Understanding the nonlinearity and predictability of the solar dynamo

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The 11-year solar cycle is caused by a dynamo mechanism operating in the plasma of the solar convection zone. In this dynamo, the stretching of the poloidal field by the differential rotation gives rise to the toroidal field, which produces bipolar magnetic regions (BMRs) as observed on the surface. The decay of these tilted BMRs generates a poloidal field, the seed for the next cycle's toroidal field. While the poloidal to toroidal part is largely linear, other parts in the dynamo loops involve some nonlinearity and stochasticity. In this presentation, I shall discuss three important nonlinearities, which arise due to (i) the toroidal flux loss through magnetic buoyancy[1], (ii) latitudinal variation of BMRs[2], and (iii) change in the BMR tilt with the magnetic field[3]. I shall also discuss the effect of these nonlinearities in stabilising the solar dynamo and producing some critical features of the solar cycle. I shall also discuss the stochasticity that is involved in the solar dynamo due to the stochastic nature of the hughly turbulent convection in the convection zone[4]. Stochasticity and nonlinearity together act to produce the observed modulation in the solar cycle and thus limit the long-term prediction of the solar cycle. Finally, I shall show that the popular Waldmeier effect, which says that the strong cycles rise more rapidly than the weaker ones, is hidden in the previous cycle polar field. The rise rate of the polar field after reversal can be used to make the prediction of the next cycle[5]. This, therefore, extends the scope of the solar cycle prediction to much earlier than the usual time.

References:

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