NON-LOCAL MEMORY EFFECTS OF THE ALPHA-EFFECT IN DYNAMO THEORY

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The alpha-effect is a useful tool for interpreting the generation of dynamos. The traditional alpha-effect represents the electromotive force, approximated to be instantaneous in time and local in space. However, the approximation is valid only when the magnetic Reynolds number Rm is smaller than unity and inappropriate when Rm is larger than or equal to the order of unity, which is the condition satisfied in the Earth's core or solar convection zone.

We have examined the non-instantaneousness and non-localness of the mean electromotive force, the generalized alpha-effect, in G.O.Roberts (1972)'s kinematic dynamo model. We solved the fluctuating part of the induction equation explicitly and calculated the response function of the mean electromotive force as a function of Rm. The response for Rm < O(1) is instantaneous and local, which is the typical picture of the alpha-effect. When Rm is larger than or equal to O(1), the instantaneous and local alpha-effect is controlled by developed boundary layers, as suggested by previous works for high Reynolds number limit. In addition to the alpha-effect, non-instantaneousness and non-localness become significant, where the characteristic time of the memory is around the magnetic diffusion time. Above a certain value of Rm, Rm > O(1), the effect of the small-scale dynamo appears after the magnetic diffusion time, invalidating the well-known high Reynolds number limit. Our result implies that the non-local memory effect of the mean electromotive force should be important to understand geophysical and astrophysical dynamos.

Alpha-effect, Kinematic dynamo, Memory

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