ABSTRACT:

Name of Responsible Researcher:	[redacted]
Proposal Title:	**Complex networks and fractal analysis of time series of interest for space and astrophysical plasma systems**

Describe the main issues to be addressed: objectives, methodology and expected results. **The maximum length for this section is 1 page** (use letter size format, Verdana font size 10 or similar).

Time series are one of the basic means to extract information for physical systems. They can provide information on the underlying dynamics of the system, or highlight universalities across seemingly unrelated problems. The possibility to extract useful information from time series alone is even more relevant when dealing with physical systems where direct control of experimental variables or numerical parameters is not feasible, which is usually the case in space and astrophysical contexts, resorting to in situ space probe observations and gathering of radiation from remote sources through telescopes.

The intrinsically nonlinear features of space and astrophysical plasmas pose a major challenge to the understanding of their dynamics. Among the various approaches that have been developed to deal with this issue, the increasing realization that nonlinearities in plasmas lead to emergent, complex behaviors, has opened the possibility to use a new family of techniques and insights, usually developed in other research fields, and that have proved to be useful to describe and model the behavior of plasmas.

In effect, complexity in plasmas manifests itself through a variety of phenomena, such as fractal and multifractal dynamics, self-organized criticality, turbulence, or chaos emergence. In this project, we are interested in exploring the complex description of plasmas, by focusing on the study of problems related to space and astrophysical systems, where plasma physics is relevant, and where, due to its nature, time series are the essential source of information available.

Specifically, we propose to do this by means of complex networks, visibility graphs, and fractal approaches. To this end, we will make use of observational data (such as light curves from distant stars, or time-series related to the Sun's and the Earth's magnetic activities), and data from simulations of magnetohydrodynamic turbulence, which allows to gain intuition on actual physical systems, and carry out systematic studies under controlled conditions.

Complex networks can capture the evolution of spatiotemporal patterns and reveal nontrivial structures in the data, which we will study by means of time-based complex networks, as well as by community detection algorithms to establish correlations between distant measurements. Visibility graphs, on the other hand, have the potential to discriminate various underlying dynamics, by mapping a time series into a complex network. We will apply this method to time series related to solar activity, and to curve lights of variable stars. Finally, fractals are able to describe the apparently irregular behavior of physical systems, and we will consider several definitions of fractality, based on 2D plots or purely on time series, to study issues such as MHD turbulence, description of coronal hole boundaries, and complexity of variable stars light curves.

We expect to contribute to the understanding of plasma systems, taking into account their complex behavior with approaches which have not traditionally been used to study space and astrophysics systems, but that have seen an increasing amount of applications in this field, providing new insights and perspectives to study the highly nonlinear regimes typically present in such environments.