

Boğaziçi MATH COLLOQUIUM

When charge stirs a fluid: Well-posedness and Instability for Euler–Maxwell system

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Abstract:

When an electrically conducting fluid, such as a plasma, interacts with an electromagnetic field, two very different dynamics compete. The vorticity of the fluid is carried along by the flow. The electric and magnetic fields move as waves at the speed of light and are damped by Ohm's law. In two dimensions, Yudovich's classical theory guarantees that a fluid with bounded vorticity behaves well. Once the Lorentz force acts on the fluid, however, its vorticity is no longer conserved. The question becomes whether Maxwell's equations give enough control to keep it bounded.

In this talk, I will show that the answer depends on Gauss's law, that is, on whether the electric field is allowed to carry charge. Without charge, the system is locally well-posed for bounded vorticity and electromagnetic fields with $3/2$ derivatives in Sobolev space. The key observation is that fluid particles move slower than light, so they cannot "surf" an electromagnetic wave. This leads to a new estimate for waves sampled along such trajectories. With charge allowed, the same regularity is not enough. I will construct smooth initial data, as small as we like, whose vorticity becomes as large as we like almost instantly. The latter phenomenon suggests that concentrated charge relaxing in a weak magnetic field stirs the fluid.

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