TURBULENCE *REDUCES* MAGNETIC DIFFUSIVITY IN A LIQUID SODIUM EXPERIMENT

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1 Introduction

- How are turbulent fluctuations organized under the influence of both rotation and magnetic field?
- Do these fluctuations contribute positively or negatively to the generation of a large-scale magnetic field by dynamo action?
- Recent experimental studies report a turbulent *increase* of magnetic diffusivity by up to 30% (Frick et al, 2010; Rahbarnia et al, 2012).
- We have performed an inversion of the data measured in our DTS liquid sodium experiment, which shows that turbulence *reduces* magnetic diffusivity in a large part of the experiment.

2 Method

- The DTS experiment is a spherical Couette flow, with a spinning inner sphere, in a strong dipolar magnetic field produced by its central magnet.
- We measure flow velocities, surface electric potentials, and induced magnetic field in a sleeve at 6 different radii (P1 to P6 in Fig 1).
- The rotating inner sphere produces a time-varying magnetic field, which diffuses and is advected in the sodium shell.
- Using a numerical solution of the induction equation, we invert for the flow map (Fig 1) and for the radial profile of effective diffusivity (Fig 2) that best explain the observations.

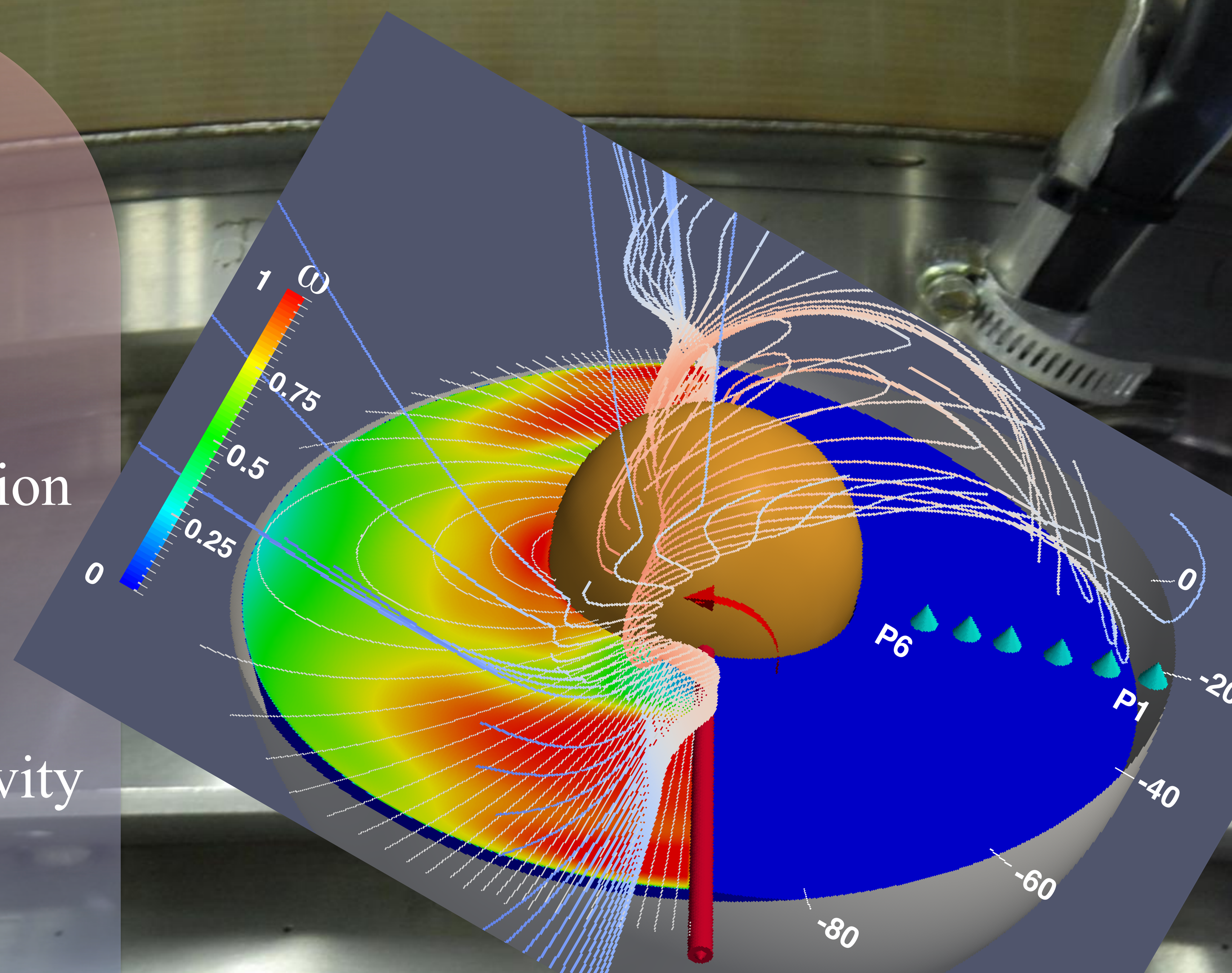

Fig 1. Angular velocity map (left) and magnetic field lines (right) reconstructed by inversion of DTS data at Rm ~100.

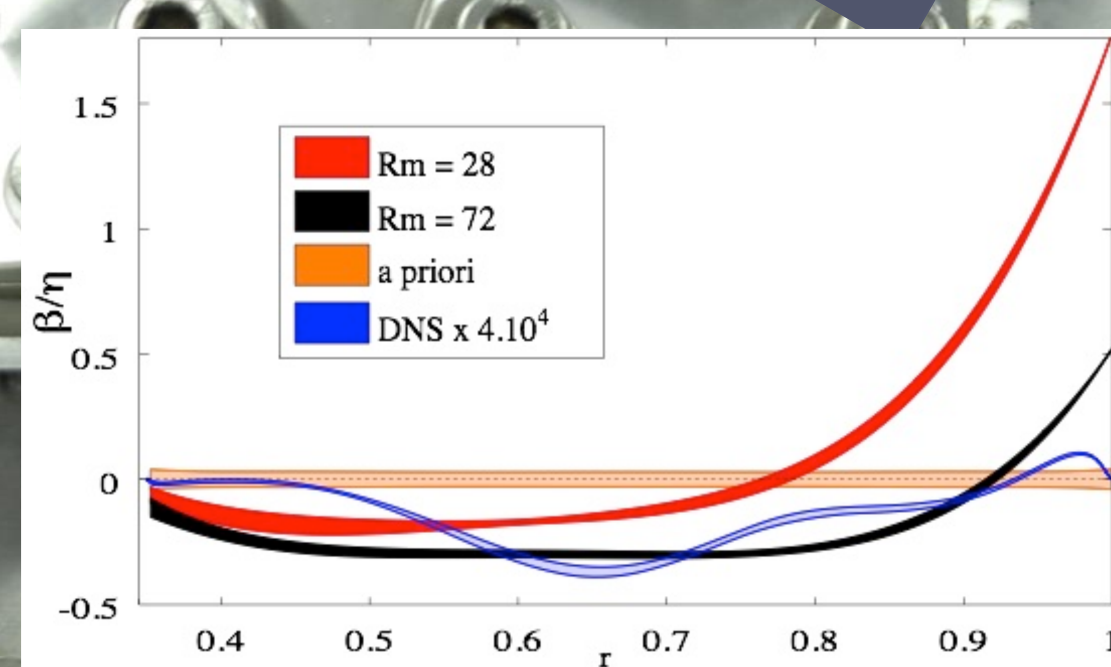

Fig 2. Radial profiles of the turbulent contribution to magnetic diffusivity in the DTS experiment

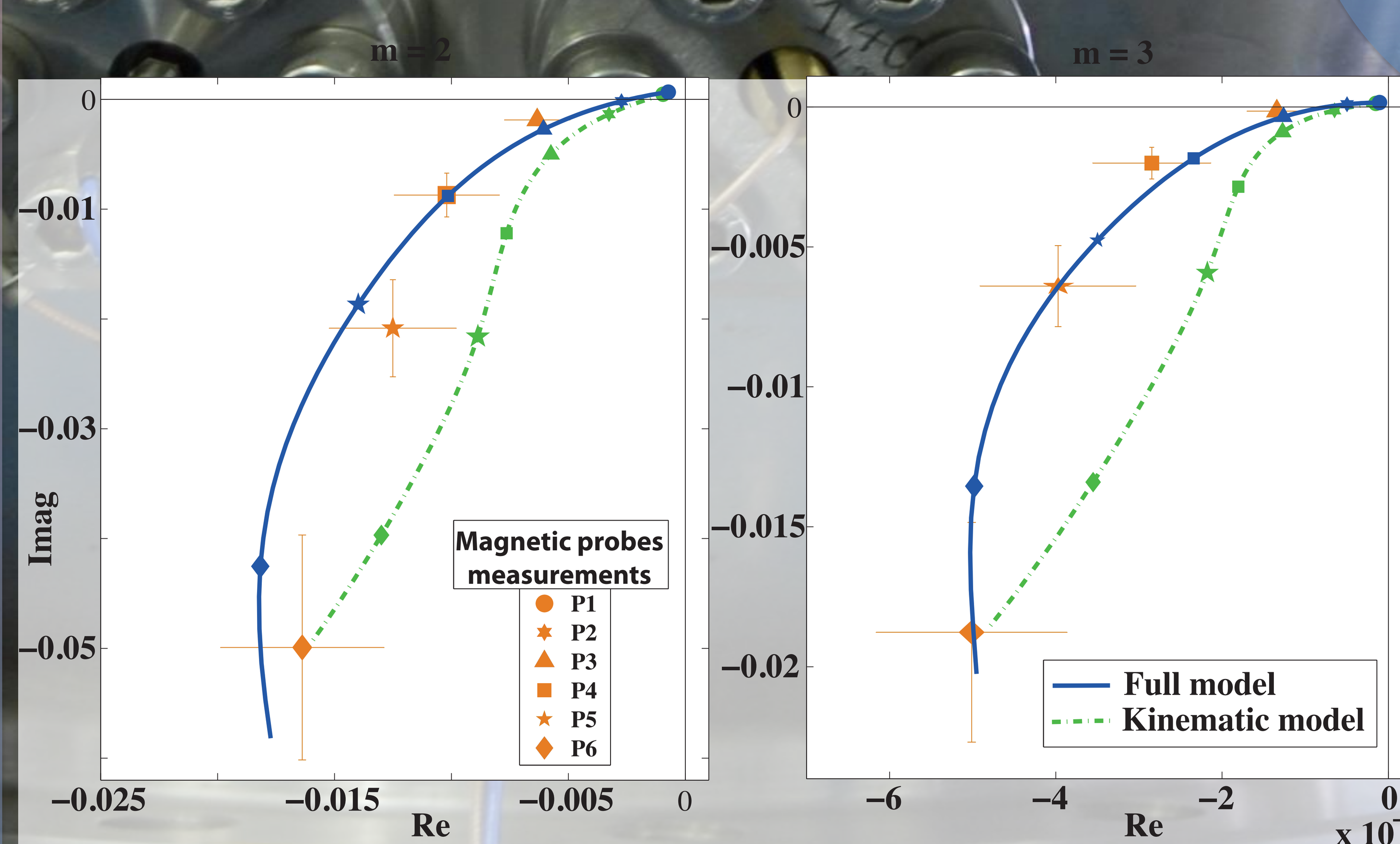

Fig 3. Evolution of the time-varying magnetic field in the complex plane. Lines show the predictions of our full model with (solid blue) and without (dashed green) turbulent diffusivity. The symbols with error bars are our measurements at radial positions P1 to P6.

Results 3

- The radial profiles of the turbulent contribution to magnetic diffusivity (Fig 2) show that turbulence *reduces* magnetic diffusivity by up to 30% in the region around the inner sphere, where the magnetic field is strong.
- The fit to the data is improved when we add turbulent diffusivity in the inversion (Fig 3).
- A full numerical simulation of the DTS experiment confirms that magnetic diffusivity dominates the turbulent *emf* (Fig 4) and is negative (blue profile in Fig 2).

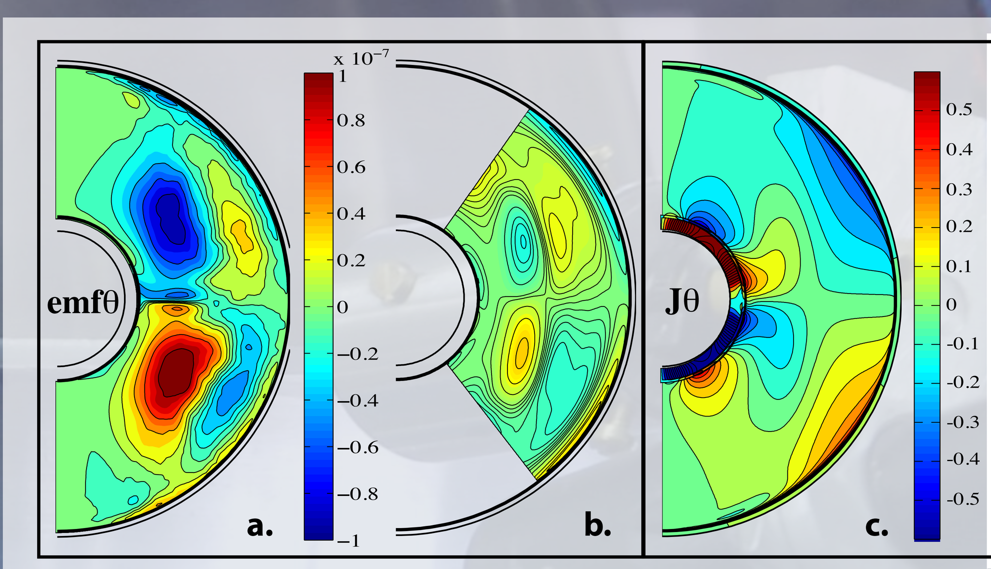

Fig 4. Turbulent contribution to the mean *emf* in a Direct Numerical Simulation of DTS. *a.* full *emf*. *b. emf* reconstructed from the projections on α and β. *c.* Mean electric current density. (θ-components).

Conclusions 4

- We present the first experimental evidence for a *negative* turbulent magnetic diffusivity.
- It could be characteristic of the magnetostrophic regime expected for planetary cores, where the Lorentz and Coriolis forces dominate.

References

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