6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Analyzing the solar activity using the horizontal visibility graph method

Tomás Zurita-Valencia[1], Víctor Muñoz[1]
[1] Departamento de Física, Facultad de Ciencias, Universidad de Chile, Santiago, Chile.
e-mail (speaker): tomas.zurita@ug.uchile.cl

Various measures of complexity can provide relevant ways to study the complexity in the dynamics of magnetized plasma. In this case, the sun and its behavior will be studied through the use of complex networks. We take two time series associated with solar activity, namely total sunspot and global mean magnetic field, taken from 1975 to 2015. Both time series will be analyzed through the Horizontal Visibility Graph (HVG) technique [1]. Formally, given a series of data Y_N, it is said that each value of the time series corresponds to a node, and two arbitrary nodes y_a and y_b "see" each other if for every node y_c the relation y_a, $y_b > y_c$ is satisfied. Then, once the HVG criterion is established, the method leads to a complex network. The HVG allows to study statistical properties of time series such as reversibility [2], and it has been successfully used to study a variety of physical systems [3,4].

We take sunspots [5] and mean magnetic field on the surface of the Sun [6], both measurements carried out from May 16, 1975, to December 6, 2015.

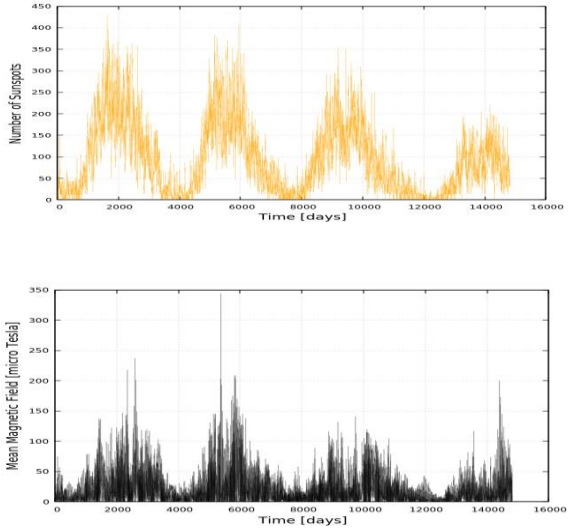

Figure 1: Sunspots (top) and mean magnetic field (bottom).

In this network analysis, we calculated different metrics, such as betweenness centrality (BC), degree centrality (DC), eigenvector centrality (EC) and the clustering coefficient (CC). We will show the results for BC due to its interesting sensitivity respect to the solar cycle.

We found a specific metric of the complex networks that is sensitive to the solar cycle, Betweenness Centrality (BC), which quantifies the frequency at which a node acts as a connecting bridge along the shortest path between any other two nodes.

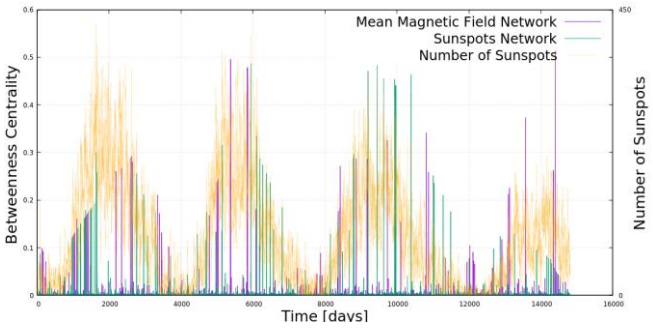

Figure 2: Betweenness Centrality for both networks using the HVG. Number of sunspots are shown in orange as solar activity reference.

Furthermore, from the connections established within the networks, we also observed that they follow an exponential topology for their degree distribution, which is the fraction of nodes with k connections over the total amount of nodes, $P(k) = n_k/n$.

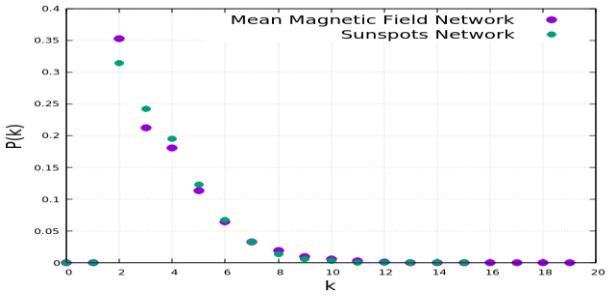

Figure 3: Degree distribution for each network.

References

[1] Lacasa, L., Luque, B., Ballesteros, F., Luque, J., & Nuno, J. C. (2008). From time series to complex networks: The visibility graph. Proceedings of the National Academy of Sciences, 105(13), 4972–4975.
[2] Lacasa, L., Nunez, A., Roldán, É., Parrondo, J. M., & Luque, B. (2012). Time series irreversibility: a visibility graph approach. The European Physical Journal B, 85(6), 1–11.
[3] Acosta–Tripailao, B., Pastén, D., & Moya, P. S. (2021). Applying the Horizontal Visibility Graph
Method to Study Irreversibility of Electromagnetic Turbulence in Non-Thermal Plasmas. Entropy, 23(4), 470
[4] Muñoz, V. & Garcés, N. E. (2021). Analysis of pulsating variable stars using the visibility graph algorithm. Plos One, 16(11):e0259735.
[5] Sunspot data from the World Data Center SILSO, Royal Observatory of Belgium, Brussels.
[6] The Wilcox Solar Observatory (WSO) project, http://wso.stanford.edu