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Continuous Component of Solar Activity Spectrum and Solar Dynamo

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Abstract.

Temporal spectrum of solar activity consists of a continuous part as well as eigenfrequency which correspond to the famous 11-year cycle. Nature of continuous elements of activity spectrum can be connected with nonlinear dynamo effects however an explanation in the framework of the linear mean-field dynamo approach seems to be possible as well. A scenario of the later explanation is suggested.

Introduction

Solar 11-year activity cycle is the most pronounced feature of solar activity. Solar dynamo is believed to be the physical mechanism underlying this activity cycle. More specifically, the cycle is connected with excitation of an eigen solution in mean-field solar dynamo equations. The imaginary part of corresponding eigen value gives the cycle length while the real part of the eigen value corresponds to the growth rate of the large scale magnetic field. Of course, this grows is saturated by various nonlinear effects and can not be observed directly.

The problem is that the 11-year cycle is far to be the only detail containing in solar activity spectrum. Various oscillations from about 1 year up to centuries have been reported as (quasi) biannual oscillations, mid-term oscillations, Gleissberg cycle etc. These oscillations seem to be substantially less regular rather the 11-year cycle. [*Frick et al., 2020*] consider them as continuous elements of solar activity spectrum.

Interpretation of the oscillations under discussion as continuous elements of solar activity spectrum requires a physical explanation for the elements. The point is that continuous spectrum is something different from eigensolution and the traditional explanation for dynamo action has to be somehow modified.

A most straightforward idea here is to claim that the continuous part of the spectrum arises as a nonlinear saturation of the excited eigensolution similarly to the continuous spectrum in turbulence or convection. This explanation suggested by [*Obridko et al., 2020*] exploits the same idea as famous Kolmogorov scenario for turbulent spectra. The only difference is that Kolmogorov considers multiplications of wave vectors while here one have to consider multiplication of frequencies from that one of 11-yers cycle up to frequencies which corresponds to events with duration of about 1 month.

This straightforward idea look reasonable indeed for many elements of continuous spectrum known however not covers however all known possibilities here. Indeed, stars without pronounced activity cycles which could be identified with excited eigensolution are possible and V833 Tau seems to be an instructive example here [*Stepanov et al., 2020*]. One more point is that the timescales longer rather 11-year cycle (say, Gleissberg cycle) are difficult for this explanation.

It looks attractive to suggest a mechanism for continuous spectrum generation just in the linear mean-field dynamo equations. It is just the aim of this paper.

Bohr-Sommerfeld conditions for spherical dynamos and continuous activity spectrum.

The explanation under discussion departs from the classical Landau scenario for transition to turbulence. Landau believed that enlarging intensity of fluid motion drivers one excites more and more eigenfrequencies in linearized version of governing equations for fluid motion. Due to various nonlinearities and instabilities each spectral line corresponding to an eigenfrequency has a finite width. If the density of spectral lines is high enough taken together they could be considered as a continuous spectrum. Each eigensolution arising can be obtained in the framework of a short-wavelength approximation from distribution of drivers of motion and boundary conditions similar to the Bohr-Sommerfeld conditions in quantum mechanics. The scenario is underlying by expectation that spectral problems for various equations of mathematical physics are more or less similar to that one for Schroedinger equation in quantum mechanics.

Indeed, mean-field dynamo equations for a spherical shell are formally similar to the Schroedinger equation [*Kuzanyan and Sokoloff, 1996*]. The point however is that this similarity is not perfect and dynamo equations do demonstrate some specific features. In particular, [*Galitsky and Sokoloff, 200?*] obtained the Bohr-Sommerfeld conditions for dynamo equations to learn that they can be satisfied for the leading growing solution while the value responsible for dynamo drivers distribution looks similar to a deep potential well and one could be expect excitation of many eigensotution.

Physical meaning of the Bohr-Sommerfeld condition is that the wave travelling inside the potential well reflects properly at the borders of the well what allows for the wave to exist unlimited times. Dealing with a problem where the Bohr-Sommerfeld conditions can not be properly satisfied for many possible eigenvalues, one can expect that corresponding magnetic oscillation survives for a limited time only and looks like (quasy)biannual, mid-term and other solar activity oscillations apart from the much more stable 11-year cycle/

Scenario suggested here requires a confirmation (or rejection) from the spectral theory of linear differential operators and is an open problem of functional analysis. Corresponding discussion is obviously out of the scope of this very paper.

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Conclusions

1. Temporal spectrum of solar activity consists of a continuous part as well as eigenfrequency which correspond to the famous 11-year cycle.
2. Nature of continuous elements of activity spectrum can be connected with nonlinear dynamo effects however an explanation in the framework of the linear mean-field dynamo approach seems to be possible as well.
3. A scenario of the later explanation is suggested.

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