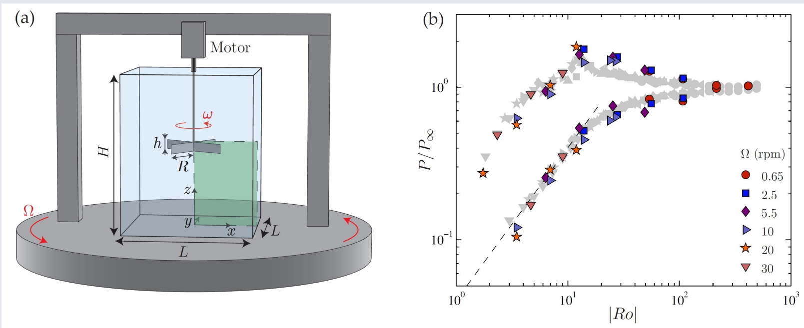
Energy transfers in rotating turbulence

P.-P. Cortet, N. Machicoane, A. Campagne, F. Moisy (FAST, UPSud), B. Gallet (SPEC, CEA).

Rotation of planets and stars is a key ingredient of the turbulent dynamics in geophysical and astrophysical flows. Yet a comprehensive understanding of the influence of a global rotation on turbulence has still not been achieved. This is particularly true in the regime of strong rotation where turbulence is dominated by the dynamics of inertial waves, the internal waves specific to rotating fluids, resulting from the restoring action of the Coriolis force.

In this project, we were interested in the fundamental question of the nature of the energy transfers in rotating turbulence, and particularly in the relevance of the weak turbulence theoretical framework to describe this state. We have developed a new rotating turbulence experiment in which the injected power could be directly measured. It consists in an impeller set in rotation in a water tank, the ensemble being itself driven under rotation by a precision rotating platform. We have demonstrated a strong rotation-induced "drag reduction", i.e. a reduction in the global dissipated power when rotation strengthens, which turns out to agree with the scaling law predicted by the weak turbulence formalism. However, measurements of the turbulent velocity fluctuations by particle image velocimetry suggested another interpretation to this drag reduction: it is actually the result of an inhibition of the turbulence related to the bidimensionnalization of the large cale vortices of the flow. This result suggests that, to approach experimentally the weak turbulence regime, it is crucial to inject energy preferentially in wavy modes rather than in vortical modes.

For even stronger background rotation, a new regime is observed: the quasi-geostrophic (vertically invariant) mean flow driven by the impeller rotation is subjected to "barotropic" azimuthal modulation. This modulation drives a relative velocity between the impeller blades and the mean flow, which leads to the excitation of a wake of inertial waves behind each blade, similar to the wake of surface waves behind a ship. We speculate that the nonlinear interaction of these wakes could form, at larger Reynolds number, a particular state of inertial wave turbulence.



(*a) An impeller is set under rotation at a rate ω in a water-filled tank. The ensemble is driven under rotation by the "Gyroflow" rotating platform at a rate Ω. The torque Γ developed by the motor of the impeller is measured as well as the velocity field in the vertical green area. (b) Mean dissipated power $P=\langle \Gamma \omega \rangle$ in the flow (in grey) normalized by its value P_∞ without rotation as a function of the control Rossby number $Ro=\omega/\Omega$ (the upper branch corresponds to the anti-cyclonic case $\omega\Omega<0$ and the lower branch to the cyclonic case $\omega\Omega>0$). Colored markers correspond to the global dissipated power estimated from the measurements of the velocity fluctuations. The good agreement between the two data series shows that the transfers of energy still follow the scaling law for isotropic turbulence without rotation.*

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