Dynamos with anisotropic conductivity

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The magnetic field of the Earth and other planets, of the Sun and other stars, is thought to be generated and maintained by dynamo action. Cowling's theorems have played an important role in identifying impossible cases for dynamo action: two-dimensional flows of an electrically conducting fluid cannot generate a magnetic field, an axisymmetric magnetic field cannot be generated by a dynamo process... Hence, when theoretical or experimental dynamo models have been obtained, they were necessarily complex enough to escape those theorems. However, it has always been noted that Cowling's theorems apply for an isotropic electric conductivity tensor only. We have identified simple flow configurations and anisotropic tensors of conductivity leading to dynamo action. A two-dimensional flow with localized shear can generate a magnetic field that can even be an axisymmetric magnetic field.

The great advantage of our dynamo solutions is that they are analytical solutions, making them the simplest dynamo solutions obtained until now. This is useful to investigate their properties and to teach the topic to undergraduate students. Moreover, these dynamos are in principle relatively easy to reach experimentally and I will report on an ongoing project of building such an anisotropic dynamo.

Although our motivation for anisotropic dynamos is primarily driven by theoretical, experimental and educational purposes, they are also possibly at work in natural objects. In stars, in galaxies, the electrically conducting fluid, the plasma, can have an anisotropic tensor of conductivity, under the action of the magnetic field, rotation, stellar wind or supernovae explosions. In the Earth's core, one can imagine that an anisotropic inner core, with transient or oscillatory rotation could be a factor of magnetic field generation.

Mots-Clés : Dynamo, analytical solutions, experimental model