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Instability of electrically-driven MHD flow in a modified cylindrical annulus filled with liquid GaInSn

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Planetary magnetic fields such as that of the Earth are thought to be generated by motions of electrically conducting fluids and can be described by the theory of magnetohydrodynamics (MHD). Liquid cores of such astrophysical bodies are dominated by Coriolis and Lorentz forces. Instabilities developing in this magnetostrophic regime are poorly known, numerical studies being far from the actual parameters.

We study the destabilization of a flow of liquid GaInSn in a modified cylindrical annulus experimentally and numerically. The flow is driven by the Lorentz force resulting from the injection of a radial electrical current under an imposed axial magnetic field. The novel feature compared to previous studies with similar geometry [Moresco and Alboussière, JFM, 2004] is the form of the electrodes, the inner one being a disk electrode, the outer one a ring electrode. A shear layer, termed the Shercliff layer, develops at the edge of the disk electrode.

Using magnetic fields up to 1 T and forcing currents up to 150 A, we reach Hartmann numbers up to 2000 and Reynolds numbers of the order of 10ˆ5 which are hardly accessible in numerical simulations. We measure the liquid-metal motions by ultrasonic Doppler velocimetry and potential differences.
We characterize the flow in terms of a mean flow and fluctuations. Initiating from the Shercliff layer at low forcing currents, we observe mainly monochromatic oscillations that grow in frequency and space with increasing forcing current and magnetic field strength. The threshold of instabilities is dependent on the field strength.

For the regime of low Hartmann and Reynolds numbers, we also perform numerical simulations of the flow in our setup using the quasi-static approximation. With 2.5 D finite element modelling, we are able to track the threshold of linear stability for the base flow. First results coincide well with the observations from the lab experiment.

Future experiments are currently developed to further investigate the magnetostrophic regime in a rapidly rotating spherical shell filled with liquid sodium [Hollerbach et al., JFM, 2013].