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From precession driven numerical fluid dynamos to planetary dynamos

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The debate about the possible contribution of precession to dynamo action is not new (see for example Bullard 1949 and Malkus 1968). Modern astrophysical observations of some planetary dynamos could also bring arguments to this issue, although a definite evidence is still lacking. Thanks to the development of computing resources, it was only recently that numerical proofs were able to conclude that dynamo action occurs for two geometries of a precessing container: spherical (Tilgner 2005 and 2007) and spheroidal (Wu and Roberts 2009). Since both shapes are not convenient for large scale experiments, it is useful to look if similar results obtain for cylindrical containers.

Such a numerical study requires a non linear MHD code describing the coupling between a time dependent flow and the magnetic field. We use a new hybrid code named "SFEMaNS", which is able to describe non linear MHD problems with an external insulating envelope, conductivity and magnetic permeability jumps with any axisymmetric interface (Guermond et al. JCP 2007, 2009). SFEMaNS is based on a spectral method in azimuthal direction and involves finite elements in meridional planes.

A priori, five parameters govern the flow: the aspect ratio of the container, the precession angle and precession rate (forcing parameters), the Ekman and Prandtl magnetic Reynolds numbers (fluid parameters: E and Pm). Choosing for example the container length equal to its diameter, a precession axis orthogonal to rotation axis and a precession rate (0.15, say), the non magnetic flow breaks its central symmetry when the Ekman number becomes small enough (E is then about 0.001). The non linear MHD problem starts after a small magnetic seed field is added. When the magnetic dissipation is small enough, i.e. for magnetic Prandtl numbers Pm above a critical value Pm*(E), dynamo action appears indeed after parity breaking of the flow, as was also observed for the spherical and spheroidal dynamos.

Optimization of the numerical dynamo to help for the design of an experimental device asks for lowering the critical magnetic Reynolds number Rm* = Pm*(E) / E. The first runs give Rm* comparable to the maximal achievable Rm, i.e. about a few hundreds for the DRESDYN precession project (European platform for dynamo experiments and thermohydraulic studies at FZD in Dresden). By a careful exploration of parameter space, Rm* may hopefully turn to much smaller values. An account will be given of this stage which needs much computing time and is currently in progress.

A great jump in flow parameters is required to apply computational results (using generally Pm about unity and E greater than 10-4) to natural dynamos involving liquid metal flows (Pm=10-5 and E = 10 -15 for the Earth) and also to experimental devices using liquid sodium (Pm=10 -5 and E about 10 -8 for the metric size of DRESDYN proposal) . As it often occurs, an urgent task of the on going numerical study will thus to bring support to crucial scaling laws such as Pm*(E).

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