Dependence of the Nonhelical Dynamo on Shear: Numerical Exploration of the Magnetic Shear-Current and Stochastic-α Effects

A. Hankla[1], C. Fendt[1]

[1] *Max Planck Institute for Astronomy, Heidelberg, Germany*

Under certain conditions, a well-ionized plasma can generate its own magnetic field in what is known as a "dynamo". The need for a theory to describe dynamo action is evident from e.g. the Earth (whose magnetic field would have decayed long ago if not for a dynamo); however, the standard "α effect" mechanism fails in systems that lack reflectional symmetry, for instance near the midplane of accretion disks around black holes. Two competing models attempt to fill this shortcoming: the "stochastic α" effect, relying on random fluctuations of this same α coefficient, and the "magnetic shear-current" effect, suggesting that the off-diagonal resistive term η_{yx} can be negative, hence providing a sort-of reverse diffusion of the field [1]. The goal of this work is to disentangle the contributions of these models by investigating the dependence of stress and magnetic energy production on a simple system's degree of shear.

Using unstratified shearing boxes, we investigate a range of shearing parameters q, defined such that the orbital velocity $\Omega \sim r^{-q}$, from near rigid body ($q = 0$) to Keplerian ($q = 1.5$) rotation. Although many parameters behave according to predictions, an unexpected break occurs in others (e.g the ratio of Maxwell stress to magnetic energy) around $q = 1.2$. This effect is only present in "tall" boxes whose length in the z-direction is at least twice as long as the radial length, supporting Ref. [2]'s hypothesis that the dynamo can only act when longer vertical modes are allowed. We investigate the transport coefficients to shed light on this break.

Another as-yet unexplained feature of these dynamos is the periodic reversal of the toroidal magnetic field, similar to the sun's 11-year cycle, which could explain the origin of knots in black hole jets [3]. We characterize the unstratified dynamo's reversal as a function of shear (complementary to Ref. [4]'s analysis for stratified shearing boxes) to motivate future theoretical work on the origin of the reversals within the context of the magnetic shear-current effect.

References

[1] J. Squire and A. Bhattacharjee, J. Plasma Phys. **82** (2016)

[2] J. Shi, J. Stone, and C. Huang, MNRAS **456** (2016)

[3] D. Stepanovs, C. Fendt, and S. Sheikhnezami, ApJ **796**, 29 (2014)

[4] O. Gressel and M. Pessah, ApJ **810**, 59 (2015)