Autumn MIST 2018 Abstracts

Richard B. Horne (Invited), British Antarctic Survey

The Van Allen Radiation Belts: Early History and Current Challenges

James Van Allen and his team discovered the Earth's radiation belts back in 1958, the first major discovery of the space age. Designed to detect cosmic rays, the detectors saturated and it soon became clear the Earth is surrounded by belts of high energy charged particles, mainly electrons and protons, which pose a hazard to satellites and humans in space. In this talk we will discuss some of the early observations, we will outline some of the early ideas on how the radiation belts are formed and why these ideas could not explain the variability of the radiation belts. We outline our current understanding of how electrons are accelerated to MeV energies, the controversy between radial diffusion and acceleration by resonant wave-particle interactions, and discuss some of the scientific challenges we have yet to overcome at the Earth and planets.

Sarah Glauert, British Antarctic Survey

30 Years in the Earth's Radiation Belts

Society is becoming increasingly reliant on satellite technology. Historically most satellites were in geostationary orbit (GEO) or low Earth orbit, but now Global Navigation Satellite Systems and GEO satellites using electric orbit raising pass through the heart of the radiation belts and other satellites orbit in the slot region. Since high-energy electrons can potentially cause damage to satellites via internal charging, understanding the radiation environment and its extremes is important. However, there is little long-term data available on the high-energy electron flux throughout the belts.

We present a 30-year simulation of the high-energy electron flux between the outer edge of the inner belt and GEO calculated using the BAS-RBM, a physics-based model that includes the effects of wave-particle interactions, radial transport and losses to the atmosphere and magnetopause. Validation is provided using measurements from the GIOVE-B spacecraft, with correlation coefficients from 0.72 to 0.88. The simulation shows the 'climatology' of the radiation belts. Orders of magnitude variations in the flux can be seen on both short (days) and long (months) time scales. Solar cycle variations are clearly visible and slot region filling can be seen during active conditions. The worst-case spectrum agrees well with an independently derived result.

Mark Clilverd, British Antarctic Survey

Electron Precipitation from the Outer Radiation Belt During the St Patrick's Day Storm

Recently, a model for 30–1000 keV radiation belt driven energetic electron precipitation (EEP) has been put forward for use in climate models. That EEP model is based on precipitation data spanning 2002-2012 from the constellation of low Earth orbiting POES satellites. In this presentation we will test the EEP model's ability to represent the EPP during the large geomagnetic storm of 18 March 2015, known at the St Patrick's Day storm. In a study of narrow band sub-ionospheric VLF transmitter data collected during March 2015, continuous phase observations have been analysed throughout an entire geomagnetic storm period for the first time. Using phase data from the UK transmitter, GVT (22.1 kHz), received at an AARDDVARK site in Reykjavik, Iceland, electron precipitation fluxes from L=2.78-5.44 are calculated for magnetic local noon time (12 MLT), and magnetic midnight (00 MLT). Good agreement is seen between VLF phase modelling and POES zonal mean fluxes (within a factor of 2) during the 8 days of storm-induced precipitation. The similarities and differences between electron precipitation characteristics determined from observations and models will be discussed.

Frances Staples, UCL (MSSL)
Where is the Magnetopause During Flux Dropout Events in the Outer Radiation Belt?

Under steady-state conditions the magnetopause location is described as a pressure balance between internal magnetic pressures and the external dynamic pressure of the solar wind. The question is, does this approximation hold during more dynamic times?

Under more extreme solar wind driving, such as high solar wind pressures or strong southward-directed interplanetary magnetic fields, this boundary is significantly more compressed than in steady-state, playing a significant role in the depletion of magnetospheric plasma from the Van Allen Radiation Belts, via magnetopause shadowing. Large step-changes in solar wind conditions enable the real magnetopause to have a significant time-dependence which empirical models cannot capture.

We use a database of >42,000 magnetopause crossings, to determine how the real magnetopause differs from a statistical model, and under which conditions. We find that observed magnetopause is on average ~10% closer to the radiation belts during periods of sudden dynamic pressure enhancement, such as during storm sudden commencement, with a maximum of 42% closer. Our results demonstrate that empirical magnetopause models such as the Shue et al. [1998] model should be used cautiously to interpret energetic electron losses by magnetopause shadowing.

Ravindra T. Desai, Imperial College London
Global MHD and Test-Particle Simulations of Radiation Belt Behaviour During Shock-Driven Magnetospheric Compressions

The Van Allen radiation belts dynamically vary across timescales ranging from minutes to days and thus pose significant challenges to modelling efforts. Here, we employ combined MHD and test-particle simulations to explore how rapid large-scale morphological changes to the global magnetosphere control radiation belt behaviour. Relativistic Lorentz and Guiding Centre test-particle integrators are implemented to sub-cycle beneath the Gorgon MHD field solver, and phase-space weightings are used to evolve radiation belt distributions. We focus our simulations on magnetospheric compressions driven by fast-forward interplanetary shocks which rapidly drive the 'dayside' magnetopause from >10RE to <6RE. As the shock-front propagates through the simulated magnetosphere, a magnetosonic pulse adiabatically accelerates protons and electrons up to MeV energies and transports them radially inwards. This process is examined for varying dipole tilts, and the drift orbits of electrons and protons constrained at various stages during the compression. In particular, non-dipolar field-lines are shown to cause particles to execute Shabansky orbits as they become trapped within off-equatorial field-strength minima. This effect modulates particle fluxes across the outer radiation belt, including at radial distances encompassing geostationary orbit. These results demonstrate the relevance of this modelling technique to radiation belt forecasting.

Geraint Jones, UCL Mullard Space Science Laboratory
A Radiation Belt of Energetic Protons Located Between Saturn and its Rings

During April-September 2017, at the end of the hugely successful Cassini-Huygens mission to Saturn, in situ measurements were obtained for the first time in the region between the planet's rings and its cloudtops. Cassini's Magnetosphere Imaging Instrument, MIMI, could detect any radiation belt occupying this region, which is unique in that it is isolated from Saturn's outer radiation belts and the rest of the magnetosphere by the extensive main ring system. Unlike at Saturn's main radiation belts, any trapped electrons and heavy ions were at only present at levels too low for detection by MIMI in this region. However, energetic protons were present in abundance, occupying magnetic field lines close to the equator, and overlapping the positions of the inner edge of the D ring. An overview will be given of this newly-observed radiation belt, together with potential sources for the proton population, and the application of radiation belt data to probing the nature of Saturn's rings. Full details of this work are available in Roussos, Kollmann, et al., DOI: 10.1126/science.aat1962

Emma Woodfield, British Antarctic Survey

Chorus Waves Are Better at Accelerating Electrons at Saturn Than Previously Assumed

Until recently the electron radiation belts at Saturn were thought to be created by acceleration due to radial diffusion; recently however Z-mode waves, found in abundance inside the orbit of Enceladus, have been found to strongly accelerate electrons at Saturn. Whistler mode chorus waves on the other hand, despite strongly accelerating electrons at both the Earth and Jupiter, have been dismissed as ineffective at Saturn. In this work we use the BAS Radiation Belt model to show that chorus waves at Saturn have a much larger effect that previously assumed. The strongest acceleration occurs away from the region of the strongest waves, but in a region where the plasma density off the equator works in harmony with the observed waves. The acceleration in this region is strongly pitch angle dependent and leads to butterfly pitch angle distributions over short timescales which then become increasingly flat distributions as the acceleration continues.

Hayley Allison, British Antarctic Survey / University of Cambridge

On the Effect of the Seed Population in Earth's Electron Radiation Belt Region

Trapped by the terrestrial magnetic field, two rings of electrons surround the Earth, forming the electron radiation belts. These dynamic structures present hazards to operating satellites, the threat of which can change dramatically on the time frame of hours. Lower energy electrons are injected into the system from the night-side plasmasheet and are subsequently accelerated up to considerably higher, and more damaging, energies by a range of mechanisms. Understanding how changes in the lower energy population affect the enhancement of >1 MeV electrons may help us to better understand the occurrence of high energy electrons in the radiation belt region. By using various low energy boundary conditions in the BAS Radiation Belt Model, we explore how changes to the low energy seed population affect the amount of high energy electrons produced. The duration of the active period and the time frame for changes on the low energy boundary are important to accurately recreate observations of the 1 MeV electron flux. Additionally, the minimum energy of the Radiation Belt Model is varied, and is also shown to have a notable impact on the level of the resulting 1 MeV flux.

Clare Watt, University of Reading

Variability of Quasilinear Diffusion Coefficients for Plasmaspheric Hiss

In the Outer Radiation Belt, the acceleration and loss of high-energy electrons is largely controlled by wave-particle interactions. Quasilinear diffusion coefficients are an efficient way to capture the small-scale physics of wave-particle interactions due to magnetospheric wave modes such as plasmaspheric hiss. The strength of quasilinear diffusion coefficients as a function of energy and pitch-angle depends on both wave parameters and plasma parameters such as ambient magnetic field strength, plasma number density and composition. For whistler mode waves in the magnetosphere, observations indicate large variations in the amplitude and wavenormal angle, but less is known about the variability of the magnetic field and number density at a particular location. We use contemporaneous in-situ measurements from the Van Allen Probe mission to demonstrate the variability of the factors that control pitch-angle diffusion coefficients, and then compare with the variability of the resulting diffusion coefficient. We show that the distribution of calculated diffusion coefficients is highly non-Gaussian with large variance, and that the parameterisation of wave-particle interactions by geomagnetic activity may not be the optimal method. We discuss why the variability of diffusion is important when modelling the physics of the Outer Radiation Belt, and identify key unknowns for future investigations.

Sarah Bentley, University of Reading

A Probabilistic Model of the Waves Driving Radial Diffusion in Earth's Radiation Belts

Radial diffusion is responsible for the energisation and transport of radiation belt electrons. Current models of the ultra-low frequency (ULF) waves driving this diffusion are deterministic, producing a single output for each set of input parameters. Meanwhile, weather and climate models increasingly use stochastic parameterisations to account for the effects of sub-scale processes and model uncertainty. To apply stochastic parameterisation to radial diffusion, we require probabilistic forecasts of the power in ULF waves in order to estimate diffusion coefficients.

We present a statistical model of ULF wave power parameterised by solar wind speed vsw, variance in proton number density var(Np) and southward interplanetary magnetic field Bz. We predict ground-based ULF wave power across a range of frequencies, latitudes and magnetic local time sectors. Power can be reproduced probabilistically or deterministically, either by sampling from conditional probability distributions or by using the mean. Probabilistic predictions of ULF waves faithfully reproduce the original power distributions over long time periods, whilst time series constructed using the mean predict power in the next hour better than assuming power persists from previous hours. Our model can be used to establish probabilistic radial diffusion coefficients and to investigate the underlying physics in a novel manner.

Ned Russell Staniland, Imperial College London

Quantifying the Stress of the Saturnian Magnetosphere During the Cassini Era

In this study, the complete magnetic field dataset collected by the Cassini spacecraft is used to track the global stress state of the Saturnian magnetosphere during the Cassini era. Analogous to the Earth Dst Index, we measure the near-equatorial region of Saturn's inner magnetosphere to determine whether the system is stretched, compressed or near its ground state. In this region, the governing magnetic field contributors are the internal field and the magnetodisc current sheet. Azimuthal currents flowing in the equatorial plasma disk radially stretch Saturn's magnetic field lines, the extent of which varies due to both internal and external stresses that modify the current sheet parameters. While the stress state displays a dependence on local time, it is also shown to vary temporally. We conclude that the Saturnian magnetosphere remained in a quiet state for a significant period of the Cassini orbital mission at Saturn, with occasional large-scale deviations observed. These results have implications for the broader study of giant magnetospheres, which are found both within and outside of our solar system. They also reveal how dynamic the magnetosphere of Saturn is compared to the magnetosphere of Earth, improving our understanding of the terrestrial environment.

Omakshi Agiwal, Imperial College London

Modelling the Structure of Saturn's Nightside Current Sheet During Cassini's F-ring Apoapsis Passes

The Cassini spacecraft conducted 20 orbits during northern summer at Saturn, called the 'F-ring' orbits. The orbits' apoapsis passes correspond to the spacecraft crossing Saturn's magnetotail current sheet in approximately 2 days. Current sheet crossings are identified by a reversal in the radial component of the magnetic field. Observations show that the nature of the crossing differs from orbit to orbit, despite their similar trajectories. Crossings are observed at a range of positions above and below the expected magnetic equator, with some cases even showing multiple crossings during the same orbit. We consider a model which combines the perturbation effects of the northern and southern planetary period oscillation (PPO) systems observed at Saturn on a hinged magnetotail current sheet. Depending on the relative phase between the two systems, the current sheet undergoes a combination of thickness modulations and north-south displacements. For 14 F-ring orbits, the model offers a plausible description for the different types of crossings observed in the magnetic field data. It also confirms that these crossings occur in a regime where the northern PPO system dominates the southern, as would be expected for northern summer at Saturn.

Nahid Chowdhury, University of Leicester

Exploring Key Characteristics in Saturn's Infrared Auroral Emissions

We newly analyse spectral data from Saturn's northern aurorae collected using adaptive optics observations made on the VLT-CRIRES facility at Paranal. This dataset offers a higher spectrally and spatially resolved view of Saturn's northern auroral emissions than ever before and the infrared emission produced by the H3+ molecule has been used to compute auroral emission intensity, ion line-of-sight velocity and temperature profiles. We observe a dawn-dusk asymmetry in the auroral emission intensity with a distinct dawn-side enhancement known to be associated with solar wind compressions in the magnetosphere. Our line-of-sight velocity structure disputes findings of previous studies that had access to lower resolution datasets and we note an intriguing feature appearing to suggest the presence of a dark region in the aurorae linked to an increase in the velocity of ions flowing there. A drop in the thermospheric temperature is also detected at a position in the thermosphere that corresponds to the centre of the northern pole. The findings of this work will aid ongoing investigations into the processes driving the energy mechanisms in Saturn's upper atmosphere and also inform current models of Saturn's magnetic field and the interaction between upper atmospheric layers.

Benjamin G. Swithenbank-Harris, University of Leicester

Analysis of Jupiter's Dark Polar Region During the Juno Approach Phase

Jupiter's auroras are a manifestation of the dynamics within the planet's magnetosphere. Here we present measurements of the extent of the Dark Polar Region (DPR), a crescent-shaped region devoid of emission along the dawnside between the main auroral oval and the highly dynamic polar 'swirl' region. This region is of importance since it maps to the outer magnetosphere, although it is unclear whether it lies on open or closed field lines. Using ultraviolet images obtained by HST-STIS between the 16th May and 18th July 2016, we examine the morphology and variability of the DPR over long timescales. Coupled with interplanetary data taken during the approach phase of the Juno spacecraft, we demonstrate the influence of varying solar wind conditions on the DPR with regards to its width and extent. In particular, we show that the DPR is more variable but with a greater overall width during solar wind compressions, while during rarefactions the DPR is thinner but can extend toward larger local times.

Christopher Lorch, Lancaster University

Radial and Azimuthal Currents Within the Jovian Magnetodisc

Jupiter's magnetosphere is coupled with its ionosphere by currents. Field aligned currents (FAC) connect the ionosphere to the magnetodisc, flow through the magnetodisc as radial and azimuthal currents, and close in the ionosphere through Pedersen currents. This current system is not azimuthally symmetric, but exhibits structures in local time. Khurana (2001) was the first to explore these variations using spacecraft data. We build upon his work to include all spacecraft data until June 28th 2018, determining the local time asymmetries in Jupiter's radial and azimuthal currents in the system. Our study reveals previously unmapped current densities and their divergences in the dusk to pre-noon sector. We use the recent JRM09 internal field model (Connerney et al [2018]) and updated current sheet geometry models (Khurana & Schwarzl [2005]). We compare our results to global MHD simulations by Walker & Ogino (2003) and find our current densities are in agreement with model predictions. We also compare our derived current densities and divergences with those determined by previous studies.

Emma Davies, Imperial College London

Radial Evolution of an Interplanetary Coronal Mass Ejection: ACE/WIND, Artemis and Juno Observations

Interplanetary coronal mass ejections, ICMEs, are the main drivers of space weather at Earth which can have severe effects to systems both in space and on the ground. ICMEs with a strong southward magnetic component are the most geo-effective, thus the strength and orientation of an ICME is important in forecasting space weather severity. Understanding their evolution as they propagate through the heliosphere is therefore essential.

Relatively few studies have used multi-spacecraft observations to analyse ICME evolution as radial alignments between spacecraft are rare. While most such recent studies have focussed on the inner heliosphere, Juno cruise phase data provides a new opportunity to study ICME evolution beyond 1 AU.

We present analysis of one ICME registered by Juno on the 25th October 2011 that is of particular interest: firstly, due to its large maximum magnitude field strength which caused a strong geomagnetic storm at Earth, and secondly due to its close radial alignment with near Earth spacecraft. This illustrates the utility of studying ICMEs from the Juno cruise phase towards understanding the chain of evolution from spacecraft in the inner heliosphere, to Earth and beyond into the outer heliosphere.

Liz Tindale, University of Warwick

The Solar Cycle-Independent Scaling Properties of Solar Wind Bursts and the Implications for the Power Spectral Density and PDF

Time series of in-situ observations of solar wind parameters show randomly spaced bursts where the variable exceeds a high threshold. These bursts can be the signature of different physical processes, from turbulent eddies to transient structures of solar origin, and each process varies in its likelihood of occurrence over the solar cycle. However, Tindale et al. [2018] showed that the duration of a burst is related to its integrated area above the threshold via a power law whose exponent is invariant over the solar cycle. This indicates that at all solar cycle phases, and for a wide range of event sizes, a burst of a given size will persist for a characteristic duration. Here, we study how this robust scaling property of the bursts links to other well-known characteristics of solar wind time series, including the power-law form of the power spectrum and the approximately lognormal probability distribution of observations. We find that while the form of the power spectrum enables the existence of long-duration bursts, it is the probability distribution of values that specifies their scaling properties.

E. Tindale, S.C. Chapman, N.R. Moloney and N.W. Watkins (2018), JGR Space Phys., 123(9), doi: 10.1029/2018JA025740

Luca Franci, Queen Mary University of London

Hybrid Simulations of the Interplay Between Plasma Turbulence and Magnetic Reconnection and Comparison with In-Situ Observations

The interplay between turbulence and magnetic reconnection in collisionless plasmas is of great interest in many different astrophysical environments, e.g., in the interstellar medium, in accretions disks, and in stellar coronae and winds. The disruption of current sheets efficiently generates ion-scale coherent structures, which can enhance electromagnetic fluctuations and shape the power spectrum around the ion scales. Indeed, our high-resolution 2D and 3D hybrid (kinetic ions, fluid electrons) simulations of plasma turbulence show evidence that magnetic reconnection acts as a trigger for the generation of a sub-ion-scale cascade in collisionless space and astrophysical plasmas. We also present a remarkable qualitative and quantitative agreement with observations in the Earth's magnetosheath by the NASA's Magnetospheric Multiscale (MMS) mission, for what concerns the spectral properties of the electromagnetic and plasma fluctuations over a wide range of scales and their intermittent behavior.

Harneet Sangha, University of Leicester
Bifurcating Region 2 Currents and Sub-Auroral Polarization Streams

We analyse the magnetosphere-ionosphere (MI) field-aligned currents (FACs) associated with substorms using the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE). The expanding and contracting polar cap model (ECPC) describes how the auroral oval expands and contracts during the different substorm phases. We observe a new phenomenon seen in the AMPERE dataset, which we believe to be the formation of a new region 2 (R2) current in the dusk sector, which occurs following substorm onset. We interpret the phenomenon as the FACs associated with sub-auroral polarization streams (SAPS), which are strong westward flows in the dusk sector mid-latitude ionosphere, and thought to be formed when plasma injections enter the inner magnetosphere during the substorm expansion phase. We present examples of concurrent observations of flow channels by the Super Dual Auroral Radar Network (SuperDARN) of ionospheric radars and auroral observations from the Special Sensor Ultraviolet Spectral Imager (SSUSI) auroral cameras onboard the Defense Meteorological Satellite Program (DMSP) spacecraft.

David Price, University of Southampton
Observations of Joule Heating Associated with an Auroral Arc Above Svalbard

We present preliminary results, retrieved from a new analysis method, identifying significant Joule heating adjacent to a bright auroral arc observed over Svalbard. A combination of both the ESR (EISCAT Svalbard Radar) and the University of Southampton's Auroral Structure and Kinetics (ASK) instrument is used to measure the particle precipitation energies at high temporal resolution over the course of the event. These energies are then used as an input for Southampton's ionospheric model to retrieve a corresponding sequence of N2 volume emission rate profiles. The modelled N2 volume emission rate profiles are combined with a range of potential neutral temperature profiles to generate a large library of synthetic N2 1PG spectra. These spectra are then fit to the equivalent spectrum measured by the University Of Southampton's HiTIES (High Throughput Imaging Echelle Spectrograph) instrument to determine the best fitting temperature profile. The outcome is a time series of the most realistic neutral temperature profiles in the E-region ionosphere, at high cadence, for the duration of the auroral event. This allows us to distinguish between temperature changes due to variations in emission altitude and isolate any changes due to localised joule heating associated with the arc's electric fields.

Oliver Allanson, University of Reading
Electron Diffusion in Self-Consistent Numerical Experiments: Incoherent Broadband Waves

The diffusion of electrons in energy and pitch angle space by whistler mode waves is a cornerstone of our current theoretical framework of acceleration and loss in Earth's Outer Radiation Belt. The quasilinear theory of wave-particle interactions provides us with a tractable method to estimate the amount of diffusion that occurs for a range of wave and ambient plasma conditions. However, the whistler mode manifests in different ways throughout the outer belt: naturally generated chorus and hiss waves, and large amplitude nonlinear wave packets; artificially generated transmitter waves; and lightning generated whistler waves. It is likely that, formally speaking, the quasilinear theory is not applicable in all of these cases. In order to test the theory, we model the interactions between driven whistler-mode waves and ambient background plasma. Specifically, we propagate incoherent, broadband whistler-mode waves through conditions characteristic of equatorial magnetic latitudes in the plasma trough. We explore whether quasilinear diffusion is a reasonable description for different wave amplitudes.

Martin Archer, Queen Mary University of London

First Direct Observations of a Surface Eigenmode of the Dayside Magnetopause

The abrupt boundary between a magnetosphere and the surrounding plasma, the magnetopause, has long been known to support surface waves. It was proposed that impulses acting on the boundary might lead to a trapping of these waves on the dayside by the ionosphere, resulting in a standing wave or eigenmode of the magnetopause surface. No direct observational evidence of this has been found to date and searches for indirect evidence have proved inconclusive, leading to speculation that this mechanism might not occur. By using fortuitous multipoint spacecraft observations during a rare isolated fast plasma jet impinging on the boundary, we show that the resulting magnetopause motion and magnetospheric ultra-low frequency waves at well-defined frequencies are in agreement with and can only be explained by the magnetopause surface eigenmode. We therefore present the first definitive observations of this mechanism, which should impact upon the magnetospheric system globally.

Alexander Bader, Lancaster University

Short-Periodic Flashing in Saturn's UV Aurora

Saturn's aurora represents the ionospheric response to plasma processes occurring in the planet's entire magnetosphere. Short-lived ~1h quasiperiodic high-energy electron injections, frequently observed in in-situ particle and radio measurements, should therefore entail an associated flashing auroral signature. We use high time-resolution UV auroral imagery from the Cassini spacecraft to evidence the continuous occurrence of such flashes and investigate their properties. We find that their recurrence periods ~1h and preferential occurrence near dusk match well with previous observations of electron injections and related auroral hiss features. A large spread in UV auroral emission power, reaching up to more than 30% of the total power, is observed independent of the flash locations. Based on an Hubble Space Telescope observation showing the evolution of one such auroral feature we suggest a globally common acceleration process initiated by continuous small-scale magnetodisc reconnection.

M. J. Birch & J. K. Hargreaves, University of Central Lancashire

On the Origin of Quasi-Periodic Fluctuations in Electron Content at Very High Latitudes in the F-Region

Observations of F-region electron content at very high latitude by incoherent scatter radar, magnetic flux density at GOES satellites, and properties of the solar wind at L1, all reveal the presence of quasi-periodic fluctuations with period 20-30 minutes. We present a statistical analysis from 10 days of these observations which provide evidence of a causal connection between these parameters, the likely origin being variations of particle and magnetic flux density within the solar wind.

Téo Bloch, University of Reading

Towards the Objective Classification of Coronal Hole and Streamer Belt Solar Wind

The accurate classification of solar wind data is important for understanding the solar wind itself, developing consistent statistical analyses and creating accurate models of space weather affecting the Earth.

We present two new solar wind classification schemes developed independently using unsupervised machine learning. Both schemes aim to classify the solar wind into 3 types: coronal hole wind; streamer belt wind, and difficult to classify data. They are created using non-evolving solar wind parameters which are measured or derived from Ulysses' latitude-scan data, and subsequently applied to the whole of the Ulysses and ACE datasets. The first scheme is built around the oxygen charge state ratio, and the proton specific entropy. The second uses these as well as the carbon charge state ratio, the alpha to proton ratio, the iron to oxygen ratio, and the mean iron charge state.

The physical basis of the chosen parameters result in a reliable classification scheme grounded in the properties of the solar source regions. We demonstrate significant disparities (minimum ~8%, maximum ~22%) with the traditional speed thresholding approach.

Thomas Bradley, University of Leicester
Planetary Period Modulation of Reconnection Bursts in Saturn's Magnetotail

We conduct a statistical analysis of 2094 reconnection events in Saturn's magnetotail previously identified in Cassini magnetometer data from intervals during 2006 and 2009/2010. These consist of tailward-propagating plasmoids and planetward-propagating dipolarizations, with approximately twice as many plasmoids as dipolarizations. These are organized by three related planetary period oscillation (PPO) phase systems, the northern and southern PPO phases relative to noon, the same phases retarded by a radial propagation delay, and the local retarded phases that take account of the azimuth (local time) of the observation. Clear PPO modulation is found for both plasmoid and dipolarization events, occurring preferentially by factors of ~3 at northern and southern phases where the tail current sheet is expected to be thinnest, compared with the antiphase conditions. Local retarded phases best organize the event data with the modulation in event frequency propagating across the tail as the PPO systems rotate. This indicates that the events are localized in azimuth, rather than simultaneously affecting much of the tail width. Dividing these events into temporal intervals also shows a correlation between phase modulation and the relative amplitudes of the two PPO systems which is southern dominant during 2006, and near-equal during 2009/2010.

Dave Constable, Lancaster University
Vlasov Simulations of MI-Coupling in the Jovian System

Acceleration of field-aligned currents along planetary magnetic fields can result in the generation of aurora. The distribution of plasma along individual field lines determines the resulting potential structure along it, with the plasma distribution determined by the particle sources within the system. Along the Jupiter-Io field line, strong centrifugal and gravitational forces, coupled with large magnetic mirror ratios impinge the propagation of heavy ions, ionospheric plasma and magnetospheric electrons, respectively. The resulting field-aligned accelerating potential occurs close to the minimum of the sum of the centrifugal and gravitational potentials, causing precipitating particles to be accelerated, and thus, resulting in auroral emission.

In order to understand the dynamics in the Jovian system, an existing 1-D fully-kinetic Vlasov model developed for Earth is being adapted. The code is a parallelised 1-D spatial, 2-D velocity space code, which models the evolution of plasma species along magnetic field lines and thus, determines the structure of the auroral acceleration region. By utilising a non-uniform spatial grid, fine resolution can be obtained in specific regions of interest. An overview of the model, as well as a description of modifications to treat species as a fluid will be presented.

John Coxon, University of Southampton
Filamentary Currents in Five FTEs Observed by MMS

We present observations of five flux transfer events (FTEs) which were observed within a twenty-minute period on 3 October 2016. We employ magnetic field, electric field and plasma measurements from the Magnetospheric Multiscale (MMS) spacecraft located on the dusk flank of the magnetopause during a period of predominantly duskward IMF. The FTEs observed are of reverse polarity, indicating that they are moving towards the

Southern Hemisphere. Of the events observed, we determine that two of our events are crater-type FTEs whereas the other three do not show crater-type signatures. We observe filamentary bidirectional field-aligned current signatures during all but one of the FTEs, similar to recent observations of signatures during a crater FTE (Trenchi et al, submitted). We also observe larger regions of unidirectional field-aligned current in the two crater FTEs. We examine our results in the context of previous observations linking crater FTEs to the separatrix.

Gareth Dorrian, Nottingham Trent University

Statistical Modelling of the Coupled F-Region Ionosphere-Thermosphere at High Latitude

Linear modelling is employed to demonstrate the statistical significance of various ionosphere, thermosphere, and geophysical parameters upon the variability of the plasma density and structure, ion and neutral temperatures in the coupled ionosphere-thermosphere system. The data for these models is sourced from the EISCAT Svalbard Radar (ESR), and a co-located Fabry-Perot Interferometer during the hours of polar darkness and covers parts of Solar Cycles 23, and 24. In the first instance we produce single-term linear models of these, ranking the results of each in terms of their statistical significance. Season and F10.7 flux are found to be the dominant variables that explain the variability of ionospheric plasma density in the F-region. The Kp and Dst index are found to be of most significance in accounting ionoshperic and thermospheric temperatures. We also produce multi-term linear models which show the combinations of variables that best explain the observed variability. We demonstrate that they make better predictions of the coupled ionosphere-thermosphere system than is possible using a purely climatological approach.

Joe Eggington, Imperial College London

Identifying the Location, Extent and Evolution of the Reconnection X-Line in Global MHD Simulations

Magnetic reconnection is a key driver of magnetospheric dynamics at Earth. Although locally magnetopause reconnection appears as a quasi-2-D process with a well-defined X-line and inflow/outflow regions, the full 3-D nature of reconnection is much more complex, occurring predominantly along the magnetic separator: a continuous line along which differing magnetic topologies meet and which is terminated by magnetic null points. The global reconnection rate is determined by the length of the separator and the parallel electric field along its extent, which are highly sensitive to changes in driving conditions.

Using the Gorgon MHD code, we have implemented an algorithmic approach to tracing out the separator in global magnetospheric simulations. The location of the separator for various interplanetary magnetic field orientations and dipole tilts is explored, and thus the impact on energy transfer rates across the entire magnetopause. We relate this to changes in the closely coupled magnetosphere-ionosphere system (e.g. the strength of region-I field-aligned currents). We also identify separators in the magnetotail, and the appearance of multiple magnetic null points in this region. Finally, we show the usefulness of this technique in studying the occurrence of flux transfer events, and discuss its implementation in comparing to spacecraft observations.

Colin Forsyth, UCL Mullard Space Science Laboratory

Average Thermal Electron Spectra in the Inner Magnetosphere as a Function of L, MLT and Kp

The inner magnetosphere plays host to the plasmasphere, ring current and radiation belts. Using data from the HOPE instrument on the RBSP-A spacecraft, we calculate the average omni-directional electron spectra as a function of location (L and MLT) and geomagnetic activity (Kp). These spectra are calculated on an 'adaptive' grid which increases in spatial resolution until a lower limit of data points within each cell is reached. At low Kp, this provides an average grid size of 1.36 MLT x 0.35 L, but above a Kp of 5, the MLT resolution is no greater than 6 hrs. Our results show: (1) there is a distinct dawn-dusk asymmetry in the <100 eV electron differential number flux at low activity levels; (2) as activity increases, there is a proportionally greater increase in the 100-1000 eV and >10 keV electrons; (3) the electron flux dependence on L varies strongly with energy and Kp. Our results show distinct differences in the inner magnetosphere electron population with both location and geomagnetic activity. Such differences may play a key role in the dynamics of the inner magnetosphere, such as the generation and propagation for a variety of waves associated with particle acceleration and diffusion.

Imogen Gingell, Imperial College London
Observations of Reconnection Within the Transition Region of Earth's Bow Shock

Magnetic reconnection at thin current sheets results in the transfer of energy from electromagnetic fields to particles, resulting in acceleration and heating of the plasma. Reconnection at small-scale current sheets is expected to play a major role in energy dissipation in turbulent plasmas, and similar processes may contribute to the partition of energy within the transition region of collisionless shocks. Recent hybrid and particle-in-cell simulations have demonstrated that instabilities in the shock foot can generate structures such as current sheets and magnetic islands that are closely associated with reconnection. Here, we discuss several observations of current sheets and flux ropes by the Magnetospheric Multiscale mission at Earth's bow shock. For select case studies, we demonstrate the presence of electron jets and heating associated with active reconnection sites. Many of the observations represent an unusual mode of reconnection exhibiting ion-scale current sheets without any indication of an ion response. Hence, we discuss implications for reconnection onset time and the structure of the shock transition region. Finally, we estimate the integrated impact of magnetic reconnection on shock energetics in the available parameter regime.

Gregory Hunt, Imperial College London
Current Densities Associated with Saturn's Intra-D Ring Field-Aligned Current System

The final 22 and a half orbits of the Cassini spacecraft passed through the gap between Saturn and the inner edge of the D ring. The azimuthal magnetic field measurements revealed a signature consistent with an interhemispheric field-aligned current system that usually flows north to south on and inside D-ring magnetic field lines. The peak magnetic field perturbation is ~10-40 nT which we will show corresponds to currents flowing in the intra-D ring current sheets typically in the range ~0.5–2.0 MA rad^-1. These values are consistent with those presented from the early proximal orbits, and are comparable to the values for the high latitude auroral field-aligned currents. However, we will show that field-aligned current densities are typically ~5-15 nA m^-2, more than an order of magnitude smaller than the auroral current densities of typically ~50-150 nA m^-2, and we explore the origins of this difference. We will also discuss the variable form of the azimuthal field perturbations and the implications for the variability of the current densities.

Seong-Yeop Jeong, MSSL(UCL)
Particle-In-Cell Simulations of Electron Strahl Scattering in the Solar Wind

We present our research on electron-strahl scattering in the solar wind by using particle-in-cell simulations. Observations in the solar wind confirm that the electron strahl scatters into the halo population in the inner heliosphere. As the most likely candidate for such a scattering mechanism, we introduce the oblique whistler-wave instability, which is driven by the resonance of the oblique whistler wave with respect to the Interplanetary Magnetic Field (IMF) with the electron strahl. Using kinetic theory, we find the dispersion relation and analytical expressions for the threshold of the oblique whistler-wave instability. At the same time, the electron strahl loses total kinetic energy with a decrease of the velocity parallel to the IMF and an increases of the velocity perpendicular to the IMF. To demonstrate the validity of these theoretical results, we use the particle-in-cell simulation method. Our simulation results show a good agreement with the theoretical predictions and provide clear evidence supporting the validity of the strahl-to-halo scattering scenario. Our simulation results provide additional, nonlinear characteristics for the whistler-wave instability which have not been found in the analytical theory.

Shannon Jones, University of Reading
Distortion of the 12th December 2008 Coronal Mass Ejection Storm Front

We are investigating the effect of the solar wind on coronal mass ejections (CMEs) by looking at how CME storm fronts are distorted under varying solar wind conditions. Here we use part of a novel dataset, created with the help of many citizen scientists, to examine the distortion of the Earth-directed 12th December 2008 CME in heliospheric imager data.

Alexander Richard Lozinski, British Antarctic Survey
Evaluation of Solar Cell Radiation Damage during Electric Orbit Raising

Electric propulsion technology now enables satellite operators to achieve geostationary orbit efficiently without the use of chemical propellant via electric orbit raising. This includes the compromise of a longer raising period, during which satellites traverse the hazardous radiation environment of the Van Allen belts.

Increased radiation exposure during electric orbit raising must be accounted for by mission planners through the use of environment models such as NASA's AP8/AE8. However, case studies such as the CRRES mission show our predictive capability is limited by dynamic changes to the proton belt and slot region that can occur in large solar energetic particle trapping events, raising the risk for spacecraft shielding to be under-designed.

We show the accumulation of solar cell damage due to non-ionising dose for a variety of electric orbit raising scenarios based on real trajectories, and discuss how varying key engineering parameters affects the result.

In particular, we show that the trajectory, solar cell coverglass thickness and state of the proton belt can affect solar panel degradation accrued during electric orbit raising by up to ~10%. We conclude more real-time information is required on the transient nature of the outer proton belt to help assess radiation damage.

Lorenzo Matteini, Observatoire de Paris / Imperial College London
On the 1/F Spectrum in the Solar Wind and its Connection with Magnetic Compressibility

A puzzling property of fast solar wind magnetic fluctuations is that, despite their large amplitude, they induce little variations in the strength of the magnetic field, thus maintaining a low level of compressibility in the plasma.

At the same time, in addition to the well-known Kolmogorov MHD inertial range spectrum with slope -5/3, larger scales of fast streams are characterised by a shallower slope, close to -1. This 1/f range is considered the energy reservoir feeding the turbulent cascade at smaller scales, although its origin is not well understood yet.

These aspects are usually addressed as separate properties, however, we suggest that a link between the two exists and we propose a phenomenological model in which a 1/f spectrum for large scales can be derived as a consequence of the low magnetic compressibility condition. Remarkably this model, although simple, can capture most of the variability observed in situ in the solar wind and explain spectral differences in wind regimes. Moreover, our model provides a prediction for the evolution of the 1/f range close to the Sun that it will be possible to test soon thanks to the forthcoming observations of Parker Solar Probe.

Nigel P. Meredith, British Antarctic Survey

Global Model of Plasmaspheric Hiss from Multiple Satellite Observations

Gyroresonant wave particle interactions with plasmaspheric hiss play a fundamental role in the dynamics of the Earth's radiation belts and inner magnetosphere, affecting the loss of radiation belt electrons. Knowledge of the variability of the wave power of plasmaspheric hiss as a function of both spatial location and geomagnetic activity, required for the computation of pitch angle and energy diffusion rates, is a critical input for global radiation belt models. To build a comprehensive model of plasmaspheric hiss in the inner magnetosphere we combine plasma wave data from eight satellites, equipped to measure wave magnetic field intensities. The new model extends the coverage and improves the statistics of existing models based on data from individual satellite missions, particularly at mid to high latitudes. We develop geomagnetic activity dependent templates to separate plasmaspheric hiss from chorus emissions enabling us to isolate the plasmaspheric hiss emissions. In this presentation the global morphology of the average plasmaspheric hiss wave power will be examined as a function of frequency and geomagnetic activity. Implications for the source of plasmaspheric hiss and radiation belt modelling will be discussed. The results will also compared with previous models of plasmaspheric hiss based on wave electric field measurements.

Michaela Mooney, UCL, Mullard Space Science Laboratory

Evaluating Auroral Forecasts Against Satellite Observations

During periods of high geomagnetic activity, particles precipitating into the upper atmosphere can cause auroral emission and affect long-range radio communications, whilst the accompanying geomagnetic storm could potentially induce strong currents in oil pipelines and electricity transmission lines at ground level. These effects may impact industry sectors such as aviation, energy and defence. Forecasting the location and probability of aurora is therefore of interest to many end users. In addition, forecasting when the aurora may be visible can also be a key tool in promoting public awareness and engagement with space weather. The OVATION Prime-2013 auroral precipitation model (Newell et al., 2014) is currently in operation at the UK Met Office and delivers a 30-minute forecast of the probability of observing the aurora in the polar regions of the northern and southern hemispheres. Using techniques developed for terrestrial weather forecast verification, we evaluate the performance of this operational implementation of OVATION against the boundaries of auroral emission regions determined by the far-ultraviolet (FUV) observations of the auroral oval captured by the IMAGE satellite over the period 2000-2002.

Lauren Orr, University of Warwick

Information Flow in Directed Networks of Substorms

We obtain the dynamic directed network for substorms for the first time. SuperMag offers 100+ ground based magnetometer observations at minute resolution. We calculate the canonical cross correlation between each pair of magnetometers' vector magnetic field time series and apply a station and event specific threshold [see Dods et al. 2015] to form a time varying network. This directed dynamical network is based on the non-zero lag at which magnetometers are maximally canonically cross correlated. We present individual event case studies to show how the network dynamics can be captured by a few key network parameters. Once we have these parameters, we can compare across many, here 40, substorms. We carefully selected these isolated events based on ground station coverage. The directed network then quantifies information flow. For example, we can identify the direction and timing/rate at which the substorm current wedge expands, for both specific events and on average. Some features are common to all substorms, but there is also considerable variation, which we can quantify. By looking at connections within and between specific spatial regions we can quantify how information propagates. This can be compared with different scenarios for how the ionospheric current system evolves.

Denise Perrone, Imperial College London

Radial Evolution of Pure Coronal-Hole Plasma in the Inner Heliosphere

Spacecraft observations have shown that the proton temperature in the solar wind falls off with radial distance more slowly than expected for an adiabatic prediction. Here, we focus on the radial evolution of well-defined streams (which maintain their identity during the expansion) of pure coronal-hole plasma, by means of re-processed particle data from HELIOS mission between 0.3 and 1 AU. We have identified 16 intervals from three different sources and measured at different radial distances. The observations show that, independently of the source, (i) the proton density decreases as expected for a radially expanding plasma, unlike previous analysis that found a slower decrease; (ii) the magnetic field deviates from the Parker prediction, with the radial component decreasing more slowly than expected; (iii) the double-adiabatic invariants are violated and an increase of entropy is observed; (iv) the collisional frequency is not constant, but decreases as the plasma travels away from the Sun. The present work provides an insight into the heating problem in fast solar wind, fitting in the context of the next solar missions, and, especially for Parker Solar Probe, it enables us to predict the high-speed solar-wind environment much closer to the Sun.

Jade Reidy, University of Southampton

Multi-Scale Observation of Two Polar Cap Arcs Occurring on Different Magnetic Field Topologies

We present two case studies with multi-scale observations of polar cap arcs occurring in the northern hemisphere over Svalbard that are consistent with different magnetic field topologies. These two events were first observed in images from the Special Sensor Ultra-violet Spectrographic Imager (SSUSI) instruments on board Defence Meteorological Spacecraft Programme (DMSP) spacecraft. Particle data from the SSJ/5 instrument (also on board DMSP) show one arc to be consistent with occurrence on closed field lines (it was associated with electron and ion precipitation and was observed in both hemispheres) and the other arc to be consistent with occurrence on open field lines (it was associated with electron-only precipitation). These events are investigated using images from an all-sky camera and the Auroral Structure and Kinetics (ASK) instrument which has a small (6°) field of view, both located on Svalbard. The ASK observations are used in conjunction with an ionospheric model to obtain an estimate of the energy and flux of the precipitation for each event. These estimates are compared to measurements from the spacecraft instruments to demonstrate that the different topologies can be determined by both spacecraft and ground based observations.

John Ross, British Antarctic Survey

The Effects of VLF Transmitters on the Inner Radiation Belt

Earth based Very Low Frequencies transmitters emit at frequencies of ~20kHz and the waves can leak through the ionospheric D layer into the magnetosphere. This wave power is highly spatially localised around the transmitters and strongest on the nightside. Unlike in the slot region, plasmaspheric hiss waves are ineffective at diffusing electrons by wave particle interactions in the inner belt. VLF waves have higher frequencies and consequently may be more effective and hence able to reduce bottlenecks in electron diffusion and therefore decrease electron lifetimes. DEMETER observations show wisp features in electron flux that are thought to be signatures VLF wave-particle interactions.

Observations of VLF whistler waves by the Van Allan probe satellites are used to calculate MLT and longitude dependent electron diffusion coefficients for individual VLF transmitters resulting from wave particle interactions. To capture this spatial dependence, we construct a 1D pitch angle diffusion model incorporating MLT and longitude. We then show that despite their power being strongly depend on longitude and MLT, their effects are well approximated by simpler averaged models. Changes in electron decay timescales resulting from the addition of transmitters are explored as well as the consequences of interrupted operation of the strongest transmitters.

Jasmine Kaur Sandhu, MSSL (UCL)
The Variability in Substorm – Ring Current Coupling

Substorms are a highly dynamic process that results in the global redistribution of energy within the magnetosphere. The occurrence of a substorm can provide the inner magnetosphere with hot ions and consequently intensify the ring current population. However, substorms are a highly variable phenomenon that can occur as an isolated event or as part of a sequence. In this study we determine the extent to which substorms enhance the ring current energy content and compare how the energy enhancement varies with substorm type.

Using Van Allen Probe observations, we quantify how the total ring current energy content changes during the substorm process. We find that 9% of the total energy released at substorm onset is transferred into the ring current population, and energises the ring current by 17% on average. We establish that the ring current response to substorms is strongly dependent upon the current state of the ring current and the type of substorm activity. We present clear magnitude and local time differences that illustrate the complexity and variability of the substorm-ring current coupling, along with an interpretation of the details of this relationship.

Christopher Scott, University of Reading
Using Ghost Fronts Within STEREO Heliospheric

Multiple fronts associated with one Coronal Mass Ejection (CME) are frequently observed in images from the Heliospheric Imager instruments on board the STEREO spacecraft. Here we present an analysis of the Earth-directed CME launched on 12 December 2008. By comparing the relative position of the outer and inner 'ghost' fronts seen in the STEREO HI1-A camera with the positions of features determined from three CME models, we show that these two fronts correspond to the expected position of the flank and nose of the CME. The presence of a shock for this event was ruled out by consideration of the low CME speed and by studying in-situ spacecraft data. Of the three CME models considered; a self-similar expanding circle (SSE-C), a self-similar expanding ellipse (SSE-E) and a kinematically distorting flux rope (KDFR), best agreement with the observations was found for the SSE-E and KDFR models. Enhanced scattering due to parts of the CME front crossing the Thomson sphere was ruled out as a cause of the multiple fronts observed in this example. Multiple fronts could provide information about the longitudinal shape of the CME front, which would improve space weather forecast models through data assimilation.

Robert Shore, British Antarctic Survey
New Techniques for Electric Field Variability Characterisation from SuperDARN Radar Data

We present the results of applying a meteorological analysis method called Empirical Orthogonal Functions (EOF) to month-long samples of polar ionospheric plasma velocity data from SuperDARN. Our goal is to provide a new reanalysis model of ionospheric electric field variability, spanning a full solar cycle at 5 min resolution.

The EOF method is used to characterise and separate contributions to the variability of plasma motion in the northern polar ionosphere. EOFs decompose the noisy and sparse SuperDARN data into a small number of independent spatio-temporal basis functions, for which no a priori specification of source geometry is required. We use these basis functions to infill where data are missing. This infill only converges when it reinforces patterns present in the original data, thus providing a self-consistent description of the plasma velocity at the original temporal resolution of the SuperDARN data set.

We summarise the challenge of interpolating data coverage to regions which are not directly measured by SuperDARN, and we discuss our progress in developing techniques to overcome these challenges.

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David Stansby, Imperial College London

In-Situ Solar Wind Categorisation Inside 1 AU

Although traditionally the solar wind is split into slow and fast components, the solar wind speed distribution is not bimodal, making the slow/fast distinction arbitrary. In contrast, we show that the temperature anisotropy distribution is bimodal inside 0.8 AU, with clearly identifiable anisotropic and isotropic populations. At 0.3 AU all fast solar wind is anisotropic, but there is also a comparable amount of slow solar wind that is anisotropic, agreeing with previous studies showing the existence of a 'slow Alfvénic' wind with the same properties as the fast wind.

We show for the first time that all of the anisotropic wind is highly Alfvénic, suggesting that regardless of speed it originates from magnetically open coronal hole field lines on the Sun. In contrast isotropic wind consists solely of slow speeds and is evenly split between Alfvénic and an Alfvénic component, which we conclude originates in or near active regions, and a non-Alfvénic component, which we conclude consists of small transient structures. Our results demonstrate one way in which information on the origins of the solar wind is lost by the time it has traveled to 1 AU.

Julia E. Stawarz, Imperial College London

The Relationship Between Electron Magnetic Reconnection and Magnetosheath Turbulence

It has long been suggested that magnetic reconnection can occur at intense small-scale current sheets generated within turbulent plasmas. However, the role that this fundamental process plays in the turbulence is still not fully understood. Recently, Phan et al. [Nature, 577, 202-206, (2018)] reported, using Magnetospheric Multiscale (MMS) observations in Earth's magnetosheath, a novel form of magnetic reconnection where the dynamics only couple to electrons without any ion involvement. It was suggested that this type of reconnection may be driven by turbulence; however, the details of the turbulent environment were not examined in that study. In this work, we examine the properties of the turbulence in the Phan et al. event with a focus on energy spectra and the statistics of the current structures. The study reveals statistical properties consistent with a turbulent plasma and potential signatures at length scales associated with the reconnecting current sheets, supporting the hypothesis that electron reconnection is driven by the turbulent environment.

Rhys Thompson, University of Reading

Exploring the Impacts of Variability in the Radial Diffusion Problem

A number of modern radiation belt models simulate high energy electrons by solving a three dimensional Fokker-Planck equation for the electron phase space density, comprising of radial, pitch angle and energy diffusion. Radial diffusion is an important process, where electrons are drawn inwards from the outer boundary to lower L from substorm injections on the nightside, or pushed outwards to the magnetopause to produce loss. This process is characterised by a radial diffusion coefficient generally assumed to be deterministic, and one of the most widely used parameterizations is based on the median of statistical ULF wave power and time dependent on the geomagnetic index Kp. This study performs a series of idealised numerical experiments on radial diffusion, introducing temporal and spatial variabilities to the aforementioned deterministic diffusion coefficient based on the statistics from which it was produced. We show that understanding the temporal variation of the underlying ULF wave power, spatial correlations of diffusion across L-Shells, as well as the underlying distribution and variance of the radial diffusion coefficients are important to produce a robust description of ULF wave-particle interactions over long timescales in the magnetosphere.

Samuel J. Wharton, University of Leicester

Monitoring the Morphology of the Magnetosphere with ULF Waves

The magnetosphere is a dynamic structure that supports a variety of wave populations, including resonant ultralow frequency (ULF) waves. The occurrence and frequencies of resonant ULF waves vary with magnetic local time and solar wind driving conditions as they depend on the magnetic field geometry, and also on the field-aligned plasma mass density, which is difficult to measure.

Recent advances have shown that a variety of ground-based instruments can be used to measure field line eigenfrequencies. This enables the calculation of magnetospheric plasma mass densities. The distribution of that plasma can be found if multiple harmonics can be measured too. We have developed an algorithm based on the cross-phase technique to monitor the local eigenfrequencies of the geomagnetic field and applied it to multiple magnetometers over a long time scale. Our observations demonstrate considerable asymmetries in the ULF wave field. The dataset also shows the occurrence and frequencies of resonant ULF waves change with varying solar wind and geomagnetic conditions, helping us to understand the source mechanisms of these waves. Finally, we are able, for the first time, to show that ground-based instruments can be used to map the mean plasma mass density of the magnetosphere.