaces the Mach number. We first show that when the vorticity is changed from a Rankine profile to a Gaussian profile, the radiative instability discovered by Broadbent & Moore [3] disappears. However, when it is the potential vorticity which is fixed, the instability does not disappear. The results obtained by Ford in [4] for a Rankine potential vorticity profile can be extended in that case to a Gaussian profile. Nevertheless, we show that there is a critical Mach number (or Froude number) below which the flow remains stable.

The nonlinear saturation of the instability is also examined and compared to the simulations by Chan et al [5] and Schecter and Montgomery [6].

REFERENCES

[1] S. Le Dizès and P. Billant, *Radiative instability in stratified vortices*, Phys. Fluids **21**, 096602, 2009.

[2] P. Billant and S. Le Dizès, *Waves on a columnar vortex in a strongly stratified fluid*, Phys. Fluids **21**, 106602, 2009.

[3] E.G. Broadbent and D.W. Moore, *Acoustic destabilization of vortices*, Proc. R. Soc. Lond. A **392**, 279-299, 1984.

[4] R. Ford, *The instability of an axisymmetric vortex with monotonic potential vorticity in rotating shallow water*, J. Fluid Mech. **280**, 303-334, 1994.

[5] W.M. Chan, K. Shariff & T.H. Pulliam, *Instabilities of two-dimensional inviscid compressible vortices, J. Fluid Mech.* **253**, 173-209, 1993.

[6] D.A. Schecter & M. T. Montgomery, *Conditions that inhibit the spontaneus radiation of spiral inertia-gravity waves from an intense mesoscale cyclone, J. Atmos. Sci.* **63**, 435-456, 2006.