Masters Project Title: Ionospheric Characteristics of ULF (Ultra Low Frequency) Waves

Overall Research Project: INTPART project: Magnetic Pulsations and transients: the Sun-Earth connection and impact on the high latitude ionosphere (Research Council of Norway)

Timeline: 1 year (60 ECTS)

Main Supervisor: Assoc. Prof. Lisa Baddeley (UNIS)

Co-supervisor: Prof. Slava Pilipenko (Institute of Physics of the Earth, Moscow)

Project Description: Ultra Low Frequency (ULF) waves (with timescales of a few seconds to minutes), manifest themselves as periodic fluctuations in the Earth's magnetic field (see Menk 2011 for a review). These signatures can be observed both in the Earth's magnetosphere and ionosphere. The energy source for the waves can be either external or internal to the Earth's magnetosphere. The ionosphere acts as a sink for the wave energy. The vast majority of statistical studies into ULF waves have used ground magnetometer data and HF radar data (eg. Shi et al. 2018), with whilst some case studies have focused on UHF radar data (eg. Baddeley et al. 2017, Belakhovsky et al. 2016). ULF wave signatures in UHF/VHF radar data are often difficult to identify and hence have generally been limited to case studies. However, UHF/VHF radar studies are the only way of directly measuring ionospheric temperatures so can provide direct information regarding the amount of energy dissipated into the ionosphere. This project will start with a database of potential ULF wave signatures observed by the EISCAT Radars to

- determine the wave characteristics (frequency, latitudinal extent, scale size etc.)
- estimate the amount of energy dissipated into the ionosphere
- identify any additional signatures in additional datasets (eg. Ground magnetometer data, GNSS data, HF radar data, photometer data)
- identify possible energy sources (either internal or external to the magnetosphere)

The results from the project will be incorporated into a larger international research project (the INTPART research project) and hopefully provide input parameters to ionospheric models of ULF waves. Funding assistance for travel and accommodation on Svalbard is available through the project. There is also the possibility to travel to a scientific conference to present the work, as part of the INTPART project, at the completion of the Masters thesis (also funded through the project).

Methods: The student will familiarize themselves with the different categories of ULF waves and their energy source (through the reading of several scientific papers). The research work will then entail:

- the downloading, analyzing and processing of data from online databases (for instrumentation listed above).
- A visit to the EISCAT Svalbard radar where the student will be in charge of an experiment to monitor the ionosphere for ULF wave signatures.
- Preparation and writing of thesis manuscript.
- Preparation and presentation of results at a science conference (subject to availability of conference and progression in the project)

Fieldwork: The student will be instructed how to use the EISCAT Svalbard Radar before running their own experiment to hopefully increase the database of events (NB: The ionosphere cannot be controlled so there is no guarantee of increasing the dataset!)

Experience: Programming experience essential – preferably with matlab (python and IDL are also acceptable). Background knowledge of ionospheric / magnetospheric physics is also required.

References:

- Baddeley, L. J., D. A. Lorentzen, N. Partamies, W. Denig, V. A. Pilipenko, K. Oksavik, X. –C., Chen and Y. Zhang (2017), Equatorward Propagating Auroral Arcs driven by ULF Wave Activity: Multipoint Ground and Space based Observations in the Dusk Sector Auroral Oval, , J. Geophys. Res.: Space Physics: 122, doi: 10.1002/2016JA023427
- Belakhovsky, V., V. Pilipenko, D. Murr, E. Fedorov, and A. Kozlovsky (2016) Modulation of the ionosphere by Pc5 waves observed simultaneously by GPS/TEC and EISCAT, Earth Planets Space, 68:102, doi: 10.1186/s40623-016-0480-7.
- Menk, F., (2011), The Dynamic Magnetosphere, Springer, ISBN : 94-007-0501-8, Chapter 13 – Magnetospheric ULF Waves: A review
- Shi, X., Ruohoniemi, J. M., Baker, J. B. J., Lin, D., Bland, E. C., Hartinger, M. D., and Scales, W. A.,(2018) Survey of ionospheric Pc3-Pc5 ULF wave signatures in SuperDARN high time resolution data, J. Geophys, Res.: Space Physics, 123, 4215-4231, doi: 10.1029/2017JA025033