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Measurements and Simulations of Fluctuation-Driven Magnetic Fields in Flowing Liquid Metal

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The Madison Dynamo Experiment is designed to self-generate magnetic fields from flows of liquid sodium in a simply-connected spherical geometry. A velocity field is produced in the experiment by two counter-rotating impellers. The flow is very turbulent, with a fluid Reynolds number greater than 10^6. The role of turbulent velocity and magnetic field fluctuations in magnetic field generation is explored by applying an external magnetic field to the flowing sodium, and measuring the resulting magnetic field. An external dipole moment is measured which the mean axisymmetric velocity field is incapable of generating. Since the external induced magnetic field is axisymmetric, the dipole moment must be generated by fluctuations. The experimental approach to understanding these fluctuations involves measurement of the axisymmetric magnetic field in the sodium experiment, measurement of the velocity field in a dimensionally identical water experiment, and the calculation of the axisymmetric magnetic fields induced by both the mean flow and by fluctuations. The presence of a strong diamagnetic field, generated by fluctuations, is identified and its spatial structure presented. Such a fluctuation-driven magnetic field is also found in simulations of the experiment, which are used to elucidate the nature of the fluctuations, and how they induce the diamagnetic field.