Spring MIST 2025
Abstracts

7^{th} – 9^{th} April 2025

College Court
University of Leicester

Oral Presentations

Session 1: SMILE

Heavy Ion Influences at the Magnetosheath and the need for Elfen

Jenny Carter - University of Leicester
Susan Lepri, Jim Raines, Jonathan Eastwood, Ravindra Desai, Bhargav Narasimha-Swamy, Piyal Samara-Ratna, Simona Nitti, Dimitra Koutroumpa

The solar wind heavy ion influence at the dayside magnetosheath and their role in magnetosphere-ionosphere coupling has yet to be quantified. In addition, heavy ions charge exchange with exospheric neutrals and emit high energy emissions. These emissions allow for imaging of large-scale structures and dynamics in the magnetosheath, and underpin the observations of imminent missions such as LEXI and SMILE. Nightside knowledge of heavy ions is also poor, and various competing processes such as diffusion through the magnetosheath flanks or dual-lobe reconnection may feed and maintain the low-latitude plasma sheet in this region.

The Elfen mission will tackle these two science goals or both the dayside and nightside of Earth. Elfen is a ∼16U CubeSat with a desired circular, low-latitude orbit to 12 RE or greater. It will carry two instruments; a mass spectrometer, T-FIPS, to determine the in situ heavy ion composition, and a magnetometer, MAGIC, to help determine the contemporaneous plasma regime of the Earth's magnetosphere traversed by the spacecraft. T-FIPS will make composition measurements at 10 second cadence on the nightside, and at a minimum of 1 minute on the dayside. MAGIC will have sensitivity of 2 nT at a cadence of 10 Hz.

We will discuss the possible influence of heavy ions on the day and nightside of the magnetosheath, and our progress developing Elfen.

Global MHD and Test-Particle Simulations of Solar Wind Charge Exchange from the Earth's magnetospheric boundaries

Ardra Ramachar - University of Warwick
Ravindra Desai

The intricate energy exchanges within the Sun-Earth system, including geomagnetic storms, can influence both ground and space technologies crucial for modern society. Effective forecasting and mitigation of space weather necessitate vigilant monitoring of the Earth's magnetosphere. However, this task is hindered by limited in-situ satellite measurements and ground-based observations. The Solar Wind Charge Exchange (SWCX) mechanism, which involves X-ray emissions from the interaction of heavy, high charge state solar wind ions, forms the basis for the upcoming SMILE (Solar wind Magnetosphere-Ionosphere Link Explorer) mission, designed to image the global magnetosphere using these X-rays. Our project aims to interpret SMILE's X-ray datasets through Global Magnetohydrodynamics (MHD) simulations, enhanced to incorporate heavy ions and X-ray emissions. In this talk, we will present an analysis of SWCX from the Earth's magnetopause and cusp regions under various solar wind conditions, along with the initial comparisons between the predictions of the global MHD model and those generated from our embedded kinetic particle model.

The SMILE Data Fusion Facility (DFF) and SMILE multi-spacecraft and ground-based studies

Yasir Soobiah - University of Leicester
Jenny Carter and Tim Yeoman

The upcoming Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) joint ESA-CAS mission, will provide the novel imaging of the Earth's dayside magnetopause and magnetic field cusp by the SMILE Soft X-Ray Imager (SXI) as well as the simultaneous observations of the Northern hemisphere auroral regions by the SMILE Ultraviolet Imager (UVI). The SMILE imagers will be supported by in-situ measurements from a Light Ion Analyser (LIA) and Magnetometer (MAG).

The monitoring of the Earth magnetopause position and auroral responses by SMILE will provide important details on magnetic reconnection and geomagnetic storms and their related magnetospheric/ionospheric processes. This will provide the opportunity for additional science with various ground-based space-weather instruments. This paper will introduce the use of the SMILE Data Fusion Facility (DFF) under development by the University of Leicester to allow the side-by-side comparison of SMILE SXI images, SuperDARN radar maps of the ionosphere and SuperMAG ground magnetic field measurements and capabilities to plan future conjunctions between SMILE and different ground-based observatories.

The SMILE and ground-based data will also be combined with investigations of dayside cusp reconnection signatures by NASA's Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites (TRACERS) and the sub-storm current wedge by Electrojet Zeeman Imaging Explorer (EZIE) missions. This paper will present the initial preparations for studies between SuperDARN and the TRACERS mission.

Session 2: Magnetosphere

Finding Magnetospheric Dynamics with Observed Imbalances in Earth's Open and Closed Magnetic Flux

Maria-Theresia Walach - Lancaster University
Nithin Sivadas, Mai Mai Lam

Earth's magnetosphere is an unstable system. We observe this in many aspects of the system, for example, substorms. A key indicator of the state of the system is the amount of open magnetic flux and the rate at which it is changing. These measures are intimately tied to the driving of the system (i.e. dayside reconnection) but also, the response of the system (i.e. nightside reconnection). When they become imbalanced, extraordinary phenomena such as substorms can dominate magnetospheric dynamics. Understanding when and how these imbalances occur is therefore a key to understanding our magnetosphere.

Using auroral data from the IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) spacecraft, we calculate the amount of magnetic flux in the open region of the magnetosphere and the amount of flux in the auroral region. The open flux is indicative of the amount of flux which is convecting towards the nightside and the closed flux in the auroral region is indicative of the amount of magnetic flux which is convecting towards the dayside. Together, the two quantities tell us how much of the magnetosphere is convecting. By investigating the timing of the peaks and troughs in these timeseries, we evaluate when the system is unstable and when day- and nightside reconnection occurs. We study these timeseries statistically and the relation between their peaks and troughs.

Overall, and over long timescales, a balance between day- and nightside reconnection must exist because the amount of magnetic flux in the magnetosphere is finite. On timescales of minutes to 100s of minutes however, we find that imbalances occur. We observe that the magnetosphere can become imbalanced on timescales from minutes to ∼3 hours, with the median timescale being 24 minutes. Without consideration of any driving parameter or any other dataset and by simply investigating statistically the convecting magnetic flux content, we find two distinct statistical distributions: one where dayside reconnection is dominant and one where nightside reconnection is dominant. We find that the two show differences in their statistical behaviour, indicating that nightside flux closure can be up to 4 times higher than flux opening.

Investigating the spatial extent of the northern magnetospheric cusp using conjugate ground and space based methods

Fiona Ball - University of Southampton

F. Ball and R. C. Fear

The polar cusps remain an important area of magnetospheric study due to their role in the coupling of the solar wind and magnetosphere by dayside reconnection at the magnetopause. Signatures of magnetopause reconnection include in-situ observations of magnetosheath plasma in the high- and mid-altitude cusp, and poleward moving auroral forms (PMAFs) in the ionosphere, which are signatures of field line convection. We present an event study of cusp extent from the 16th of December 2017, when the Cluster mission made a latitudinal pass of the northern cusp and the EISCAT Svalbard radar was run in a conjugate measurement campaign. The overall footprint of observations over the entire event time spans 6.8h MLT, an unusually large measurement for cusp extent, although the near-instantaneous measurements during the event give an extent between ∼3-5h MLT. Possible explanations for cusp behaviour during the event as influenced by upstream solar wind conditions are discussed, such as the IMF By component.

Solar Wind Influence on Dual-Lobe Reconnection and Horse-Collar Aurora

Gregory Kennedy - University of Leicester

Stephen Milan, Gemma Bower, Suzanne Imber, Michaela Mooney

Horse-collar aurora (HCA) are an auroral formation generated by the geomagnetic reconfiguration during prolonged periods of northward-directed interplanetary magnetic field (IMF). HCA formation has been linked to dual-lobe reconnection (DLR) closing open flux at the dayside magnetopause, resulting in a reversal of the typical ionospheric twin-cell convection pattern and a poleward motion of the dawn and dusk portions of the open/closed field line boundary (OCB). This morphology gives rise to a horse-collar or teardrop-shaped polar cap.

We aim to investigate two key aspects of HCA: a) whether the dim region within the HCA is open flux, and b) whether there exists a correlation between the DLR rate and upstream solar wind parameters. This study uses HCA arc velocity as a proxy measurement for DLR rate, allowing us to infer correlation between IMF parameters and DLR rate.

Far-ultraviolet spectral images from the Special Sensor Ultraviolet Spectrographic Imager instrument on-board the Defense Meteorological Satellite Program spacecraft were used to measure the location of HCA in successive polar passes. At the current stage of the study we find a linear relation between HCA closing velocity and the total IMF magnitude and Bz magnitude. No relation was found between HCA closing velocity and solar wind flow speed or IMF By. The timescale for a full closure of the magnetosphere by DLR was also estimated for the events.

Plasma Observations in the distant magnetotail under Northward IMF

Michaela Mooney - University of Leicester
S. E. Milan, G. E. Bower, G. Kennedy

The structure and dynamics of the magnetosphere are significantly different during intervals of northward interplanetary magnetic field (IMF) compared to when the IMF is southward. Under northward IMF, reconnection can occur at high latitudes in both hemispheres simultaneously which can close significant amounts of open flux, resulting in an almost entirely closed magnetosphere which has been linked with characteristic auroral signatures, including horse-collar auroras and cusp-aligned arcs.

Under northward IMF the magnetosphere is dominated by closed magnetic flux and associated trapped particle populations which are thought to provide the source population for auroral cusp-aligned arcs (Milan et al., 2023; Mooney et al, 2024). However, the structure and properties of the distant magnetotail under northward IMF are poorly understood. We have performed a statistical analysis of ARTEMIS crossings of the distant magnetotail (XGSE $\sim$ -60 RE) between 2011 - 2016 to investigate the magnetic field and plasma characteristics in the magnetotail under northward IMF compared to southward IMF conditions. Under southward IMF, the magnetotail is dominated by magnetic pressure with no significant associated plasma population. However, under northward IMF we find that statistically the central distant magnetotail contains denser, hotter plasma and that the plasma pressure in the magnetotail is typically larger than the magnetic pressure. We suggest that the observed hotter, denser plasma population in the central magnetotail could indicate that the plasma sheet extends down to the distant magnetotail under northward IMF.

Preliminary Results from Examination of Cluster Magnetopause Crossings for TPA-IMF Magnetic Reconnection Events

Nawapat Kweeyanun - University of Southampton
Robert Fear

Transpolar arcs (TPAs) emission poleward of the Earth's main auroral ovals have been linked to closed magnetic field lines. Auroral images evidence suggest that these field lines may extend to the high-latitude magnetopause and reconnect with the northward interplanetary magnetic field (IMF), and a recent investigation of in situ Cluster magnetopause crossing observations confirms that this should be the case (Kaweeyanun et al. 2025, submitted). There have been reports of high-latitude reconnection involving the IMF and closed magnetotail field lines – termed "non-lobe" reconnection, and a question remains if TPA-IMF reconnection is the cause underlying these observations. We present here a multi-instruments analysis of 13 Cluster magnetopause crossings between 2001-2006 where "non-lobe" reconnection has been identified. Preliminary results indicate potential involvement of TPAs in more than half of these events with some of the remaining cases being hindered by lack of suitable auroral data. If validated, the study will establish not only an explanation for "non-lobe" reconnection, but also a confirmation that TPA-IMF reconnection is common, which is expected from the current understanding of ionospheric plasma flows. An expanded catalogue of confirmed TPA-IMF reconnection cases also provides further insights into the phenomenon that can help its future detection especially when data is partially unavailable.

Session 3: Radiation Belts

How do fundamental modelling choices affect radial diffusion in Earth's Radiation Belts?

Sarah Bentley - Northumbria University
J Stout, R J Thomspon, D J Ratliff, C E J Watt

Earth's radiation belts contain high energy, geomagnetically trapped charged particles that are responsible for several space weather hazards. Using conserved quantities associated with the motion of these particles, the radiation belts can be modelled through a basic diffusion equation. On longer timescales, this can be approximated as simply as a 1d diffusion equation, representing the changing drift orbit of the electrons as they interact with electromagnetic fields.

Ensemble modelling - running a model many times to represent variations in the underlying physics - is increasingly being adopted by the space physics community to capture the uncertainty, which can be inherent to the system or due to observations or models. But before we can interpret the physics from an ensemble, we must understand what variation arises solely from the modelling method. We investigate the role of fundamental model choices to the evolution of the system, including the details of an initial enhancement, the location of the plasmapause and the outer boundary size and condition.

Our first key result suggests that because the amount of diffusion changes depending on where you are in the modelling domain, the size of the domain affects the way the system evolves. Both the location of the outer boundary, and the numerical condition used there, change the way in which the system evolves, raising questions about operational choices today. The second result we will highlight allows us to quantify how model components contribute to the evolution of the system. Surprisingly, we find that the gradient of the phase space density (PSD) contributes more to the evolution of the system than the diffusion coefficient DLL. This contradicts our current understanding and has consequences whether correct or incorrect.

Bridging the Data Gap: Deriving Complete Electron Boundary Conditions from Incomplete Satellite Observations

Aaron Hendry - British Antarctic Survey
Sarah Glauert, Nigel Meredith

The BAS Radiation Belt Model (BAS-RBM) is a state-of-the-art global model of the Earth's radiation belts. By combining this model with data from flagship radiation belt satellite missions, we have been able to investigate the impact of different wave modes on radiation belt electron dynamics, carry out long-term simulations of the radiation belts, and forecast the evolution of radiation belt fluxes up to 24 hours ahead of time.

The BAS-RBM is primarily driven by two inputs: diffusion coefficients and boundary conditions, both derived from real-world data sources. In particular, driving the BAS-RBM requires knowledge of the full electron flux pitch angle distribution at a range of energies and L-shells for the full simulation period. As we will show, even with high-quality modern satellites such as RBSP and Arase, extracting these fluxes from data alone is generally impossible, and requires some degree of modelling, interpolation, or otherwise filling in gaps in the data. In this presentation, we will give a brief overview of the process of deriving the electron boundary conditions needed to drive the BAS-RBM, discuss methods of bridging the gap between satellite data and model input, and compare our results with real-world events to investigate the efficacy of our approach.

Using a Random Forest to understand and accurately predict flux levels in Earth's Van Allen Radiation Belts

Dylan Weston - Northumbria University
I.J.Rae, A.W.Smith, C.E.J.Watt

The Van Allen Radiation belts are highly dynamic in both intensity and location, meaning that the belts are difficult to predict for spacecraft operators. Forecasting models exist, in part, to minimise any additional damage caused by this natural hazard. Both physics-based and machine learning models already exist; physics-based models allow for a deeper understanding of the system, and machine learning models offer a computationally cheap way to make a forecast but do not necessarily provide physical insight.

We present a machine learning model capable of forecasting the Outer Radiation Belt with considerable skill 3 days in advance, and even with some skill up to 6 days in advance. We use a Random Forest classification model to predict if the daily $\sim$2 MeV electron flux level across each L* Shell exceeds its respective 60th percentile. Each model shows a high level of accuracy at both nowcasting and forecasting up to 6 days in advance, a longer forecast than current operational models. Using feature importance, we determine the key inputs into each model in order to gain an insight into which drivers are important at which L* shell and the timescales over which they have an impact. Interestingly we find solar wind inputs are not required for accurate forecasting for the vast majority of our Outer Belt models. Instead using only geomagnetic conditions from between 1- and 7- days prior, meaning that models such as these could be operationally viable for space weather stakeholders.

Extending Quasilinear Theory with Second Order Perturbations

Samuel Hunter - University of Birmingham
Oliver Allanson, Adnane Osmane, Sean Elvidge

Electrons in the Earth's radiation belts are trapped when pitch angles are outside the loss cone. Their motion is described by quasilinear theory in most current models, which describes bulk motion of particles with both advection and diffusion terms. To provide a more detailed analysis of electron dynamics, it is essential to utilise a nonlinear approach. This can involve looking at wave-particle interactions beyond perfect resonance, which creates "resonance-broadening" terms. In addition, we can study higher order perturbations of parameters such as pitch angle, energy, position, and gyrophase.

The Vlasov equation approach is typically used to create analytical advection and diffusion coefficients, but Allanson et al. (2022) derive a more intuitive formalism under the weak-turbulence approximation derived from the Lorentz force and equations of motion in pitch-angle – energy phase space. These derivations lead to diffusion equations that match quasilinear theory at large timescales.

Here we will present preliminary results building on the work by Allanson et al. on second order corrections to quasilinear theory and hypothesise potential implications such as improved descriptions of advection at certain timescales and pitch angles that have previously proved difficult to analyse.

The effect of energy diffusion on electron loss timescales in the Earth's radiation belts

Sarah Glauert - British Antarctic Survey
Richard Horne

The electron flux in the Earth's radiation belts is highly variable and understanding the causes of this is important as high radiation levels can cause temporary issues or even permanent damage to satellites orbiting through the belts. One driver of this variability is the interactions between electromagnetic waves and electrons which can lead to pitch angle, energy and mixed pitch angle and energy diffusion of the electrons.

Many codes that simulate the behaviour of the radiation belts use electron loss timescales to account for the loss of electrons. These timescales are typically calculated from pitch angle diffusion coefficients by assuming pure pitch angle diffusion. However, this assumption may not always be valid as interactions between some waves and electrons produce significant energy and mixed diffusion. Using diffusion models that include all the waves typically present in the radiation belts, we present a systematic investigation of where and when energy diffusion has a significant effect. Our results demonstrate that loss timescales calculated assuming pure pitch angle diffusion are a reasonable approximation inside the plasmasphere for energies of 300 keV and above. Additionally, pitch angle distributions calculated by neglecting energy diffusion are, with a few exceptions, a reasonable approximation to the full calculation, and mixed pitch angle and energy diffusion has the most significant effect on calculations outside the plasmapause.

Session 4: Planetary

Discovery of H_3^+ and infrared aurora at Neptune

Henrik Melin - Northumbria University
Luke Moore, Leigh N. Fletcher, Heidi B. Hammel, James O'Donoghue, Tom S. Stallard, Stephanie N. Milam, Michael Roman, Oliver R. T. King, Naomi Rowe-Gurney, Emma E. Thomas, Ruoyan Wang, Paola I. Tiranti, Jake Harkett, Katie L. Knowles

The bright and dynamic displays infrared auroral emissions were first observed in the infrared at Jupiter, Saturn, and Uranus over 30 years ago, but they have remained elusive at Neptune. The 1989 Voyager 2 flyby only saw faint hints of these emissions at the outermost planet, suggesting that perhaps the Sun's omnipotent influence on magnetospheric dynamics is perhaps less efficient in the outer Solar System. Auroral emissions in the infrared from the giant planets are from the molecular ion H_3^+, produced via the ionisation of molecular hydrogen, and these emissions can be used as a remote probe that sample the local conditions in the atmosphere, i.e., temperature and ion density. Using the unrivalled sensitivity of the James Webb Space Telescope, astronomers have now for the first time detected H_3^+ and distinct auroral emissions at Neptune for the first time. Surprisingly, these observations reveal that the upper atmosphere has cooled significantly since 1989, with a temperature over half of what Voyager 2 saw. The faint sunlight that the planet receives this far from the Sun provides minimal heating, and so the northern and southern lights are likely a significant heat source for the upper atmosphere, which can clearly change over timescales much shorter than the orbital period. These detections open up a new chapter in understanding the outermost planet of the solar system, and how the ice giants couple with their surrounding space environments.

Unveiling Uranus' Upper Atmosphere: H_3^+ Vertical Profiles from JWST Observations

Paola Tiranti - Northumbria University

H Melin, T S Stallard, L Moore, E M Thomas, K L Knowles

Uranus is an odd, mysterious and challenging planet to study. Its tumbling magnetic field, which switches polarities every half rotation (8.6 h), generates a dynamic and complex plasma environment which is still largely unknown and unexplained. JWST Programme #5073 observed Uranus continuously for a full rotation (17.24 h) to investigate ionospheric dynamics and temporal variations. JWST/NIRSpec covers a spectral region containing a number of H_3^+ emission lines with which we can probe physical and chemical properties of Uranus' ionosphere. Here, we present the first H_3^+ temperature and ion density vertical profiles above Uranus' planetary limb across different longitudes. This work provides crucial constraints for magnetosphere-ionosphere coupling models and offers new insights in the mechanisms driving Uranus' aurora. Additionally, these parameters will help quantify the role of auroral heating in shaping the overall planetary budget in the upper atmosphere.

JWST/NIRSpec observations of Jupiter's time variable H_3^+ auroral emissions

Oliver King - University of Leicester

J. D. Nichols, J. T. Clarke, I. de Pater, L. N. Fletcher, H. Melin, L. Moore, C. Tao

H_3^+ is one of the key components of the auroral emissions from the Solar System's giant planets. Produced from auroral precipitation ionising neutral hydrogen molecules, H_3^+ can have lifetimes $\sim$100 s in the Jovian ionosphere, leading to highly variable emission in active regions. H_3^+ radiates strongly in the near infrared with a temperature and density dependent spectrum, providing a significant source of cooling for the upper atmosphere of Jupiter

We present spatially and temporally resolved JWST observations of Jupiter's north polar auroral H_3^+ emissions. In January 2024, JWST/NIRSpec observed Jupiter, acquiring 3 – 5 µm spectra at 0.1 arcseconds/pixel ($\sim$300 km/pixel) with a time resolution of $\sim$30 s. This spectral range includes the bright H_3^+ emissions around 3.5 µm and 4 µm, which we can use to probe the H_3^+ density and temperature in the Jovian ionosphere. The high sensitivity, spectral, spatial and temporal resolutions offered by JWST offers an unprecedented window into the evolution and time variability of H_3^+ at Jupiter.

We have developed a custom Monte Carlo wrapper of the h3ppy Python package to fit and model the observed H_3^+ spectra and study the evolution of temperature and number density during transient events. We show that during transient brightening events column density rapidly increases (over $\sim$30s) while the temperature decreases, suggesting that brightening is caused by the production of a cooler layer of H_3^+.

Space Weather at Mars in May 2024

Mark Lester - University of Leicester

Sanchez-Cano, B., Lee, C., Ying Koo, L., Fowler, C., Semkova, J., Turner, A., Cicchetti, A., Hanna, C., Holmstrom, M., Joyce, S., Lillis, R., Meggi, D., Orosei, R., Owens M., and Stergiopoulou, K

The sun was particularly active during May 2024 resulting not only in brilliant auroral displays at Earth, but also significant space weather activity at Mars. We focus on the period between 10 May and 24 May at Mars, during which time the MARSIS radar on Mars Express, travelling over the South Pole, was subjected to radar blackouts as a result of the absorption of the radar signal by an enhanced ionospheric layer on the nightside. These radar blackouts have been demonstrated to relate to solar energetic particles through joint observations with MAVEN. The first evidence of a radar blackout in May 2024 is on the 14 May. However, other instruments, such as the Dosimeter on Trace Gas Orbiter, measure the largest event since being in orbit about Mars on the 20 May. We propose that the SEP responsible for these two events have different acceleration mechanisms and we discuss their impact at Mars.

The Martian Ionosphere revealed by 20 years of MARSIS data, and a helpful AI

Simon Joyce - University of Leicester

Simon Joyce, Katerina Stergiopoulou, Caitlin Hanna, Dhruv Singhve, Mark Lester and Beatriz Sanchez-Cano

The continued success of the Mars Express mission has produced a large dataset of Active Ionospheric Sounding (AIS) data which is used to study the Martian ionosphere. The size of this dataset, containing over 2 million ionograms across 20 years, provides an opportunity to study the behaviour of the ionosphere under various conditions. However, traditional analysis methods are too time consuming to fully exploit the dataset.

We present initial results of applying AI classification to the full AIS dataset. The current version of the classifier is able to classify all ionograms according to whether or not the ionosphere was detected. The complete classified dataset reveals global patterns in the ionosphere, and the behaviour of the ionosphere across the terminator. Preliminary results show seasonal variations in plasma structure across the terminator region. The AI classifier is also a powerful tool for identifying regions of interest for further investigation, for example, the occurrences of ionospheric layers on the night-side, which may be linked to magnetic field structures and auroral emission.

Characterising the spatiotemporal variability of the Martian topside ionosphere over crustal magnetic fields using near-simultaneous MEX and MAVEN observations.

Dikshita Meggi - University of Leicester

Sanchez-Cano, B., Fowler, C. M., Turner, A., Tian, R., Joyce, S., Lester, M., Xu, S., Fang, Xiaohua.

This study investigates the spatiotemporal ionospheric variability over crustal magnetic fields in the southern hemisphere of Mars and its unmagnetized regions. To resolve the dynamics multi-point observations are crucial. We identify events in 2015 when Mars Express and MAVEN spacecraft trajectories nearly overlapped. We select events in the dayside ionosphere over crustal field regions, in which at the same latitude are within $\pm 10°$ longitude, $\pm 5°$ solar zenith angle and ± 1 hour of UT. We create 2D ionospheric maps with radar sounding observations by MARSIS on Mars Express, and compare to in-situ MAVEN data. We observe the same plasma structure to move by $\sim 5°$ in latitude and 12 km in altitude over comparable crustal fields, on a $\sim$32-minute timescale. MEX and MAVEN observed electron density enhancements of 15% and 45% relative to a Chapman layer, respectively. The development of wave-like activity extending down to 150-200 km is also observed and will be discussed in this presentation.

Session 5: Thermosphere and Ionosphere

Dynamics of Space-Time TEC High Density Regions seen in JPL GIMs: Variations with Latitude, Season and Geomagnetic Activity

Martin Cafolla - University of Warwick

Sandra Chapman, Nick Watkins, Xing Meng, Olga Verkhoglyadova

Total Electron Content (TEC) is widely used to monitor the response to solar and geomagnetic activity in the ionosphere. Analysis of how TEC structures change over time can help mitigate the potential risks extreme space weather events pose on navigation and communication systems. Global Ionospheric Maps (GIMs) produced by the Jet Propulsion Laboratory (JPL) provide over 20 years of GNSS observations at a spatial resolution of $1° \times 1°$ longitude/latitude every 15 minutes from 2003. We translate these maps into geomagnetic coordinates centered about the sub-solar point and isolate the top 1% of TEC values to define High Density Regions (HDRs) of TEC. We demonstrate how this quantile threshold of TEC varies for data between the calendar years 2003 and 2022. We have written an algorithm that utilizes image processing tools in Python to detect and track HDRs. This gives a set of contiguous, uniquely labelled space-time TEC HDRs over 2 solar cycles, for which we explore the statistical dependencies upon latitude, season and geomagnetic activity. We find that HDRs distributed by peak area naturally divide into two populations, separated by an HDR area of 8.0×10^6 km^2. This is at the continental scale. We look at these populations under quiet ($Kp < 4$), moderate ($4 \leq Kp < 7$) and extreme ($Kp \geq 7$) storm conditions; sub-continental HDRs form primarily in four magnetic latitude clusters and follow lines of constant magnetic latitude. Continental scale HDRs form around the same latitudes as smaller HDRs but have more complex paths. Due to the statistical nature of our results, they reveal reproducible trends in the formation and subsequent motion of TEC enhancements and may be informative to predictive ionospheric models at these spatial/temporal scales.

The Necessary Synergy Between Modelling and Observations to Achieve the Goal of Forecasting Space Weather

Anasuya Aruliah - University College London
Ian McWhirter, Santosh Bhattarai, Elliot Dable, Laura Aguilar, Subir Mandal

The trickiest geophysical conditions to predict are moderate to extreme geomagnetic activity levels. The February 2022 loss of 38 of 49 Starlink satellites, launched during predictions of moderately active conditions alerted the satellite community to their need for better models. The first ever fine in 2023 by the US Federal Communications Commission of $150,000 for failing to remove a defunct satellite certainly focussed minds. There is a necessary synergy between modelling and observations. Empirical models (e.g. NRLMSISE-00, DTM and IRI) fit spherical harmonics to long-term databases of observations to estimate chemical composition, temperature and density for the neutral thermosphere and ionosphere. Whereas physics-based models use these same databases to provide boundary conditions and to inspire new insights. Meanwhile observations from ground-based instruments (e.g. Fabry-Perot Interferometers, Incoherent and Coherent Scatter Radars, magnetometers and riometers) and satellite instruments (e.g. Langmuir probes, mass spectrometers and radiometers) are interpreted using physics-based models to understand underlying physical and chemical mechanisms. Here we present a comparison of observations and models to show the necessity of a global network of observatories for space weather monitoring, that is equivalent to that used by the meteorological community. Climate change is seen as a cooling and contracting of the thermosphere. The current solar cycle looks to be radically different from its predecessor, such that we experienced the largest geomagnetic storm for over two decades in May 2024, which brought gorgeous auroral displays to middle latitudes, and loss of satellite tracking that took days to recover. The consequences of atmospheric drag requires urgent attention for control of the exponentially growing satellite mega constellations in Low Earth Orbits, and also space junk. Data assimilation of near real-time observations into physics-based models is the best that space weather forecasting can offer. Nature is complicated, and we cannot afford to stop observing.

Instrumental Bias with ruin your Data Assimilation

Benjamin Reid - University of Birmingham

The goal of data assimilation is to combine both models and observations to produce a representation of a complex system which is better than either separately. Most data assimilation techniques can be thought of as a statistical method to weight the contribution from observations and the contribution from models based on their respective errors. These techniques generally assume that the errors are due to some noise process, and have zero mean. There is little study of what occurs if this zero-mean assumption is violated.

This presentation will show the outcome of an ionospheric data assimilation experiment where several international calibration standards are compared, and all are shown to have significant systematic errors. These improper calibrations cause errors in reconstructed electron density of over 100%, when compared to in-situ measurements. This can be addressed by including instrument calibration self-consistently in the data assimilation state.

Statistical modeling of high latitude sporadic-E climatology: A Sporadic-E module for E-CHAIM

David Themens - University of Birmingham

C. Arras, B. Reid, A.M. McCaffrey, D. Sydorenko, R. Rankin, K. Meziane, J. Ruck, and P.T. Jayachandran

Sporadic-E, thin metallic ion layers in the lower ionosphere compressed via neutral wind shears or externally imposed electric fields, pose considerable challenges for High Frequency (HF) radio propagation modeling. As their name suggests, these layers can appear to be quasi-stochastic, requiring both an abundance of metallic ions and a mechanism through which to compress them into thin, dense layers; as such, modeling Sporadic-E has been a persistent and long-standing challenge in ionospheric modeling. With physics-based models now beginning to develop the capability to capture the processes that produce these structures, we will here revisit empirical modeling of Sporadic-E at high latitudes and examine the capability of existing measurements to adequately constrain an empirical model. Using Radio Occultation (RO) measurements of these Sporadic-E layers, we have constructed a probabilistic model of Sporadic-E, its altitude, and its intensity over high latitude regions. This presentation will provide an overview of this model and examine its performance via independent validation against both other RO and ground-based observations. We will furthermore examine the modeled behaviour and use the model to understand the climatological dynamics of Sporadic-E at high latitudes. Further discussion will explore how to implement this model within the existing Empirical Canadian High Arctic Ionospheric Model (E-CHAIM) and will explore the interplay between magnetospheric driving and thermospheric tides in controlling the convergence necessary to form Sporadic-E layers at high latitudes.

Multiple Structuring Processes in Fine Scale Aurora

Kamalam Thillaimaharajan - University of Southampton

Daniel Whiter, Mervyn Freeman, Nicholas Brindley, Robert Fear, Betty Lanchester

The structuring mechanisms for the fine scale aurora (spatial scales of few kilometres or less) are not well understood, and it is not clear whether the spatial brightness variations are linked to flux or energy of precipitating electrons or both. We use data from a high resolution multi spectral imager called ASK (Auroral Structure and Kinetics) from which we obtain energy, energy flux, and number flux of the precipitating electrons. We examine spatial histograms of these parameters and find that the energy flux distribution typically consists of two peaks, which may be linked with different simultaneous acceleration mechanisms or electron populations. We have also observed three peaks (trimodal) and four peaks (quadrimodal) in the histogram in some events. We have also noticed that for the same frame (time), the histograms of energy flux and number flux can have different numbers of peaks. These findings can provide useful information to constrain theories and to understand the multiple structuring processes present in fine scale aurora.

Diurnal Periodicity in Earth's radio emissions

Alexandra Fogg - Dublin Institute for Advanced Studies

Caitríona M. Jackman, Simon J. Walker, Matthew J. Rutala

Planetary radio emissions have potential as a very valuable remote diagnostic of planetary rotation rates as well as magnetospheric dynamics. Auroral Kilometric Radiation (AKR) is Earth's strongest natural radio emission, and is anisotropically beamed from a source locked to auroral latitude magnetic field lines. These field lines are tied to the deep interior of the rotating planet, and hence it is theorised that an observer at a fixed local time will observe a diurnal variation in AKR power, as if the Earth and its emission were a lighthouse. In this study we explore this proposed 24 hour periodicity in AKR power using a decade of observations from Wind/WAVES.

Session 6: Atmosphere

Gravity Wave Variability in the Arctic Mesosphere

Subir Mandal - British Antarctic Survey

Tracy Moffat-Griffin, Corwin J. Wright, Pierre-Dominique Pautet, Mike J. Taylor, Takuji Nakamura, and Andrew Kavanagh

We have investigated the variability of short-period (<1 hour) atmospheric gravity waves (AGWs) in the high-latitude mesosphere - lower-thermosphere - ionosphere (MLTI) region. These small-scale AGWs, which contribute approximately 70% of the AGW momentum budget, play a crucial role in energy and momentum transport in the Earth's upper atmosphere. To analyse AGW activity, we utilise airglow images of OH (3,1) band and Na emissions measured during the Arctic winter from Norway. These images are processed using 3D Fourier Transformation (Matsuda-transform) to derive phase velocity spectra, allowing us to quantify AGW spectral power across different phase speed ranges and propagation directions. This has allowed us to examine the intra-day, day-to-day, and interannual variability of AGWs. To investigate the observed AGW variability, we incorporate ERA5 wind datasets (lower atmosphere), meteor radar winds (airglow emission altitudes), and the Arctic Oscillation Index, providing insights into the drivers of AGW activity during Arctic winter. This research is supported by the MesoS2D (Mesospheric Sub-seasonal to Decadal Predictability) and DRIIVE (Drivers and Impacts of Ionospheric Variability with EISCAT-3D) projects. We will present key findings in detail during the meeting.

A Publicly Available 70-year simulation of the whole atmosphere

Matthew Brown - University of Birmingham

Sean Elvidge, David R. Themens

The Whole Atmosphere Community Climate Model with thermosphere and ionosphere extension (WACCM-X) has been used to simulate the global atmosphere from the year 1950 to 2024 at hourly, 1.9 by 2.5-degree resolution. This, over 70 TB, dataset has been made publicly available to enable further research without the need to run the model. This can support research areas such as long-term trends, over seven decades of geomagnetic storms, and machine learning. Variables stored include neutral total and constituent densities, electron density, winds and temperatures. As well as describing the methodology of the 70+ year WACCM-X run, this paper also shows the long-term underprediction of the model's neutral density compared to CHAMP derived densities. Additionally, a discussion on the range of possible thermospheric winds, and their impact on satellite orbit determination is presented.

Investigating the impact of energetic particle precipitation on middle atmosphere climate chemistry using high altitude measurements of NO in conjunction with AMPERE.

Rebecca Coulson - University of Leicester
Darren Wright and Steve Milan

The influence of geomagnetic activity on the coupled magnetosphere-ionosphere-neutral atmosphere system has significant impact on middle atmosphere climate chemistry. It is now considered a driver for influencing the concentration of chemical species such as NO which can act catalytically to deplete ozone. This is important as its removal in the stratosphere can have vital consequences for the environment and heating of our planet. We present a multi-instrumental study which combines satellite measurements linking the energy transfer from Energetic Particle Precipitation (EPP) to the formation of nitric oxide (NO) in the mesosphere via the "direct effect" and stratosphere via the "indirect effect". The study utilises the Solar Occultation For Ice Experiment (SOFIE) dataset, extending the work by Smith-Johnson et al. (2017), to determine the relative change in NO density over the solar cycle from 2008 to 2019. We have also been able to determine the average response of NO within the mesosphere and stratosphere as a result of geomagnetic storms between 2008 and 2014, through application of a Superposed Epoch Analysis. This demonstrates a strong direct feature at the onset of the storms in both hemispheres. However, the indirect response varies, extending lower into the stratosphere in the southern hemisphere than the northern hemisphere. This analysis is complemented by field aligned currents derived by the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) to analyse the variability in the NO density following periods of intense geomagnetic activity and associated EPP. This will provide a greater understanding of the energy transfer and coupling mechanisms between the magnetosphere, Mesosphere and Lower thermosphere regions (MLT) and the middle atmosphere and offer insights on the impacts of space weather on Earth's climate.

Operational Impacts of Geomagnetic Storm-Induced Atmospheric Density Changes: Insights from the May 2024 Gannon Geostorm

Laura Aguilar - University College London
C. Constant. I. Brown, E. Dabble, M. Ziebert, S. Battharai, A. Aruliah

The interaction between Low Earth Orbit (LEO) satellite dynamics and the thermosphere remains a critical area of research, particularly under varying space weather conditions. Atmospheric density variations driven by solar and geomagnetic activity significantly influence orbital decay rates, manoeuvring requirements, and long-term satellite lifetime predictions. This study employs a dual-method approach, first utilizing EISCAT radar observations to investigate upper atmospheric variability in the Arctic region under quiet geomagnetic conditions. And second, Two-Line Element (TLE)-SGP4 data analysis to assess the orbital evolution of 20,655 LEO satellites after the onset of the Gannon geomagnetic super-storm that hit the Earth in May 2024. By examining satellite decay patterns under such solar conditions, this research identifies key relationships between altitude, eccentricity, and orbital drag effects, revealing that satellites below $\sim$722 km altitude experience significantly enhanced decay during geomagnetic storms, with a maximum decay of 83.82km, but an average decay of 0.33km, while most satellites decay between 0-0.20km. Those orbiting above $\sim$722km remain largely unaffected by atmospheric drag effects. The resilience of effective constellation manoeuvring after the storm is clearly present for Oneweb, maintaining stable altitude, followed by Starlink exhibiting a broader decay distribution despite important adjustments. CubeSat-based constellations like Planet Lab and Spire, lacking active propulsion, were among the most affected. Regression modelling of the TLE-SGP4 derived orbital parameters explain 21.5% of the variance in decay rate observations. Further Machine Learning applications suggest that altitude and eccentricity are primary drivers of orbital clustering, while BSTAR's role in predicting decay remains highly context-dependent. These findings lay the foundation for three key research directions: (1) developing targeted alerts for post-storm orbital adjustments based on inclination-altitude studies, (2) improving long-term orbit lifetime estimation models, and (3) refining the dynamic definition of the Top of Atmosphere (TOA) through a closed-loop approach integrating orbital dynamics and geophysical data. This work is directly relevant to satellite operators, space weather monitoring agencies, and atmospheric modelers, providing a data-driven framework for improving pre and post-storm manoeuvering strategies, enhancing space situational awareness, and refining atmospheric models used for orbit prediction. The inherently multidisciplinary nature of this research underscores the need for strong collaboration between academia, operational space agencies, and industry stakeholders. As the population of LEO satellites continues to grow, ensuring the resilience and sustainability of space operations requires integrating research findings into real-time operational decision-making, reinforcing the Research-to-Operations-to-Research (R2O2O2R) cycle to continuously improve the predictive capabilities of both orbital and atmospheric models."

Session 7: Heliosphere

Differences in solar wind measurements between L1 (OMNI) and near-Earth (Cluster spacecraft) affecting the accuracy of magnetospheric coupling functions

Neil Rogers - Lancaster University
James Wild, Adrian Grocott

Various aspects of Earth's magnetospheric dynamics and geomagnetic activity may be statistically inferred from measurements of the upstream solar wind (SW) at the L1 libration point. SW-magnetosphere coupling functions relate plasma metrics (e.g., velocity, density) and the interplanetary magnetic field to the terrestrial responses (e.g., geomagnetic indices, or cross-polar cap potential (CPCP)). However, the effectiveness of such predictions is limited by uncertainties in the propagation time offsets and spatio-temporal incoherence of solar wind structures as they propagate between L1 and the Earth. We quantify these uncertainties by comparing NASA's OMNI solar wind measurements (Papitashvili, 2024) near L1, time-shifted to a model Bow Shock nose location, with a new 22-year database of ESA Cluster-1 and Cluster-3 measurements for which these satellites were located inside the pristine solar wind (over 5000 hours in total). Methods for determining bow shock crossings and filtering the Cluster measurements are described, including the filtering of measurements in the quasi-parallel foreshock. We further examine the impact of uncertainties on predictions of CPCP (derived from SuperDARN radar measurements (Thomas and Shepherd, (2018)) and the Polar Cap index combination, PCC (Stauning, 2021), in response to the solar wind 'reconnection electric field' EKL (Kan and Lee, 1979) coupling function and discuss whether the saturation of these responses may be explained by statistical uncertainty in the measurement of EKL.

Automated Identification of Features in Velocity Distribution Functions during Magnetic Reconnection from the Magnetospheric Multiscale (MMS) Mission

Cara Waters - Imperial College London
Jonathan P. Eastwood, Naïs Fargette, Harry C. Lewis, Harley M. Kelly, Martin O. Archer

Magnetic reconnection is a fundamentally important process in space plasmas due to its role in changing magnetic topology and the associated release of energy in the form of heated plasma exhausts. Within these exhausts we often observe complex structure in velocity distribution functions (VDFs) that are the signature of a variety of underlying particle acceleration processes. For example, counter-streaming beams are often seen in ion VDFs, and crescent structure is observed in electron VDFs in the electron diffusion region. Several key questions in magnetic reconnection now require detailed examination of the evolution of VDFs in three dimensions through an entire event. In the case of Magnetospheric Multiscale (MMS), this can be extremely time-consuming given the high time-cadence of the measurements. To address this problem, here we present a new approach to automating VDF analysis. We propose a combination of machine learning methods to identify separate features within ion VDFs. We demonstrate that an unsupervised machine learning process based on non-linear dimensionality reduction and clustering algorithms can quickly resolve distinct populations of ions in the VDF by applying this to a case study using MMS data at the magnetopause. We demonstrate that this method allows for rapid analysis of VDFs recorded during a reconnection event and reveals new information about how the complexity of the VDF and key properties of its component plasmas vary. We discuss possible future applications of this work, for example in the solar wind, noting that the method does not require any assumption about the shape of the underlying distributions and so in principle can identify more complex structure than combinations of e.g. Maxwellian beams.

Investigating the structure of magnetised Coronal Mass Ejection models

Helen Norman - University of Warwick
Ravindra Desai, Tony Arber, Hannah Rüdisser, Emma Davies

Coronal Mass Ejections (CMEs) are large parcels of plasma expelled from the sun that carry a magnetic field, and cause space weather effects when they impact the Earth's magnetosphere. In-situ observations and geo-effectiveness of these phenomena can be highly varied and difficult to reproduce with models, meaning that we do not have a long term accurate forecast of space weather impacts. The signatures of CMEs can also be seen in decreases of the ambient Galactic Cosmic Ray (GCR) background, known as Forbush decreases (Fds). These have been studied since the invention of neutron monitors but the mechanisms of interaction with CMEs that produce these decreases are not completely understood. Current attempts to model Fds have only included shocks or ejecta of CMEs separately and therefore do not capture the full magnetic geometry of many CMEs. We present work modelling Fds with full-orbit test particles, using several analytic and magnetohydrodynamic models of CMEs with magnetic fields. Through comparing these CME models, and their particle data, we aim to gain a greater understanding of how to more accurately reproduce observed CME magnetic structure and in-situ particle data in forecasting and scientific models.

Using Cluster as a Solar Wind Monitor to Investigate Uncertainties in OMNI Time Propagation

Joel Richardson - Lancaster University

Magnetospheric dynamics at Earth are driven by coupling between the magnetised solar wind and the magnetospheric magnetic field and plasma. Numerous studies reveal that the magnetosphere exhibits a non-linear response to solar wind drivers, with saturation observed under strong external forcing. Whilst this saturation could be the consequence of a physical process, another possibility is that the uncertainties in the time delays applied by OMNI, to propagate measurements from the L1 Lagrange point to the bow shock nose, introduce a "regression to the mean" effect. Instead, Cluster's orbit allows in-situ monitoring of upstream solar wind conditions for part of each orbit during several months of each year. When located in the solar wind, delays between Cluster and the bow shock are of the order of few minutes rather than an hour for OMNI data. By using ESA's Geospace Region and Magnetospheric Boundary identification (GRMB) database, we can filter Cluster data to isolate pristine solar wind data and compare these measurements with OMNI predictions to investigate inaccuracies in OMNI's time propagation. Early findings will be presented that outline the comparison between the datasets, discussing potential implications for investigating solar wind–magnetosphere coupling.

Extended Lead-Time Geomagnetic Storm Forecasting with Solar Wind Ensembles and Machine Learning

Matthew Billcliff - Northumbria University

Andy Smith, Matt Owens, Luke Barnard, Wai Lok Woo, Nathanial Edward-Inatimi, Jonathan Rae

Geomagnetic storms are large disruptions of the magnetosphere, which can disrupt satellites, communications systems, and power grids, causing significant technological and economic impacts. Current forecasting models utilise L1 satellite data, constraining lead time to a few hours', often insufficient for effective mitigation. To extend lead times, we are investigating how to extend the lead times of these forecasts with solar data. Associated spatial and propagation uncertainties of solar data are captured with a solar-wind ensemble of the computationally efficient one-dimensional HUXt numerical model, rather than a 3D-MHD based model. The solar-wind ensemble is processed through logistic regressions, weighting ensemble members by comparison with historical observed velocities, and filtering out high error ensemble members. The optimal ensemble size, found to be 90 members, balances computational efficiency and accuracy, capturing key solar wind variability. Our approach demonstrates substantial predictive capability, achieving an accuracy of 69.6% and an F1 score of 0.636 for storms defined as maxHp30 $>$ 4.66 within a 24-hour forecast window. We assess the proposed model's performance across various storm intensities and lead times, with highest accuracy achieved on extreme storms, maxHp30 $>$ 8, at 6 hour lead time of 93.8%, and F1 Score of 0.933. The reason for this high performance is that the ML component realises that the ambient solar wind ensemble can't match the observations, so there is probably a CME. Overall, we show that the coupled numerical model and machine learning approach has great potential to increase our lead time on geomagnetic storms.

Cause-mic Universe: Causal Analysis of Solar Variability

Nachiketa Chakraborty - University of Reading

Space-weather is the result of rapid variability in the solar magnetic field which can severely affect space- and ground-based infrastructure. Two closely related space-weather phenomenon, flares and coronal mass ejections (CMEs), occur when free magnetic energy is converted into photons and kinetic energy, respectively. The sequence of events/processes leading to these outbursts and their "causal drivers" (or triggers) are challenging to predict. Particularly, when different drivers combine to produce effects different from their individual influence. We need causal inference methods to disentangle such (direct vs indirect, individual vs synergistic) effects. We demonstrated this for solar wind forecast uncertainty. Now we wish to apply the similar framework to other aspects of solar variability including flares. We discuss the prospects of doing this both from a scientific perspective but also potentially impacting forecasting.

Session 8: Waves

Modelling the Statistics of Whistler Mode Chorus: Wave Action models in Near-Earth space

Daniel Ratliff - Northumbria University
Oliver Allanson, Julia Stawarz, Dovile Rasinskaite, Suman Chakraborty

Whistler-Mode Chorus (WMC) waves are an important contributor to space weather, as intense WMC activity has the potential to energise particles to hazardous levels. This has motivated several studies into their statistics to determine when and where large amplitude WMC activity is expected and inform how wave activity is implemented in radiation belt modelling. Conventionally believed to be largely Gaussian in nature, WMC data shows active wave regions have significantly non-Gaussian statistics in tandem with large amplitude chorus activity – so what drives this change in statistical nature and how might we model it?

This talk presents a theoretical framework, informed by Van Allen observations, to produce and explore WMC wave statistics via a wave action model. This first-generation of the model describes the energy transfer between parallel-propagating WMC waves in the magnetosphere via 4-wave interactions facilitated by wave-particle interactions. This approach not only generates frequency and amplitude distributions representative of the non-Gaussian statistical observations within the Van Allen probe dataset but links these statistical changes to a key non-dimensional index. This index, like that used by NOAA and ECMWF to characterise extreme ocean dynamics, provides a simple "yardstick" in identifying regions of increased (and possibly dangerous) wave activity in WMC wave regions.

Diffusion coefficients for resonant relativistic wave-particle interactions using the PIRAN code

Oliver Allanson - University of Birmingham
Thomas Kappas, James Tyrrell, Gregory Cunningham, Adrian Garcia, Sean Elvidge

Quasilinear diffusion coefficients can be used to characterise the statistical response of charged particles to perturbations by plasma waves, via resonant wave-particle interactions. The calculation of these coefficients is sufficiently complicated and arduous to render it prohibitive to many potential users, because of the expense in time spent developing the code. We present and describe the open-source PIRAN software package ('Particles In ResonANce'). This package is written using Python, has comprehensive documentation, and allows the user to calculate local and bounce-averaged relativistic diffusion coefficients in energy and pitch-angle space via the two main current proposed methods in the literature.

Analysis of a ULF power enhancement at geosynchronous orbit following an extreme IMF southward turning

Chiara Lazerri - University College London

Colin Forsyth, Andrey Samsonov, Andrew Fazakerley, Martin Archer

Magnetospheric ultra-low frequency (ULF) waves are an important contributor to energy transport across the system and a driver of energisation and loss of radiation belt electrons. In this work, we analyse the enhancement in ULF wave power observed near noon by the GOES 13 and 15 spacecraft, following a large and rapid southward turning of the interplanetary magnetic field (IMF). We find these magnetic field oscillations to be monochromatic, in the PC5 range (i.e. 2-7 mHz), and mostly compressional, although with a significant radial component. After the southward turning, we also determine the presence of multiple magnetopause crossings in THEMIS A, D, and E, located in the post-noon magnetopause, which indicate an oscillatory behaviour of the boundary. Magnetospheric PC5 waves can be driven by multiple internal or external mechanisms. In this talk, we'll investigate the potential causes of the PC5 wave power enhancement, including direct driving by the solar wind (e.g. dynamic pressure quasi-periodic fluctuations), magnetopause motion (e.g. Kelvin-Helmholtz waves, magnetopause standing eigenmodes), and magnetic reconnection. Internal sources such as drift-mirror instability and drift-bounce resonance will also be considered.

Investigating chorus wave peak amplitudes on short timescales during the Van Allen Probes era

Rachel Black - University of Exeter/British Antarctic Survey

Oliver Allanson, Nigel Meredith, Andrew Hillier, Dave Hartley

Earth's radiation belts can be described by two zones containing energetic charged particles; a more stable inner belt, and a highly dynamic outer belt. Wave-particle interactions have been identified as one of several processes responsible for the dynamics of electron populations within the outer region. The most common method used by the international community for reproducing radiation belt dynamics involves Fokker-Planck diffusion models. Whilst, in many cases, these models effectively describe the global changes and interactions within the region, the Fokker-Planck approach depends upon a quasilinear theory. This assumes "small" wave amplitudes; however, recent observations have shown that this assumption may not always hold, with chorus waves being one of the most notable cases of high-amplitude waves.

Within two datasets of differing resolutions, the Van Allen Probe satellites provide multiple years' worth of information on the various waves and background fields inside the radiation belts. In this work, we present preliminary results of investigations comparing the lower resolution 'survey mode' data, with the high-resolution 'burst mode' data, captured during the mission. In particular, the work focusses on identifying chorus wave events in both datasets and assessing how the underlying variability may alter our interpretations of the wave properties. Utilizing the higher resolution data in conjunction with the survey data allows closer inspection of the larger amplitude waves, and their potential implications for energetic electron dynamics in radiation belt modelling.

Theory and Modelling of Large Scale Plasmapause Surface Waves

Tom Elsden - University of St Andrews
David Southwood, Oliver Allanson, Martin Archer, Michael Hartinger, Andrew Wright

The plasmapause in Earth's magnetosphere represents the boundary between the plasma which co-rotates with the Earth (plasmasphere), and the more tenuous plasmatrough outside. The density change across the plasmapause can be large, changing by approximately 1-2 orders of magnitude depending on the prevailing conditions. This would suggest it to be a location where magnetohydrodynamic (MHD) surface waves can form, and indeed, this has been proposed in previous works to explain ultra-low frequency (ULF) wave observations around the plasmapause location. The main question is how such a large scale surface wave on the plasmapause would be excited. In this talk, I'll present a model whereby surface waves at the plasmapause are driven by energy input from the magnetopause through solar wind driving. I'll show how we derive an analytical form for the amplitude of these modes with this new driven boundary condition at the magnetopause. We test the excitation of these waves in several MHD simulations, where the model geometry, wavenumbers and temporal dependence of the magnetopause driver are varied. We establish that surface waves on the plasmapause can be excited by driving from the magnetopause, and that this still occurs with impulsive and continuous broadband driving. The azimuthal scale of the wave is a critical factor for this excitation, with longer azimuthal scales more favourable for driving larger amplitude surface waves. This mechanism provides new insight for how large scale and large amplitude ULF waves can access the inner magnetosphere, with potential implications for their interaction with radiation belt particles.

MMS Observations of Surface Waves on the Dusk Flank Magnetopause During Northward IMF

Tom Wakefield - University College London
Andrew Fazakerley, Colin Forsyth

During prolonged periods of northward interplanetary magnetic field (IMF), the Earth's plasma sheet becomes significantly colder and denser. The Kelvin-Helmholtz instability (KHI) at the magnetospheric flanks and dual lobe reconnection (DLR) at high latitudes are proposed mechanisms for solar wind entry, contributing to the formation of this cold, dense plasma sheet (CDPS).

On 15 October 2019, during 25 hours of near-continuous northward IMF, the four Cluster spacecraft observed an unusually cold (Te $<$ 100 eV) and dense (Ne $>$ 2 cm^{-3}) mid-tail plasma sheet. Simultaneously, the four MMS spacecraft observed a thick ($>$3 RE) low-latitude boundary layer (LLBL) inside the dusk flank magnetopause, consisting of CDPS-like material. As the spacecraft exited the LLBL into the magnetosheath, they observed semi-periodic oscillations in the magnetic field, plasma density, and temperature, indicative of multiple magnetopause crossings.

Analysis of these crossings identifies KH surface waves propagating tailward with a steepened leading edge. Wave structure and stability analysis suggest the KH waves are in the early nonlinear phase, where vortex-induced reconnection could facilitate magnetosheath plasma transfer across the magnetopause.

We assess the roles of DLR and KHI in forming this flank LLBL and discuss how magnetospheric convection cycles might subsequently couple these processes to the mid-tail plasma sheet.

Session 9: Geomagnetism and GICs

Why do Some Sudden Commencements Generate "Disproportionate" Geomagnetically Induced Currents?

Andy Smith - Northumbria University
C. J. Rodger, K. M. Pratscher, D. H. Mac Manus, I. J.Rae, D. Ratliff, M. A. Clilverd, E. Lawrence, C. D. Beggan, G. S.Richardson, A. R. Fogg, D. M. Oliveira, T. Petersen, M. Dalzell

A key space weather hazard is the generation of Geomagnetically Induced Currents (GICs) in grounded, conducting infrastructure (e.g., power networks). These GICs are driven by the changing magnetic field at the surface of the Earth and in extreme cases can cause disruption or even damage to power systems. Due to a sparsity of GIC measurements around the globe, the rate of change of the magnetic field (e.g., H') is often used as a proxy, under the assumption that larger rates of change of the geomagnetic field will be related to larger GICs. While a range of magnetospheric processes can result in large GICs, in this work we focus on one: Sudden Commencements (SCs). SCs are rapid, coherent changes in the geomagnetic field caused by the impact of a large increase in solar wind dynamic pressure (e.g., an interplanetary shock). Globally, in one-minute cadence ground magnetic field data SCs appear relatively homogenous, lasting only a few data points. However, it has previously been found that in New Zealand SCs on the dayside have been linked to 30% larger measured GICs for a given H'. We investigate a deceptively simple question: why?

In this work we examine the sub-minute structure of SCs in New Zealand and their impact on the resulting GICs. We introduce an analytical model that describes the key features of the magnetic field signature, allowing us to fully describe the key features of an SC. The use of parameters (e.g., maximum H') from the fitted analytical model strengthens the correlation between maximum H' and GIC during SCs, but leaves remnant dependencies which are yet to be explained. We conduct synthetic experiments with our analytical SC model and a high resolution magnetotelluric-derived map of the southern part of New Zealand to examine which properties of an SC make it more-likely to cause disproportionately large GIC.

Field-aligned currents observed from the ground

John Coxon - Northumbria University
James Weygand, Denny Oliveira

We employ ground magnetometers in North America, Greenland, and Antarctica and use the Spherical Elementary Current (SEC) technique in order to investigate the Birkeland currents (also known as field-aligned currents) flowing between January 2015 and December 2016. We convert the measurements into altitude-adjusted corrected geomagnetic (AACGM) coordinates, and then average across each day for which we have data to obtain global maps in both the Northern and Southern Hemispheres for the period in question, before statistically examining the data.

Spatial-temporal implications of high latitude magnetometer measurements

Kendra Gilmore - Northumbria University
Sarah Bentley, Andy Smith, Clare Watt

Understanding the magnetic field and how it changes is a key component in advancing our understanding of the near-Earth environment. In many cases, magnetic indices like Kp, Dst, and AE are used to investigate and predict Space Weather and magnetospheric behaviour. These indices aggregate information from several magnetometers into one value at the cost of spatial-temporal resolution. However, the morphology of the auroral oval is location and time dependent. A combination of different magnetometer stations would provide the necessary spatiotemporal information needed for improved realistic auroral predictions. To show the benefit of local magnetometers in contrast to global descriptions, we first compare the power spectra, as these contain information on the temporal structures measured by the magnetometers. We continue our investigation focusing on diurnal periodicities, uncovering that high-latitude stations exhibit significant non-linearity in the harmonics of the diurnal periodicity in comparison to global as well as indices-based descriptions. We suggest that the driver for this non-linearity is linked to the location of the auroral oval, and its signature is lost in global descriptions. This presents the opportunity to use a network of magnetometer stations to constrain the location of the auroral oval without the need for satellite-based imaging of the polar region.

Investigating the seasonal influence on the auroral electrojets using magnetically conjugate measurements in Greenland and the British Antarctic Territory

Mervyn Freeman - British Antarctic Survey

Season is known to influence the strength of ground geomagnetic disturbances associated with the substorm and convection electrojets and therefore be an important factor in identifying substorms. Previous studies of this effect have almost exclusively used northern hemisphere magnetometer data which permits only statistical analysis because a given hemisphere is in only one seasonal state at a given time. Here instead we use magnetically conjugate observations in order that magnetospheric events can be simultaneously seen under the different seasonal states of the opposite hemispheres. The data used are from the Danish Meteorological Institute magnetometer chain in Greenland and the British Antarctic Survey magnetometer chain in Antarctica which cover a common extended corrected geomagnetic (CGM) latitude range between 65 and 78 degrees at approximately 2 degrees resolution. We find that: (i) Both northward and southward geomagnetic disturbances between 65 and 78 degrees CGM latitude are very similar in both hemispheres around equinox when solar illumination and conductance are similar. (ii) Northward geomagnetic disturbances between 65 and 78 degrees CGM latitude are generally larger in summer hemisphere. This is consistent with the eastward convection electrojet being driven by the solar wind electric field and its conductance increasing with stronger solar illumination. (iii) Southward geomagnetic disturbances are generally less extreme in the summer hemisphere for ¿73 degrees CGM latitude in Greenland and between 69-73 CGM latitude in Antarctica. This appears consistent with the amplification of the substorm electrojet by the Cowling effect due to a latitudinal gradient in ionospheric conductance. In some cases large geomagnetic bays seen in one hemisphere are completely suppressed in the opposite hemisphere, highlighting a potential problem in our current ability to reliably identify substorms.

Importance of one second magnetometer data when investigating geomagnetic disturbances

Gemma Bower - University of Leicester
Milan, S.E; Imber, S; Beggan, C; and Gjerloev, J.W

Geomagnetic disturbances (GMDs) are rapid changes in the magnetic field of the Earth that are necessary for the creation of geomagnetically induced currents (GICs). GICs are currents that are induced at the surface of the Earth and are known to cause damage to infrastructure such as power grids and pipelines. One-minute resolution ground magnetometer data has been available for decades and has been the basis of many studies showing the frequency and intensity of GMDs. In recent years one-second resolution has become available via SuperMAG. We compare the number of GMDs identified in data from the stations that provide one second SuperMAG data to the number found in the one-minute data and ten second averaged data from these stations. We find that the one-second data consistently records higher magnitude GMDs and that difference in number of high magnitude GMDs in the second data compared to the minute data is exaggerated at lower latitudes. This therefore shows the importance of one second resolution data in detecting the most rapid changes in the magnetic field.

Exploring the impact of railway track circuit design on their susceptibility to geomagnetic disturbances

Cameron Patterson - Lancaster University
J. A. Wild, D. H. Boteler

DC track circuit signalling systems are widely utilised across Great Britain's AC-electrified railway lines, and their ability to accurately detect trains is crucial for the smooth and safe operation of a railway network. These systems detect the presence or absence of trains in sections along a line using electric circuits, as such, they can be susceptible to interference from geomagnetically induced currents. Modelling has been used to explore which parameters of track circuit design have the largest impact on the technology's susceptibility to geomagnetic disturbances. The parameters studied included the section length, leakage to the ground, which is strongly dependent on ground resistivity, and the differing polarity configurations employed in adjacent track circuits. Results shows that section length had the largest impact, with longer sections being more at risk. Leakage also had a significant effect, with increased leakage, i.e., less resistive ground, increasing susceptibility to misoperation. Results from this study will be presented.

Poster Presentations

Extreme Neutral Temperature Changes in the Aurora

Kate Barton - University of Southampton
Daniel Whiter, Andrew Kavanagh, Srimoyee Samaddar

The aurora is a significant source of heat in the high latitude ionosphere and thermosphere. We present results from a new technique to map neutral temperatures at high spatial and temporal resolution (0.05s) by imaging temperature dependent auroral emissions from the N2 1P band system. The resulting maps show rapid temperature changes on the order of several hundred Kelvin. The technique measures neutral temperatures at the altitude of the auroral emissions so the observations require careful interpretation to separate neutral temperature changes from spatial variation in auroral altitude across each image. Temperature height profiles are obtained by binning pixels by electron precipitation energy to obtain average neutral temperatures at multiple specific altitudes. The resulting profiles show large neutral temperature changes across all altitudes between 100 km and 200+ km. These are compared to ion temperature profiles from the EISCAT Svalbard radar to better understand Joule heating and ion-neutral coupling in the extreme electrodynamic environment surrounding aurora.

The energy transfer rate of coherent structures in the kinetic and inertial ranges of solar wind turbulence

Alina Bendt - University of Warwick
Sandra Chapman

Solar Orbiter observations provide an unprecedented opportunity to study plasma turbulence in the solar wind. On magnetohydrodynamic scales intermittent structures mediate the cascade, due to non-linear wave-wave interactions and coherent structures. Those coherent structures are often quantified and identified by the Partial Variance Increment (PVI). We obtain magnetic field fluctuations from observations of homogeneous turbulence by wavelet decompositions which preferentially resolve either signatures of coherent structures or wave-packets. Comparing the PVI obtained from both wavelet decompositions determines the PVI threshold above which fluctuations may be coherent structures. We find a single PVI threshold in each of the kinetic and inertial ranges above which coherent structures typically dominate. This suggests a ubiquitous constraint on the turbulent phenomenology. The energy transfer rate associated with coherent structures across different plasma conditions is presented. The behaviour is found to differ with plasma parameters. This can then inform estimates of the heating rates of the solar wind due to the turbulence.

Thermospheric impacts and modelling of the May 2024 G5 and October 2024 G4 geomagnetic storms

Matthew Brown - University of Birmingham
Sean Elvidge, David R. Themens

As the largest storm in the mega-constellation age, the May 2024 G5 storm had the potential to produce significant impacts upon the thermospheric environment and objects within low Earth orbit. The October 2024 G4 storm provides another major storm within a similar satellite environment.

Two-Line Elements (TLEs) through the storms reveal drag increased from background levels for around a day after storm onset, with objects whose perigees are as high as 900 km also experiencing this. They also reveal the Starlink constellation rapidly responded through orbit-raising. The TLEs of objects immediately post-storm were notable for delayed publication and outliers, with them reporting too low semi-major axis values for several debris objects at higher altitudes. Accelerometer-derived densities for the GRACE-FO satellite provide an observation against which thermospheric models can be compared. None of the thermospheric models, neither assimilative, numerical, nor empirical match the GRACE-FO densities, but individually capture different aspects of the G5 storm well. The empirical models (NRLMSISE-00, MSIS 2.0 and DTM2020) capture the absolute densities during the storm well, but overpredict for the next 2 days, while the DST-driven empirical model JB2008 and the assimilative WAM-IPE model captures the temporal nature of the storm well but under and over-predict the absolute densities, respectively. SWPC's WAM-IPE highlights how a poor Kp forecast dominates the neutral density forecast.

In search of the substorm onset instability

Ishbel Carlyle - Northumbria University
Jonathan Rae, Andy Smith, Clare Watt

The physics of substorm onset is one of the most important remaining unknowns in Earth's magnetic environment. How, when and why stored energy is released in Earth's magnetotail is a problem that has eluded scientists since the start of the space age. Recent work has highlighted the role of plasma instability in detonating substorm onset (e.g., see review by Rae and Watt, 2016), linking the first signatures of auroral disturbances, termed "auroral beads", to the presence of specific instabilities operating in the magnetotail. Moreover, these instabilities can be linked into the magnetotail through kinetic Alfven waves (Kalmoni et al., 2018). In this work, we replicate and extend the work of Kalmoni et al. (2018) to far higher spatial and temporal resolution, to understand the precipitating energy flux range and spatial scales of the instability. We find that the auroral beads have "beads-within-beads", and we use similar analysis to determine whether there is a consistent mechanism across spatial and temporal scales, or whether smaller-scale instabilites are necessary to detonate the substorm

Developing a Pitch angle Anisotropy Index (PAI) to study the pitch angle anisotropy of outer radiation belt relativistic electrons using Van Allen Probe observations

Suman Chakraborty - Northumbria University
Jonathan Rae, Shannon Killey, Biswajit Ojha, Clare E J Watt

In this study, we use 7 years (2012 - 2019) of pitch angle resolved electron flux measurements from Van Allen Probe-B spacecraft to study the variation of near-equatorial pitch angle distributions (PADs) of outer radiation belt ($L \geq 3$) relativistic electrons ($E \geq 0.5$ MeV) with different levels of geomagnetic activity. We calculate a pitch angle anisotropy index (PAI) to categorize the PADs into three types: pancake, PAI ≥ 1.05; butterfly, PAI ≤ 0.95; and flattop, 0.95 ¡ PAI ¡ 1.05. Our statistical results show that L shells ≥ 5 are dominated by pancake PADs on the dayside (9 ¡ MLT ¡ 15), butterfly PADs on the nightside (21 ¡ MLT ¡ 3), and flattop PADs in the dawn (3 ¡ MLT ¡ 9) and dusk (15 ¡ MLT ¡ 21) sectors, across almost all relativistic energies. In the inner L shells, the pancake and flattop PADs exhibit dependence on both L-shell and energy, with the occurrence rate increasing with decreasing L and increasing energy. For the butterfly PADs, we discovered a second population of low-L butterflies that are present at almost all local times. When the variation of electron PAI is compared with solar wind dynamic pressure Pdyn and geomagnetic indices SYM-H and AL, Pdyn is found to be the dominant parameter in driving the outer radiation belt pitch angle anisotropy. During periods of enhanced Pdyn, pancake PADs on the dayside become more 90-degree-peaked, butterfly PADs on the nightside exhibit enhanced flux dips around 90-degree pitch angle along with an enhanced azimuthal and radial extent, and flattop PADs turn into either pancake or butterfly PADs.

Using vorticity to characterise meso-scale ionospheric flow variations

Gareth Chisham - British Antarctic Survey
Mervyn Freeman

Using line-of-sight velocity measurements made by SuperDARN (The Super Dual Auroral Radar Network) radars with overlapping fields of view, it is possible to estimate the vorticity of the ionospheric convection flow over a wide range of scales. Here we exploit previous statistical analyses of 6 years of SuperDARN vorticity measurements to study the spatial variation of meso-scale flows in ionospheric convection. By making certain assumptions, we can statistically separate probability density functions (PDFs) of vorticity made at different locations in the ionosphere into two populations: (i) That due to the large-scale two-cell convection flow driven primarily by magnetic reconnection, and (ii) that due to meso-scale flow structures driven by processes such as turbulence. The resulting PDFs are fit by model functions using maximum likelihood estimation, and the spatial variation of the estimators is determined. The spatial variations of the large-scale vorticity estimators are ordered by the average convection flow, which is highly dependent on the IMF direction. The spatial variations of the meso-scale vorticity estimators appear independent of the senses of vorticity and IMF direction, but have a different character in the polar cap, the cusp, the auroral region, and the sub-auroral region.

Integrating Machine Learning for Auroral Image Analysis and Wind Predictions in the Scandinavian Region

Eliot Dable - University College London
Anasuya Aruliah

Satellite operations are highly sensitive to space weather effects on the thermosphere-ionosphere system. Accurate prediction of neutral and ionospheric parameters is critical for mitigating the impact of space weather disturbances, particularly as traditional models struggle with real-time forecasting due to computational constraints and lack sufficient accuracy on a smaller spatial scale. Recent advancements in machine learning offer a new paradigm by integrating diverse observational datasets. The Scandinavian region, with its extensive ground-based and satellite measurements, including All-Sky Camera (ASC) imagery, provides a unique opportunity to improve our understanding of thermospheric and ionospheric dynamics. Here we present a machine learning-based predictive model that fuses ground-based observations with ASC imagery to forecast key neutral parameters in real time. By refining techniques and implementing robust learning algorithms, this approach enhances space weather prediction capabilities, with implications for both fundamental research and practical satellite operations.

Exploring UBK coordinates in realistic field models

Tom Daggitt - British Antarctic Survey
Sarah Glauert

Descriptions of charged particle motion within the magnetosphere are greatly simplified by describing the position of the particle in UBK coordinates, where U is the electric potential, B is the magnetic field strength at which the particle mirrors, and K is the modified form of the second adiabatic invariant. There has been much previous work using these coordinates to describe particle motion, but this has primarily been done with simple electric and magnetic field models. For realistic magnetic field models, the transformation from XYZ to UBK coordinates cannot be analytically inverted, greatly increasing the difficulty of using the UBK coordinate system. We present a method for transforming to and from UBK coordinates using arbitrary geomagnetic and electric field models, which can be used to efficiently trace charged particles.

Adapting Ensemble-Calibration Techniques to Probabilistic Solar-Wind Forecasting

Nathaniel Edward-Inatimi - University of Reading
Mathew Owens, Luke Barnard, Harriet Turner, Matthew Lang, Mike Marsh, Siegfried Gonzi, Pete Riley

Solar-wind forecasting is critical for predicting events which can affect Earth's technological systems. Typically, forecasts combine coronal model outputs with heliospheric models to predict near-Earth conditions. Ensemble forecasting generates sets of outputs to create probabilistic forecasts which quantify forecast uncertainty, vital for reliable/actionable forecasts. We adapt meteorological methods to create a calibrated solar-wind ensemble and probabilistic forecast for ambient solar wind, a prerequisite for accurate coronal mass ejection (CME) forecasting. Calibration is achieved by adjusting ensemble inputs/outputs to align the ensemble spread with observed event frequencies. We produce hindcasts in near-Earth space using coronal-model output over Solar Cycle 24, as input to Heliospheric Upwind eXtrapolation with time dependence (HUXt) solar-wind model. Making spatial perturbations to the coronal model output at 0.1 AU, we produce ensembles of inner-boundary conditions for HUXt, evaluating how forecast accuracy was impacted by the scales of perturbations applied. We found optimal spatial perturbations described by Gaussian distributions with variances of 20° latitude and 10° longitude; these might represent spatial uncertainty within the coronal model. This produced probabilistic forecasts better matching observed frequencies. Calibration improved forecast reliability, reducing the Brier score by 9% and forecast decisiveness increasing AUC ROC score by 2.5%. Improvements were subtle but systematic. Additionally, we explored statistical post-processing to correct over-confidence bias, improving forecast actionability. However, this method, applied post-run, does not affect the solar-wind state used to propagate CMEs. This work represents the first formal calibration of solar-wind ensembles, laying groundwork for comprehensive forecasting systems like a calibrated multi-model ensemble.

Investigating the statistical properties of critical variables that govern whistler-mode chorus wave-particle interactions

Emily Grant - Northumbria University
Clare Watt, Jenny Wong, Nigel Meredith

The behaviour of high-energy electrons in Earth's outer radiation belt is strongly influenced by wave-particle interactions, which are often modeled using diffusion coefficients derived from quasi-linear theory. Variability in both wave and plasma properties within the outer belt is considerable, making it essential to characterise these fluctuations within localised regions of the inner magnetosphere. Using observational data from Van Allen Probe A we examine the statistical properties of several critical variables, including electron number density, magnetic field strength, and the ratio of electron plasma frequency to electron gyrofrequency. By investigating the covariation between these plasma properties and evaluating how sensitive the diffusion coefficients are to changes in these variables, we aim to improve diffusion coefficient modeling. Due to the significant spatiotemporal variability in the diffusion coefficients, selecting an appropriate grid size is crucial. An optimal grid size can help resolve between the temporal and spatial contributions in the satellite observations, thereby ensuring that the analysis captures both the localised and broader-scale dynamics within the magnetosphere. The findings from this investigation will inform future modeling efforts, providing a robust framework to understand and predict the behaviour of high-energy electrons in this region.

Coronal Mass Ejection Arrival Time Predictability Varies With the Solar Cycle Due to Solar Wind Structure

Dechen Gyeltshen - University of Reading
Matthew Owens, Luke Barnard

Space weather events can have a range of socioeconomic impacts like disruption to electric power supply, failure of Global Navigation Satellite Systems (such as GPS), direct harm to human health, etc. Effectively taking preventive measures requires accurate space weather forecasts. This includes predictions of solar events like Coronal Mass Ejections (CMEs). CMEs are large structures of magnetised plasma ejected from the Sun's atmosphere into the heliosphere. The interaction of CMEs with the Ambient Solar Wind (ASW) during propagation affects arrival kinematics at Earth. Since the ASW structure changes during the solar cycle, we hypothesise that variability in the transit time and arrival speed of CMEs changes with the solar cycle. We use the HUXt solar wind model to conduct simulations of an average and a fast CME scenario propagating through the varying ASW environment from 1975 to 2023. For our test scenarios, variability of both transit time and arrival speed increase with decreasing solar activity. This indicates lower predictability of CME arrival times and speed during solar minimum, and vice versa. For the average CME scenario, the typical spread in transit times is 20.3, 16.6 and 13.8 hours for the lower, middle and upper terciles of solar activity. The fast CME scenario demonstrated reduced variability with values of 16.5, 12.8, and 10.6 hours. Similar results are found for arrival speeds.

Long-term variations in Mars' radiation environment using highly-energetic particles over two solar cycles

Caitlin Hanna - University of Leicester

Beatriz Sanchez-Cano, Mark Lester, Adrian Martindale, Jingnan Guo, Dikshita Meggi, Rong Tian, Simon Joyce

Mars' radiation environment is extremely variable due to the influence many factors such as incoming galactic cosmic rays and solar transients. Understanding this variability and the consequent Martian system response is crucial for risk prediction for future robotic or human exploration. Much variation occurs over the short-term. However, the focus of this study is on long-term variability as a first step to characterise the environment. Work from Guo et al., (2015) using the Radiation Assessment Detector (RAD) on Mars Science Laboratory (MSL) shows the dose rate at the surface of Mars is influenced by the solar cycle, seasonal changes in the atmosphere, and diurnal variations. In this study, we build on this work to investigate longer term trends over two solar cycles. We focus on highly energetic particles detected by Mars Odyssey, Trace Gas Orbiter (TGO), Mars Atmosphere and Volatile EvolutioN (MAVEN), and MSL, and investigate the effects of space weather on the radiation environment.

AI-driven analysis of dangerous space weather: Combining ground- and space- based measurement

Maria Hasler - Northumbria University

John C. Coxon, Andy W. Smith

The Sun emits a highly conductive plasma known as the solar wind. Upon reaching Earth this gives rise to various phenomena, collectively referred to as space weather. Understanding space weather is important in our modern society, as severe space weather can cause major damage to energy and satellite systems. One aspect of space weather which is currently not well-understood is how information is passed from space to the ground through the ionosphere. It is important to understand these dynamics, as they play a critical role in our ability to forecast dangerous space weather effects. The ionosphere itself is difficult to measure due to its location, which is too high for airplanes and weather balloons but too low for satellites to directly measure. Further, as the flow of information through the ionosphere from space to ground is dynamic and highly non-linear, the ionospheric current systems and their impacts are challenging to analyse. The availability of the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) in Low Earth Orbit and SuperMAG on the ground, gives us the opportunity to study the ionospheric current systems and their results on the ground more directly. Due to the non-linear nature of current systems, the identification of correlations and patterns is challenging. To address these complexities and their impact on ground we will investigate novel techniques from machine and deep learning.

Observations and electrodynamics of an omega band aurora at Tromsø, Norway

Rosie Hodnett - University of Leicester
Steve Milan, Satonori Nozawa, Tero Raita

Omega bands are a dawn-sector phenomena which appear as wave-like structures in the aurora, which often look like a chain of the Greek letter Ω. Omega bands have recently been shown to be responsible for large variations in dB/dt which can trigger geomagnetically induced currents (GICs), which are a significant space weather hazard. Signatures of an omega band event are visible in the European Incoherent SCATter (EISCAT) data at Tromsø, Norway (69.6 °N, 19.2 °E), alongside observations from multiple instruments situated near Tromsø. The omega band is clearly identifiable in the Tromsø all sky camera data from 00:00 – 03:00 UT as it propagates eastward. This event is of interest for several reasons. During this event, the polar cap and field aligned current systems are expanded, and there are multiple intensifications in the AL index. These features are often misidentified as substorms, however in this case the fluctuations in the westward electrojet result from the omega band. Large ground-based magnetic perturbations are visible, and associated 'spikes' in dB/dt are identified in the auroral dawn sector. Data from the EISCAT UHF and VHF radars allow us to see enhancements in the ionospheric electron density which occurred as the upwards field aligned current and luminous aurora passed overhead. Additional electron density enhancements in the D region ionosphere were observed, which correspond to enhancements in cosmic noise absorption measured by nearby riometers. We present an overview of the electrodynamics of this omega band event at Tromsø.

What to do when you don't have a solar wind monitor

Caitriona Jackman - Dublin Institute for Advanced Studies
Charlie Bowers, Alexandra Fogg, Daragh Hollman, Seán McEntee, Matt Rutala, Simon Walker, Affelia Wibisono

In this presentation we showcase the work of the DIAS Planetary Magnetospheres group to tackle the challenge of interpreting magnetospheric data sets when we lack an upstream monitor of the solar wind. We know that the solar wind interacts with magnetized planets in our solar system to a greater or lesser degree and there is broad interest in tracking the link between magnetospheric dynamics and external (solar wind) and internal driving. Our recent work in this area includes: (i) the application of machine learning models to infer solar wind properties from magnetosheath measurements at Mercury, (ii) the use of terrestrial Auroral Kilometric Radiation and other geomagnetic indices to probe the timeline for solar wind-magnetosphere coupling at Earth, (iii) the development of ensemble models to track the solar wind from the inner heliosphere out to Jupiter and beyond, and (iv) the examination of auroral and planetary disk observations in wavelengths from X-ray to UV to elucidate the influence of the Sun at the gas and ice giant planets.

A novel method to remotely analyse Jupiter's ionospheric flows

Rosie Johnson - Aberystwyth University
Tom Knight, Tom Stallard, Russel Mapaye

Ground-based telescope observations of H_3^+ are currently the only way to remotely measure the ionospheric flows at the giant planets. At Jupiter, they are critical for supporting the Juno mission

since JIRAM lacks the spectral resolution to measure the Doppler shift of the H_3^+ spectra, from which the line-of-sight velocity can be derived and the ionospheric flows inferred. Past studies have identified sub-rotating H_3^+ velocities in Jupiter's main auroral emission, in line with corotation breakdown theory. Observations also revealed a stationary region in Jupiter's polar aurora, suggesting a solar wind coupling through either a Dungey-like open field and return flow or Kelvin Helmholtz instabilities. Recent simultaneous observations of H2 and H_3^+ IR emission showed asymmetric ionospheric jets, suggesting a current system consistent with Juno findings that links the main auroral emission to both upward and downward currents. Although the ionospheric currents have been inferred from these studies, rigorous mapping of the ionospheric flows requires the true velocity vector to visualise the actual direction of these flows. We have developed a novel analysis method using vector decomposition to derive the true velocity vector from the H_3^+ line-of-sight velocity component. We used the VLT-CRIRES dataset taken on 31 December 2012, previously analysed by Johnson et al. (2017). This dataset contains six complete scans of Jupiter's northern auroral region, each with a different viewing angle due to Jupiter's rotation over the observations. Utilising the overlapping fields of view, we perform a vector decomposition analysis to derive the velocity vector. The resulting map shows, for the first time, the true velocity vector of the H_3^+ ions and the direction of the ionospheric flows in Jupiter's northern auroral region. These preliminary results provide a proof of concept as well as new insights into the ionospheric flows and current systems in Jupiter's northern auroral region.

Variability in the auroral ionosphere: observations from EISCAT from days to years

Andrew Kavanagh - British Antarctic Survey
Jade Reidy, Subir Mandal

The high latitude ionosphere is highly variable, being driven by multiple processes with their origins in space weather and the neutral atmosphere. The balance between these drivers is still not well understood, though it has been increasingly recognised that the influence of the neutral atmosphere can be significant. In this study we use data from the EISCAT UHF incoherent scatter radar to examine the variability of several ionospheric parameters (e.g. density, temperature, and ion flow) and how they relate to space weather activity and potentially to processes originating in the lower atmosphere, including periods of Joule heating and the passage of Travelling Ionospheric Disturbances (TID). This work is supported by the NERC Highlight topic DRIIVE and the NERC Large Grant MesoS2D.

Potential Detection of Dual Lobe Reconnection Associated with Horse-Collar Auroras via Near-Magnetopause Cluster Observations

Nawapat Kaweeyanun - University of Southampton
Robert Fear

The presence of horse-collar auroras (HCAs) during northward interplanetary magnetic field periods offers opportunities to study unique dynamics in the Earth's high-latitude magnetosphere. Horse-collar auroras have been linked to closure of the polar cap and dual lobe magnetic reconnection, which also results in closure of the dayside terrestrial magnetic field. However, dual lobe reconnection has not been observed in situ at the same time as an HCA. On 14 April 2007, the Defense Meteorological Satellite Program (DMSP) orbiter F17 ultraviolet imager (SSUSI) and spectrometer (SSJ) captured visual and particle flux evidence of an HCA extending from nightside to cusp where an emission spot was present. During this event, the Cluster satellite crossed the high-latitude southern magnetopause, observing bidirectional plasma motion in the magnetosheath and significant plasma populations in the magnetosphere. The former is likely consistent with recently closed dayside magnetic field lines, while the latter is likely consistent with closed magnetotail field lines characteristic of HCAs. Supported by a positive Walén test, we conclude that dual lobe reconnection associated with an HCA may have been detected directly for the first time. Analysis of this event is ongoing and may produce further insights into magnetic flux transport during HCA events.

Quantification of D-region energetic electron precipitation energies and fluxes due to EMIC waves using multi-instrument observations

Mai Mai Lam - British Antarctic Survey
Mark Clilverd, Jade Reidy, Tero Raita, Antii Kero

The north of Scandinavia boasts a multitude of instruments that can be used to quantify and characterize the precipitation of energetic electrons into the D-region ionosphere at about 50 - 90 km. Here we make use of the European Incoherent Scatter (EISCAT) UHF radar (Tromsø, Norway), the Sodankylä Geophysical Observatory (SGO) VLF receiver at Kilpisjärvi (KIL), Finland, and the SGO array of search coil magnetometers (SCM). We investigate how the electron density (Ne) profiles changes when energetic electron precipitation occurs due to wave-particle interaction with electromagnetic ion cyclotron (EMIC) waves in the outer radiation belts. We focus on EMIC waves seen in the SCM data for dayside Magnetic Local Times (MLTs) across northern Scandinavia, during the interval 18th – 26th March 2023. We use the VLF receiver observations of the 16.4 kHz transmissions from the Noviken NATO facility in Norway (code JXN), which we support by referring to the U.S. Navy Long Wave Propagation Capability (LWPC) code to infer the state of the ionospheric waveguide. The transmitter-receiver pathway JXN-KIL ($\sim$365 km long) reveals clear signatures of changing D-region altitudes. EMIC waves are clearly seen in the SCM data from Abisko, Sweden, which is on the JXN-KIL pathway and about $\sim$130 km from the UHF radar. A persistent layer of high electron density Ne appears in the EISCAT UHF observations at $\sim$ 66 km during the time of a train of EMIC waves. Our analysis provides evidence of energetic electron precipitation due to wave-particle interaction with EMIC waves at L-shell L $\sim$ 5, and an associated change to the altitude of the D-region ionospheric waveguide. We quantify the percentage changes in Ne, the altitudes (energies) of the precipitation causing those changes, and compare with expected values in the literature.

Incorporating data assimilation into BAS-RBM

Matthew Lang - British Antarctic Survey
Richard Horne, Sarah Glauert

Accurate forecasting of Earth's radiation belts becomes increasingly important as society becomes more dependent upon satellites, which orbit through the radiation belts. Satellites can be damaged by electrostatic charges resulting from internal charging caused by high energy electrons. Accurate forecasting of electron fluxes within the radiation belt helps satellite operators plan to reduce the impacts of space weather events.

In order to ensure that forecasts are optimally initialised and remain close to the true state of the radiation belts, we are utilising a technique called data assimilation, to constrain radiation belt electron fluxes to available observations. Data assimilation is a necessary component of numerical

weather prediction, responsible for massively improving weather forecasts over the past 30 years. Data assimilation produces an optimal estimate of a system (along with any associated uncertainties), by merging numerical model simulations with observational data and taking into account the errors present in both.

In this presentation, we will show our current progress in implementing a data assimilation scheme into the British Antarctic Survey's Radiation Belt Model (BAS-RBM), discussing the challenges associated with this and ensemble runs using BAS-RBM, showcasing the sensitivity of BAS-RBM in response to its inputs.

New dynamics of NBZ auroras

Steve Milan - University of Leicester

Michaela Mooney, Gemma Bower, Gregory Kennedy, Benoit Hubert

We present the first observations of a three-hour quasi-periodic intensification of the polar auroras during a prolonged interval of strongly-northward interplanetary magnetic field (IMF). This takes the form of a localised spot of auroral emission that appears near the pole which subsequently spreads sunwards and antisunwards to produce a sun-aligned auroral arc. This arc eventually merges with the dayside and nightside auroral zones. Twin reverse-cell convection in the noon-sector ionosphere suggests that this occurs during on-going dual-lobe magnetic reconnection which has closed the magnetosphere. We propose that the polar auroral dynamics are an indication of reconnection in the magnetotail, bearing similarities to southwards-IMF substorms. We further suggest that this process may be responsible for the cusp-aligned auroral morphology frequently observed when the IMF is directed northwards.

Orbyts Research in School Partnerships: At the Heart of Great Science is Opportunity

Michela Mooney - University of Leicester

J. K. Sandhu, S. Nitti, G. Kennedy, R. Coulson, U. U. Bhat, C. J. Lao, W. Dunn, A. Bray and the wider Orbyts Management Team

STEM subjects suffer from a systemic lack of diversity and long-standing barriers to inclusion. Girls, Black students and students from low-income backgrounds are highly under-represented at all levels of physics from age 16+. Meanwhile, UK science education faces substantial shortages in physics teachers, with 1 in 7 UK schools not having a physics teacher. The Orbyts programme aims to address these issues by partnering passionate science researchers with school students to work on original science research projects.

At the Leicester Orbyts Hub we have successfully run 8 researcher-school partnership projects since 2022, directly involving around 80 school students in cutting-edge science research. The science in these projects has included supporting research for the upcoming SMILE mission, solar wind charge exchange at the magnetopause, the impact of space weather on Earth's atmospheric climate chemistry, estimating the age of asteroid families and auroral phenomena during large geomagnetic storms and under Northward IMF.

The long-term engagement and partnership style of Orbyts projects is key to widening access to science. Orbyts researchers provide relatable role models and humanise science research on an individual level, breaking down harmful stereotypes and misconceptions of who can be a scientist. Our programme evaluation shows that Orbyts delivers profound improvements in inclusivity (e.g.

the programme sees 100% increases in girls taking A-level physics when run at GCSE and similar impact across income background and ethnicity).

The research-focus of an Orbyts partnership supports researchers to carry out their science research in a different context while mentoring and inspiring young people. The programme has proven to enhance essential transferable skills for our researchers including communication skills training, project leadership and applied pedagogical experience.

Tracking composition changes in the solar wind through spectral analysis of SXI/SMILE data.

Simona Nitti - University of Leicester
J.A. Carter, S.F. Sembay, S.E. Milan

Continuous monitoring of the solar wind ion composition is essential for understanding solar-terrestrial interactions, especially the Solar Wind Charge Exchange (SWCX) signal. The SWCX signal, a soft X-ray emission (<2 keV), arises from interactions between highly ionised solar wind particles (e.g., O7+, O8+, C6+) and neutral atoms. This emission is ubiquitous across the solar system, occurring wherever the solar wind meets interstellar neutrals within the heliosphere or interacts with planetary environments such as those of Mars, Venus, Jupiter, Pluto, and Earth.

In this study, we explore how SWCX emissions from Earth's exosphere can be used to infer solar wind composition through spectral analysis. By building on previous SWCX studies using XMM-Newton spectral data, we simulate future SMILE observations to evaluate its ability to track solar wind composition variability. Our goal is to demonstrate that SMILE's Soft X-ray Imager (SXI) can serve as a valuable tool for solar wind composition monitoring through spectral data. Set to launch in 2025, SMILE will provide unprecedented soft X-ray imaging of large-scale magnetopause dynamics. While its primary objective is to capture images of Earth's subsolar magnetosheath, SXI's CCD-based spectral capabilities allow us to extend its utility beyond imaging. This feature enables us to explore additional scientific questions, including those addressed in this study. This research is particularly timely given the degradation of the heavy ion spectrometer aboard the Advanced Composition Explorer (ACE), a key solar wind monitor at L1, which has left us without reliable near-Earth ion composition data since 2011.

Understanding the most extreme types of space weather: geomagnetic storms

Atlas Patrick - Northumbria University
Coxon, J; Bentley, S; Morton, R; Walach, M; Murphy, K

Planetary radio emissions have potential as a very valuable remote diagnostic of planetary rotation rates as well as magnetospheric dynamics. Auroral Kilometric Radiation (AKR) is Earth's strongest natural radio emission, and is anisotropically beamed from a source locked to auroral latitude magnetic field lines. These field lines are tied to the deep interior of the rotating planet, and hence it is theorised that an observer at a fixed local time will observe a diurnal variation in AKR power, as if the Earth and its emission were a lighthouse. In this study we explore this proposed 24 hour periodicity in AKR power using a decade of observations from Wind/WAVES.

Comparing TS04 with Dipole Approximations Under Varying Geomagnetic Conditions

Brad Ramsey - British Antarctic Survey

Understanding the dynamics of Earth's radiation environment requires accurate magnetic field modelling, particularly in assessing electron transport and wave-particle interactions. Codes, such as PADIE, which calculate diffusion coefficients due to wave-particle interactions, typically assume a dipole field. We compare the Tsyganenko TS04 model with a dipole approximation under different geomagnetic conditions, universal times, and seasonal variations, with the aim of creating a better approximation of Earth's magnetic field for use in PADIE and the BAS-RBM.

A Solar Orbiter Data Preparation Pipeline for Instability Analysis of the Solar Wind

Hao Ran - University College London

Daniel Verscharen, Georgios Nicolaou, Jesse Coburn, Charalambos Ioannou, Xiangyu Wu

The interplay between kinetic instabilities and Coulomb collisions plays a crucial role in the radial evolution of the solar wind, making it a key topic in space plasma physics. In this work, we present a data preparation pipeline for applying Solar Orbiter observations to advanced theoretical tools such as the Arbitrary Linear Plasma Solver (ALPS). We detail our methodology for ion species separation using a Gaussian Mixture Model (GMM) clustering algorithm based on Solar Wind Analyzer measurements. Additionally, we describe our approach to calibrating Electron Analyzer System (EAS) data to ensure accurate electron measurements. Finally, we showcase preliminary instability analysis results derived from these processed data and ALPS. The code developed in this project will be open-sourced upon completion.

A Statistical Study on the Azimuthal Wave Numbers of Pc5 ULF Waves

Sam Rennie - University of Leicester

Steve Milan, Suzie Imber

Magnetospheric ultralow frequency (ULF) waves in the Pc5 frequency band ($\sim$1.7-6.7mHz) are known to play significant roles in the solar-terrestrial energy pathway and the radial transport of energetic electron populations in the outer radiation belt. The azimuthal wave number, m, of a ULF wave is of particular importance as it determines which electron populations it will resonantly interact with and offers clues as to its drivers. Typically, due to a limited understanding of m-numbers, radial diffusion coefficients assume that waves propagate eastward and have a large azimuthal scale size (m=1).

Presented here is a statistical study of the azimuthal wave numbers of 182 ULF waves that have been identified in the backscatter recorded by the Hankasalmi SuperDARN radar operating in its common mode over two years. SuperDARN can be used to study Pc5 waves of a wide range of scale sizes and therefore m-numbers. Considered in the study are the distribution of m-numbers and their relationships with local time, other wave properties, and wave drivers.

Assessing the Variability of the Magnetic and Plasma Environment Upstream of Ganymede and Europa

Alexandre Santos - University College London
Nicholas Achilleos, Dimitrios Millas, William Dunn, Patrick Guio

Ganymede, one of Jupiter's moons and the largest in the Solar System, possesses a unique combination of an intrinsic magnetic field - generated by a dynamo within its interior - and an induced field, thought to be produced from the interaction between Jupiter's time-varying magnetic field and the moon's subsurface ocean layers. Europa, another Jovian moon, similarly exhibits an induced field, but lacks an intrinsic field generated at its core. The surrounding plasma plays a crucial role in modulating the induced fields of both moons, making it essential to our understanding of the near-Ganymede and near-Europa magnetic conditions.

We present an application of the UCL-AGA magnetodisc code to the study of the magnetic and plasma environments that surround Ganymede and Europa. We explore the effect of the hot plasma population on the magnetic field near both moons, which in turn affects the induced field, and examine the variability of the ambient field and plasma conditions at different moon orbital radii. We compare our model results with Juno magnetic field measurements taken during recent flybys of the two moons and estimate the impact of magnetospheric configuration changes on the observed field. Additionally, we explore the effects of current sheet dynamics on the overarching magnetic and plasma environments.

Escaping plasma structures in the Martian magnetotail as observed during two special MARSIS high-altitude campaigns

Katerina Stergiopoulou - University of Leicester
Katerina Stergiopoulou, Mark Lester, Simon Joyce, David Andrews

The nightside ionosphere of Mars is formed by plasma transport from the dayside and electron precipitation. Significant progress has been made in our understanding of its composition and structure at low altitudes, however, what happens at higher altitudes remains unclear. Moreover, the response of escaping plasma structures to changing solar wind conditions will shed light on the dynamic evolution of the system. Mapping the paths of escaping plasma structures will result in a better understanding of the evolution of atmospheric escape at Mars and the contribution of escaping plasma structures to the total atmospheric loss. In this study we probe escaping plasma structures utilising two special campaigns of ESA's Mars Express mission as well as observations from NASA's MAVEN mission, in the high-altitude nightside ionosphere of Mars. Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) is the radar on board Mars Express and samples the ionosphere at altitudes no higher than $\sim$1200 km. However, in our study we look at observations from consecutive orbits during two special MARSIS campaigns, each consisting of 5 orbits, that took place in September 2023 and April 2024, for which MARSIS was operated at altitudes up to 4000 km. We see a variable nightside ionosphere at high altitudes that changes between consecutive MEX orbits. MARSIS detects plasma structures appearing at different altitudes or disappearing between orbits, however, a consistent plasma presence in the terminator region is observed. We compare with MAVEN measurements to better evaluate both the escaping plasma structures and the solar wind conditions. MAVEN too sees plasma structures at high altitudes on the nightside, changing between orbits, confirming the variability of the high-altitude nightside ionosphere. Combining Mars Express and MAVEN data we further investigate the effect of changing solar wind conditions to the plasma structures.

Unexpected heat on Uranus

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Uranus's stands as an enigma within the field of planetary science. What little we know of its ionosphere and aurorae have proven perplexing, whether this be ultraviolet (UV) or infrared (IR) emissions, considerable intensity and column density variability have been observed across the surface of Uranus's ionosphere [Lamy et al., 2012, 2017, 2020, Lam et al., 1997, Melin et al., 2019 and Thomas et al., 2023]. For IR emissions only two observations have published spatial intensity maps with 10 years between them, hence a wide variety of parameters could explain any emission intensity or physical parameter variability observed. To address this, our investigation maps out three half planet scans of Uranus (using Keck NISRPEC) in October 2023 and January 2025 and by comparing these intensity scans to prior JWST observations in December 2021 we aim to discuss and explain potential drivers in Uranus's ionosphere. Furthermore, by fitting the half planet scans to current magnetic field models Q3mp [Connerney et al., 1987] and AH5 [Herbert et al., 2009] we hope to extract an approximate longitude system which has remained undetected since Voyager II.

The Martian ionosphere response to the S1222a Marsquake

Rong Tian - University of Leicester

Rong Tian, Beatriz Sanchez-Cano, Chunhua Jiang, Mark Lester, Dikshita Meggi, Simon Joyce, Yutian Chi, Christopher M. Fowler, Yuming Wang

Large seismic events can induce significant ionospheric disturbances at Earth, which are typically observed through variations in electron density and magnetic field. However, there have been no reported studies to date on whether seismic activity affects the ionospheres of other planets. We focus on the largest Marsquake detected by InSight, an M4.7 event in magnitude, named S1222a. This quake is a unique and significant event as it is the largest Marsquake accompanied by surface waves observed to date. Data from the MAVEN, Mars Express, and TIANWEN-1 satellites, are employed in this study to systematically investigate the ionospheric response to the seismic waves. Our investigation finds a correlation between magnetic and ionospheric perturbations that occur following the seismic activity. Specifically, we identified a coupled oscillation $\sim$70 minutes after the Marsquake in the magnetic field and ion density with a period of $\sim$2.5 minutes in the MAVEN data. In this presentation, we report on all these observations that indicate detection of seismic waves in the ionosphere for the first time in another planet than Earth.

Global MHD and Test-Particle simulations of outer radiation belt flux drop- out events

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The radiation belt electron flux can exhibit dramatic variations across a range of spatial and temporal scales, including global-scale radial transport, mesoscale injections, and local-scale wave-particle interactions. Long-term radiation belt variability has been successfully captured by solving the Fokker Planck diffusion equation (e.g., BAS-RBM), incorporating radial, pitch-angle and energy diffusion and imposed upon semi-empirical Tsyganenko magnetic models. However, during geomagnetic storms, non-diffusive processes become significant. Enhancements in the partial ring current and dawn–dusk electric fields, and associated magnetic field distortions can lead to violation of the third adiabatic invariant and rapid outward radial transport. Electron flux dropouts often occur in the outer radiation belt during geomagnetic storms across several orders of magnitude over a wide range of L shells. These irreversible electron losses occur either by precipitating into atmosphere or by escaping through magnetopause. In this study, we employ global magnetohydrodynamic and test-particle (MHD-TP) simulations to investigate the dropout mechanisms by introducing an ensemble of test particles into the global MHD fields and tracking their trajectories. We aim to distinguish the relative contributions of magnetopause shadowing and wave–particle interactions in producing the observed rapid changes in electron flux.

Wave-Particle Interactions in Whistler-Mode Chorus waves: Theory and Simulations of High Energisation

Adam Toulson - Northumbria University
Daniel Ratliff

Whistler mode chorus (WMC) waves are a heavily investigated phenomena existing within the magnetosphere. Whilst theories exist for their formation, there are still several factors of their evolution that are currently less well understood. This project aims to identify key drivers for WMC formation and evolutions by creating a new theoretical model based upon variations of the dispersion relation. From this the Nonlinear Schrondinger equation (NLSE) can be derived giving information on the waves velocity dispersion and nonlinearity. These properties come from the interplay between dispersive effects and nonlinear intensity effects. Furthermore, the product of these coefficients forms the modulation instability criterion, a key element of WMC formation as this instability allows for wave packet formation as a theorised reasoning for WMC occurrence. Upon manipulation of the dispersion relation by adding in additional factors possibly influencing WMC, we undertake a sensitivity analysis to provide insight into which variables contribute the most to WMC intensity and occurrence rates. We investigate these models numerically, using In Situ measurements from the Van Allen Probes, benchmarking them to see which variation performs best against observations. The resulting models and key factors shed light on possible indices that may be used to indicate WMC activity and intensity, similar to those used in oceanic wave forecasting.

Characteristics of the Auroral Kilometric Radiation During Substorms

Simon Walker - Dublin Institute for Advanced Studies
Alexandra Ruth Fogg and Caitríona M Jackman

Auroral Kilometric Radiation (AKR) is a strong Earth-based radio emission generated by the acceleration of electrons along auroral latitude magnetic field lines. AKR is closely linked to auroral ionospheric activity, with greater irradiance correlating with stronger auroral electrojets and enhanced particle precipitation. AKR provides a means to remotely sense ionosphere-magnetosphere coupling, which becomes most dynamic during magnetospheric substorms. These substorms exhibit clear onset signatures in auroral imagery and ground-based magnetometer data. Using these signatures and an AKR burst list identified from Wind/WAVES observations, we investigate the properties of AKR that indicate substorm occurrence, contributing to a greater understanding of ionosphere-magnetosphere dynamics throughout the substorm timeline.

Solar Wind Interactions with Comets

Sarah Watson - University of Reading

Comets are directly influenced by the solar wind and one of the most spectacular interactions is a tail disconnection event. This can occur when a solar wind structure such as a CME, a faster solar wind stream or a change in magnetic field polarity (Heliospheric Current Sheet crossing) causes the tail of the comet to be completely detached from the nucleus. Using a combination of amateur observations and STEREO HI data, multiple disconnection events from different comets have been analysed using the HUXt solar wind model. This uses a reduced physics approach and can be used alongside data assimilation to provide solar wind conditions for bodies in the solar system. Comets cover a large range of latitudes and therefore can provide an insight into the solar wind conditions out of the ecliptic plane. The aim is to test how effective the model is outside of the ecliptic plane, using the comet tail disconnection events as in-situ probes. These events therefore have the potential to be a source of in-situ information about the solar wind for regions of the solar system which are currently unoccupied by spacecraft, therefore improving solar wind modelling.

Observing the Magnetopause with SMILE

Samuel Wharton - University of Leicester
Jenny Carter, Steve Sembay, Yasir Soobiah, Simona Nitti, Tianran Sun, Andy Read

Due for launch at the end of 2025, the SMILE mission carries a soft X-ray imager that will be able to view the dayside magnetosheath on a global scale for the first time. This promises to revolutionise our understanding of solar wind-magnetospheric coupling. A key challenge of this new data source is identifying the 3D magnetopause position in the noisy 2D images. We present a parameterised 3D X-ray emissivity model through which images can be produced and compared to simulated data. By adjusting the model's parameters so that the model and real images match, we can then calculate the magnetopause position from the optimised model. The method is robust under a range of orbital positions and viewing geometries, and we use the SXI simulator to create realistic, noisy counts images that we can test the model on. We find the method is still effective for noisy images and show that the uncertainty and accuracy of the magnetopause measurements is sufficient for the mission requirements.

Combining diffusion and convection in the electron radiation belt of Saturn

Emma Woodfield - British Antarctic Survey
V. K. Jordanova, S. A. Glauert, J. D. Menietti

The electron radiation belts at Saturn present a challenge for traditional diffusive methods of modelling radiation belts. At energies in the middle range of the radiation belt, the electron drift motion can stagnate because the gradient and curvature drifts oppose the corotation at Saturn (due to the direction of the planetary magnetic field). Thus, the assumptions behind radial diffusion as a radiation belt process are not always met. In addition, there is a global scale electric field, observed to point from approximately local noon to midnight, which can cause rapid convective transport in a range around the stagnation energy (often referred to as the corotation drift resonance, CDR). Therefore, to properly simulate the electron radiation belt at Saturn, an approach combining both diffusion and convection is required with careful consideration of the energy ranges involved. Our approach to this new paradigm is to borrow from experience at the Earth, where models of the ions in the ring current have combined the effects of convection and diffusive loss processes for some time. One such model is RAM-SCB (ring current-atmosphere interactions model with self-consistent magnetic field); we will discuss the adaptation of RAM-SCB to model the electron radiation belt at Saturn.