Doctoral School of Physics - Eötvös Loránd University (ELTE)

Semester 2 (Springl 2022/2023) report by **Lisboa Nogueira Guilherme Augusto**
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PhD Program: Astronomy and Space Physics.
Supervisor(s): Petrovay Kristóf
Ph.D. Thesis title: Modelling periodic and quasiperiodic variations in solar activity.

Introduction: In recent years solar activity has undergone a remarkable change, switching to a quieter state as compared to the period of strong activity ("Modern Maximum") in the second half of the 20th century. The realization of the importance of solar activity variations as the single most important natural external driver of terrestrial climate change, has led to renewed attention on understanding the solar dynamo and forecasting cycle-to-cycle variations.
In contrast to more traditional studies of the solar dynamo where emphasis was on understanding the root of the basic 11-year periodicity, with attention on the detailed spatial structure of the models but often in a linear approach, the focus on cycle-to-cycle variation implies that nonlinearities and/or stochastic variations in the models must be given special attention. Therefore, our approach will be to consider spatially truncated models of a lower dimensionality and focusing on a deeper understanding of temporal variation. The objective is to carry out a detailed analysis of the relative importance of nonlinear deterministic feedback mechanisms and stochastic fluctuations in determining intercycle variations of solar activity. The results of this analysis are expected to yield constraints on solar dynamo models and help improving forecasts of solar activity. The analysis will imply two kinds of spatially truncated models of the solar dynamo: 1) Theoretical modeling: a combination of axisymmetric mean field dynamo models (in 2D and truncated to 1D as in the updated Leighton model) and surface flux transport simulations (in 1D and 2D) will be considered, and a detailed comparative analysis of various models and their chosen parameter profiles (e.g.meridional circulation profile) will performed. In such models, the effect of various nonlinearity mechanisms and types of stochastic forcing can be readily tested, covering a large domain in parameter space. 2) Data assimilation from observations (during the secondment to USFD, 8M): here the source term in the surface flux transport simulations will be partly or fully fed in from actual observations, allowing the reproduction of actual variations of solar activity in specific solar cycles, including forecasts for Cycle 25.

Description of research work carried out in current semester: During the second semester of my PhD (Spring 2022), The focus was kept on getting familiarized with the research topic. The primary work was regarding validating the Algebraic Method developed, using real data from the sun. The possibility of some outliers on the data came up, especially at the beginning of the history in acquiring the magnetograms. It was decided that a better agreement could be observed if the cycle 21 was left out. It is possible to observe a good improvement in the agreement of the proposed method and the observed data in figure 2, compared with figure 1. To check the existence of the outliers, we plotted the initial axial dipole divided by the flux on the Y-axis, along with the sine of the 2 times the latitude of the Active region on the X-axis, as shown in Figure 3.

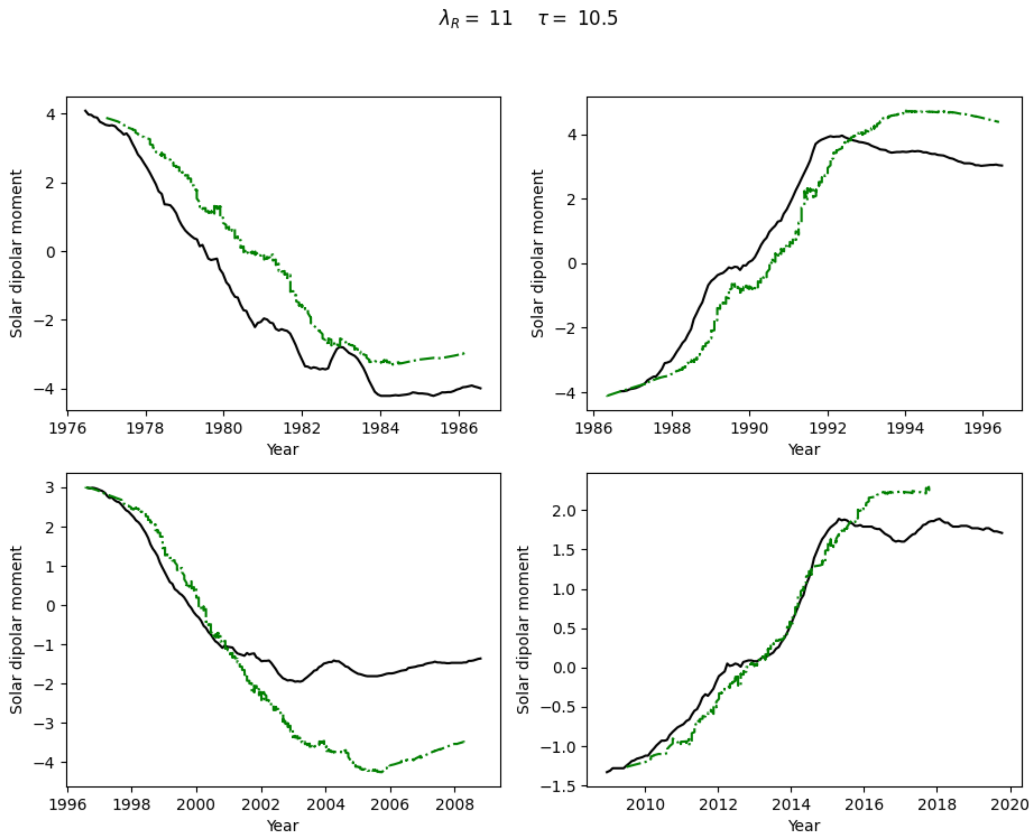

Figure 1 – Data of active region dipole moments determined from NSO carrington maps and the modeled one (dashed line)

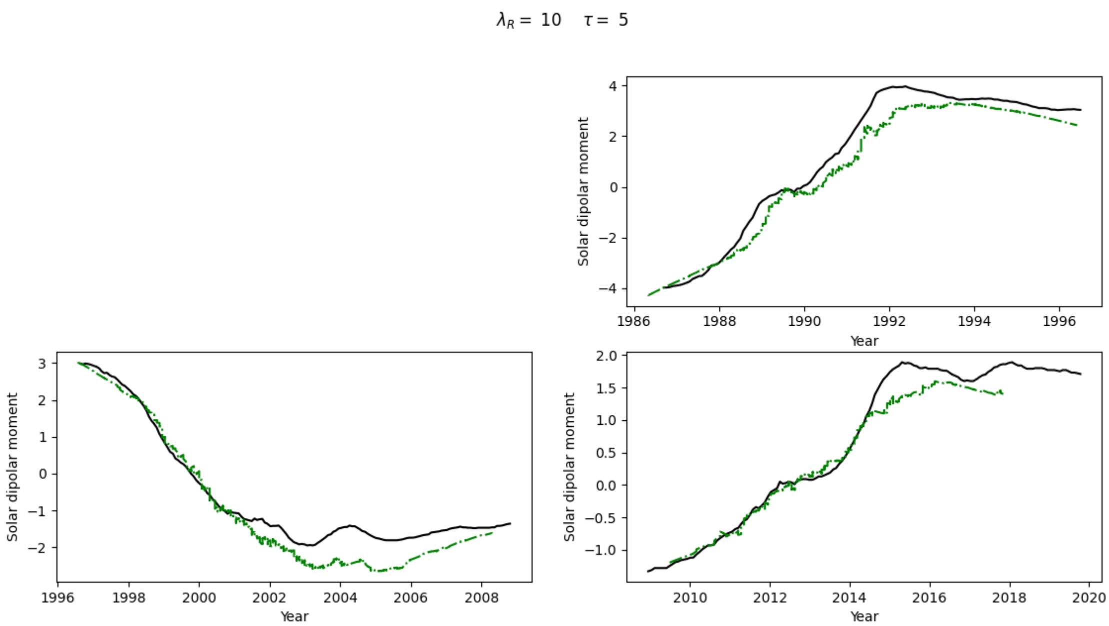

Figure 2 – Data of active region dipole moments determined from NSO carrington maps and the modeled one (dashed line) excluding Cycle 21

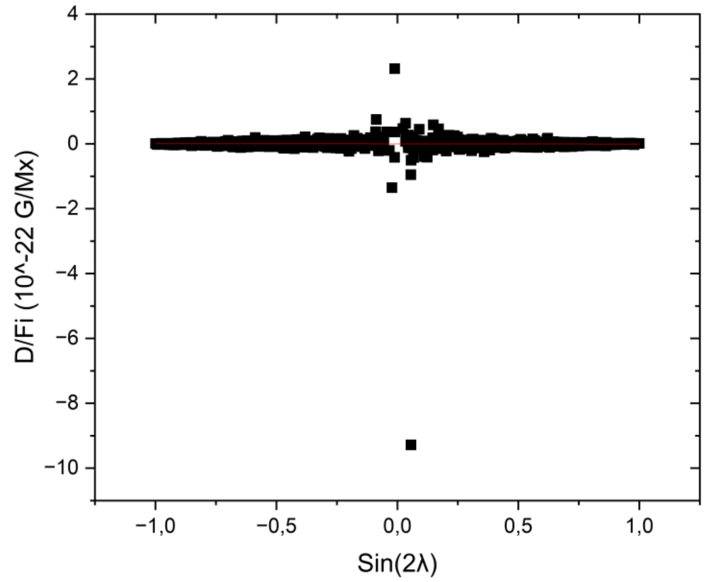

Figure 3 - Initial axial dipole divided by the flux on the Y-axis and the sine of the latitude of the Active region on the X-axis.

The equation of a bipolar active region with a tilt α, that leads to intercycle variations on the solar cycle is given by:

$$\delta Di = 3/(4\pi R^2)\ \Phi\ d \sin\alpha \cos\lambda \qquad (1)$$

Which can be rewritten as:

$$\frac{\delta Di}{\Phi} = \frac{3}{4\pi R^2} d \sin\alpha \cos\lambda \qquad (2)$$

The tilt angle α is proportional to the latitude, which gives us:

$$\frac{\delta Di}{\Phi} = \frac{3}{4\pi R^2}\ d \sin(2\lambda) \qquad (3)$$

From equation (3), it is possible to use the data to obtain a correlation between the quantity $\frac{\delta Di}{\Phi}$ and the sin (2λ). From the plot it will be possible to obtain the parameter d, which can be very useful. For instance, it will be possible to assign an initial separation d to active regions that we do not have much information about. In historical data, the information available is only the latitude and size. The next step is to find this correlation after applying some data correction due to Hale and Joy's law.

Publications: No publications on this semester.

Studies in current semester:

Subjects

- Seminar in modern astronomy 4 (csmcsilsz4g17gm)
- Introduction to Astronomy 2. (csbevcsil2g17ea)
- Solar Physics (FIZ/5/057)
- Lineáar and nonlinear MHD waves (FIZ/5/054)

Other courses

- SWATNet Workshop 5: SWATNet Workshop 5 “Mini-Master of Business Administration (Mini MBA)” on 23– 24 March 2023
- SWATNet School 3: “Space Weather and our Technology-Based Society” on 12 – 14 June 2022
- SWATNet Workshop 6: “Entrepreneurship in Space Physics” on 15 – 16 June 2023
- SOLARNET Summer School: “Solar atmospheric dynamics – From waves to instabilities and jets” on 25 – 30 June 2023

Conferences in current semester: No conference attended this semester