The evolution of magnetic structures during eruptive flares, from the solar corona to the interplanetary medium

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My research aims at understanding the mechanisms at the origin of coronal mass ejections (CMEs) and their evolution in the interplanetary medium. CMEs are big blasts of solar plasma ejected during eruptive flare events that can harm the Earth and other planets environments. To investigate CME initiation, I use numerical methods to understand the evolution of structures observed with satellites. Especially, the numerical simulations I help developing aim at understanding the physical processes at heart in the changes of magnetic structures and to unveil the key physics for solar flares. Thus, I was able to reproduce and understand the 3D dynamics of the sudden restructuration of magnetic field and the CME launching. Those magnetic structures, also referred to as magnetic clouds when propagating in the interplanetary medium, can be measured in situ by spacecraft. From a sample of a multitude of detected magnetic clouds, I proposed models of their global structures by statistically analyzing the results from spacecraft measurements.

My research has different goals. Combining observations of the Sun with numerical models provides a good understanding of eruptive flares mechanisms. This knowledge is essential for the detection of regions generating strong flares, and ultimately it will enable us to apprehend solar eruptive activity and impacts on our societies. On the other hand, the study of CME launching during the eruption associated with their detection in the interplanetary medium gives insights on the propagation of such large magnetic structures. This propagation is a key element for space weather since these structures interact with the Earth's magnetic shield, leading to solar auroras, but also to damages on electric grids and radiation harmful to humans.

Although seen as too long-term or too theoretical, solar physics plays a major role in understanding the environment of the planet we live on. Since our societies are becoming more and more dependent on energy supplies relying on electrical grids, and on telecommunication and entertainment relying on satellites, the effect of solar activity has a growing potential to harm human activities. Studies quantifying the money lost on damaged satellites and electrical grids already show a strong dependency with the Sun's dynamics. These studies could be furthered with nationwide data to make policy-makers aware of the necessity of such a discipline. In particular, the results of my study already show that the basis of space weather, associating multi spacecraft measurements with data-driven simulations, is already available.