High-frequency wave activity in a structured solar wind: Parker Solar Probe observations

October 5, 2020

1 Short summary

Parker Solar Probe is today the first mission that has literally penetrated into the solar atmosphere. Since its launch in 2018 the mission has already revolutionized our perception of the solar wind. Our team at the LPC2E (Orléans) is in charge of a magnetic field sensor that is the first to probe the solar wind at high frequencies, between 10 kHz and 1 MHz. The first observations made by that instrument reveal surprising results such as the magnetic signature of type III bursts and dust impacts.

This PhD project aims at exploring these high-frequency magnetic signatures and constrain the physical models that explain their origin. This is an exploratory study with a mix of data analysis (involving many different approaches, including some machine learning), theoretical modelling and the exploitation of data coming from several instruments.

2 Description

The overall context of this project is NASA's Parker Solar Probe mission, which was launched on August 12, 2018. Parker Solar Probe is the first-ever mission to penetrate deep into the solar corona, where it aims at unravelling the mechanisms that heat the solar corona and accelerate the solar wind. Eventually, in 2024, the spacecraft will get within 9 solar radii of the solar surface, providing unprecedented opportunities to study the solar wind close to its source region.

The payload of Parker Solar Probe includes instruments that measure in situ particle distributions, electric and magnetic fields, and view the Sun sideways. The only non-US instrument is the SCM search-coil magnetometer that is operated by our team from the LPC2E (Orléans) with support from CNES. The SCM measures magnetic fluctuations between 3 Hz and 1 MHz.

The first observations from Parker Solar Probe have revealed a highly structured solar wind, with a wealth of different types of waves and structures emanating from the Sun. Their magnetic signature below a few kHz reveals classical types of waves: ion-cyclotron, whistler waves, etc. The high-frequency end of the spectrum (typically from 20 kHz - 1 MHz) however, is uncharted territory. This range has not yet been measured in the solar wind and our SCM instrument is the first to provide access to it. The objective of this thesis is to explore this high-frequency range, identify the different types of waves and structures that are observed in it, characterise them, and use these results to constrain the models. We are particularly interested in developing a better understanding of the instabilities that are associated with energetic electron beams whose distinctive signatures are type III radio bursts. These radio waves have recently been found to have a magnetic signature. In addition, we also see magnetic signatures from large dust impacts, see Figure 1. This unexpected result opens new perspectives for understanding the current distribution associated with impacting dust particles.

The PhD candidate will be directly involved in the scientific exploitation of these exciting new results and will actively collaborate with members of the FIELDS consortium who are mainly in Berkeley, Boulder,

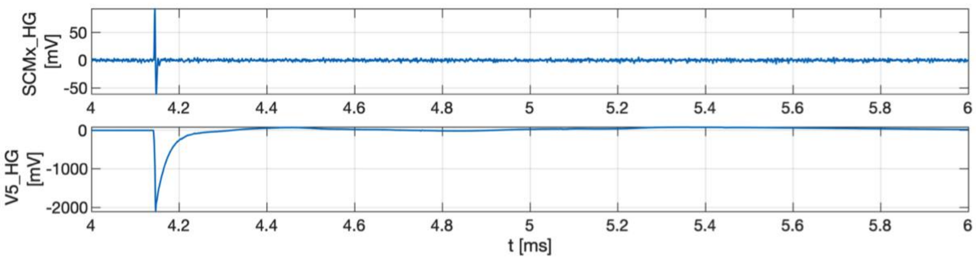

Figure 1. Example of a dust impact with its distinctive signature in the electric field (below) and in the magnetic field (above). While dust signatures are routinely observed in the electric field, this is the first time that they are also (weakly) visible in the magnetic field.

and at the Paris Observatory. Experts from the latter, in particular, will assist in the analysis of dust impacts.

A similar SCM instrument is flying on the Solar Orbiter mission, which was launched in 2020. While Solar Orbiter does not come as close to the Sun, it offers a unique opportunity to investigate the radial dependence of the high frequency waves we see. Therefore, the observations from both missions will be compared.

In a second time, the PhD candidate will explore the possible sources from the Sun's lower atmosphere (jets in coronal holes, reconnection signatures, etc.) of magnetic field deflections that have been named "switchbacks". These structures, which have received considerable attention, seem to be ubiquitous in the young solar wind, see Figure 2. The PhD candidate will combine analyses of remote-sensing observations of the Sun's lower atmosphere and in-situ observations from Parker Solar Probe. For each encounter with the Sun different telescopes (space-borne and ground-based) co-observe the expected sources of the wind; Parker Solar Probe itself does not carry such instruments.

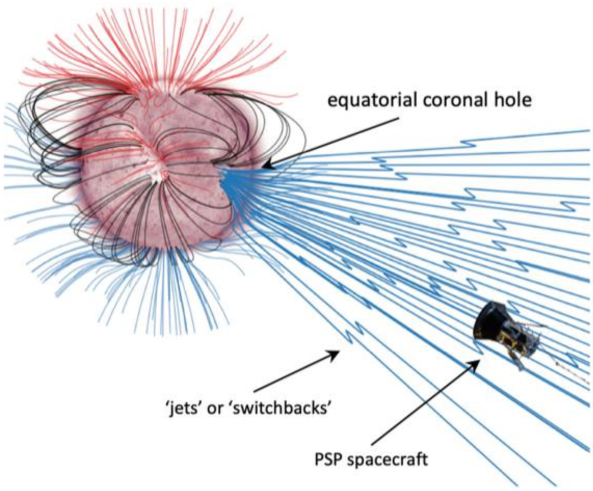

Figure 2. Schematic view of switchbacks observed by Parker Solar Probe in the solar wind originating from coronal holes (From Bale et al., Nature 2019).

Because of the exploratory nature of the subject, we look for someone who is eager to look with us into new and exciting data that have received little attention so far and can work autonomously. The successful candidate will learn to master a large variety of data analysis methods (including some machine learning tools) that are required to study waves and transients in space plasmas. He/she will also learn to collect and compare observations coming from different instruments (waves/particles and UV emission/spectro-imaging) to build a physical picture of what we observe.

At the LPC2E we are an international team of 5 scientists who mainly work on the SCM data from the

Parker Solar Probe and Solar Orbiter missions, with two computer engineers who assist us in making the data available.

3 Advisors

- Thierry DUDOK DE WIT (Professor at the University of Orléans) has a keen interest in data analysis techniques and mainly works on solar-terrestrial physics. He is also the lead Co-investigator of the SCM instrument on Parker Solar Probe and the Co-investigator of the SCM instrument on Solar Orbiter.
- Clara FROMENT (CNRS researcher) has core expertise lies in remote-sensing observations of the solar atmosphere (UV telescopes). She also analyses waves propagation with the SCM instruments and is involved in different activities related to connection science between in-situ instruments of Parker Solar Probe and Solar Orbiter and telescopes observing the Sun's atmosphere.

4 Profile of candidate

Applicants should have a keen interest in space science and a record of academic excellence. They must have an M.Sc. degree or equivalent in physics or a related field. A training in astrophysics or space science are clear assets and a good command of a programming language is mandatory. French language skills are not mandatory, however helpful.

5 Location and Organisation

The successful candidate will be hosted by the Laboratoire de Physique et Chimie de l'Environnement (LPC2E), a research lab with a staff of approximately 90. The LPC2E has strong expertise in space missions, radio-astronomy, and in balloon sounding of the atmosphere. We develop instruments that have flown or are flying on several space missions such as Cluster, Solar Orbiter, BepiColombo, Parker Solar Probe and soon Taranis.

The LPC2E is located in the outskirts of Orléans, a medium-size city that is located at the Loire river, 1 hour south of Paris by train. Living conditions are considerably cheaper in Orléans than in Paris. The CNRS campus of Orléans offers an exceptional research environment with state-of-the-art facilities. The working languages in our team are English and French as we come from different countries. Complimentary French language courses available at the University of Orléans.

6 Funding scheme

If selected, this PhD scholarship should be co-funded by CNES and by the regional council (Région Centre - Val de Loire). Interviews will then be carried out early April 2021 and the contract should start early October 2021. In France, the duration of a PhD contract is 3 years.

7 Useful links

- The Parker Solar Probe mission : `http://parkersolarprobe.jhuapl.edu/`
- The Solar Orbiter mission : `https://www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter`
- LPC2E : `https://www.lpc2e.cnrs.fr/`