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Influence of the multipolar order of the source on the viscous decay of inertial waves
19th International Couette-Taylor Workshop (ICTW19)

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In rotating fluids, the restoring action of the Coriolis force allows for the propagation of a specific class of waves called inertial waves. These waves are of first interest for geo- and astrophysical flows [1, 2, 3]. They can for example be excited in the liquid core of planets by tidal, precession or libration motions. The most remarkable feature of inertial waves is their anisotropic propagation in a direction tilted by an angle $\theta = \sin^{-1}(\sigma/2\Omega)$ from the rotation axis, selected by the ratio between the wave frequency σ and the background rotation rate Ω [4]. While the direction of the wavevector is imposed by the dispersion relation, the selection of the spatial scales is governed by boundary conditions and by viscous effects.

The viscous spreading of an inertial wave beam emitted from a 2D point source has been characterized experimentally by Cortet *et al.* [5]. This work however did not address the issue of the influence of the multipolar order of the source on the decay law of the wave amplitude. For the analogous problem of internal waves in stratified fluids, Voisin [6] showed theoretically from a non-uniform asymptotic expansion that the decay exponent should be a function of the multipolar order of the source.

In this work, we derive theoretically the decay exponents for the inertial wave problem using a quasi-parallel approximation, similar to the work of Thomas and Stevenson [7] for the case of internal waves. We demonstrate the key role played by the instantaneous flowrate of the source: a zero flowrate (dipolar or higher order source) imposes a vorticity decay steeper than a nonzero flowrate (monopolar source).

We designed an experiment aiming to confirm these predictions for the wave beam emitted by two different sources: a pulsating cylinder (monopolar source) and a vertically oscillating cylinder (dipolar source). The wave beam is measured over a large range of distances x using a two-camera-multi-resolution particle image velocimetry (PIV) system (fig. 1(a)). The whole experimental apparatus is mounted on a platform rotating at a constant rate. The measured decay exponents, different for both sources, are in good agreement with the predictions.

These findings are of first interest for localized wave beams propagating in geo- and astrophysical fluid systems. Such wave beams often originate from the eruption of Ekman layers at critical latitudes, caused by precession or libration motions in the fluid core of planets or by interactions between tides and topography in oceans. These wave beams have a non-zero instantaneous flow rate, so they can be described as originating from a localized monopolar source. The combination of beams emitted by such monopolar sources can yield far-field beams corresponding to either a monopolar or dipolar effective wave source depending on the phase shift between each monopolar source.

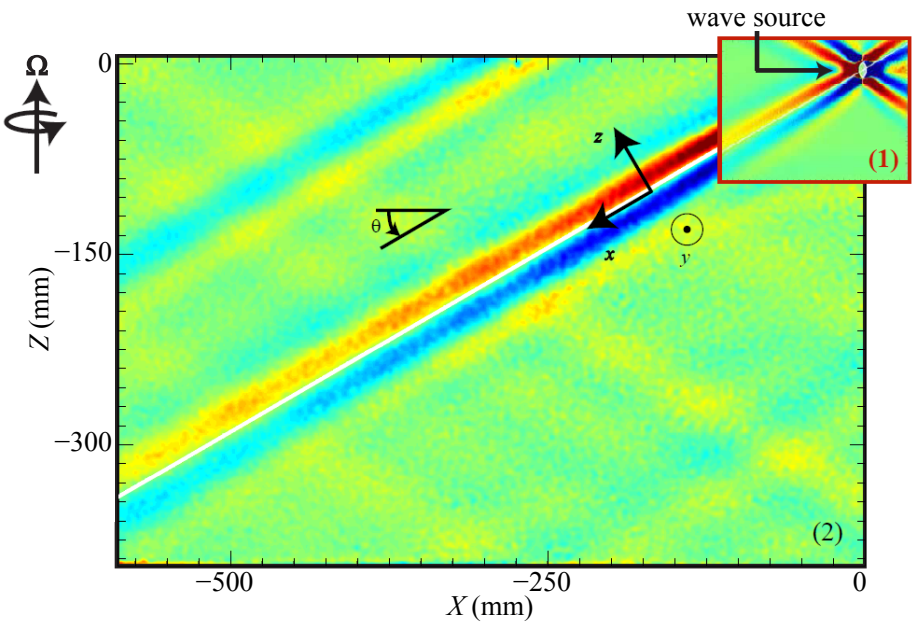

Figure 1: Vorticity fields measured by both cameras: one is a close view around the source while the other extends over large distances from the source. The scales are the same for both fields but the colormap is different for better visibility.

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