TURBULENCE IN THE MAGNETOSTROPHIC REGIME

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Abstract DTS experiment was built to explore the magnetostrophic regime in which the Coriolis and Lorentz forces are comparable (see Brito et al, 2011). This regime consist in a rotating spherical couette flow submitted to a strong dipolar magnetic field. The mean flow generate a large part of the induced magnetic field through the omega-effect (Parker, 1955) [3]. The actual issue is to evaluate the fluid turbulent contribution to the large scale inducted magnetic field considering the α and β-effect.

INTRODUCTION

Numerical models of the geodynamo are very successful in recovering the main characteristics of the EarthÕs magnetic field. Nevertheless, the structure and dynamics of unresolved small-scale motions remains enigmatic, and it is not known whether they contribute to the large-scale magnetic field or to its destruction. Both effects have been reported in laboratory experiments of very turbulent flows submitted to weak magnetic fields. In particular, the observation of a dipolar magnetic field aligned with the axis of the axisymmetric mean flow in the Madison experiment demonstrates an α effect capable of producing a large-scale magnetic field (Spence et al., 2006) [4]. On the other hand, a large β effect, which increases magnetic diffusion and hence the dynamo threshold, has been measured in the Perm torus experiment (Frick et al., 2010) [2]. In both cases, symmetry reasons are invoked to exclude potential contributions of the mean flow itself.

EXPERIMENTAL SET UP

Little is known of such turbulent effects in flows that are constrained by both rotation and a strong magnetic field, the situation that prevails in planetary cores. We have addressed this issue, using data from the DTS experiment. The DTS has been designed to explore the magnetostrophic regime, in which the Coriolis and the Lorentz forces are comparable. It consists of a rotating spherical Couette flow in a shell filled with 50 litres of sodium and submitted to a strong dipolar magnetic field. This field is produced by a permanent magnet enclosed in the inner sphere, which is made of copper. Mean flow in the shell is roughly known from velocity profiles measured along several ultrasound Doppler velocimetry rays. It led Brito et al (2011) [1] to conclude that the flow is characterized by a super-rotating Ferraro region, around the equator of the inner sphere, and a geostrophic region from the edge of the Ferraro region to the outer sphere, where the imposed magnetic field is weaker (Figure 1.).

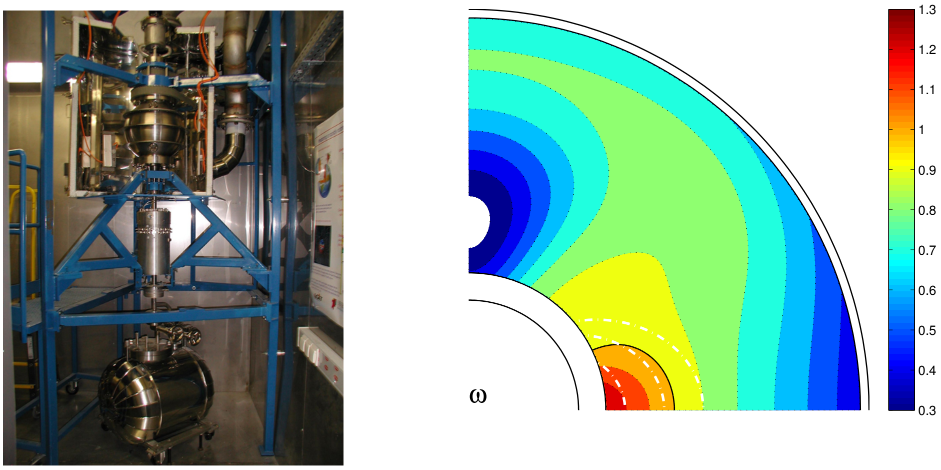

Figure 1. The picture on the left hand side is the DTS setup in Isterre sodium lab (Grenoble). On the right hand side we plotted the meridian Angular velocity mean flow in the sodium shell. Solution is abstained from experimental data inversion. Velocity is normalized to the inner sphere rotation frequency.

TURBULENCE APPROACH

Our approach is to compute a cinematic induction model in DTS configuration and compare it with magnetic field measurements. Inverse problem method allow us to obtain the best velocity pattern solution which fit the actual experimental data. One of those patterns is shown Figure 1. The remaining misfit could stand for deviations from mean axisymetric flow and would reveal some cooperative effects of turbulent fluctuations to the mean magnetic field.

As an additional constrain to our inversion model, we have analyzed the magnetic signal produced by the weak non-axisymmetric components of the applied magnetic field. When the inner sphere rotates, these components create a periodic signal, which is advected by the mean flow as it diffuses across the liquid sodium shell. We now look forward to evaluate deviations from a mean flow adevction model in order to quantify the effect of small-scale motions on the effective magnetic adevction (α-effect) and diffusivity (β-effect). Our preliminary results indicate that small-scale turbulent motions do not strongly alter the response of the mean flow in the magnetostrophic regime.

References

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