Observation of fluctuation-induced magnetic fields in a flow of liquid metal.

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Determining the role of velocity and magnetic field fluctuations in the generation of magnetic fields is fundamental to understanding how astrophysical dynamos function. Magnetic field generation by the action of flowing liquid metal is now being actively studied in a number of laboratory experiments (Gailitis et al. 2002). The Madison Dynamo Experiment is used to study a flow consisting of two counter-rotating helical vortices predicted to produce a self-excited magnetic field for sufficiently fast flow speeds (Dudley and James 1989). The flow is generated by impellers in a one-metre-diameter sphere of liquid sodium (Nornberg et al. 2006). Sodium is the liquid metal of choice for its high electrical conductivity. Due to the low viscosity of sodium, the flows generated in the experiment are very turbulent. One of the goals of the experiment is to address the effect of turbulence on magnetic field generation.

Axisymmetric magnetic fields, induced by the flowing sodium when exposed to a coaxial axisymmetric magnetic field, are presented. The induced fields are easily measurable and have large fluctuations, consistent with magnetic field being advected by a turbulent flow. The mean velocity field of the flowing sodium is determined by measuring the velocity field of an identical-scale water model of the experiment, using Laser Doppler Velocimetry (Forest et al. 2002). The mean measured induced magnetic fields are compared to magnetic fields expected to be induced by the mean flow. Some features of the measured field are well described by the fields predicted, but other features cannot be explained. An external dipole moment is measured which cannot be generated by the mean axisymmetric velocity field, proof of which is given (Spence et al. 2006). The measured toroidal and poloidal induced magnetic fields within the sphere are significantly weaker than the predicted field. These effects are attributed to large scale currents generated by the action of fluctuations: a turbulent electromotive force. Using the measured magnetic field and the measured velocity field, the field due to the turbulent electromotive force is calculated. The field is in opposition to the applied field and the fields induced by the mean flow, indicating a diamagnetic effect. Results of simulations of the experiment will also be presented. The fields due to the turbulent electromotive force are observed in the simulations, and are consistent with the fields generated by the experiment.

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