

TURBULENT FLOWS DRIVEN BY THE MECHANICAL FORCING OF AN ELLIPSOIDAL CONTAINER

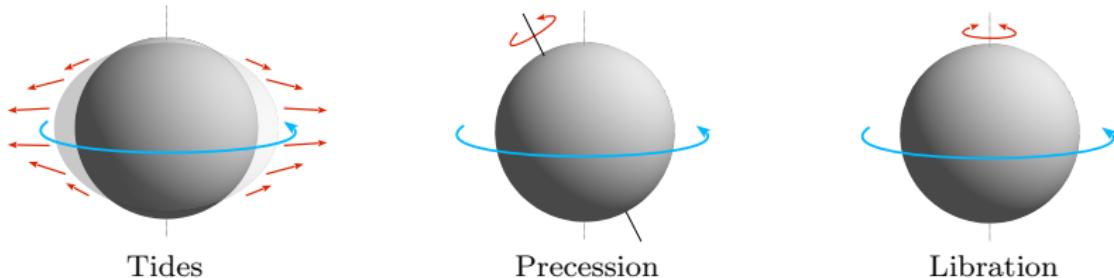
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New Challenges in Turbulence Research IV
École de Physique des Houches, March 20–25 2016



Sources of motion in planetary interiors

- Classical approach: thermo-solutal convection
- Gravitational interactions lead to various large-scale mechanical forcings:



- These forcings can destabilise the solid-body rotation and generate intense motions:
 - Waves
 - Zonal flows
 - Turbulence

Experimental setups

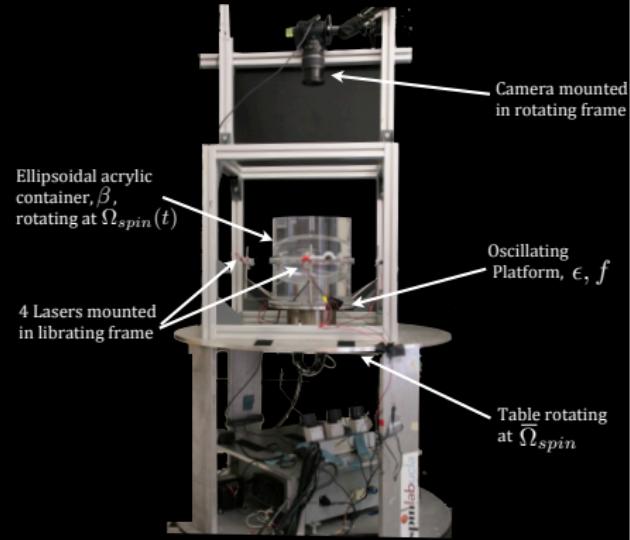
a.

Tides



b.

Libration



Numerical approach

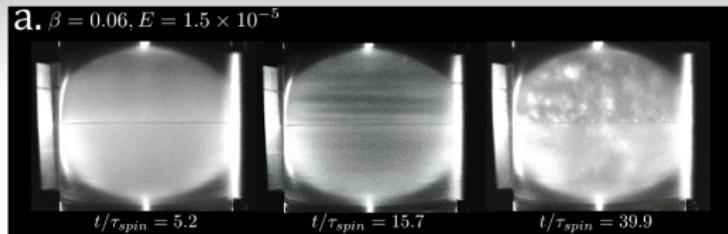
Spectral element code **Nek5000**

<http://nek5000.mcs.anl.gov>

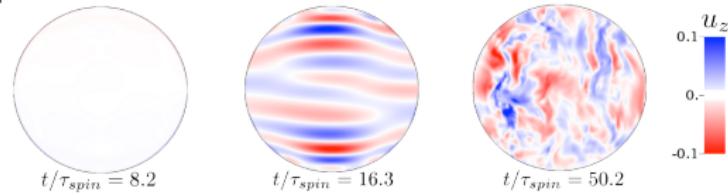
- E hexahedral elements
- N^3 tensor-product Gauss-Lobatto Legendre collocation points
- Algebraic convergence with E
- Exponential convergence with N
- 3rd order explicit Adams-Bashforth scheme for convective terms
- 3rd order implicit Backward Differentiation scheme for diffusive and pressure terms

Overview

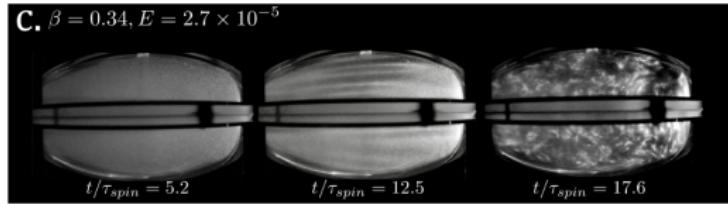
Tides



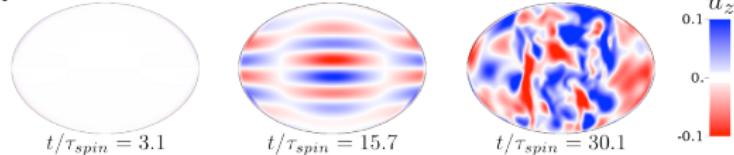
b. $\beta = 0.09, E = 5 \times 10^{-5}$



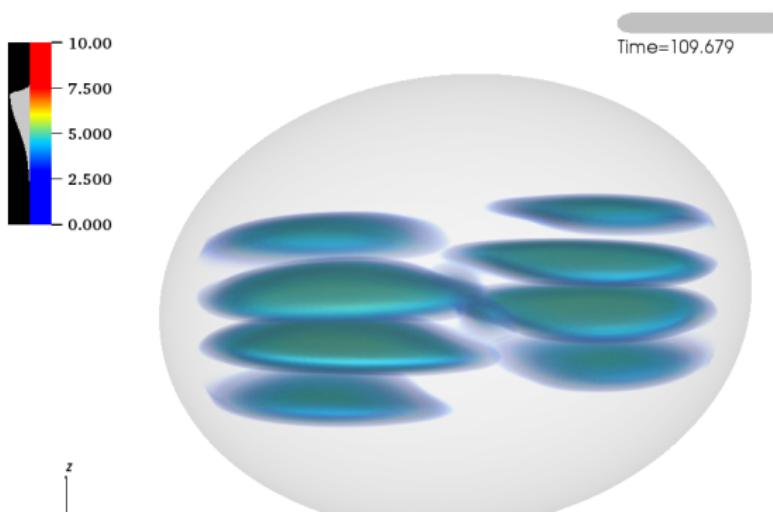
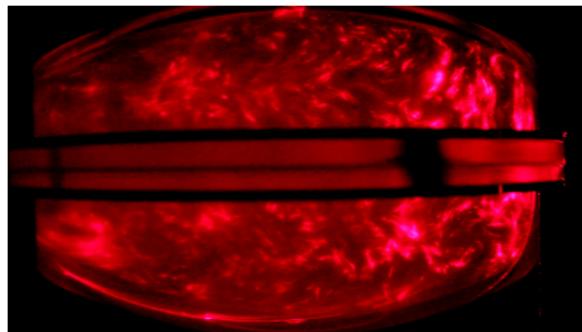
Libration



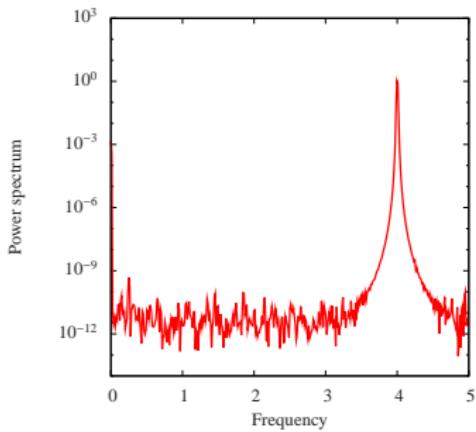
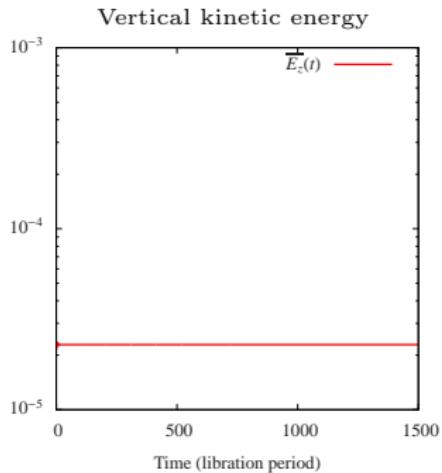
d. $\beta = 0.34, E = 10^{-4}$



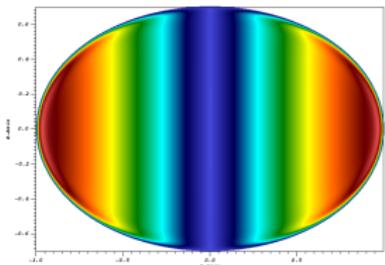
Movies



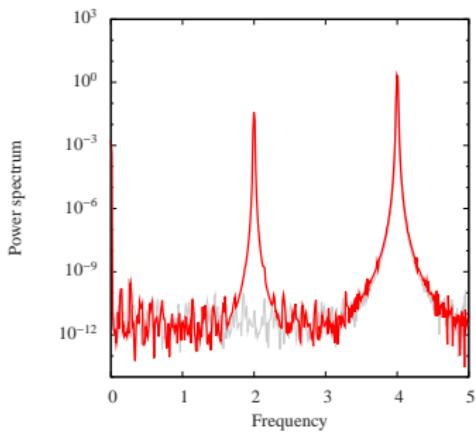
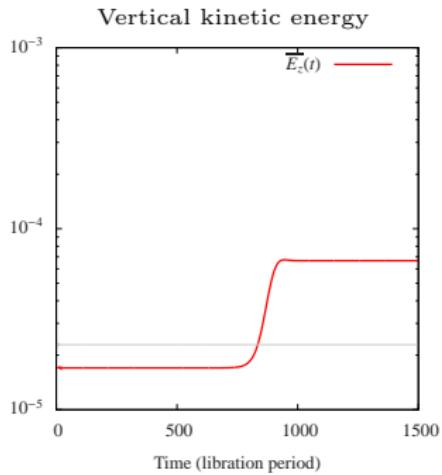
Stable case: $E = 10^{-3}$



Total velocity amplitude

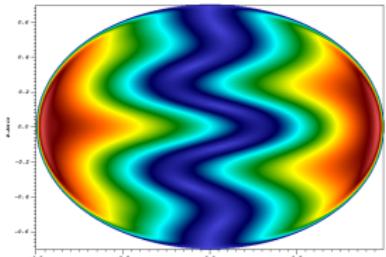


Marginal case: $E = 5 \times 10^{-4}$

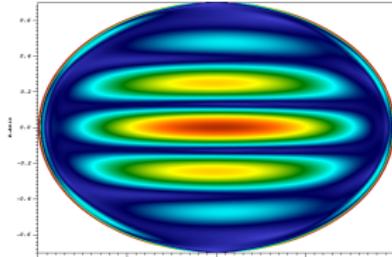


Elliptical instability

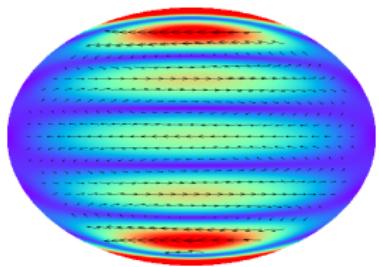
Total velocity amplitude



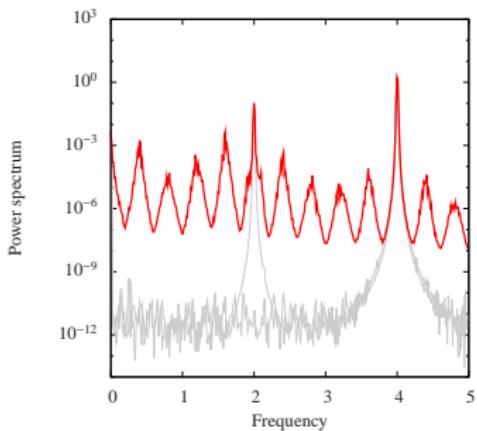
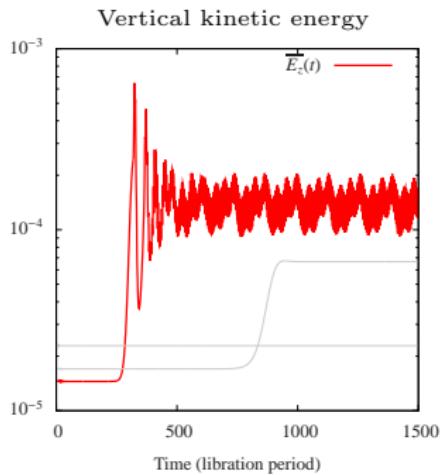
Fluctuating velocity amplitude



Eigenmode $m = \pm 1$, $\omega = \pm 1.95$

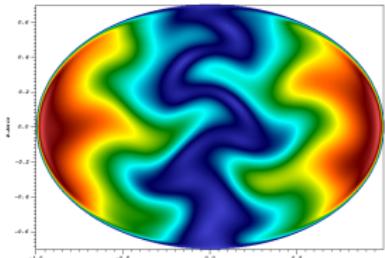


Transitional case: $E = 3.5 \times 10^{-4}$

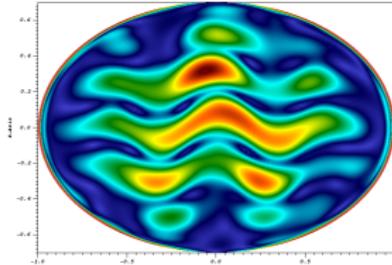


Triadic interactions

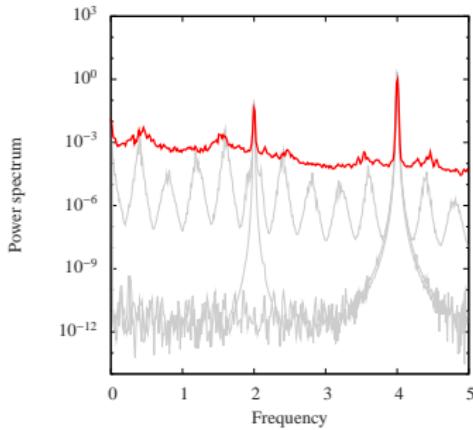
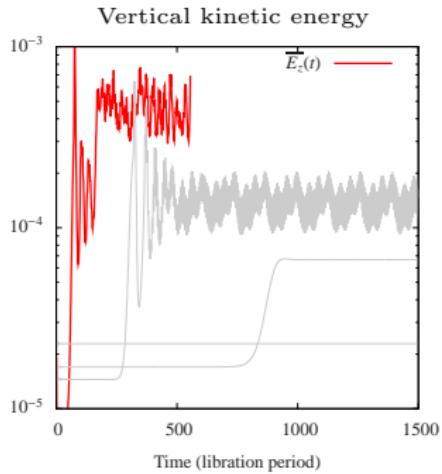
Total velocity amplitude



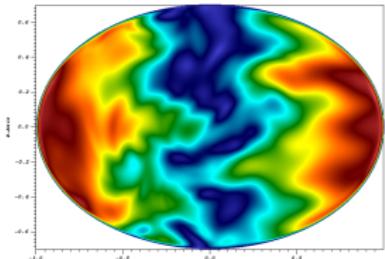
Fluctuating velocity amplitude



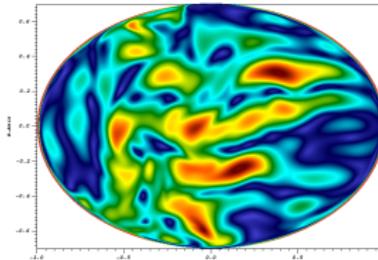
Turbulent case: $E = 10^{-4}$



Total velocity amplitude

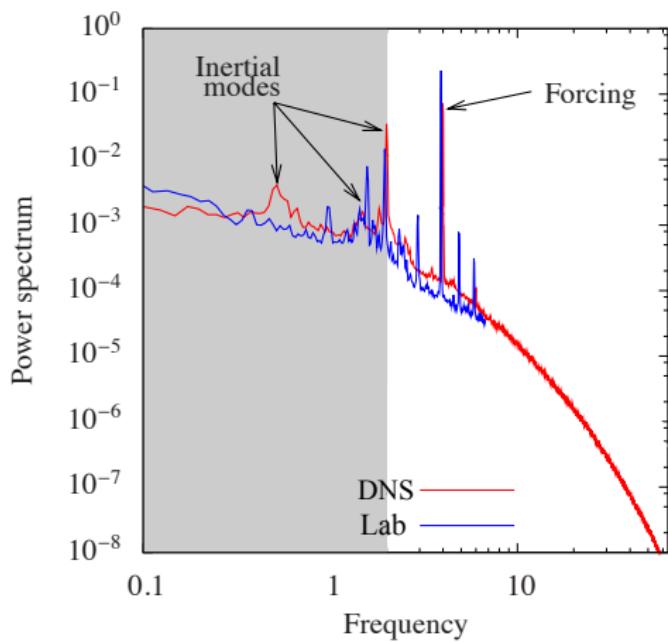


Fluctuating velocity amplitude

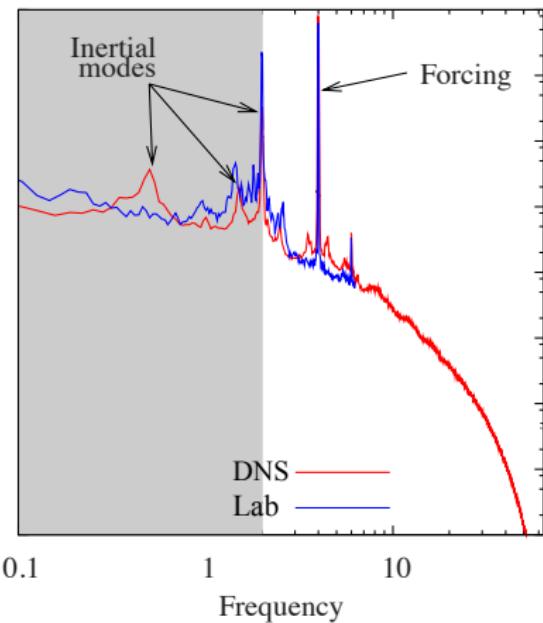


Comparison with the experiments

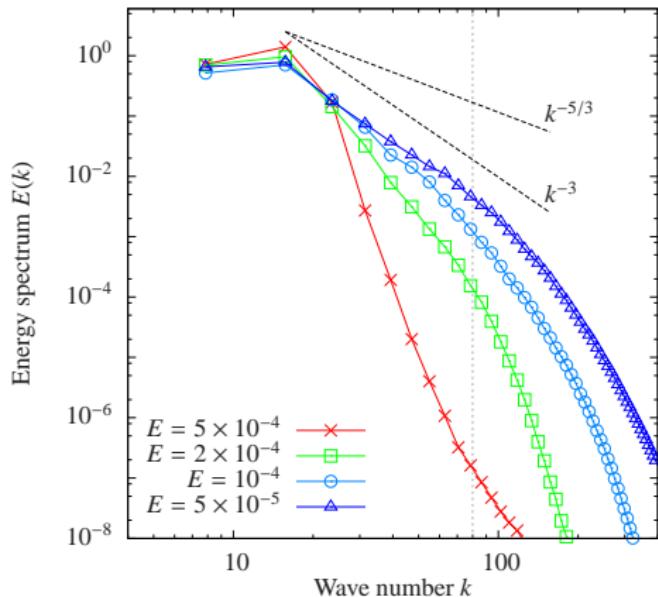
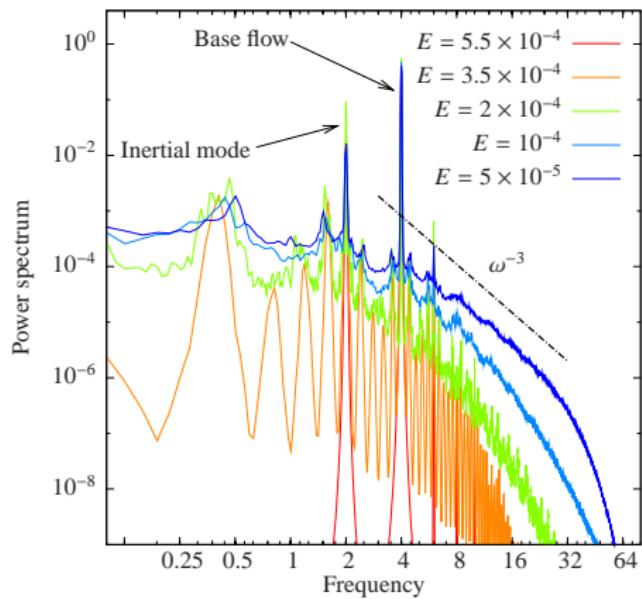
a. Tides



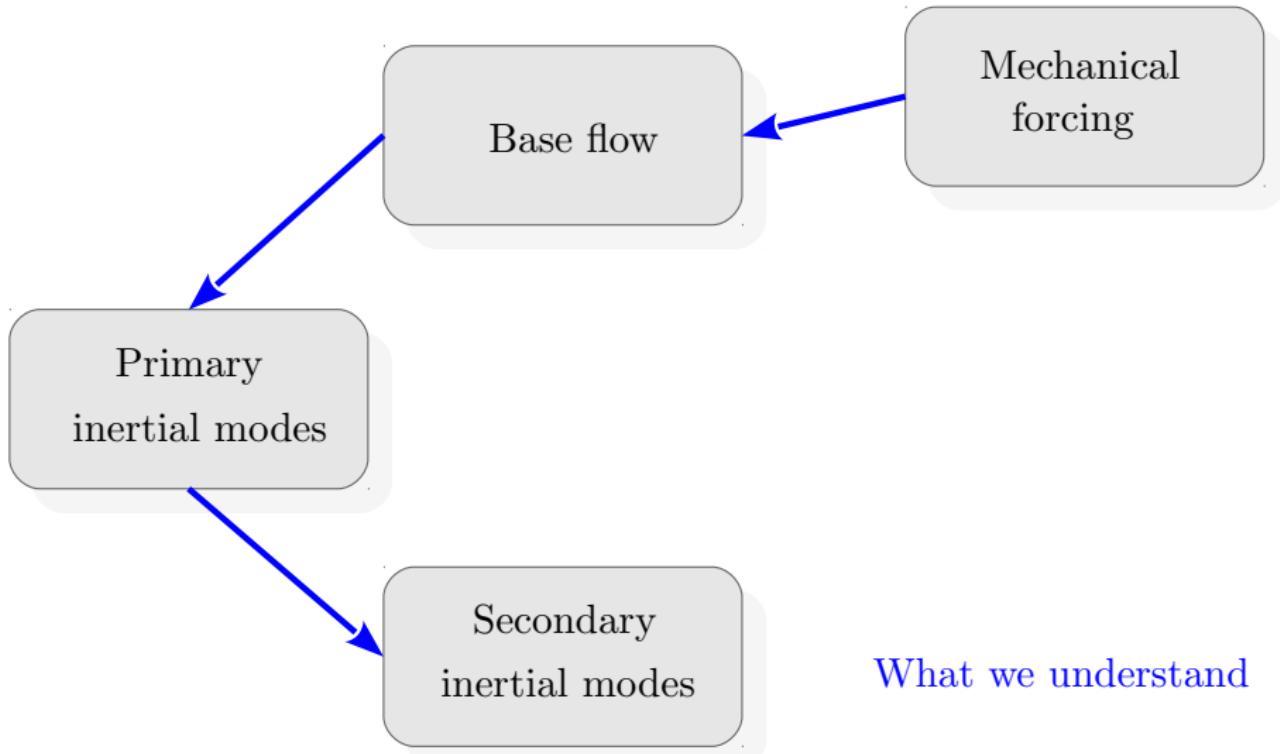
b. Libration



Temporal and spatial power spectra

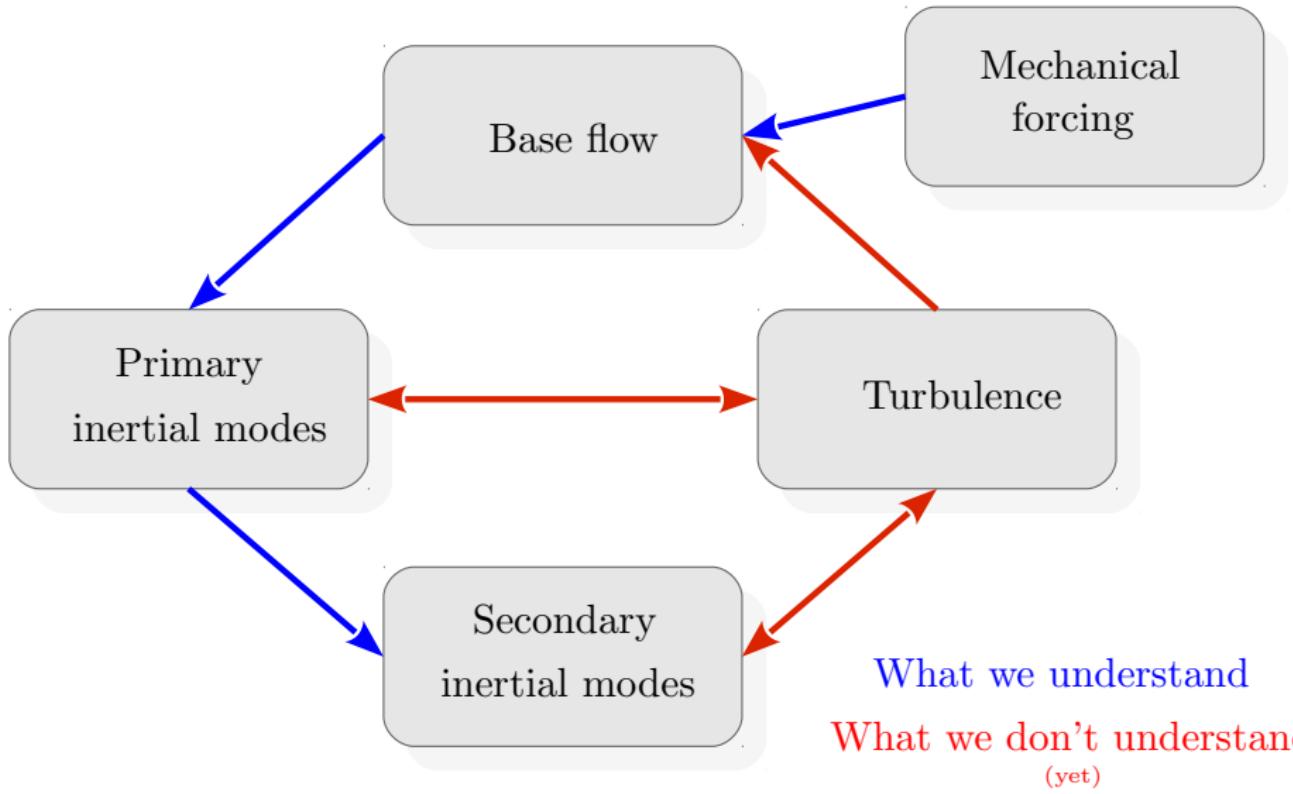


Summary



What we understand

Summary

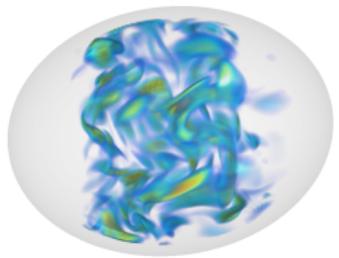
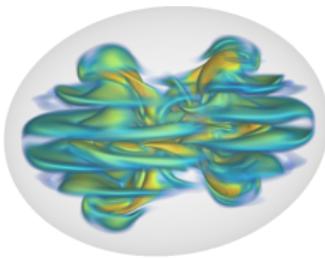
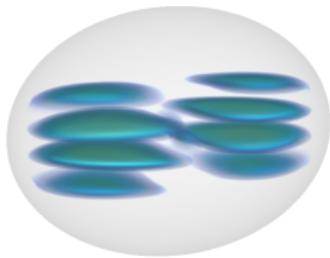


Conclusions & Perspectives

- Saturation of the mechanically-forced elliptical instability can lead to **sustained rotating turbulence** and **enhanced zonal flows**.
 - ⇒ Scaling for the saturation amplitude?
 - ⇒ **Sustained** versus **intermittent** regimes?
 - ⇒ Dynamo action?
 - ⇒ Coupling with stable stratification?

Thank you for your attention!

→ Post-doc position available at IRPHE (MHD numerics)



- “Experimental study of global-scale turbulence in a librating ellipsoid”, *Physics of Fluids* **26**, 126601 (2014)
- “Generation and maintenance of bulk turbulence by libration-driven elliptical instability”, *Physics of Fluids* **27**, 066601 (2015)