# “Autumn MIST 2019 Take 2”

## Abstract book

## Friday 24 January, Geological Society

# Contents



# Talk Session 1

**Mathew Owens (Invited)**, University of Reading

*Sun to mud: The challenges of forecasting within the coupled space-weather system*

Forecasting space weather with a lead time of more than an hour requires propagation of information through the whole Sun-Earth system. Changes in the dominant physical processes, as well as the characteristic spatial and temporal scales, means this is best achieved using separate models for each physical domain (e.g., the photosphere, corona, heliosphere, magnetosphere, ionosphere, etc). The fundamental sources of uncertainty and available observational constraints differ greatly across these models, meaning coupling them presents a wealth of scientific and engineering challenges.

**Stuart Bale**, UC Berkeley/Imperial College/Queen Mary

*Some early results from the Parker Solar Probe FIELDS instrument*

The NASA Parker Solar Probe mission launched on August 12, 2018 and reached its first perihelion of 35.7 solar radii on November 5, 2018. The FIELDS instrument suite made the first measurements of the solar wind magnetic field, DC electric fields, plasma waves, quasi-thermal noise, and radio emissions below ~20 MHz at this distance from the Sun. Here we present the status of the FIELDS instrument and an overview of early results from the first few perihelia. FIELDS measures large switchbacks of the radial magnetic field, copious ion cyclotron waves, whistler and Langmuir waves, as well as magnetized turbulence and interplanetary dust.

**Diego de Pablos**, MSSL/UCL

*Connecting small-scale dynamics in the solar atmosphere to in-situ solar wind measurements*

One of the primary aims of the Solar Orbiter mission is to quantify how the Sun creates and controls the heliosphere. To achieve this, the spacecraft supports both remote and in-situ observations of the solar atmosphere and the solar wind. Quantifying the origin and evolution of these outflows requires pre-emptive observation of the source region for a given stream of plasma that is subsequently measured in-situ. However, the high-resolution imaging instruments cover a relatively small fraction of the solar disc, and the spacecraft telescope pointing must be uploaded three days before observation campaigns start. As a result, selecting observation regions requires the ability to model the likely connectivity of the spacecraft to the solar surface several days in advance, and to afterwards verify that the connection was indeed made.

This work uses methods that enable us to predict likely sources of the solar wind sampled by a spacecraft. We make use of available space-borne and ground-based instrumentation, modelling the solar wind by combining ballistic tracing and magnetic field modelling techniques. We then attempt to correlate the occurrence rate of small-scale dynamic features in the vicinity of the predicted solar wind source region with in-situ measurements of the solar wind stream.

**Sofija Durward**, Lancaster University

*IMF variability at Mars: a statistical study*

Due to the absence of a continuous upstream solar wind monitor at Mars, little is known about the variability of the interplanetary magnetic field (IMF) as it reaches the planet. As such it is often assumed that the IMF is slow changing, although it is likely that this is a poor assumption. It is expected that corotating interaction regions (CIRs) will be more prevalent at Mars than at Earth, and interplanetary coronal mass ejections (ICMEs) may have evolved so that their signatures are different from terrestrial observations.

This study uses pristine interplanetary magnetic field measurements upstream of Mars to quantify the autocorrelation of the measurements at later times. Using historic measurements from both the Mars Global Surveyor and the current MAVEN mission, we provide an insight into the solar cycle dependencies of the steadiness of the interplanetary magnetic field at 1.5AU and allow for more accurate estimation of IMF properties hours after the previous measurement.

**Alexander Bader**, Lancaster University

*Cassini's Grand Finale – a glimpse of Saturn's auroral acceleration region?*

NASA's Cassini spacecraft passed across Saturn's auroral region at low altitudes several times during the Grand Finale phase of the mission. Coincident auroral imagery and measurements of fields and charged particles during two such orbits provide important information about Saturn's acceleration region. Upward field-aligned current regions coinciding with bright auroral arcs feature upward proton beams reaching energies of tens of keV, without concurrent wave signatures visible, indicating that strong parallel potentials may be responsible for the acceleration of auroral particles. Downward current regions are instead characterized by upward proton conics with a distinct low-energy cutoff above 50 keV, which may be transversely energized by plasma wave features also observed in these regions. Generally, signatures observed during these orbits bear resemblance to the terrestrial auroral acceleration region, but the processes seem to be much more energetic.

**Gabrielle Provan**, University of Leicester

*Solar wind and Planetary period modulations of reconnection events in Saturn's magnetotail*

Tail reconnection at Saturn can be detected with the Cassini spacecraft via deflections of the magnetic field, low frequency extensions of Saturn's kilometric radiation, and plasma injections observed via charged particle counts. Cassini's F-ring and proximal orbits provide ideal conditions to view such features over a period of 9.5 months to identify preferential conditions for their occurrence. We identify several large-scale tail reconnection events during this interval, supported by UVIS and HST auroral observations, showing clear night-side plasma injections associated with such tail activity. These events are then compared with planetary period oscillation (PPO) phases, propagated Solar wind (SW) models, and solar energetic particle and galactic cosmic ray counts. Results show that large-scale reconnection takes place during magnetospheric compressions caused by coronal mass ejections and corotating interaction regions, however, we also find that these SW modulated events have a preference to take place during near-ideal PPO anti-phase conditions for which the tail current sheet will be thinned and stretched out (Bradley et al., 2018JA025932). We conclude that reconnection is favored by optimum conditions from the SW external to the magnetosphere in concert with the PPO phasing internally, rather than being dependent on one condition or the other.

**Affelia Wibisono**, MSSL/UCL
*Temporal and Spectral Studies of Jupiter's X-ray Aurorae with XMM-Newton During a Compression Event Observed by Juno*

In June 2017 XMM-Newton observed Jupiter's X-ray aurorae during a definite magnetosphere compression event for the first time. This was confirmed by Juno which was concurrently at apojove.

Pulsations in auroral X-ray emissions have been detected in ~30% of observations (Jackman et al., 2018) in the pre-Juno era. We ran wavelet and Fast Fourier transforms on the lightcurve to reveal that the northern aurora pulsated with periods of ~23-28 minutes which slowed down and stopped part way through the second planetary rotation. The southern aurora was weakly pulsing at ~23-35 minutes in the second rotation which then increased in intensity in the third rotation.

There are two constituents to the X-ray aurorae. Hard X-rays with energies above 2 keV are produced by bremsstrahlung by precipitating electrons. Soft X-rays have lower energies and are due to charge exchange processes between precipitating ions and neutrals in Jupiter's atmosphere (Branduardi-Raymont et al., 2007, 2008). The ions' origins are still unclear - are they from the solar wind or from Io's volcanoes? We created solar wind and iogenic plasma models and showed that for this observation, the iogenic model fitted the auroral spectra best, meaning that the precipitating ions are from Io.

**James Waters**, University of Southampton
*Towards a multi-decadal dataset of auroral kilometric radiation source parameters with Wind*

Auroral Kilometric Radiation (AKR) is radio emission that originates in particle acceleration regions along magnetic field lines that coincide with discrete auroral arcs. For decades, radio astronomy instruments aboard various spacecraft have been used to derive the source directions and flux densities of radio emissions of various origin. The Wind spacecraft has been in operation for 25 years and its flight characteristics (spin-stabilised, orthogonal antennae) have been considered in the development of techniques involving direction-finding and polarimetry of a radio source. Such techniques allow for the angular coordinates, the angular radius and the Stokes (flux and polarisation) parameters to be retrieved, and have been used previously to study solar radio emissions. With full polarisation considered, the long timespan of Wind data can produce a utile dataset, in particular here to study the variability of AKR during substorm phases.

# Talk Session 2

**Sean Elvidge**, SERENE, University of Birmingham

*Probabilistic Forecasting of the Ionosphere/Thermosphere*

Probabilistic weather forecasting is the norm in the metrological community, however in the upper atmosphere we have been slower to adopt such approaches. This paper will describe how AENeAS (the Advanced Ensemble electron density [Ne] Assimilation System; a physics-based ionosphere thermosphere data assimilation model) is used to generate probabilistic nowcasts and forecasts. Based upon a variant of the ensemble Kalman filter (the local ensemble transform Kalman filter), and using kernel density estimation, probability distribution functions can be derived for various space weather phenomena including, but not limited to, the total electron content (TEC) and ExB drifts. These distributions are then the basis of probabilistic forecasts. Suitable metrics for validation (such as the Brier Skill Score) and how well the model performs will also be presented.

**Ingrid Cnossen**, British Antarctic Survey

*Simulated trends in ionosphere-thermosphere climate due to predicted main magnetic field changes from 2015 to 2065*

The strength and structure of the Earth's magnetic field is gradually changing. During the next ~50 years the South Atlantic Anomaly (SAA) is predicted to expand, deepen, and continue to move westward, while the magnetic dip poles move north-westward. We used simulations with the Thermosphere-Ionosphere-Electrodynamics General Circulation Model to study how predicted changes in the magnetic field will affect the climate of the thermosphere-ionosphere system from 2015 to 2065. The global mean neutral density in the thermosphere is expected to increase slightly, by up to 1% on average, or up to 2% during geomagnetically disturbed conditions ($Kp \geq 4$). This is due to an increase in Joule heating power, mainly in the southern hemisphere. Global mean TEC changes range from -3% to +4%, depending on season and UT. However, regional changes can be much larger, especially in the SAA region during daytime. The mechanism behind the TEC changes is not fully understood yet, but likely related to changes in plasma transport. The predicted increase in neutral density associated with main magnetic field changes is very small compared to observed trends and other trend drivers, but the predicted changes in TEC could make a significant contribution to observationally detectable trends.

**Richard Boynton**, University of Sheffield

*Spatiotemporal forecasting of the inner magnetosphere: a machine learning approach*

This research aims to forecast the spatiotemporal evolution of emissions and electron fluxes throughout the inner magnetosphere. The machine learning technique based on NARMAX models is employed to deduce the forecasting models using solar wind and geomagnetic indices as inputs. It is challenging to develop spatiotemporal models of parameters as the inner magnetosphere as the data is sparse and machine learning techniques require large amounts of data. Two methods are trialed to model the spatial variability of the waves and electron fluxes. The first was to bin the data into spatial regions and develop individual models for each bin and the second method was to use spatial coordinates at the time of the measurements as the inputs to the model. The first method was used to develop electron flux models at geostationary orbit and shows that the models accurately forecast the electron fluxes at different magnetic local times. The second method was applied to model the Hiss, chorus, and magnetosonic waves and also the electron fluxes throughout the radiation belts from 1.5 RE to 6 RE. The electron flux model reproduces the enhancements and decay of the outer radiation belts as solar wind changes.

**Oliver Allanson**, University of Reading

*Scattering and energisation of radiation belt electrons by incoherent waves*

Interactions with whistler-mode waves cause local acceleration and loss of high energy electrons in the Earth's outer radiation belt. Using the EPOCH particle-in-cell code, we study the electron response due to interactions with incoherent whistler-mode waves. The relatively simple configuration of field-aligned waves in a cold plasma is used in order to benchmark our novel method, and to compare with previous works that used a different modelling technique. In this boundary-value problem, incoherent whistler-mode waves are excited at the domain boundary, and then propagate through the ambient plasma. Electron diffusion characteristics are directly extracted from particle data across all available energy and pitch-angle space.

The 'nature' of the diffusive response is itself a function of energy and pitch-angle, such that the rate of diffusion is not always constant in time. However, after an initial transient phase, the rate of diffusion tends to a constant, in a manner that is consistent with the assumptions of quasilinear diffusion theory. As the wave power is increased, significant changes in electron energy and pitch angle can occur on very short timescales. These changes have a resonant origin, but appear to be due to a combination of both diffusive and non-diffusive dynamics.

# Lightning Talks

**Chris Arridge**, Lancaster University

*Ikuchi: 3D Views of Solar System Magnetospheres*

**Caitriona Jackman**, University of Southampton

*New dataset of magnetopause and bow shock crossings from Cassini mission: list details and applications*

**Clare Watt**, University of Reading

*What are the fundamental modes of energy transfer and partitioning in the coupled Magnetosphere-Ionosphere system? A proposal submitted to ESA Voyage 2050*

# Talk Session 3

**Matthew Brown**, University of Southampton

*Future secular neutral density trends at low Earth orbit altitudes and their implications for the space debris environment*

Carbon dioxide (CO2) and nitric oxide (NO) cause global cooling in the upper atmosphere, leading to thermospheric contraction and secularly decreasing atmospheric density over time. A future "worst-case scenario" has been modelled with the Whole Atmospheric Community Climate Model with thermosphere and ionosphere extension (WACCM-X) by following the CO2 emission profile of the Representative Concentration Pathway (RCP8.5) developed by the IPCC. The global mean annual mean thermospheric densities at certain yearly intervals in this simulation are used to calculate the evolving thermospheric density trend through to the year 2100. The cumulative effect of this trend sees a reduction of up to 70% in thermospheric density at 500 km in 2100 when compared to the year 2000. An initial investigation into the impact this cumulative trend will have upon the space debris environment has been performed by studying the increase in orbital lifetime of objects in Low Earth Orbit (500 km and below). Objects in roughly circular orbits at 400 km, such as the International Space Station, have lifetimes in 2100 that are twice as long as those in the year 2000.

**Heli Hietala**, Imperial College London

*Magnetosheath Jets in Global 3D Hydrid Simulations*

Collisionless shocks generate a multitude of transient structures in their surroundings, both upstream and downstream. Some of the most prominent phenomena observed at the Earth's bow shock are magnetosheath jets - localized enhancements of dynamic pressure with typical observed scales of about 1 Earth radius (10s of ion inertial lengths). Notably, the majority of the jets cannot be explained by direct solar wind driver. In contrast, they are thought to be related to kinetic processes in the foreshock and at the bow shock, their occurrence rate being much larger downstream of the quasi-parallel bow shock. Upon impact with the magnetopause, the jets can, e.g., launch various magnetospheric waves modes, trigger magnetopause reconnection, and cause localized auroral brightenings.

It is very difficult to observationally investigate the 3D properties of localized transients with the existing 3-5 spacecraft constellations. The 2D nature of previous simulations, on the other hand, may have limited the magnetosheath and jet flow patterns, therefore affecting their structure. The global 3D hybrid-Particle-in-Cell simulations we have performed under quasi-radial interplanetary magnetic field conditions exhibit rich dynamics, including formation of jets. Here we investigate the jets' complex 3D shape and their relation to the magnetic field.

**Caoimhe Doherty**, MSSL/UCL

*A case study of reconnection signatures observed in Earth's magnetospheric cusps*

The magnetospheric cusps are dynamic areas of the magnetosphere. Their location, shape and size are heavily dictated by the upstream solar wind and interplanetary magnetic field (IMF). Signatures of particle precipitation and magnetic flux motion in the cusp regions are thought to be evidence of magnetopause reconnection. Here we present a case study of observations at high latitudes and in particular in the high altitude magnetospheric cusps, and test whether they can be interpreted as signatures of magnetopause reconnection. A feature of the case study event is that the IMF changes from a steady northward to a steady southward configuration while Cluster traverses the northern hemisphere cusp close to the reconnection site. Additionally, we use data sets from the SuperDARN and EISCAT radars to provide global context and to search for ionospheric signatures of reconnection such as PMAFs that may be related to cusp signatures observed by Cluster.

**Michaela Mooney**, MSSL/UCL

*Evaluating Auroral Forecasts Against Satellite Observations*

Enhanced auroral activity at Earth can cause disruption to long-range radio communications and give rise to ground induced currents. These effects make forecasting the location and probability of the aurora of interest to many sectors such as aviation, energy and defence. 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. By applying terrestrial weather forecast validation techniques, we evaluate the performance of this operational implementation of OVATION against auroral emission boundaries determined from global far-ultraviolet (FUV) observations captured by the IMAGE satellite between 2000 and 2002.

Our analysis shows that the operational model performs well overall; however, the model performance is lower in the dayside magnetic local time (MLT) sectors. We also see a decrease in the model performance during periods of high Kp (greater than Kp 7).

The OVATION-Prime 2013 model accurately forecasts the location of the auroral oval under nominal space weather conditions but may be less reliable during periods of more severe geomagnetic activity when the potential space weather risk to infrastructure is higher.

**Han Zhang**, University of Durham

*Three dimensional simulations of the most extreme space weather event on record: The 23 July 2012 Interplanetary Coronal Mass Ejection observed by STEREO-A*

The Carrington event of 1851 has long represented a benchmark for the study of extreme space weather events. In 2012, however, STEREO-A observed an event of the same if not greater magnitude where an initial coronal eruption propagated outwards and ‘cleared the path’ for a successive larger eruption from the same active region which reached 1 a.u. with an estimated shock speed of ~2,300 km/s. In this paper, we describe three-dimensional hydrodynamic and magnetohydrodynamic simulations of the 23rd July 2012 event, and, using remote observations and coronal models as inputs, are able to reproduce key features of this event. To further evaluate the phenomenon of an initial eruption pre-conditioning the solar wind, the launch-time of the successive ICME is varied with respect to the first. Notably, it is found that the successive ICME is able to reach velocities more than 50% greater than without an initial preconditioning event, although a complex inverse density trend does not directly translate this into a more geoeffective event. These results provide context for future space weather monitoring endeavours and assist in understanding the requirements for ICME forcasting.

# Poster Sessions 1 & 2

# Lower Library

**Jade Reidy**, British Antarctic Survey

*Comparing high energy electron precipitation from radiation belt models to satellite observations*

Particle precipitation is one of the loss mechanisms from the Earth's Radiation Belts whereby particles trapped by the Earth's magnetic field are scattered into the loss cone due to wave-particle interactions. Based on previously published work, we calculate the magnetic local time (MLT) dependent electron precipitation using bounce-averaged pitch angle diffusion coefficients for chorus, plasmaspheric hiss and EMIC waves, and atmospheric collisions. We compare this MLT-dependent electron precipitation to the electron precipitation calculated by the British Antarctic Survey Radiation Belt Model (BAS-RBM) for the March 2013 storms. The BAS-RBM solves a 3D Fokker-Plank diffusion equation with a set of drift averaged diffusion coefficients that characterise the wave-particle interactions and atmospheric collisions, and also includes the effect of radial transport. In order to compare with data from the Polar Orbiting Environmental Satellite (POES), we converted the MLT-dependent electron precipitation to an integral flux to compare to the >300 keV electron channel. We find the MLT-dependent calculation based on the diffusion coefficients reproduces the occurrence of the electron precipitation measured by POES but with some significant differences. We discuss the origin of these differences and ways to improve the model.

**Lorenzo Matteini**, Imperial College London

*Large scale 1/f magnetic field spectrum in the solar wind close to the Sun*

We investigate properties of the spectrum of magnetic field fluctuations observed by PSP in the solar wind inside 0.3 AU. We focus on large scales (low frequencies in the spacecraft frame) above the MHD-inertial range with typical spectral index -5/3, where the spectrum displays a shallower slope, close to -1. The radial evolution of the break scale separating the inertial and 1/f ranges is investigated for different wind regimes and compared with analogous conditions observed by Helios at 0.3 AU and beyond. We analyze data taking into account different physical parameters that can play a role in the evolution of the fluctuations, such as their absolute and relative amplitude, the flow expansion rate, and the estimated non-linear time of turbulent interactions. Observations are discussed in the framework of existing models for the solar wind 1/f spectrum and results are compared with theoretical predictions.

**Timo Laitinen**, University of Central Lancashire

*Bayesian analysis of STEREO turbulence observations for solar energetic particle transport*

The propagation of Solar Energetic Particles (SEPs) in the heliosphere is controlled by the turbulent solar wind magnetic fields. To model the SEP propagation, we need information on the turbulence power and composition. Typically turbulence is modelled to have a slab and a 2D component, which contribute to propagation along and across the mean field direction, respectively. Careful turbulence analysis suggests that the 2D component dominates over the slab component. However, this result has been derived by using long observation periods of well-chosen data, whereas for analysing turbulence during an SEP event typically requires short time frames, from hour to days. In this work, we derive the temporal evolution of solar wind turbulence, as observed by the STEREO spacecraft, using the method introduced by Bieber et al (1996). We quantify the uncertainties of the turbulence composition by using Bayesian inference. Our results are in general in line with the other workers, however we demonstrate the temporal variance of the turbulence parameters and the significance of uncertainties. We compare the STA and STB observations of turbulence at the same heliolongitudes, and discuss the results and the issues affecting the analysis and uncertainties of the turbulence composition.

**Luca Franci**, Queen Mary University of London

*Impact of the turbulence strength on the spectral properties and on electron acceleration*

We present results from hybrid simulations of plasma turbulence with an intermediate plasma beta, exploring different combinations of injection scale and turbulence strength. Varying both parameters so that the nonlinear time is constant, the magnetic field structures look very different but the spectral properties are the same, just rescaled in power, showing a remarkable self-similarity. For a fixed injection scale and different turbulent strength, the evolution is the same, just rescaled with the nonlinear time, and we don't only observe the same spectra but also the same structures with the same shape and size in the same locations. This suggests that all the processes involved (e.g., reconnection) might depend on the rescaled nonlinear time.

Coupling these simulations with test-particle electrons, we address the interaction of transrelativistic electrons with plasma turbulence at ion and sub-ion scales. Two different mechanisms for electron energisation are identified. One is consistent with stochastic acceleration in turbulence ( "second-order Fermi" mechanism), yielding to moderate electron energisation, while the other involves electron trapping in turbulent magnetic structures, resulting in efficient, fast electron energisation due to drift acceleration. The second mechanism ("first-order Fermi") is efficient only for certain combinations of turbulence strength and electron energy.

**Tom Elsden**, University of Leicester

*The Effect of Fast Normal Mode Structure and Magnetopause Forcing on FLRs in a 3-D Waveguide*

We consider the excitation of waveguide modes in a nonuniform dipole equilibrium and, further, their coupling to field line resonances (FLRs). Waveguide modes are fast compressional ultralow frequency (ULF) waves, whose structure depends upon the magnetospheric equilibrium and the solar wind driving conditions. Using magnetohydrodynamic simulations, we consider how the structure of the excited waveguide mode is affected by various forms of magnetopause driving. We find that the waveguide supports a set of normal modes that are determined by the equilibrium. However, the particular normal modes that are excited are determined by the structure of the magnetopause driver. A full understanding of the spatial structure of the normal modes is required in order to predict where coupling to FLRs will occur. We show that symmetric pressure driving about the noon meridian can excite normal modes which remain around to drive resonances for longer than antisymmetric driving. Further, the critical quantity in terms of efficient coupling is the magnetic pressure gradient aligned with the resonance.

**Steven Sembay**, University of Leicester

*The Soft X-ray Imager (SXI) on the forthcoming SMILE Mission*

The joint European Space Agency (ESA) and Chinese Academy of Sciences (CAS) Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission is due to be launched in 2023. SMILE will study the interaction of the solar wind with the Earth's magnetosphere. SMILE will gather remote-sensing (X-ray) measurements of Earth's magnetospheric cusps, magnetopause, and bow shock, while also providing simultaneous auroral imaging (UV) of Earth, and coordinated in situ measurements (plasma and magnetic). Here we describe the UK-led Soft X-ray Imager (SXI) instrument which will detect the emission caused by the solar wind charge exchange (SWCX) process enabling the determination of the position of global boundaries within the magnetosphere on timescales of minutes.

**Allan Macneil**, University of Reading

*Helios Observations of Strahl Electrons on Magnetic Switchbacks*

The 'strahl' component of the solar wind electron population is a field-aligned, typically anti-sunward, suprathermal (>100 eV) beam. Intervals where the strahl instead travels sunward along the field indicate local heliospheric magnetic field (HMF) inversions (also known as 'switchbacks'). These inversions have been suggested as remnant structures from interchange reconnection processes; candidate mechanisms for the production of slow solar wind. Using Helios observations, we radially profile the pitch angle distributions (PADs) of sunward strahl electrons which are present during HMF inversions, in comparison to anti-sunward strahl in a statistical study spanning ~0.3-1 AU. We find the sunward PADs to be the broader and less intense of the two. However, both populations become increasingly broad and less intense with radial distance. These results suggest that both are subject to continuous scattering during propagation through the heliosphere, and that sunward strahl is more strongly scattered at a given heliocentric distance. We conclude that the longer and more variable path from the Sun to the spacecraft, along inverted magnetic field, leads to the additional scattering of the sunward strahl. The results also suggest that the relative importance of scattering along this inverted field drops off with heliocentric distance.

**Wayne Gould**, Lancaster University

*Deciphering the Solar Wind at Saturn*

The effects of the solar wind on Saturn's magnetosphere are poorly understood because there are no consistent means of direct detection of the solar wind at Saturn. This limits our knowledge of the solar winds impact to case studies of single or few events where Cassini was outside the magnetopause. We present the current results of a robust statistical analysis of Saturn Kilometric Radiation data from Cassini to determine magnetospheric proxies for the solar wind. Unique to the project is the use of Mutual Information as a validation test of the relationship between SKR and solar wind variables from propagation models. Finding and confirming the relation of these indirect proxies to solar wind propagation models presents the opportunity to open up years of data to interpretation with respect to the solar winds behaviour at the outer planets, using data sets from past missions such as Cassini. This will improve our understanding of how planetary magnetospheres respond to changes in the solar wind.

**Josh Wiggs**, Lancaster University

*Hybrid Magnetospheric Modelling at the Outer Planets using Python*

Modelling planetary magnetospheres is essential to develop understanding of how these dynamic regions of space respond to forcing from both internal and external sources of mass, momentum and energy. Obtaining an exact solution for the governing equations describing these complex systems is very difficult. Therefore, simplified models are required for investigation. The size of planetary magnetospheres presents additional complications when creating models of them as important dynamics occur on spatial scales ranging from planetary radii down to the kinetic ion and electron levels. Such challenges are present in simulating bulk plasma transport in Jupiter's inner and middle magnetosphere, where plasma flows from Io's plasma torus radially outwards. The process of radial transport is attributed to the centrifugal-interchange instability. A hybrid kinetic-ion/fluid-electron approach is taken to modelling these magnetospheric plasma flows. Hybrid techniques are able to capture large-scale flow dynamics as well as interactions between particles. Whilst most models of this type are written in C/C++ or Fortran, the aim in this project is to provide a Python codebase that allows for prototype physical effects to be examined before incorporation into an optimised implementation. Writing a version in a modern accessible language also has pedagogical value.

**Samuel Wharton**, University of Leicester

*Determining Dayside Cold Plasma Dynamics during Geomagnetic Storms with ULF Waves*

Magnetic field eigenfrequencies determine where in the Earth's magnetosphere and radiation belts ULF wave power is distributed. Recent work has shown that the eigenfrequencies of magnetic field lines decrease during geomagnetic storms, which can be caused by the magnetic field weakening or the plasma mass density increasing. Currently, studies investigating the plasma mass density changes have produced conflicting results about whether it increases or decreases.

In this work, we have applied the cross-phase technique to magnetometer data during 132 geomagnetic storms and then used a superposed epoch analysis to understand the average variation in the eigenfrequencies. In conjunction with a Tsyganenko magnetic field model, we have then solved the MHD wave equation to calculate the average plasma mass density change.

This work shows that the eigenfrequencies decrease for $L > 4$ by as much as 50%, while they increase for $L < 4$. The corresponding equatorial plasma mass density is shown to increase for $L > 4$ by more than a factor of 2, while it decreases for $L < 4$. We discuss these observations and also show how ULF wave power can penetrate deeper into the magnetosphere during the main phase and discuss its implications.

**Jefferson Agudelo**, MSSL/UCL

*Identifying and Quantifying the Role of Magnetic Reconnection in Space Plasma Turbulence*

One of the outstanding open questions in space plasma physics is the heating problem in the solar corona and the solar wind. In-situ measurements, as well as MHD and kinetic simulations, suggest a relation between the turbulent nature of plasma and the onset of magnetic reconnection as a channel of energy dissipation, particle acceleration and heating. Non-linear interaction between counter propagating Alfvén waves drives plasma towards turbulent states. On the other hand, since the interaction between particles and waves becomes stronger at scales near the ion and electron gyroradious, turbulence can enhance conditions for reconnection and increase the number of reconnection sites. Therefore, there is a close link between turbulence and reconnection. We use particle in cell (PIC) simulations to study the onset of reconnection in a 3D solar wind-like box in Alfvénic turbulence. We identify in our simulations characteristic features of reconnection sites as steep gradients of the magnetic field strength alongside with the formation of strong current sheets and inflow-outflow patterns of plasma particles near the diffusion regions. These results will be used to quantify the role of turbulence as a precursor of reconnection and the role of reconnection as a dissipation mechanism in turbulence.

**Mayur Bakrania**, MSSL/UCL

*A statistical study of solar wind electron populations using machine learning techniques*

Solar wind electron velocity distributions at 1 au consist of three main populations: a thermal ‘core’ (<50 eV) population and two suprathermal (50–1000eV) populations called halo and strahl. The core and halo are quasi-isotropic, whereas the strahl travels radially outwards along the IMF in the parallel and/or antiparallel field direction. Using spin-averaged data from the Cluster PEACE instruments, we analyse energy and pitch angle distributions to classify these populations. Initially, we use supervised and unsupervised algorithms to classify halo and strahl differential energy flux distributions, allowing us to calculate strahl width and relative number densities. Subsequently, we apply unsupervised algorithms to phase space density distributions across ten years, enabling us to perform a statistical study of how the core/halo and core/strahl breakpoint energies vary with different omni-parameters. We find good agreements with previous results when determining the relative number densities of the three populations, with the added bonus of not averaging over small-scale variations. The results of our statistical study show a significant decrease in both breakpoint energies against solar wind speed. By fitting Maxwellians to the core, based on our study, we discuss the relative importance of the core temperature on halo and strahl electrons.

**Samuel Walton**, MSSL/UCL

*How Coherent are Flux Variations in the Outer Radiation Belt?*

The electron population inside Earth’s outer radiation belt is highly variable and typically linked to geomagnetic activity such as storms and substorms. These variations can differ with radial distance, such that the fluxes at the outer boundary are different from those in the heart of the belt. Using data from the Proton Electron Telescope (PET) on board NASA’s Solar Anomalous Magnetospheric Particle Explorer (SAMPEX), we have examined the correlation between electron fluxes at all L-shells within the radiation belts for a range of geomagnetic conditions, as well as longer-term averages. Our analysis shows that fluxes at L≈2-4 and L≈4-10 are well correlated within these regions, with coefficients in excess of 80%, however, the correlation between these two regions is low. These correlations vary between storm-times and quiet-times. We examine whether, and to what extent this correlation is related to the level of enhancement of the outer radiation belt during geomagnetic storms, and whether the plasmapause plays any role defining the different regions of correlated flux.

**Richard Haythornwaite**, MSSL/UCL

*Ion velocities in the Enceladus plume*

Ion velocities have been measured during the Enceladus E3 and E5 flybys using CAPS instruments on the Cassini spacecraft. Data from three sensors in the CAPS instrument has been examined from two flybys that occurred during 2008. Positive ion measurements from CAPS Ion Beam Spectrometer and Ion Mass Spectrometer have been used to measure positive ion velocities. CAPS Electron Spectrometer has been used to complement the positive ion findings with measurements of negative ion velocities. Two positive ion velocities are found, corresponding to previously found fast and slow neutral emissions from Enceladus. Negative ions were found to be near stagnant or northerly travelling, implying a deceleration mechanism within the plume. The understanding of Enceladus plume dynamics allows insight into the fissure structure of the ice shell around the south pole of Enceladus.

**Carl Haines**, University of Reading

*Forecasting Geomagnetic Activity: Analogue Ensemble and Support Vector Machine Approaches*

Variability in near-Earth solar wind conditions gives rise to space weather which can have adverse effects on space- and ground-based technologies. In particular, enhanced solar wind interaction with the Earth's magnetosphere can increase the frequency and intensity of the substorm process which in turn can enhance ionospheric current systems. The resulting inductive effects can interfere with power transmission grids, affecting today's technologically centred society to great disruption and cost. It is therefore important to forecast the intensity and duration of geomagnetic storms to improve decision making capabilities of operators of effected systems. The 150-year long geomagnetic index aaH gives a substantial history of observations from which predictive schemes can be built. Here we take advantage of this through two pattern-matching forecast techniques, both utilising the large dataset. We investigate an Analogue Ensemble Forecast (AnEn), which produces a probabilistic forecast by explicitly identifying analogues in the historical dataset, and a Support Vector Machine (SVM), which produces a deterministic forecast through dependencies identified by a machine-learning approach. The two methods are analysed using a number of forecast metrics and compared. A cost/loss analysis is given to reveal the potential economic value of the forecasts.

**Rhys Thompson**, University of Reading

*Pro-L* - A probabilistic L* mapping tool for ground observations to the magnetic equator*

Both ground and space observations are used extensively in modelling space weather related processes within Earth's magnetosphere. In radiation belt physics modelling, a key phase-space coordinates is L*, which indicates the location of the drift paths of energetic electrons in the equatorial plane. Global magnetic field models allow a subset of locations on the ground to be mapped along field lines to a location in space and transformed into L*, provided that location maps to a closed drift path. This allows observations from ground, or low-altitude space-based platforms to be mapped into space and inform radiation belt modelling. Many data-based magnetic field models exist; however these models can significantly disagree on mapped L* values for a single ground location, during both quiet times and storms. We present a state-of-the-art probabilistic L* mapping tool, Pro-L*, which produces probability distributions for L* corresponding to a given ground location. Pro-L* has been calculated over a high-resolution magnetic latitude by MLT grid in the Earth's northern hemisphere. We have developed the probabilistic model using 11 years of L* calculations for 7 popular magnetic field models. Usage of the tool is highlighted for both event studies and statistical models, and potential applications discussed.

**Peter Stephenson**, Imperial College London

*Multi-Instrument Analysis of FUV emissions in the Southern Hemisphere of comet 67P*

Several datasets from the Rosetta cometary mission are used in a multi-instrument analysis to model the brightnesses from line emissions in the far ultraviolet (FUV) at comet 67P. The analysis is used to determine whether dissociative excitation of neutrals by electron impact is the key source of emissions in the southern hemisphere away from perihelion. The modelled brightnesses are compared to observations by the Alice FUV imaging spectrograph. We model the brightness of Lyman-β, OI1356, OI1304, CI1657 and CII1335 emissions from the dissociation of the four major neutral species at 67P: $H_2O$, $CO_2$, CO, $O_2$. The suprathermal electron population is probed by an electrostatic analyser and the neutral column density is constrained by several instruments: a mass spectrometer, pressure sensor, sub-mm spectrometer and an IR spectrometer. Initially we use a nadir viewing geometry over the shadowed nucleus to confirm that electron impact is the key driver of emissions in the southern hemisphere at large heliocentric distances. We then consider several corotating interaction regions that impact comet 67P during the summer of 2016. We demonstrate that the variations in the FUV are driven by the changes in the electron population in both nadir and limb viewing geometries.

**James Lane**, Lancaster University
*Magnetotail fast flows and their association with IMF By driven magnetotail asymmetries*

The Interplanetary Magnetic Field (IMF) By component can have a profound effect on the solar wind-magnetosphere coupling by introducing a 'twisted' magnetotail configuration, giving closed magnetotail field lines an induced By component in the same sense as the IMF By. Generally, tail reconfiguration excites plasma flows which have been shown to have a preferred dawn-dusk direction, dependent on both the penetrated IMF By and hemisphere. This expectation in the case of IMF By > 0 is to observe dawnward flows above the neutral sheet, and duskward flows below the neutral sheet, with the opposite correlation for IMF By < 0 [e.g. Pitkänen et al, 2013]. We present a case study of a series of fast flows in the magnetotail observed by Cluster under positive IMF By conditions. However, the flow observed is duskward in the northern hemisphere and dawnward in the southern hemisphere, consistent with that of an IMF By < 0 configuration. Inspection of the SuperDARN ionospheric convection maps reveals a global dawn-dusk asymmetry consistent with a twisted magnetotail for positive IMF By. Further analysis of the Cluster multi-spacecraft data indicates the presence of a localised negative-By twist in the tail – a possible explanation for the unexpected flow directions.

**Imogen Gingell**, University of Southampton
*The statistics of magnetic reconnection at Earth's bow shock*

Recent observations and simulations have shown that magnetic reconnection can occur within the transition region of Earth's bow shock. In order to determine the frequency of reconnecting structure and determine their significance to the energetics and dynamics of collisionless shocks, we have performed a comprehensive survey of burst mode observations of the bow shock by Magnetospheric Multiscale (MMS) during its mission Phase 1. We have now identified over 200 current sheets with signatures of active reconnection. These structures are observed in approximately 40% of shocks, with slight bias towards quasi-parallel shock orientations and high Alfvén Mach numbers. This indicates that reconnection is a universal process but may be influenced by non-stationarity shock processes associated with quasi-parallel and high Mach number parameter regimes. In addition, we find that electron-only reconnection recently observed in the magnetosheath is also common at the shock transition region. However, shock reconnection sites appear to be well localised to the shock ramp, and thus are unlikely to serve as progenitors of reconnecting structures associated with magnetosheath turbulence further downstream. Finally, we also examine closely related structures such as flux ropes and other twisted magnetic field configurations.

**Aisling Bergin**, University of Warwick
*AE, Dst and their SuperMAG counterparts: What is the effect of improved spatial resolution in geomagnetic indices?*

Geomagnetic indices are routinely used to parameterise space weather events. The auroral electrojet (AE) index and disturbance storm time index (Dst) are two such indices which span multiple solar cycles and have been widely studied. SuperMAG allowed the production of higher spatial resolution analogues to AE and Dst. SME is an electrojet index which shares methodology with AE. SMR is a ring current index which shares methodology with Dst. As the number of magnetometer stations in the SuperMAG network increases over time, so does the spatial resolution of SME and SMR. Our statistical comparison between the established indices and their new SuperMAG counterparts finds that, for large excursions in geomagnetic activity, AE systematically underestimates SME for later cycles. The difference between the SME and AE indices for a particular solar cycle are of the order of difference seen in activity from one cycle to the next. We demonstrate that Dst and SMR track each other but are subject to an approximate linear shift as a result of the procedure used to map stations to the magnetic equator. A simple model based on the construction methodology of the electrojet indices can explain the observed differences between AE and SME.

**Maria-Theresia Walach**, Lancaster University
*Ionospheric convection during geomagnetic storm phases observed with SuperDARN*

The Super Dual Auroral Radar Network (SuperDARN) has in recent years been expanded to lower latitudes to observe ionospheric flows over a larger latitude range. This enables us to study extreme space weather events, such as geomagnetic storms, which are a global phenomenon, on a large scale (from the pole to magnetic latitudes of 40 degrees). We study the backscatter observations from the SuperDARN radars during all geomagnetic storm phases from the most recent solar cycle (2010-2016) and build ionospheric convection maps during these active times, parameterised by the initial, main and recovery phases of storms. We show how the ionospheric convection pattern changes throughout these storm phases and contrast these. Using spherical harmonic analysis, we can extract the dominant coefficients that define these patterns. Furthermore, we extract the transpolar voltage and analyse the latitudinal extent of ionospheric convection, which shows that ionospheric convection reaches mid-latitudes of up to 40 degrees of magnetic latitude.

**Graziella Branduardi-Raymont**, MSSL/UCL
*Imaging the Earth's magnetic environment in soft X-rays: SMILE*

It is a relatively recent discovery that charge exchange soft X-ray emission is produced in the interaction of solar wind high charge ions with neutrals in the Earth's exosphere; this has led to the realization that imaging this emission will provide us with a global and novel way to study solar-terrestrial interactions. Such imaging is one of the main objectives of SMILE (Solar Wind Magnetosphere Ionosphere Link Explorer), a joint space mission by ESA and the Chinese Academy of Sciences, which is under development and is due for launch in 2023. This presentation will introduce the scientific aims of SMILE, show simulations of the expected images to be returned by SMILE's Soft X-ray Imager for different solar wind conditions, and will discuss some of the techniques that will be applied in order to extract the positions of the Earth's magnetic boundaries, such as the magnetopause standoff distance.

**Jasmine Sandhu**, MSSL/UCL
*Challenging the Use of Ring Current Indices During Geomagnetic Storms*

The ring current experiences dramatic enhancements during geomagnetic storms, however understanding the global distribution of the ring current energy content is restricted by spacecraft coverage. Many studies use ring current indices as a proxy for the global energy content, however the usefulness and validity of these indices is debatable. We have conducted a superposed epoch analysis of Van Allen Probes data to explore the spatial distribution of energy content and identify variations during storms.

Ion observations were used to estimate energy content in L-MLT bins during storm times. The results show large enhancements particularly in the premidnight sector during the main phase, and a reduction in both local time asymmetry and intensity during the recovery phase. A comparison with estimated energy content using the Sym-H index was conducted. In agreement with previous results, the Sym-H index significantly overestimates energy content. a new finding is an observed temporal discrepancy, where estimates maximise ~ 12 hours earlier than the in situ observations. We assert that an observed enhancement in substorm activity coincident with the Sym-H recovery is responsible. The results highlight the drawbacks of ring current indices and emphasise the impacts of substorms on the ring current population.

**Andrey Samsonov**, *MSSL/UCL*
*Is the relation between the solar wind dynamic pressure and the magnetopause standoff distance so simple?*

The relation between the solar wind dynamic pressure and magnetopause standoff distance is usually supposed to be Rsub~Pd^{-1/N}. The simple pressure balance condition gives N=6, however N varies in empirical magnetopause models from 4.8 to 7.7. Using several MHD models, we simulate the magnetospheric response to increases in the dynamic pressure by varying separately the solar wind density or the velocity. We obtain different values of N depending on which parameter, density or velocity, has been varied and for which IMF orientation. The changes in the standoff distance are smaller (higher N) for a density increase for southward IMF and greater (smaller N) for a velocity increase both for northward and southward IMF. We suggest for developers of new empirical magnetopause models in the future to replace the simple relation between Rsub and Pd with a fixed N by a more complicated relation which would separate inputs in the dynamic pressure from the density and velocity taking into account the IMF orientation.

**Julia Stawarz**, Imperial College London
*Turbulence-Driven Magnetic Reconnection: A Survey of Magnetosheath Turbulence with the Magnetospheric Multiscale Mission*

Turbulent plasmas generate many intense, small-scale current sheets, which are suggested suggested as possible locations for particle energization and turbulent dissipation. However, which collisionless processes dissipate energy in turbulent plasmas is still unknown. One important process that occurs at thin current sheets is magnetic reconnection. Recent observations from Earth's magnetosheath have revealed that a novel form of "electron-only" reconnection, in which the ions never couple to the reconnected magnetic field to form ion jets, can occur in turbulent plasmas. Whether ion jets form in turbulence-driven reconnection is thought to be linked to the correlation length of the turbulent fluctuations, implying that the large-scale turbulence properties influence how reconnection interacts with different particle species. This potential lack of ion coupling may have significant implications for the partition of energy between ions and electrons within turbulent plasmas. In this study, we perform a survey of high-resolution "burst" data observed by the Magnetospheric Multiscale (MMS) mission in Earth's magnetosheath, examining both the large-scale and small-scale properties of the turbulence. We find that many of the magnetosheath burst intervals available from MMS are conducive to electron-only reconnection and examine the structure and statistics of small-scale current sheets in these intervals.

**Matt Lang**, University of Reading

*Data assimilation in the solar wind*

Data assimilation has been used in Numerical Weather Prediction (NWP) models with great success, and it can be seen that the improvement of DA methods has gone hand-in-hand with improvements in weather forecasting skill. The implementation of data assimilation for solar wind forecasting is still in its infancy and is still underused in the field. Hence, it is important to investigate the optimal implementation of these methods to improve our understanding of the solar wind.

To do this, we have generated a variational data assimilation scheme for use with a steady-state solar wind speed model based upon the Burger equation. This reletively simple scheme has the advantage of updating the inner-boundary conditions of the solar wind model allowing the updates to persist and improve the solar wind estimates throughout the whole domain.

To this effect, we present numerical experiments using our data assimilation scheme with STEREO and ACE data to improve estimates and forecasts of the solar wind in near-Earth space. Particular focus will be applied to assimilating data when the satellites are 60deg apart, such that they simulate Earth-L5 forecasting scenarios.

**Andy Smith**, MSSL/UCL

*The magnetospheric ULF wave counterpart of substorm onset*

Substorms are a cycle of energy storage and release in the terrestrial magnetosphere. During the growth phase, energy storage continues until the system reaches a state of instability, known as substorm onset. Interestingly, azimuthal structure is often observed within the brightening auroral arc in the minutes prior to onset. Termed auroral beads, these optical signatures correspond to concurrent exponential increases in ground ULF wave power.

We present a survey of magnetic field fluctuations in the magnetotail around substorm onset. Examining periods of exponential ULF wave growth, we find the ground and space based observations to be consistent, with average growth rates of ~0.01 s-1, both lasting for between one and 12 minutes. Cross-correlation suggests that the space-based observations lead those on the ground by approximately two minutes. Meanwhile, spacecraft located pre-midnight are more likely to make observations of large wave power, with locations approximately 10 RE downtail making the most frequent observations. These observations are likely the result of the linear phase of a magnetospheric instability, active in the magnetotail for several minutes prior to the peak ground ULF power.

**Tommy Bridgen**, Nottingham Trent University

*Mapping plasma features in the ionosphere observed by LOFAR*

The LOFAR (Low Frequency Array) is the largest radio telescope in the world. It is designed to observe the distant, early universe. As radio waves travel through the ionosphere the signal can be altered, allowing observations of this part of the atmosphere.

This work presents data collected from LOFAR and its observations of unexpected plasma structures in the ionosphere. A software tool was developed in R and MATLAB, which gave 3D-coordinates and a visual mapping of where these plasma structures were occurring in the D, E, and F regions of the ionosphere, along with their respective solar zenith angles over time.

This was applied to observations from the 7th of January 2019, where the formation of a rapid onset transient ionospheric feature occurred in less than a minute. This was shown to be co-located with the solar terminator at F-region altitudes.

**Peter Rowe**, Nottingham Trent University

*Observed Decay of Polar Cap Patches*

Three polar cap patches were observed by the European Incoherent Scatter (EISCAT) 42m Svalbard Radar (ESR) and the Tromso VHF radar on the 15th of December 2014. Velocities inferred from both the EISCAT radars and the Super Dual Auroral Radar Network (SuperDARN) confirmed that the polar cap patches were seen at both locations.

Four published decay rates for ionospheric plasma have been previously determined through laboratory experiments. A model that simulated the decay of the structures as seen by the 42m ESR using these four decay rates was applied, and the output was then compared with observations from the VHF radar. Out of the four reaction rates used, those published by Lindinger et al best represented the observed reaction rate. However, all four of the published reaction rates resulted in a significant underestimate of the decay observed.

**Jesse Coburn**, Queen Mary University of London

*Turbulent generation of pressure anisotropy in the solar wind.*

While it is well known that the pressure anisotropy instabilities constrain the distribution function of the solar wind protons, the generation of pressure anisotropy has not been well studied. We examine the role turbulence plays in this process with a high resolution WIND measurement of the proton pressure tensor. The data product is ~25 years of an onboard moment that, to our knowledge, has not been previously studied. We investigate fluctuations that perturb the pressure anisotropy and characterize their compressive nature. Additionally we find that the fluctuations possess power law spectrums and higher order statistics akin to typical turbulent statistics (e.g the -3/2 trace spectrum of the velocity field). We also study the Chew-Goldberger-Low invariants and find evidence for their constancy when the plasma is stable relative to the pressure anisotropic instability thresholds. Our study has implications on the heating of collisionless plasma when the turbulent amplitude is large.

**Harneet Sangha**, University of Leicester

*The Relationship Between Region 2 Field-Aligned Currents Bifurcations and the Occurrence of Sub-Auroral Polarization Streams*

We use the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) to study variations of the terrestrial field-aligned currents (FACs) related to substorms. We have previously reported a new phenomenon: a bifurcation of the region 2 (R2) current, which occurs predominantly in the dusk sector. We have proposed that the additional R2 FAC is formed by plasma injections into the inner magnetosphere, as the events appear to be associated with substorm onset. We further suggest that the bifurcations may be related to fast ionospheric flows in the sub-auroral region known as Sub-Auroral Polarization Streams (SAPS). To further constrain this relationship, we compare our occurrence list of bifurcations to two lists of SAPS occurrences, one identified using Van

Allen Probe data, the other using SuperDARN data. In this talk, we show some of the examples of these data, and how they are linked. Furthermore, we study the interhemispheric conjugacy, or otherwise, of the observed FACs, and on the seasonal dependence of the conjugacy, for the years 2010 to 2016.

**Alexandra R. Fogg**, University of Leicester
*Multi-Instrument Observations of the effects of a positive Sudden Impulse on the high-latitude ionosphere*

We present a detailed case study of the effects of a positive sudden impulse on the Earth's high-latitude ionosphere during IMF Bz>0 conditions. A sudden impulse (SI) is a rapid change in solar wind dynamic pressure, which is not followed by the commencement of a geomagnetic storm. A positive SI (increase in Psw) has been observed on 16th June 2012 in the solar wind dynamic pressure, and confirmed minutes later by a rapid increase in SYM-H. We examine the response of the high-latitude dayside ionosphere to this SI. Observations of ionospheric convection, field-aligned currents (FACs), and aurora are obtained from SuperDARN, AMPERE, and DMSP respectively. In the high-latitude dayside ionosphere, the onset of lobe reconnection is observed associated with the SI. At the same time, R0 FACs and a cusp spot appear collocated with these lobe reconnection cells. We present the first observation of the onset of lobe reconnection collocated with R0 FACs following a positive SI, under Bz>0 conditions. We also examine the response times of the high-latitude ionosphere, compared with the equatorial regions.

**Dale Weigt**, University of Southampton
*Future exploration of Chandra observations of auroral emission during Juno apojove 2017*

We present results of a jovian Chandra X-ray observation while Juno was near apojove and outline future avenues which can be explored from this dataset. Chandra observed for ~ 10 hours from 18:56 June 18th while Juno was on the dawn flank of the magnetosphere, close to the expected nominal position of the magnetopause. Using the closest magnetopause crossing from the Juno JADE and JEDI data, the magnetosphere was inferred to be compressed during the Chandra interval. A ~24-hour XMM-Newton observation overlapped the final ~ 5 hours of the 10-hour Chandra campaign, allowing both spatial and spectral X-ray analysis of Jupiter in tandem. We present light curves from Chandra; timing analysis of two significant quasi-periodic oscillations (QPOs) detected in the North polar region and map their magnetospheric origin using a flux equivalence model. We look at how we can explore any correlations between the morphology and timing variations of the X-ray hot spot to magnetospheric/solar wind conditions and compare to other heritage observations.

**Shahbaz Chaudhry**, University of Warwick
*Multi-Layer Relaxation Models for Coronal Heating*

One possible explanation for higher than expected coronal temperatures are discrete heating events known as "nanoflares" that heat the solar corona to millions of degrees. However, due to their size, nanoflares are difficult to detect, hence theoretical calculations are required. Cylindrical relaxation models have been used to calculate energy release from discrete heating events or nanoflares.

Building upon work previously done on cylindrical relaxation models in Browning [2003] and Bareford et al. [2011], a multi-layer cylindrical model is constructed, valid for an arbitrary number of layers. Cylindrical models allow for a simplified geometry which results in analytic solutions. The model is constructed as embedded concentric cylinders each with a magnetic field which is continuous across the layer boundary.

The code is used to calculate quantities such as helicity transfer and energy. These values are used to verify a process known as hyperdiffusion (Bhattacharjee and Hameiri [1986], Boozer [1986]), which offers insight into the process of relaxation. Results from the multi-layer model Lent support to hyperdiffusion being responsible for relaxation in cylindrical flux tubes. The model also provides a useful tool for calculating analytical models of force-free magnetic fields, which may be used for a variety of purposes

**Ryan Cumming**, University of Reading

*Relationship between the solar wind and ultra-low frequency waves inside and outside of geomagnetic storms*

Ultra-low frequency (ULF) waves are ubiquitous throughout Earth's magnetosphere and play an important role in the radial diffusion of radiation belt electrons. They can be easily detected using ground-based magnetometers that are in regions that magnetically map out to the outer radiation belt. Controlling factors for these waves have recently been found to include the instantaneous values of solar wind velocity, southward interplanetary magnetic field and variations in number density through a data-driven empirical study (Bentley et al., JGR 2018 and Bentley et al., SW, 2019). We specifically isolate geomagnetic storms and investigate whether the relationship between the solar wind factors and ULF waves is different during storms than it is during other times. We show the differences in the factors themselves, and also determine whether the wave amplitude displays different behaviour even when we have accounted for these differences.

**Lauren Orr**, University of Warwick

*Network Community Structure of Substorms using SuperMAG magnetometers*

This dynamic evolution of the magnetosphere during geomagnetic substorms generates large-scale ionospheric currents but there is to date no single accepted model for their structure and evolution. Graph theory offers well-established methods to quantify patterns in extensive datasets. The SuperMAG initiative recently collated 100+ ground-based magnetometers which monitor the overhead ionospheric currents. We translate this data into a time-varying directed network, based on canonical cross-correlation of the vector magnetic field perturbations measured at each magnetometer pair. We perform community detection on the network which identifies locally dense but globally sparse groups of connections in the network. These identify emerging coherent patterns in the current system as the substorm evolves and we consistently find a robust structural change from many small, uncorrelated groups of magnetometers before substorm onset, to one large global system during the expansion phase. All 40+ substorms analysed here ultimately form a single substorm current wedge. The structural shift from multiple to a single global current system occurs approximately 10 minutes after onset, emphasising the need for an understanding of the dynamical evolution of substorms which may resolve the controversy surrounding models for the substorm current system.

**Greg Hunt**, Imperial College London

*Saturn's Auroral Field-Aligned Currents: Observations from the Northern Hemisphere Dawn Sector During Cassini's Grand Finale*

We compare the northern hemisphere auroral field-aligned currents observed within the dawn sector during Cassini's Grand Finale with observations of the near-noon currents made during the set of orbits prior to the Grand Finale. We show that the position of the main auroral upward current is displaced between the two local times. This is consistent with the position of the ultraviolet auroral oval during this time interval. We show the average current profiles differ significantly within the upward current region with a swept-forward configuration with respect to planetary rotation present at dawn. We separate the planetary period oscillations (PPO) currents from the non-PPO currents and show that the main difference is due to the latter. The individual upward current sheets pass-by-pass show that the main upward current at dawn is narrower and stronger compared to near-noon. Thus, the current density is ~1.4 times higher in the dawn sector. We determine a proxy for the precipitating electron power and show that the dawn non-PPO upward current is ~1.9 times higher than at noon. These new observations from the Grand Finale may show the first direct evidence of an additional upward current at dawn likely associated with global dynamics.