LadHyX Seminar – June 5th, 10:45

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Turbulence under rotation: 2D or not 2D?

Inverse cascades, from small to large scales, occur in flows conserving two sign-definite quantities. This is the paradigm of 2D turbulence: large scales are energized because the 2D Euler equations conserve a second sign-definite quantity, in addition to the energy. 3D turbulence notoriously fails to follow such a rule, because the 3D Euler equations conserve energy and sign-indefinite helicity (the scalar product between velocity and vorticity), which can be both transferred to small scales. However, 3D flows under rotation exhibit a large-scale organization similar to 2D turbulence, while being intrinsically 3D. We show that rotation indeed generates a transfer from 3D waves to large-scale 2D motions by selecting interactions with waves of the same helicity sign, which results in an emergent sign-definite conservation law. We derive a perturbative theory describing the coupling between waves and a large-scale 2D mean flow. The theory predicts the evolution of the 2D flow with rotation and is in remarkable agreement with numerical simulations of Navier-Stokes equations. Importantly, we establish that the two-dimensionalization of 3D motions is stopped at very large rotation, a result which seemingly contradicts the linear theory of Taylor & Proudman (1916).

This talk reports joint work with Anna Frishman.