Scenario DOCTORAL TRAINING PARTNERSHIP

NERC SCIENCE OF THE ENVIRONMENT

Capturing extremes in physics-based modelling of near-Earth Space Weather

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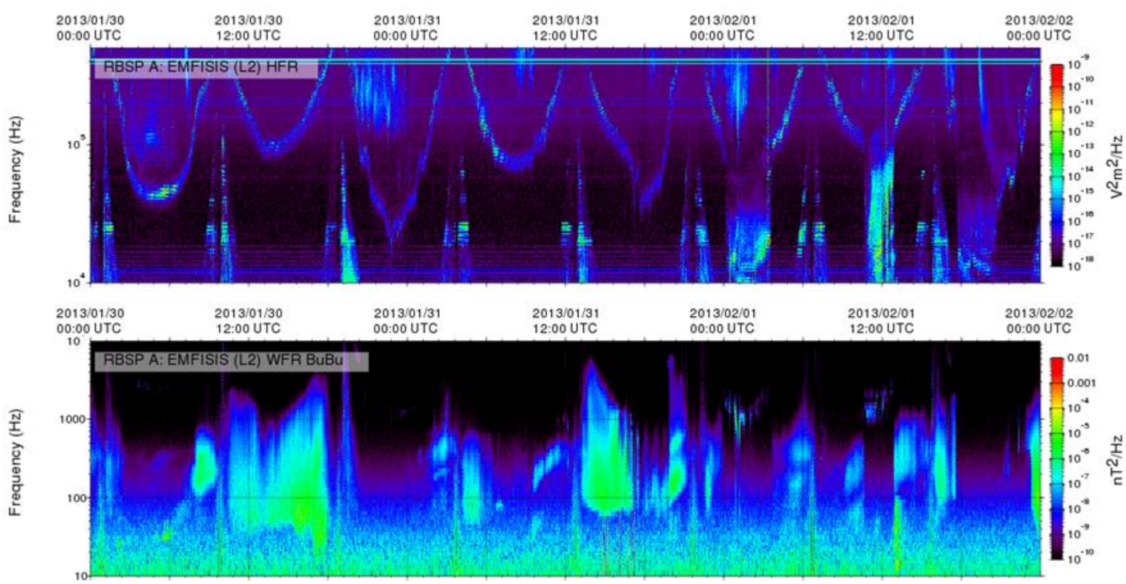
Space Weather is the name given to the natural variability of the plasma and magnetic field conditions in near-Earth Space. In the Earth's outer radiation belt – a region of space between around 2.5 and 10 Earth radii surrounding our planet – high energy electrons are trapped in the Earth's magnetic field. Although the electron density is very small, the velocities of these electrons can reach a significant fraction of the speed of light and present a dangerous radiation environment for satellites. Constellations of satellites that provide communications, location-finding and defense systems are vulnerable as their orbits traverse the heart of the outer radiation belt. The amount of high energy electrons can vary over many orders of magnitude in the course of a few hours, and the extent of the outer radiation belt can grow to beyond geosynchronous orbit, or shrink much closer to the Earth on the same timescale. The reasons for the large changes are not yet fully understood, and our ability to forecast them requires considerable improvement. Due to the sparse nature of in-situ measurements, and the relatively short time period over which we have collected relevant data, we require physics-based models to aid in the forecasting of extreme space weather in the hazardous outer radiation belt.



Three days (eight orbits) of wave data from Van Allen Probe A. The top panel displays successive U-shaped traces that indicate changing density as the spacecraft repeatedly moves from apogee at ~5.5 Earth radii to perigee at around 620km altitude. Each successive trace is different, indicating varying plasma conditions in space. The lower panel shows lower-frequency wave data – the green regions indicate waves that can interact with high-energy electrons. These are also highly variable from orbit to orbit.

The high-energy electrons that form the belt are controlled by interactions with a wide range of electromagnetic waves that are supported in near-Earth plasma. In physics-based models, these wave-particle interactions are "sub-grid", that is, they occur on time and length scales that are so short they cannot be feasibly captured by the spatial or temporal resolution of the model. Typically, the interactions are parameterized, using theoretical models and observations, and in most cases these parameterizations only capture the average properties of the interactions. This makes it difficult to model extreme events that rarely occur.

In this project, we invite you to help us construct the next generation of space weather parameterizations using in-situ spacecraft data from the state-of-the-art NASA Van Allen Probes. Then we will move on to explore numerical modelling techniques that are currently used with great success in terrestrial numerical weather prediction, and apply them to space weather. NASA Van Allen Probes have provided seven years of data covering a large section of the outer radiation belt in unprecedented detail. The electromagnetic wave and electron datasets will provide you with an opportunity to experience "big data" environments and explore data-driven analysis techniques and machine learning. We will compare results from your new models with results from more traditional approaches used by national and international radiation belt groups such as British Antarctic Survey and GFZ German Research Centre for Geosciences through research visits and ongoing collaborations.

Training opportunities:
You will have the opportunity to attend masters-level modules at the University of Reading in space weather, statistical techniques, machine learning and numerical modelling. Software engineering courses are also provided at Reading to help support your skills development and project goals.

You can attend UK-based summer schools in the science underpinning space weather, and have the opportunity to attend international summer schools (e.g. at Los Alamos National Laboratory, New Mexico) in similar topics. Two "International Summer Schools in Space Simulations" (ISSS14 and 15) will fall during span of the PhD (one likely in Europe, one likely in Asia) and will provide many training opportunities. Although the international summer schools are funded competitively and are not guaranteed, students from Reading have recently been successful in gaining funding to attend and you will be fully supported through your applications.

You will also have the opportunity for research visits to the British Antarctic Survey in Cambridge and GFZ German Research Centre for Geosciences thanks to ongoing collaborations with these groups. These visits will allow you to experience a range of different research environments, discover more about radiation belt modelling and expand your professional network, in addition to furthering the scientific goals of your project.

Student profile:
This project would be suitable for students with a degree in physics, mathematics or a closely related physical science.

References: (optional)

Watt, C. E. J., Rae, I. J., Murphy, K. R., Anekallu, C., Bentley, S. N., and Forsyth, C. (2017), The parameterization of wave-particle interactions in the Outer Radiation Belt, *J. Geophys. Res. Space Physics*, 122, 9545– 9551, doi:10.1002/2017JA024339.

http://www.reading.ac.uk/nercdtp