Study of turbulent $2.5D$ dynamos

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A wide range of magnetic Prandtl numbers Pm appears in Nature, varying from $10^{-5} - 10^{-7}$ in stellar interiors to $10^{12} - 10^{15}$ in the interstellar medium. In both large and small Pm we expect different conditions for the existence of the dynamo instability. In the limit of vanishing Pm the dynamo effect can either have a critical Pm_c or a critical magnetic reynolds number Rm_c above which magnetic fields can grow. Classical arguments expect that the cut-off wavenumber for the magnetic field occurs much before the cut-off wavenumber for the velocity field, expecting that in the limit of large Re and low Pm the dynamo instability becomes independent of Re. Recent work [1, 2] have established that in the limit of small Pm a critical Rm_c emerges. In the large Pm limit the effect of Re on the dynamo instability is less understood. The viscous scales would be responsible for the maximum shear and they would contribute to the small scale dynamo effect. We expect a change in the shearing rate due to change in Re would affect the dynamo instability.

In order to study the dynamo instability over a wide range of Re, Rm we take the limit of fast rotating flows. Here the flow is taken to be two-dimensional three component (known in the literature as 2.5 dimensional flow [3]) as a consequence of the Taylor-Proudman theorem. We study the kinematic problem of growth of a seed magnetic field without the back reaction of the magnetic field on the flow. The growth of this initial magnetic field is studied as we change Re, Rm. To understand the effect of helicity two different forcing are considered, one with mean helicity $H = \langle \mathbf{u} \cdot (\nabla \times \mathbf{u}) \rangle \neq 0$ and the other without mean helicity $H = 0$. For the helical forcing which shows the α dynamo effect the critical Rm_c depends on the domain size while in the case of nonhelical forcing there exists a Rm_c even for the infinite domain, here Rm_c in general is a function of the Re. The limiting case of very low $Pm = \frac{Rm}{Re}$ is shown to produce a dynamo with the existence of a constant Rm_c independent of Re in the case of nonhelical forcing in the infinite domain. In the limit of large Pm, the large wavenumber limit for having a dynamo instability depends strongly on Re for both types of forcing.

Références

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