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Statistical theory of dynamo

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One major problem in dynamo theory is the multi-scale nature of the MHD turbulence, which requires statistical theory in terms of probability distribution functions. In this contribution, we present the statistical theory of magnetic fields in a simplified mean field α-Ω dynamo model by varying the statistical property of alpha, including marginal stability and intermittency, and then utilize observational data of solar activity to fine-tune the mean field dynamo model.

Specifically, we first present a comprehensive investigation into the effect of the stochastic parameters in a simplified α-Ω dynamo model. Through considering the manifold of marginal stability (the region of parameter space where the mean growth rate is zero), we show that stochastic fluctuations are conductive to dynamo. Furthermore, by considering the cases of fluctuating alpha that are periodic and Gaussian coloured random noise with identical characteristic time-scales and fluctuating amplitudes, we show that the transition to dynamo is significantly facilitated for stochastic alpha with random noise. Furthermore, we show that probability density functions (PDFs) of the growth-rate, magnetic field and magnetic energy can provide a wealth of useful information regarding the dynamo behaviour/intermittency. Finally, the precise statistical property of the dynamo such as temporal correlation and fluctuating amplitude is found to be dependent on the distribution the fluctuations of stochastic parameters.

We then use observations of solar activity to constrain parameters relating to the effect in stochastic α-Ω nonlinear dynamo models. This is achieved through performing a comprehensive statistical comparison by computing PDFs of solar activity from observations and from our simulation of mean field dynamo model. The observational data that are used are the time history of solar activity inferred for C14 data in the past 11000 years on a long time scale and direct observations of the sun spot numbers obtained in recent years 1795-1995 on a short time scale. Monte Carlo simulations are performed on these data to obtain PDFs of the solar activity on both long and short time scales. These PDFs are then compared with predicted PDFs from numerical simulation of our α-Ω dynamo model, where α is assumed to have both mean α_0 and fluctuating α' parts. By varying the correlation time of fluctuating α', the ratio of the amplitude of the fluctuating to mean alpha $\langle \alpha'^2 \rangle / \alpha_0^2$ (where angular brackets $\langle \rangle$ denote ensemble average), and the ratio of poloidal to toroidal magnetic fields, we show that the results from our stochastic dynamo model can match the PDFs of solar activity on both long and short time scales. In particular, a good agreement is obtained when the fluctuation in alpha is roughly equal to the mean part with a correlation time shorter than the solar period.