POST-DOC: Analysis, modelisation and investigation of whistler type ELF signals detected by the ongoing ESA Earth Explorer Swarm and preparation of the future ESA Scout NanoMagSat mission

Job offer from the institut de physique du globe de Paris | CNRS UMR 7154

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| **Researcher in** | Ionospheric ELF signals |
| **Duration** | One year |
| **Affectation** | Geomagnetism Group, IPGP |
| **Salary** | Minimum of 2720,42 € (gross monthly)  |
| **Date of publication** | 18/11/2024 |
| **Starting date** | 01/01/2025 |
| **Location** | IPGP, 1 Rue Jussieu 75005 Paris |

### The institut de physique du globe de Paris

A world-renowned geosciences organisation, the IPGP is associated with the CNRS and an integrated institute of the Université Paris Cité. Bringing together more than 500 people, the IPGP studies the Earth and the planets from the core to the most superficial fluid envelopes, through observation, experimentation and modelling.

The research aeras are structured through 4 main unifying themes: Interiors of the Earth and Planets, Natural Hazards, Earth System and Origins.

The IPGP is in charge of labelled observation services in volcanology, seismology, magnetism, gravimetry and erosion. It also operates permanent observatories to monitor the four active French overseas volcanoes in Guadeloupe, Martinique, Réunion Island and Mayotte.

The IPGP hosts powerful computing resources and state-of-the-art experimental and analytical facilities and benefits from first-class technical support. The IPGP provides its students with geosciences training that combine observation, quantitative analysis and modelling, and that reflects the quality, richness and thematic diversity of the research conducted by the IPGP teams.

### Team Department

The Geomagnetism Team is one of the 17 research teams within IPGP. It works mainly on the study of the Earth's magnetic field, i.e. the natural phenomena that produce magnetic signals, as well as on the study of the Earth's global dynamics. The team plays a leading international role in proposing and operating space missions to monitor and study the Earth's magnetic field and ionospheric environment. The team develops advanced modelling and numerical simulation codes. In particular, it exploits data acquired in observatories and on board satellites, such as those on the ESA Swarm mission currently in operation, for which it is responsible for the absolute magnetometers. The team is also working on the preparation of the NanoMagSat mission, a future constellation of nanosatellites whose development is funded by ESA. This work is mainly carried out under contracts with space agencies (CNES and ESA, in particular). It involves close interactions with staff from these agencies and from industry (CEA, Open Cosmos, etc.), as well as with foreign researchers as part of international consortia and collaborations.

### Missions

The ESA Earth Explorer Swarm mission comprises 3 satellites launched in 2013 on quasi-polar Low Earth Orbits (LEO) slowly drifting in local time, to investigate all the sources of the Earth’s magnetic field. This mission has already been extended up to early 2026 and further extensions up to end of 2028 and beyond are already under consideration. Each Swarm satellite carries an Absolute Scalar Magnetometer (ASM) 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 the calibration of the Vector Fluxgate Magnetometers (VFM) also on board the satellites. However, ASM instruments can also acquire magnetic scalar data sampled at 250 Hz during so-called burst-mode campaigns. Since 2019 regular such burst-mode campaigns of one-week duration have been (and are still) run every month on both the Swarm Alpha and Bravo satellites. This already led to a very significant dataset.

The main signals of interest for this project will be lightning-generated whistlers in the Extremely Low Frequencies (ELF) range already routinely observed in the Swarm Burst mode data. These signals are generated by strong discharges, when a fraction of the lightning signal energy enters the ionosphere and propagates up to the satellites, even at frequencies normally trapped in the neutral atmosphere. Their propagation further depends on the magnetic field orientation and on the properties of the ionospheric plasma. The investigation of these signals can therefore provide important information about the distribution of lightning in the neutral atmosphere, the conditions allowing the ELF signal to penetrate the ionosphere, and the state of the ionosphere along the path of the signal between the lightning and the satellites.

Our team already demonstrated that the arrival-time of the various frequencies constituting a whistler can be used to measure a new ionospheric parameter, the Total square Root Electron Content (TREC, Jenner et al., 2024). This promising technique makes use of ray-tracing calculations and can be applied at mid and low-latitudes, where specific approximations of the ionospheric refractive index are possible. A few case studies have already been carried out for specific classes of whistlers, demonstrating the usefulness of this TREC measure for testing and improving empirical ionospheric models, such as the International Reference Ionosphere (IRI) model, widely used for many applications and assimilative models. However, the vast dataset of whistlers already detected by Swarm still remains to be fully exploited.

The shape of whistler spectrogram usually follows the empirical law of Eckersley (1935). It states that the arrival time of the whistler components is proportional to the inverse of the square root of their frequency. The proportionality coefficient is called the dispersion of the whistler. While most of the whistler of the Swarm Burst mode dataset follow indeed this law, some of them deviate from this pattern especially at equatorial magnetic latitudes. Ray-tracing modeling was already attempted with promising results to explain these discrepancies. However, the limitation of the current ray-tracing algorithm to 1D ionospheric and background models prevents more accurate modeling of these whistlers.

The first goal of this project will be to investigate the occurrence rate and characteristics of these unconventional whistlers in the Swarm Burst mode dataset. To interpret these signals, a need to further develop the existing modeling capabilities of the ray-tracing algorithm is anticipated, to include more accurate 2D or 3D descriptions of the ionospheric and magnetic background models. These developments will also be used to assess the validity conditions of the TREC computation technique, and identify which classes of whistlers can be used to infer TREC.

Our team is also scientifically leading the development of the ESA Scout NanoMagSat mission, which will deploy 3 nano satellites along polar and 60° inclined orbits, to complement and take over the Swarm mission. A first launch is planned end of 2027 and the full constellation will be in place in 2028. Compared to the Swarm constellation, NanoMagSat will have the enhanced ability to continuously measure 2kHz scalar and vector data.

In this context, we also wish to assess the adaptability of the TREC methodology to NanoMagSat and develop an end-to-end simulator for the mission. This will include ray-tracing modeling tests up to 800Hz with multi-component ionospheric background.

Finally, as the DEMETER mission (2004-2010) had a payload with similar magnetic vector measurement capacities as that of NanoMagSat, its data could also be used to further test the TREC technique for NanoMagSat and assess the opportunities for whistler studies in the relevant frequency range for NanoMagSat.

References:

Jenner, M., Coïsson, P., Hulot, G., Buresova, D., Truhlik, V., Chauvet, L., Total Root Electron Content: A New Metric for the Ionosphere Below Low Earth Orbiting Satellites, Geophys. Res. Lett., 51, e2024GL110559, doi: 10.1029/2024GL110559, 2024.

Eckersley, T.L., Musical Atmospherics, Nature, 135, doi: 10.1038/135104a0, 1935

### Activities

* Handling, adapting, developing and implementing technical and scientific codes
* Data processing and analysis
* Geophysical interpretation of results
* Writing scientific articles and technical reports

### Expected Skills

* General knowledge of physics, particularly electromagnetism (magnetism, electromagnetic waves, including in the ionosphere).
* Signal processing, numerical modeling
* Experience in processing of space data.
* Computing skills (in Linux environment): at least Matlab and Fortran, if possible python or c,
* Ability to communicate and interact professionally with French and foreign contacts who speak English, both in person and remotely.
* French and English read/spoken/written at a professional level.

### Obligations and risks

* Full-time (100%) at the IPGP, 1 rue Jussieu, Paris 5.
* Travels in France or abroad from one day to one week (in the context of scientific meetings and or collaborations missions),
* Ability to telework from home if necessary.

### Training and experience required

* Geophysics or Physics (if possible in connection with electromagnetic waves propagating in the ionosphere)
* PhD

### How to apply

* CV and motivation letter to be sent to contacts below
* Deadlines for applications: 18/12/2024
* Contacts: **Gauthier Hulot** (gh@ipgp.fr) and **Pierdavide Coïsson** (coisson@ipgp.fr)