Helicity and Dynamo Waves at High Magnetic Reynolds Number

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Summary

We consider dynamo action in the astrophysically interesting limit of high Rm. We show that at large Rm the role of shear is to suppress the small-scale kinematic dynamo. When the small-scale flow is helical this suppression is enough for large-scale dynamo action to occur in the form of propagating dynamo waves as predicted by Parker [1] and discussed extensively by Moffatt [2].

1 Helicity, Dynamo Waves and The Suppression Principle

We consider the generation of magnetic activity — dynamo waves — in the astrophysical limit of very large magnetic Reynolds number. We consider kinematic dynamo action for a system consisting of helical flow and large-scale shear. We demonstrate that large-scale dynamo waves persist at high Rm if the helical flow is characterised by a narrow band of spatial scales and the shear is large enough. However for a wide band of scales the dynamo becomes small-scale with a further increase of Rm, with dynamo waves re-emerging only if the shear is then increased. We show that at high Rm the key effect of the shear is to suppress small-scale dynamo action, allowing large-scale dynamo action to be observed. We argue strongly that dynamo calculations at high Rm can only be assessed if the ratio $\chi = (Rm - Rm_c)/Rm_c$ is quoted, where Rm_c is the Rm for which dynamo action first sets in. We argue that this supports a general "suppression principle" — large-scale dynamo action can only be observed if there is a mechanism, such as shear or nonlinearity, that suppresses the small-scale fluctuations. We further argue that the key quantity that determines whether large-scale kinematic (and indeed dynamic) dynamo action is ever observed is not the mean electromotive force (though of course this must be non-zero — as it will be for helical flows) but the fluctuations about that mean. In the presence of a suppressing mechanism the standard deviation of the emf is reduced significantly, allowing large-scale dynamo action re-establish itself [3, 4, 5].

References

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