Asymptotic models of rotating flows in stress-free ellipsoids

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As a canonical model of turbulence in planetary liquid cores, we study precession-driven flows in ellipsoids with stress-free boundary conditions (SF-BC). SF-BC could indeed unlock numerical constraints imposed by no-slip boundary conditions (NS-BC) for planetary applications. Although SF-BC have been employed in the pioneering work of Lorenzani & Tilgner [1], they have scarcely been used because of mathematical issues associated with angular momentum conservation [2]. We revisit the problem using numerical simulations and asymptotic analysis in the low-viscosity regime [3]. First, we extend the reduced model of uniform-vorticity flows in ellipsoids [4] to account for SF-BC. Contrary to previous expectations [2], we show that the long-term evolution of angular momentum is damped by viscosity in axisymmetric SF-BC ellipsoids when the mean rotation axis of the fluid is not the symmetry axis (but also in any triaxial ellipsoids). In the asymptotic regime of planets, we analytically obtain the primary forced flow in triaxial geometries, which exhibits a second inviscid resonance. Then, we investigate the transition towards turbulence (via bulk instabilities) in precessing ellipsoids. We show that the non-viscous inertial instabilities [5], relevant for planetary applications, can be studied using SF-BC. This is of great interest as they are often hampered in experiments or simulations with NS-BC [6,7].

References

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