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Induction measurements in the VKS2 experiment

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Abstract We report recent results from the VKS2 experiment: response to an externally imposed homogeneous magnetic field, and transport of a localized applied field.

The VKS2 experiment The VKS project in Cadarache [1] is one of several experiments dedicated to the study of the dynamo effect in an unconstrained homogeneous flows of liquid metals [2]. The acronym "VKS" stands for "von Kármán sodium" and refers to the flow generated between two counterrotating impellers in a finite cylinder. The phenomenology of the time-averaged flow is as follows. Each impeller acts as a centrifugal pump: the fluid rotates with the impeller and is expelled radially. To ensure mass conservation the fluid is pumped in the center of the impeller and recirculates near the cylinder wall. In the exact counter-rotating regime, the mean flow is divided into two toric cells separated by an azimuthal shear layer. The kinetic Reynolds number is about 10^7 and the shear layer instability is a strong source of turbulence. The VKS2 evolution result from flow optimization and numerical inspection of its dynamo behavior [3]. With respect to the first version (VKS1[1]), the motor power has been increased to 300kW and the volume of the conducting domain is twice greater. A temperature regulation allows long measurements in stationary regime. Magnetic Reynolds number between 12 and 50 are reached.

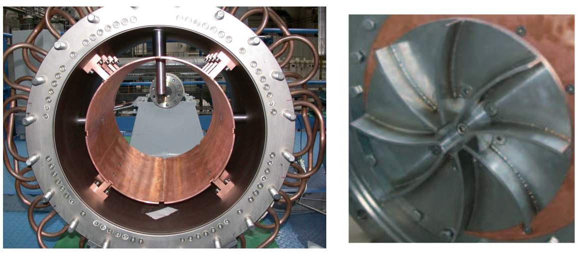

Figure 1: *VKS2 flow vessel and driving impellers*

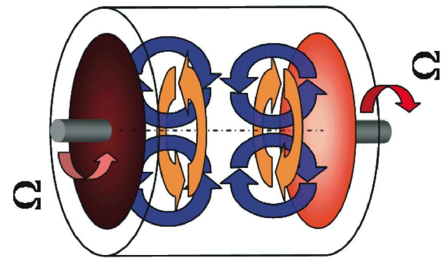

Figure 2: *Mean flow geometry*

Response to a uniform applied field [4] We apply a large scale field with a pair of coils ($B_{0y} = 2.7$G, too weak to modify the flow) in a direction transverse to the axis of rotation of the driving impellers – the direction expected for the dynamo neutral mode in the kinematic dynamo simulations [3]. Fig. 3 shows the evolution of the mean of the induced field b_y in the direction of the applied field. Once $R_m > 20$, $\langle b_y \rangle$ exceeds B_{0y}. In addition, the fluctuations of the induced component b_y are non-Gaussian, – Fig. 4 – at all R_m values. These features are in contrast with VKS1 measurements, where the induced field b_y saturated at $0.4B_{0y}$, and its fluctuations were Gaussian. However, no self-sustained dynamo regime has been reached, and at the largest R_m values we have measured a linear growth of the mean and rms values of the induced field. Note, in Fig. 3, that the measured mean values of induction deviate significantly from the ones predicted by induction from the mean flow velocity.

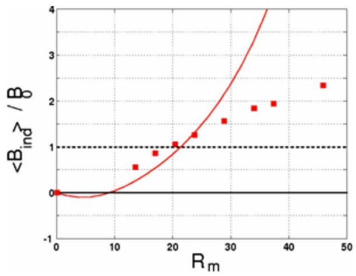

Figure 3: *Evolution of the mean induced field b_y. Solid line: numerical prediction from the mean flow.*

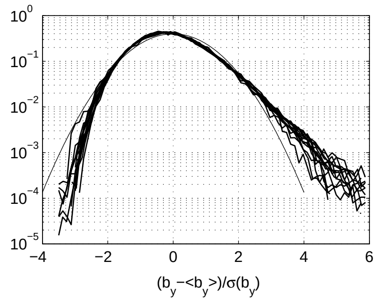

Figure 4: *Corresponding probability density functions of the fluctuations of b_y, comparison to a Gaussian*

Response to a localized applied field [5] We have studied the response when a localized field $\vec{B}_0(\vec{r})$, generated by a NdFeB cylindrical magnet, 22 mm in diameter and 10 mm in height, set within the flow vessel. The maximum value of the field created by the magnet in its vicinity is about 500 G but decays to less than 1 G, at a distance 100 mm away from the magnet. The time recordings of the fluctuations of the three components of the induced magnetic field $\vec{B}$ measured by the probe 200 mm away from the magnet, are displayed in Fig. 5 for $R_m = 30$. We observe an intermittent signal with the occurrence of bursts of magnetic field. The corresponding probability density functions (PDF) are shown in Fig. 6.

These observations are of interest for the analysis of the transport of a magnetic field by turbulence. Indeed, magnetic eigenmodes generated by dynamo mechanisms are usually strongly localized in space. Geophysical or astrophysical flows generally involve regions of strong differential rotation or strong helicity which are not located in the same part of the flow but are both believed to be necessary for dynamo action. It is thus important to understand how the magnetic field induced in one region is transported to the other by strongly turbulent flows.

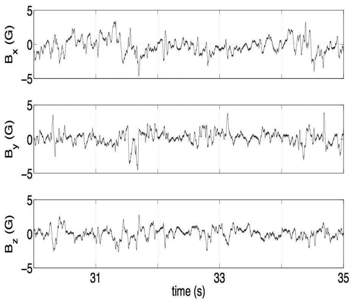

Figure 5: *Transport of a localized applied field: time evolution, at $R_m = 30$.*

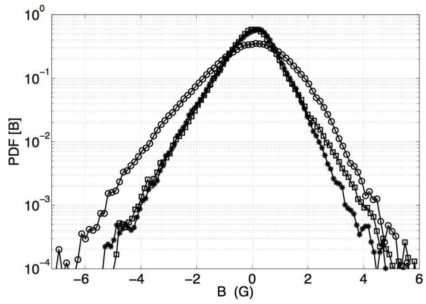

Figure 6: *Corresponding PDFs. B_x (circles) , B_y (squares), B_z (ast).*

References

[1] M. Bourgoin et al. 2002, Phys. Fluids, **14**, 2046.

[2] A. Gailitis, O. Lielausis, E. Platacis, G. Gerbeth, F. Stefani 2002, Rev. Mod. Phys., **74**, 973.

[3] F. Ravelet, A. Chiffaudel, F. Daviaud and J. Léorat 2005, Phys. Fluids, **17**, 117104.

[4] F. Ravelet et al. 2006, *Large and slow fluctuations of level and orientation of induced magnetic field in a turbulent flow of liquid sodium*, Phys. Rev. Lett., submitted.

[5] R. Volk et al. 2006, *Transport of magnetic field by a turbulent flow of liquid sodium*, Phys. Rev. Lett., to appear.