Subject offered for a contract starting October 2018

SUBJECT TITLE: Deciphering Extremely Low Frequency (ELF) lightning whistlers and other unique ionospheric magnetic signals, using 250 Hz burst mode data from the Swarm satellite constellation

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Financing: Doctoral contract with or without teaching assignment

For more information go to http://ed560.ipgp.fr, section: Offres de these (PhD offer), You must apply on the Doctoral School website

Presentation of the subject:

Swarm is a mission of the European Space Agency that was launched on November 22, 2013. It consists of three identical near-polar low Earth orbiting satellites that primarily aim at investigating all sources of the Earth's magnetic field using a constellation approach (see https://www.esa.int/Our_Activities/Observing_the_Earth/Swarm and https://swarm.cnes.fr/en/SWARM/index.htm). Each satellite of the Swarm constellation carries an absolute scalar magnetometer under the scientific responsibility of IPGP, built by CEA-Léti and provided by CNES as a Customer Furnished Instrument. These ASM instruments nominally provide 1 Hz scalar magnetic data for both scientific investigations and calibration of the rest of the magnetometry payload (which further includes a Vector Fluxgate Magnetometer (VFM) and a set of three star cameras (STR)). It can, however, also be run in a so-called burst mode, when the sampling frequency is raised to 250 Hz. This mode was tested during the commissioning phase of the mission between December 2013 and February 2014, when several sessions collected more than 150 hours of data. New regular campaigns of burst mode data acquisition will be provided from mid-2018 onwards. The mission is now planned to be running up to at least 2023.

Two types of very interesting signals have already been detected using these burst mode data: extremely low frequency whistlers produced by lightning strokes that occur in the troposphere below the satellites, and complex magnetic signals detected when the satellites cross ionospheric plasma bubbles.

Whistlers, so-called because part of their spectral content falls into the audible frequencies, are well-known phenomena. The extremely low frequency range of the signal recorded by the ASM burst mode at satellite altitude, however, is unique. These whistlers testify for the fact that a significant fraction of the lightning signal energy manages to enter the ionosphere and propagate up to the satellites, even at frequencies below the expected cut-off frequency of the ground-ionosphere wave-guide. This propagation is strongly controlled by the magnetic field orientation and by the distribution of ions and electrons within the ionosphere. Detailed investigation of how the signal manages to enter the ionosphere and of the way the signal evolves as it propagates through the ionosphere are expected to provide new ways of investigating both the ionosphere and the lightning source signals. Questions to be addressed include: Which fraction of the lightning signal energy can enter the ionosphere? Which conditions, both in terms of properties of the transition between the neutral atmosphere and the ionosphere and in terms of properties of the source signal, should be met for this to be possible and for the signal to reach satellite heights? Can the observed whistler properties, such as its dispersion, be used to constrain the distribution of charged particles along its path in the ionosphere? This last question, to be addressed by also using data from the Electric Field Instruments (EFI, also on board the Swarm satellites) and data from ground based ionosondes, is of very high operational interest. It could lead to a new powerful way of evaluating empirical ionospheric models, such as the International Reference Ionosphere (IRI), widely used for many applications. A strategy to improve such models, especially in regions where no ground measurements are available, could then ultimately be developed, taking advantage of all the information provided by the whistlers detected by Swarm. This would form the core of the present PhD project.

A second very interesting type of signals detected by the ASM burst mode is witnessed when crossing ionospheric irregularities known as ionospheric plasma bubbles. These usually occur at low latitudes in the first part of the night. Already available burst mode data reveal that small-scale current systems can occur at the boundaries of such irregularities and possibly play a significant role in the plasma bubble development. Additional data to be acquired during future burst mode sessions, combined with data acquired from the Vector Field Magnetometer (running at 50 Hz) and EFI instruments, could open new ways of investigating and interpreting the dynamics of such plasma bubbles, known to adversely affect radio communication and GNSS signals. Such investigations could also take place during the course of this PhD.

Finally, additional transient signals such as Schumann resonances, Alfvén waves, or high latitudes phenomena, could also potentially be observed using burst mode data. Assessing which of these happen to be detected (or not) from the low altitude orbits of the Swarm satellites, would also prove very valuable and lead to important scientific conclusions.

All these planned investigations are expected to improve our understanding of the Earth space environment and its connections with the lower atmosphere.

The successful candidate would join the Geomagnetism team, benefit from the considerable experience of this team with the Swarm mission and ASM instruments, as well as from well-advanced software developments, most notably for the processing of Burst mode data and forward propagation of whistlers. She/he could also be involved in the Geomagnetism team current efforts to develop a nanosatellite project (NanoMagSat, jointly with CNES and ESA) that intends to take advantage of a miniaturized version of the ASM instruments for even more systematic investigations of the Earth's magnetic field and ionospheric environment.