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MHD turbulence in a rotating spherical Couette flow of sodium with an imposed dipolar magnetic field

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Most planets of the solar system have or have had a self-sustained internal magnetic field. Fluid motions in planetary liquid cores are presumably governed by a balance between rotation and magnetic forces, a regime called magnetostrophic. We have designed an experiment DTS (Derviche Tourneur Sodium) in order to study such a magnetostrophic regime [1].

The experimental set-up is sketched in figure 1: forty litres of liquid sodium fill a spherical shell between a 7.4cm-radius copper inner sphere and a 21-cm radius outer shell made of stainless steel. Both spheres sketched in figure 2 can rotate independently around a vertical axis at different angular frequencies between -30 and 30 Hz. The inner sphere encloses a permanent magnet providing a dipolar field with a moment of 700 Am^2 (B=0.175 T at the equator of the inner sphere and B=0.008 T at the equator of the outer sphere). The magnetic Reynolds number ranges from 1 to 35.

We have set-up several types of physical measurements in order to characterize the magnetohydrodynamical fluid flow : (i) the velocity and torques delivered by both motors are recorded during the experiments, (ii) the radial and azimuthal components of the sodium velocity are measured by ultrasonic Doppler velocimetry ([2]), (iii) differences in electrical potential are measured at the surface of the external sphere, (iv) the induced magnetic field is measured outside the external sphere (vi) the dynamical pressure is measured at the outer boundary of the fluid flow.

The measurements reveal that the amplitude of the axisymmetric component of the fluid velocity can exceed that of either spheres ([3]). This super-rotation is expected theoretically and in agreement with previous linear numerical modeling ([4], [5]), but we show that non-linear effects modify its characteristics. Both axisymmetric (including realistic boundary conditions and non linear axisymmetric terms) and non-axisymmetric (three-dimensional) numerical simulations of the DTS flow will be compared with the experimental results. Experiments also demonstrate that several solutions for the fluid flow are obtained for a given forcing (fixed inner sphere rotation rate and fixed outer sphere rotation rate); furthermore, spontaneous bifurcations between these different states are also observed during a single run for a given forcing..

We have started the investigation of the instabilities and turbulence that develop in the DTS experiment. Different regions of the experiment are in different dynamical regime: near the inner sphere, magnetic forces dominate, while inertial forces play a strong role near the outer sphere. When the outer sphere is rotating, the Coriolis force inhibits vertical motions and favors azimuthal velocities. We explore the characteristics of waves and turbulence in these different regions. Analysis in time of the differences in electrical potential and induced magnetic field are in particular used to detect the propagation of waves in the DTS flow.

We will discuss the implications of these new measurements for MHD turbulence and dynamo action.

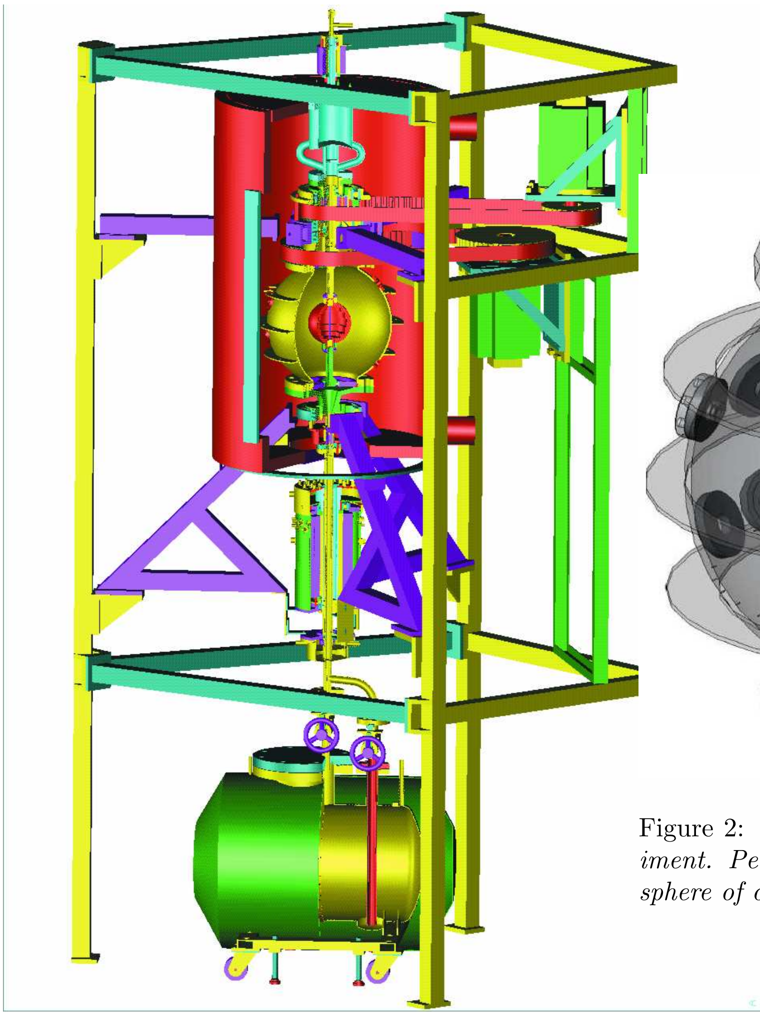

Figure 1: *Sketch of the DTS experiment.*

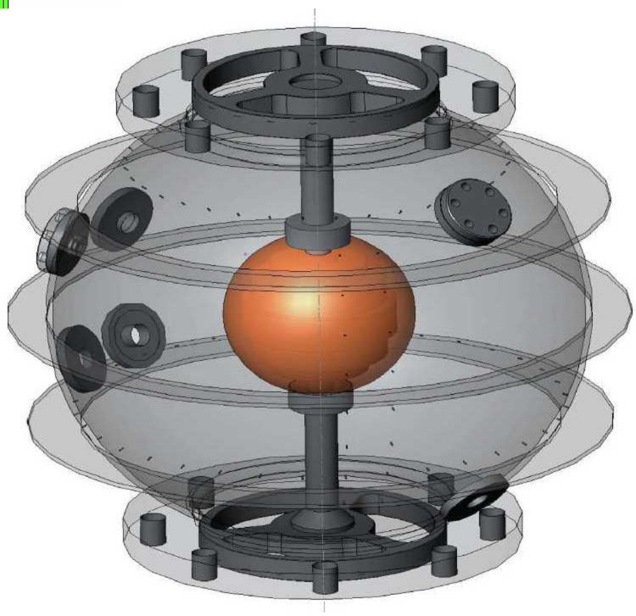

Figure 2: *Inner and outer spheres of the DTS experiment. Permanent magnets are enclosed in the inner sphere of copper producing a dipolar magnetic field.*

References

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