

Non-local memory effects of the electromotive force by a fluid motion with helicity and two-dimensional periodicity

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In the mean-field dynamo theory, the electromotive force term is the key concept which connects the small-scale magnetic field with the large-scale field. This term is usually approximated as 'the alpha-effect', assumed to be instantaneous in time and local in space. However, the approximation is valid only if Rm is smaller than $O(1)$, and inappropriate when the magnetic Reynolds number Rm is as large as that in the earth's core. It is not obvious how the electromotive force term should be expressed if Rm is larger than $O(1)$.

We examine the behaviour of the electromotive force as a function of Rm by a kinematic dynamo model. We use G.O.Roberts (1972)'s flow, which has a non-zero helicity and two-dimensional periodicity. We introduce a function ' ϕ ' as a non-local and non-instantaneous extension of the usual alpha-effect.

As a result, we found that the electromotive force if Rm is larger than $O(1)$ has a nonlocal memory effect, which strongly affects the dynamo action, while we confirm the electromotive force for small Rm can be approximated by the local alpha-effect. The results demonstrate that the non-local memory effect of the electromotive force is important in the geodynamo or the solar dynamo.