Virtual Autumn MIST Meeting 2020

Abstract booklet

Session 1:

Sandra Chapman, Centre for Fusion, Space and Astrophysics, Physics Department, University of Warwick, UK
Horne, R; Leamon, R; McIntosh, S; Watkins, N

A regular clock for the Schwabe and Hale variations in solar and geomagnetic activity

By obtaining the analytic signal of daily sunspot numbers since 1818 we construct a new solar cycle phase clock which maps each of the last 18 solar cycles onto a single normalized epoch. We consider epochs for the approximately 11 year Schwabe cycle and the approximately 22 year Hale cycle (one and two magnetic polarity reversals). This clock orders solar coronal activity and extremes of the aa index, which tracks geomagnetic storms at the earth's surface over the last 14 solar cycles. We identify geomagnetically quiet intervals that are 40% of the normalized Schwabe cycle. There is a clear switch-off and switch-on of geomagnetic activity; 1-3% of severe (aa>300nT) geomagnetic storms and 4-6% of C, M and X class solar flares occurred in quiet intervals. Hale cycle variation has been identified in several long-term parameters including recurrences on the 27 day solar rotation period in the aa index. We re-engineer Sargent’s (1985) original R27 index to obtain a high time resolution parameter for 27 day recurrence in aa which reveals that the transition to recurrence, that is, to an ordered solar wind dominated by high speed streams, is fast, occurring within 2-3 solar rotations or less.

Megan Maunder, University of Exeter
Foullon, C

Multi-Spacecraft Observations of a New Type of High-Latitude ICME

Coronal Mass Ejections (CMEs) and their interplanetary counterparts (ICMEs) are key drivers of space weather throughout the heliosphere. Their observational studies are therefore used to understand their evolution and for developing existing models and theory in space weather forecasting. Motivated by the future exploration of the solar high-latitudes by Solar Orbiter and Parker Solar Probe, we aim to contribute to the understanding of high-latitude CMEs as they develop into ICMEs. We examine a high-latitude CME and its subsequent ICME using data from STEREO, Ulysses, and OMNI. We apply a triangulation method to the remote-sensing images from the twin STEREO spacecraft and conduct a multi-spacecraft analysis using the in-situ Ulysses, STEREO, and OMNI data. This combination builds a clear picture of the ICME geometry and structure: a shock, followed by a sheath region, a magnetic cloud, and another sheath and trailing shock. This ICME differs from the known ‘over-expanding’ types observed in the high-latitudes by the Ulysses mission, in that it straddles a region between the slow and fast solar winds which in itself drives a shock.

Joel Baby Abraham, Mullard Space Science Laboratory
Owen, C J; Verscharen, D; Nicolaou, G; Stansby, D; Bakrania, M; Jeong, S-Y; Agudelo Rueda, J; Wicks, RT

Statistical analysis of solar wind electron populations using Parker Solar Probe.

Understanding the physics of coronal and solar-wind heating as well as the acceleration of the solar wind are long-standing and key problems in solar and stellar physics. The kinetic properties of the solar wind give us insight into the underlying heating and acceleration mechanisms. Following on from Helios, the advent of Parker Solar Probe and Solar Orbiter will provide unprecedented high-resolution measurements of the pristine solar wind, and its constituent particle populations, which can help us to bridge the gap between local and global kinetic processes.

Thomas Woolley, Imperial College London
Matteini, L; Horbury, T S; Bale, S D; Woodham, L D; Laker, R; Alterman, B, L; Bonnell, J W; Case, A W; Kasper, J C; Klein, K G; Martinović, M M; Stevens, M

The Proton Core Behaviour Inside Magnetic Field Switchbacks

Magnetic field switchbacks are ubiquitous in the near-Sun solar wind and persist across many different streams, yet their origins and many of their properties are still unknown. Here we use SPC measurements to compare ion velocity distribution functions (VDFs) inside and outside of nearly full magnetic field reversals. We show that the ion VDFs inside switchbacks are consistent with a rigid phase space rotation of the background plasma and that the proton core parallel temperature is not distinctly different inside and outside of these structures. As a consequence, flow speed enhancements associated to these large field reversals do not follow a typical solar wind T-V relation. We conclude that switchbacks are consistent with large amplitude Alfven pulses propagating along open magnetic field lines and discuss their possible sources.

Session 2:

Seong-Yeop Jeong, Mullard Space Science Laboratory
Verscharen, D; Wicks, R T; Fazakerley, A, N

The evolution of the electron-strahl velocity distribution in the inner heliosphere

The electrons in the solar wind exhibit an interesting kinetic substructure with many important implications for the overall energetics of the plasma. We will present the results of our theoretical model to describe the evolution of the electron velocity distribution function (VDF) in the solar wind under the action of kinetic instabilities and Coulomb collisions. We are especially interested in the oblique whistler-wave instability that regulates the strahl population of the electron VDF. For this instability, we analyse the quasi-linear diffusion equation by expressing the resonant whistler-wave as a Gaussian wave packet. This quasi-linear diffusion model explains how the whistler-wave scatters the electron strahl into the electron halo population. We also analyse the Fokker-Planck equation to compute the time evolution of the strahl electrons under the action of Coulomb collisions with core electrons and protons. To investigate the radial evolution of the electron VDF as the solar wind expands, we implement our instability and collision formalism into a global kinetic equation. The solutions to this equation will model the evolution of the electron VDF from the Sun to 1 au.

Sadie Robertson, Imperial College London
Eastwood, J P; Stawarz, J E; the MMS Team

A statistical study of magnetopause flux ropes near the Electron Diffusion Region (EDR) using Magnetospheric Multiscale mission (MMS)

During magnetic reconnection, stored magnetic energy is released resulting in particle energisation and heating. The reconnection process is controlled by the dynamics of the electron diffusion region (EDR). Helical magnetic field structures known as flux ropes can form during reconnection, and small-scale flux ropes may be an important signature of the time variability of EDR plasma processes. Flux ropes are also thought to be important for flux transport into the magnetosphere and are identified as a site for particle acceleration. The four spacecraft Magnetospheric Multiscale mission (MMS) provides a new opportunity to study this topic, being able to measure the thermal electron and ion 3D distributions at 30 msec and 150 msec time resolution, respectively. MMS has made multiple encounters with the EDR on the magnetopause. Here, we examine the occurrence and properties of small-scale flux ropes in the vicinity of these EDR encounters. We use the high time resolution plasma data to statistically analyse their properties and pitch angle distributions, providing insight into their topology and field connectivity. The results shed new light on the dynamics of the EDR and provide new information about the role of flux ropes in transporting magnetic flux and particle energisation in magnetopause reconnection.

Lauren Orr, Lancaster University
Chapman, S C; Beggan, C D

Wavelet and network analysis of magnetic field variation and geomagnetically induced currents during large storms

During geomagnetic storms rapid magnetic variations cause large, sharp enhancements of the magnetic and geoelectric field. Spatio-temporally quantifying these extremes can provide an insight into the magnitude and topology of the potential hazard. Wavelets are a tool for time-frequency localisation which are known for their ability to detect sharp changes. We apply wavelet transform analysis to both European ground-based magnetometer measurements and modelled Geomagnetically Induced Currents (GICs) from the high voltage grid of the UK. This allows us to investigate the location, in particular the latitudinal dependence, and intensity of geomagnetic storms. We further use wavelet correlation of the GIC in the grounded nodes to build a time-varying network of GIC flow around the UK during the Halloween storm of 2003. From the network we can quantitatively compare the correlation within and between different latitude bands, as well as find out which nodes are most active throughout the storm. This allows us to quantify the risk at different nodes. We will discuss this new methodology and present some initial results.

Poster session 1:

Martin Archer, Imperial College London

How do I demonstrate impact from my drop-in public engagement activity? A novel approach from a space soundscape exhibit

We are often asked to demonstrate the impact of our public engagement, with this necessarily requiring some measure of change. Impact evaluation is therefore extremely challenging for drop-in activities, one of the most common forms of engagement. We show how simply integrating pre- and post- evaluation tools, such as a graffiti wall where participants write or draw responses, can provide much needed before-and-after data. An example of this was a soundscape exhibit, where young families experienced the usually inaudible sounds (ULF waves) of Earth's magnetosphere. Analysing the data in two ways demonstrates the short-term impact of the activity:

- Quantitative linguistics: Applying Zipf's law (the power law statistics of words) reveals an increased diversity of language concerning space afterwards, highlighting participants engaged with and reflected upon the sounds.
- Thematic analysis: Finding and grouping patterns in the qualitative data shows altered conceptions of space around aspects of sound, dynamism, emptiness and electricity, areas highly relevant to the underlying space plasma.

This case has thus shown the power of data sonification in innately communicating MIST science. The method could be adopted by others more broadly.

Daniel Billett, University of Saskatchewan
McWilliams, K A, Code, M G

Ion-neutral Coupling in the E- and F-regions during a Substorm

Thermospheric vector wind fields, at both E- and F-region altitudes within a common vertical volume, were measured using a Scanning Doppler Imager (SDI) at Poker Flat, Alaska, during a substorm event. Coinciding with these observations were F-region plasma velocity measurements from the Super Dual Auroral Radar Network (SuperDARN), and estimations of the total downward and upward field-aligned current density from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE). This combination of instruments gives an excellent opportunity to examine the spatial characteristics of high latitude ionosphere-thermosphere coupling, and how a process which is triggered in the magnetosphere (the substorm) affects that coupling at different altitudes. We find that during the substorm growth phase, the F-region thermospheric winds respond readily to an expanding ionospheric plasma convection pattern, whilst the E-region winds appear to take a much longer period of time. The differing response timescales of the E- and F-region winds is likely due to differences in neutral density at those altitudes, resulting in E-region neutrals being much more 'sluggish' with regards to ion-drag. We also observe increases in the F-region neutral temperature, associated with neutral winds accelerating during both substorm growth and recovery phases.

Gemma E Bower, University of Leicester
Milan, S E; Paxton, L J

Transpolar arcs: Seasonal dependence identified by an automated detection method

Transpolar arcs (TPAs) are northward IMF auroral features that occur poleward of the main auroral oval, suggesting that the magnetosphere has acquired a complicated magnetic topology. An automated detection method has been developed to further study the occurrence of TPAs in UV images captured from the Special Sensor Ultraviolet Spectrographic Imager (SSUSI) instrument on-board the Defense Meteorological Satellite Program (DMSP) spacecraft. Via this detection method TPAs are identified as a peak in the average radiance intensity above 12.5 degrees colatitude, in two or more of the wavelengths/bands sensed by SSUSI.

Biases in the data have been investigated and it has been found that DMSP has biases due to its orbit. Observations are preferential in the northern hemisphere with the detection method missing TPAs in the southern hemisphere between approximately 0 - 9 UT. No seasonal bias has been found.

Using the detection method on observations from the years 2010 to 2016, over 5000 images containing TPAs are identified. The occurrence of these TPA images suggest a seasonal dependence, with more TPAs occurring during June in the southern hemisphere and December in the northern hemisphere. This suggests, contradictory to initial expectations that more TPAs occur in the winter hemisphere.

Shahbaz Chaudhry, University of Warwick

Network analysis of Pc waves using the SuperMAG database of ground-based magnetometer stations

First results will be presented for the dynamical directed network for Pc wave intensity and coherence during intervals of enhanced geomagnetic activity. Network-based analysis of 1 min cadence SuperMAG data has resolved the dynamics of substorm current systems (Dods et al. JGR 2015, Orr et al. GRL 2019) and the magnetospheric response to IMF turnings (Dods et al. JGR 2017). Now, with the availability of 1 sec data across the entire network of SuperMAG magnetometers we are able to apply network analysis to obtain new quantitative understanding of Pc waves. Prior to constructing the network, time series data is band-pass filter using Pc wave frequency intervals and cross-correlated ensuring the window is twice the Pc wave period of interest. To construct the network we use noise surrogates to establish a threshold to filters out insignificant cross-correlation values. Once a network is constructed, it can be characterized by a few network parameters. This may lead to the identification of new Pc indices that capture the spatial coherence and propagation of Pc activity. Quantifying the full spatio-temporal response of the magnetosphere across 100s of ground based magnetometers with a few parameters also forms the basis of statistical studies across many events.

Dave Constable, Lancaster University
Ray, L C; Badman, S V; Arridge, C S; Gunell, H

Predicting Field Aligned Currents in the Jovian Mid-Magnetosphere

While in orbit around Jupiter, Juno has observed “inverted-V” potentials on the order of megavolts aligned with magnetic field lines connected to the high-latitude regions of the ionosphere. These field lines extend to Jupiter’s middle magnetosphere at radii of 20RJ – 50 RJ. Such potential structures can accelerate charged particles, with Juno’s Jupiter Energetic-particle Detector Instrument (JEDI) observing planetward acceleration of electrons and ions towards energies of MeV.

The coupling between the Jovian magnetosphere and ionosphere is complex with many facets, including the generation of electric fields, development of field-aligned currents, precipitation and outflow of particles, all of which require consideration to fully understand the dynamics of system. We employ a 1-D spatial, 2-D velocity space Vlasov treatment of these high-latitude field lines to examine the behaviour of plasma along them. By meshing the domain with a non-uniform grid, a fine mesh can be applied to the ionospheric end of the field line, allowing small scale spatial and temporal features to be resolved. This allows the determination of potential structures and plasma density profiles along the field line, as well as precipitating particle intensity. We present results based on Juno measurements and compare the model output to in-situ data.

Matt James, University of Leicester
Yeoman, T; Jones, P; Sandhu, J K

The Lomb-Scargle Based Inner Magnetospheric Plasma Model

Van Allen Probe HOPE and EMFISIS data are used to create electron density and average ion mass models for the Earth's inner magnetosphere (2 <= L <= 5.9). To create these models, data are first split into thin L-shells, where each is considered to be a superimposition of azimuthal variations on top of a DC component, which is a function of L. Lomb-Scargle (L-S) analysis of each L-shell reveals the amplitudes and phases of spatial variations with azimuthal wavenumbers in the region 1 <= m <= 3. The average models are formed by numerically fitting polynomial functions to the real and imaginary components of the L-S analysis and combining them with the DC function. The models are then extended using machine learning to be able to provide realistic depictions of average ion mass and electron density in the inner magnetosphere under varying geomagnetic conditions. In this presentation I will describe the development and implementation of these models, and show examples of their predictions of both plasmasphere and plasmatrough densities.

Joe Kinrade, Lancaster University
Bader, A; Badman, S; Paranicas, C; Mitchell, D G; Constable, D; Arridge, C S; Cowley, S W H; Provan, G

The statistical morphology of Saturn's equatorial energetic neutral atom emission

Saturn is engulfed in a cloud of neutral gas originating from ice fissures on the surface of Enceladus. Some particles collide and exchange charge, separating electrons from ions which are guided by Saturn's magnetic field. This way, Saturn's rotating magnetosphere is loaded with mass which is eventually lost into space via ejections of plasma that stretch magnetic field lines to breaking point. Some charged particles in the outer magnetosphere do not escape, but are fired back towards Saturn with field lines as they snap back into place. These energetic ions collide with neutrals, creating energetic neutral atoms (ENA) that were detectable using the INCA camera onboard Cassini. INCA's pictures of Saturn's magnetosphere reveal dynamic regions of plasma flow, important for understanding the entire system. We have analyzed the complete INCA image set obtained over Cassini's mission, utilizing years of combined exposure to characterise Saturn's average ENA morphology. Rings of ENAs are located at distances between 7-10 Rs, where the interaction between energetic ions and the neutral cloud is largest. We also find ENA variation with Saturn's rotation period, associated with current systems that modulate the thickness of the plasma sheet every ~10 hours.

Ronan Laker, Imperial College London
Horbury, T S; Bale S D; Matteini L, Woodham, L D; Woolley T; Badman S T; Pulupa M; Kasper J C; Case A W; Stevens M; Korreck K E

Statistical analysis of orientation, shape, and size of solar wind

One of the main discoveries from the first two orbits of Parker Solar Probe (PSP) was the presence of magnetic switchbacks, whose deflections dominated the magnetic field measurements. Determining their shape and size could provide evidence of their origin, which is still unclear. We try to understand how the size and orientation of the switchbacks, along with the flow velocity and spacecraft trajectory, combine to produce the observed structure durations for past and future orbits. We searched for the alignment direction that produced a combination of a spacecraft cutting direction and switchback duration that was most consistent with long, thin structures. The switchbacks had a mean width of 50,000km, with an aspect ratio of the order of 10. We find that switchbacks are not aligned along the background flow direction, but instead aligned along the local Parker spiral, perhaps suggesting that they propagate along the magnetic field. Since the observed switchback duration depends on how the spacecraft cuts through the structure, the duration alone cannot be used to determine the size or influence of an individual event. https://doi.org/10.1051/0004-6361/202039354

Mike Lockwood, University of Reading
Owens, M J; Haines, C; Barnard, L A; Scott, C J; Chambodut, A; McWilliams K A; Thomson, A W P

Universal Time Variations in the Magnetosphere and Space Weather

We introduce the inductive effects of polar cap motions towards and way from the Sun into magnetospheric electrodynamics and show how this explains observed Universal Time variations in hemispheric geomagnetic indices. The large (and growing) hemispheric asymmetry in the offsets of the geomagnetic (dip or eccentric dipole) poles from Earth's rotational axis means that the effect is not cancelled out in global indices. By adding this effect to that of the Russell-McPherron effect on solar wind-magnetosphere coupling, that of ionospheric conductivities, and that of the solar wind dynamic pressure and dipole tilt on the near-Earth tail lobe field and cross-tail current sheet, we are able to model the persistent (and previously unexplained) "equinoctial" time-of-day/time-of-year pattern and its additional net Universal time variations that have been observed in the am geomagnetic index, and its hemispheric sub-indices an and as, since their inception in1959. We discuss the implications for the longitudinal dependence of the effects of extreme space weather events.

Allan Macneil, University of Reading
Owens, M J; Wicks, R T; Lockwood, M; Bentley, S N; Lang, M

Increasing occurrence of inverted heliospheric magnetic fields from 0.3 to 1 au

Local inversions (also known as ‘reversals’ or ‘switchbacks’) are often observed in the heliospheric magnetic field (HMF), but their origins and evolution are not fully understood. It has been suggested that inversions may be produced by near-Sun interchange reconnection; a key process in mechanisms proposed for slow solar wind release, or by coronal jets. This view places the source of inversions near to the Sun, and it follows that they would gradually decay and straighten as they propagate out through the heliosphere. Alternatively, inversions could form during solar wind transit, through phenomena such as waves and turbulence, velocity shears, or other bulk solar wind effects. Such processes are not expected to produce the above decaying radial evolution. Using Helios measurements spanning 0.3–1 AU, we examine the occurrence rate of inverted HMF, as well as other magnetic field morphologies, as a function of radial distance, and find that it continually increases. This increase may be explained by inverted HMF over this distance range being primarily driven by in-transit processes, rather than being created at the Sun. We make suggestions for the driving process based on the evolution of the magnetic field properties associated with inverted HMF.

Michaela Mooney, Mullard Space Science Laboratory, UCL
Marsh, M S; Forsyth, C; Sharpe, M; Hughes, T; Rae, I J; Bingham, S; Jackson, D R

Evaluating auroral forecasts against satellite observations

Enhanced auroral activity at Earth can cause disruption to long-range radio communications and ground induced currents making forecasting the location of the auroral oval and probability of the aurora occurring of interest to many sectors such as aviation, energy and defense.

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 the aurora occurring. By applying terrestrial weather forecast verification 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 2000-2002.

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 more geomagnetically active periods when the potential risk of damage to infrastructure due to space weather is higher.

David Nunn, Southampton University
The 1D numerical modelling of lower band VLF chorus generation using a VHS Vlasov code

In this work we perform numerical simulations of lower band VLF chorus in the equatorial region of the earth's magnetosphere. We assume parallel propagation so the code has one spatial dimension.The method employed is Vlasov Hybrid Simulation, also called the method of phase space characteristics.by Kazeminezhad and co workers. A phase space grid is first defined. The technique is to follow cyclotron resonant electron trajectories continuously forwards in time. Application of Liouville's theorem gives distribution function at the phase points occupied by the particles. Distribution function may be interpolated onto the phase space grid, whence plasma current is calculated, and the EM field may be pushed forwards in time.

The method is robust against distribution function filamentation, and for this problem far more efficient than particle in cell codes with much lower noise. It also outperforms the semi Lagrangian Vlasov method .

Using realistic data, the code simulates rising frequency chorus and also fallers and hooks and more complex spectral shapes. Frequency sweep rates match those actually observed. In the latest simulations the actual spectral structure and bandwidth of the emission closely also resemble that observed.

David Price, University of Southampton
Whiter D K
High resolution optical observations of neutral heating associated with the electrodynamics of an auroral arc

Joule heating and other ionosphere-thermosphere coupling mechanisms have significant and global consequences for the atmosphere, and as a result the inclusion of Joule heating atmospheric models is of crucial importance. However, variations in electric fields and ionospheric conductivity on sub-grid scales can lead to significant underestimation of the total Joule heating rate during active periods. Observations of these processes on the smallest temporal and spatial scales, taken during periods of rapid energy deposition associated with auroral structures, will help provide the necessary information to improve global estimates of Joule Heating.

Utilising a novel observational technique, we obtain a time series of neutral temperature altitude profiles at a time resolution of the order of seconds, revealing the response to auroral structures at unprecedented temporal and spatial resolutions. Our studies of auroral arcs over Svalbard show two distinct neutral heating processes. Joule heating, arising from an asymmetric arc-associated electric field, produced a temperature increase of approximately 50K over a large altitude range directly adjacent to an arc and on its poleward edge only. Ohmic heating, driven by intense field aligned currents, produced a localised temperature increase seen within the arcs themselves, constrained to a narrow altitude range close to the mesopause.

John Ross, British Antarctic Survey
Glauert, S; Horne, R; Watt C; Meredith, N; Woodfield, E

A new approach to constructing models of electron diffusion by EMIC waves in the radiation belts

In recent years there have been an increasing number of satellites operating in or traversing the Earth's radiation belts. These belts are comprised of charged particles that are largely confined by the Earth's magnetic field although waves can accelerate and scatter these particles. In the outer belt, electrons can be accelerated up to relativistic energies and pose a threat to satellites. Diffusion based models are used to simulate the electron population, incorporating the statistical effects of waves on the electrons. Electromagnetic ion cyclotron waves are of particular importance for the relativistic population, effectively scattering them into the atmosphere and removing them from the belts. Previous models of this interaction are based on average plasma and wave observations, however, these do not well represent the range of interactions possible. Here we take a new approach, considering each observation individually to determine their statistical effect. When included into diffusion models, this new approach significantly improves the modelling of the relativistic electron population.

Robert Shore, British Antarctic Survey
Freeman, M P

Real-time forecasts of storm-time geomagnetic activity at UK latitudes from an empirical model

Shore et al. (2019) have shown that the localised ionospheric reconfiguration timescale can be discovered from a cross-correlation of time-lagged solar wind drivers and the ensemble ground-based response. This information allows us to show statistically where the energy from a solar wind disturbance is deposited within the coupled magnetosphere-ionosphere system, and how this channeling of energy varies according to different solar wind drivers, geographic season, and solar cycle phase.

In this study, we apply the Shore et al. (2019) SPIDER (Spatial Information from Distributed Exogenous Regression) technique to the task of producing empirical, real-time forecasts of storm-time ground geomagnetic perturbation at UK latitudes. The challenges and successes of using solar wind drivers to forecast in real time are discussed.

Andy Smith, UCL/MSSL
Rae, I J; Forsyth, C; Oliveira, D M; Freeman, M P; Jackson, D R

Probabilistic Forecasts of Storm Sudden Commencements from Interplanetary Shocks using Machine Learning

Rapid changes in the surface geomagnetic field can induce potentially damaging currents in artificial conductors on the ground. One phenomenon that can produce such changes in the Earth's magnetic field are Sudden Commencements (SCs), which are associated with sharp increases in solar wind dynamic pressure usually caused by interplanetary shocks. SCs may also be followed by other longer lasting magnetospheric phenomena that cause large fluctuations in the geomagnetic field, geomagnetic storms for example. An SC that is followed by a geomagnetic storm may be termed a Storm Sudden Commencement (SSC). Therefore, the capability of predicting SC occurrence bears a high importance for the forecasting of space weather-related phenomena.

We investigate the ability of several different machine learning models to provide probabilistic predictions as to whether interplanetary shocks observed upstream of the Earth at L1 will lead to immediate or longer lasting magnetospheric activity (i.e. an SC or SSC, respectively). Four models are tested including linear (Logistic Regression), non-linear (Naive Bayes and Gaussian Process) and ensemble (Random Forest) models. Finally, the response of the different models is explored with hypothetical extreme data beyond current observations, showing dramatically different extrapolations, highlighting the significance of model selection.

David Stansby, MSSL/UCL
Berčič, L; Matteini, L; Owen, C J; French, R; Baker, D; Badman, S T

Sensitivity of Solar Wind Mass Flux to Coronal Temperature

Solar wind models predict that the mass flux carried away from the Sun in the solar wind should be extremely sensitive to the temperature in the corona. Using a range of in-situ and remote sensing measurements from Parker Solar Probe, the Solar Dynamics Observatory, and Hinode/EIS, we have tested this hypothesis by measuring the coronal electron temperature and coronal mass flux in both coronal holes and active region outflows.

We find that a three-fold increase in coronal temperature from 0.7 MK to 2.2 MK results in a large increase in coronal mass flux by over a factor of 100. This is in qualitative agreement with current solar wind acceleration models, and provides a new empirical constraint for future models to be tested against. Our work highlights how a wide range of remote and in-situ data sources can be combined to perform new tests of solar wind heating and acceleration theories.

Daniel Verscharen, MSSL, University College London
Bale, S D

Scaling the latitudinal dependence of solar-wind moments from Ulysses to the inner heliosphere

The Ulysses mission has provided us with unique measurements of the solar wind outside the plane of the ecliptic in the outer heliosphere. It revealed the average dependence of the solar wind on heliolatitude, distance from the Sun, and the phase of the solar cycle. The latest heliospheric missions Parker Solar Probe and Solar Orbiter are currently exploring the inner heliosphere and will likewise study the dependence of the solar wind on latitude, heliocentric distance, and solar cycle. We use the coasting approximation of the solar wind fluid equations and a combination of theoretical and empirical scaling laws to scale the observed Ulysses plasma moments to the inner heliosphere. This method allows us to estimate the scaled mass flux, momentum flux, energy flux, and angular-momentum flux as functions of heliolatitude. In addition, we find estimates for the position of the Alfvén radius, the sonic radius, and the beta=1 radius as functions of heliolatitude. These scaling relations provide estimates for the observations of Parker Solar Probe and Solar Orbiter in the inner heliosphere.

James Waters, Space Environment Physics, School of Physics and Astronomy, University of Southampton, Southampton, UK
Jackman, C M; Whiter, D K; Lamy, L; Cecconi, B; Bonnin, X; Issautier, K

Multipoint Remote Observations of Auroral Kilometric Radiation (AKR)

Auroral Kilometric Radiation (AKR) is radio emission that originates in particle acceleration regions along magnetic field lines that coincide with discrete auroral arcs. Found in both hemispheres, an increase in the amplitude of a particular AKR source is indicative of the presence of strong, parallel electric fields in the auroral zone, while the emission frequency of AKR gives direct insight into the altitudinal extent of the source region. The viewing geometry is complex, however, due to the primary confinement of the source regions to nightside local times and the anisotropy of the beaming pattern seen at each pole, and it is not clear how the intensity of longitudinally-seperated source regions is related. During a month-long period in 1999, the Cassini spacecraft performed a close flyby of Earth and recorded AKR for the majority of the period, while the Wind spacecraft completed close to two, precessing petal orbits. An effective empirical proxy of the source variability is applied to Wind observations to select AKR emission and compare the integrated power with previously-studied measurements from Cassini. This provides an opportunity to further explore the viewing geometry of AKR as well as the temporal relationship between AKR ignition at different local times.

Affelia Wibisono, MSSL/UCL
Branduardi-Raymont, G; Kimura, T; Dunn, W R; Coates, A J; Grodent, D; Yao, Z H

Jupiter's X-ray aurora during a mass injection and Io mass loading event observed by Hubble and Hisaki

Jupiter's dynamic FUV, EUV and X-ray aurorae were simultaneously observed by the Hubble Space Telescope (HST), Hisaki and XMM-Newton respectively in September 2019 enabling us to connect features in the different wavebands. According to solar wind propagation models, the jovian magnetosphere was hit by a solar wind shock at the time, and Hisaki revealed that Io was also loading mass into the system. HST images show that short lived brightenings in the dawnside main emission, also known as dawn storms, appeared at least twice in the northern hemisphere. Such structures are thought to be associated with reconnection events and were accompanied by distinct enhancements towards the dusk sector equatorward of the main emission; these are signatures of strong injections of magnetospheric plasma. Furthermore, the EUV and hard X-ray northern aurorae both brightened with the dawn storms indicating that more electrons precipitated into Jupiter's north pole at these times. These dawn storms did not cause the X-ray aurora to pulse quasi-periodically as it sometimes does, and the X-ray spectra were best fit by an iogenic model.

Lloyd Woodham, Imperial College London
Horbury, T S; Matteini, L; Woolley, T; Laker, R; Bale, S D; Nicolaou, G; Stawarz, J E; Stansby, D; Hietala, H; Larson, D E; Livi, R; Verniero, J L; McManus, M; Kasper, J C; Korreck, K E; Raouafi, N; Moncuquet, M & Pulupa, M P

Enhanced proton parallel temperature inside patches of switchbacks in the inner heliosphere

Switchbacks are discrete angular deflections in the solar wind magnetic field that have been observed throughout the heliosphere. Recent observations by Parker Solar Probe (PSP) have revealed the presence of patches of switchbacks on the scale of hours to days, separated by 'quieter' radial fields. We aim to further diagnose the origin of these patches using measurements of proton temperature anisotropy that can illuminate possible links to formation processes in the solar corona. We fitted 3D bi-Maxwellian functions to the core of proton velocity distributions measured by the SPAN-Ai instrument onboard PSP to obtain the proton parallel, Tpar, and perpendicular, Tperp, temperature. We show that the presence of patches is highlighted by a transverse deflection in the flow and magnetic field away from the radial direction. These deflections are correlated with enhancements in Tpar, while Tperp remains relatively constant. We interpret that patches are not simply a group of switchbacks, but rather switchbacks are embedded within a larger-scale structure identified by enhanced Tpar that is distinct from the surrounding solar wind.

Session 3:

Ned Staniland, Imperial College London, University College London
Dougherty, M K; Masters, A; Achilleos, N

First Evidence of a Cushion Region at Saturn and a Reconsideration of Why it Forms

The presence of an internal plasma source within the magnetosphere of Saturn distorts the magnetic field away from a dipole to a radially stretched magnetodisc. It has been suggested that as the field lines stretch in the magnetotail and reconnection occurs, mass-depleted flux tubes will convect towards the dayside through dawn, producing a dipolar region between the outer edge of the current sheet and the magnetopause, known as the cushion region. Whilst this structure has been observed at Jupiter, it has yet to be at Saturn despite their similarities.
We present the first examples of a cushion region seen at Saturn. However, they are at dusk rather than dawn, as would be expected. We suggest this region is not a return flow channel following reconnection, but the result of greater turbulent heating and a more unstable disc at dusk compared to dawn. We further find that magnetodisc breakdown is more likely to occur at Jupiter compared to Saturn, possibly explaining why this has been more commonly observed at Jupiter.

Dale Weigt, University of Southampton
Jackman, C M; Vogt, M F; Manners, H; Dunn, W R; Gladstone, G R; Kraft, R; Branduardi-Raymont, G

Characteristics of Jupiter's X-ray auroral hot spot emissions using Chandra

We present the first extensive statistical study of all 29 Chandra High Resolution Camera (HRC-I) observations of the jovian X-ray emissions, covering ~ 20 years worth of data from 18th December 2000. For the first time, we characterise the typical and extreme behaviour of the northern hot spot (NHS) emissions across the entire catalogue. In this new statistical study, we aim to find the variable X-ray driver by identifying the characteristics of the emissions and find their origin. We present heat maps and 2-D histograms to show the overall average hot spot morphology for the very first time, using a numerical criterion of location and photon concentration to define the hot spot emissions. We find a significant region of concentrated NHS emission at its centre, the averaged hot spot nucleus (AHSNuc), mapping to the noon magnetopause boundary. Most concentrated events from the NHS are found to originate on the dusk flank boundary of the magnetopause. We apply the Rayleigh test with Monte Carlo simulation and Jackknife testing to find any significant quasi-periodic oscillations (QPOs) within the NHS. Our results suggest that there are multiple drivers of the X-ray emissions, that may be linked to ultra-low frequency wave activity.

Session 4:

Emma Woodfield, British Antarctic Survey
Woodfield, E E; Glauert, S A; Menietti, J D; Horne, R B; Kavanagh, A J; Shprits, Y Y

The Effect of Hiss Waves on Electrons in Saturn's Radiation Belts.

Whistler mode hiss waves are generally assumed to bring about the precipitation of electrons at the Earth, contributing to their loss from the radiation belts through wave-particle scattering. At Saturn, similar broadband whistler mode waves are found at high latitudes where the plasma density is very low. In contrast, broadband hiss at the Earth is typically observed in the plasmasphere where the density is relatively high. Previous work on whistler mode chorus waves at Saturn has shown that when the ratio of the plasma frequency to the gyrofrequency dips below 1 then the whistler mode wave-particle interactions are in favour of acceleration rather than scattering. Here we investigate the effect of hiss waves at Saturn on the energy of the electrons in the radiation belts and find that they strongly accelerate electrons. Due to the high latitude location of the hiss, this acceleration is confined to mid to low pitch angles and leads to butterfly pitch angle distributions.

Josh Wiggs, Lancaster University
Arridge, C S

Modelling Plasma Transport at the Outer Planets using a Kinetic-Ion, Fluid-Electron Approach - Validation

The Jovian magnetosphere is loaded internally with material from the volcanic moon of Io, this is ionised and brought into co-rotation to form the Io plasma torus. Plasma is removed from the torus mainly via ejection as energetic neutrals and by bulk transport into sink regions in the outer magnetosphere. The physical process generally considered to be responsible for bulk transport is the centrifugal-interchange instability, moving material from the inner to outer magnetosphere whilst returning magnetic flux to the planet. We have developed a full hybrid kinetic-ion, fluid-electron plasma model to examine the transport. The technique of hybrid modelling allows for probing of plasma motions down to the ion-inertial scale, allowing for insights into particle motions on spatial scales below the size of the magnetic flux tubes. It also provides a computational framework capable of capturing large-scale flow dynamics, on the order of a planetary radii in some cases. Results from this model will allow for the examination of bulk transport on spatial scales not currently accessible with state-of-the-art models, improving understanding of mechanisms responsible for moving particles to the outer magnetosphere. In this presentation a series of benchmarks will be summarised validating the physical accuracy of the model.

Adrian LaMoury, Imperial College London
Hietala, H; Plaschke, F; Vuorinen, L; Eastwood, J P

Solar wind control of jets impacting the magnetopause

Magnetosheath jets are high dynamic pressure pulses that originate at the quasi-parallel bow shock and propagate Earthward through the magnetosheath. Upon impacting the magnetopause, jets are able to trigger magnetic reconnection, launch waves, and may create space weather effects. It appears, however, that only a small proportion of jets make it to the magnetopause, with most being braked or dissipated in the magnetosheath. New statistical analysis is presented in which we attempt to determine how the solar wind conditions upstream of the bow shock can influence the penetrative abilities of jets and the probability of them hitting the magnetopause. Making use of 13,096 jet observations made by the THEMIS spacecraft from 2008 to 2018, we find that low IMF cone angles and high solar wind speeds, amongst other factors, promote the likelihood of both jet occurrence and jet penetration. This is an important first step towards forecasting the space weather effects generated by geoeffective jets.

Beatriz Sanchez-Cano, University of Leicester
Narvaez, C; Lester, M; Mendillo, M; Mayyasi, M; Holmstrom, M; Halekas, J; Andersson, L; Fowler, C M; McFadden, J P; Durward, S

Mars' Ionopause: A Matter of Pressures

This study assesses under what circumstances Mars’ ionopause is formed on the dayside, both in regions where there are strong crustal magnetic fields and areas where these fields are small. Multiple data sets from three MAVEN dayside deep dip campaigns are utilized, as well as solar wind observations from Mars Express. The ionopause is identified as a sudden decrease of the electron density with increasing altitude and a simultaneous increase of the electron temperature. This is a physically robust approach as the electron temperature is a key parameter in determining the structure of the ionospheric profile, and, therefore, also a strong indicator of the ionopause location. We find that 36% (54%) of the electron density profiles over strong (weak) crustal magnetic field regions had an ionopause event. We also evaluate the roles of ionospheric thermal and magnetic pressures as well as the presence of solar wind particles down to the location of the ionopause. We found that the topside ionosphere is typically magnetized. The ionopause, if formed, occurs where the total ionospheric pressure (magnetic + thermal) equals the upstream solar wind dynamic pressure. Moreover, the lower edge of the ionopause coincides with the altitude where the solar wind flow stops.

Session 5:

Laura Fryer, University of Southampton
Fear, R C; Coxon, J C; Gingell I L

Observations of closed magnetic flux embedded in the lobe during periods of northward IMF.

The high latitude, lobe regions of the magnetosphere are characterised by cool, low energy plasma populations. However, during periods of northward IMF, energetic plasma populations have occasionally been observed. We present three case studies in which the Cluster spacecraft observed uncharacteristically energetic plasma populations in the lobe. For the two of the three events discussed, the plasma sheet was observed simultaneously by Double Star. These observations revealed that the energies measured in the lobe were comparable in magnitude to those observed in the plasma sheet. Additionally, images from IMAGE and DMSP/SSUSI show that transpolar arcs, which form in each event in at least one hemisphere, directly intersect the footprint of the Cluster spacecraft in all three events. This intersection of the Cluster footprint with the transpolar arcs is synchronous with the observation of the energetic plasma populations in the lobe. These results suggest that the mechanism that produces plasma at high latitudes is likely to be tail reconnection which results in a wedge of closed flux about the noon-midnight meridian. This further supports the conclusion that the observed energetic plasma in the high latitude regions of the magnetosphere is on closed field lines.

Mayur R. Bakrania, Mullard Space Science Laboratory, UCL
Rae, I J; Walsh, A P; Verscharen, D; Smith, A W

Using dimensionality reduction and clustering techniques to classify space plasma regimes

Collisionless space plasma environments are characterised by distinct particle populations that typically do not mix. Although moments of their velocity distributions help in distinguishing different plasma regimes, the distribution functions themselves provide more comprehensive information about the plasma state. Unlike moments, however, distributions are not easily characterised by a small number of parameters, making their classification more difficult. To perform this classification, we distinguish between the different plasma regions by applying dimensionality reduction and clustering methods to electron distributions in pitch angle and energy space. We test our algorithms by applying our scheme to data from the Earth's magnetotail. Traditionally, it is thought that the magnetotail is split into three regions that are primarily defined by their plasma characteristics. However, we identify 8 distinct groups of distributions, that are dependent upon significantly more complex plasma and field dynamics. We find clear distinctions between our classified regions and the ECLAT results. The automated classification of different regions in space plasma environments provides a useful tool to identify the physical processes governing particle populations in near-Earth space. Similar methods could be used onboard spacecraft to reduce the dimensionality of distributions in order to optimise data collection in future missions.

Jasmine Kaur Sandhu, Northumbria University
Rae, I J; Watt, C E J; Horne, R B; Ozeke, L G; Georgiou, M; Wygant, J R; Breneman, A; Tian, S; Walach, M-T

Identifying storm-time variations in ULF wave power and implications for radiation belt dynamics

The outer radiation belt exhibits highly complex storm time variations shaped by a multitude of wave-particle interactions. In particular, interactions with Ultra Low Frequency (ULF) waves act to radially scatter trapped electrons, known as radial diffusion. Radial diffusion has been proposed to play a key role in the energisation, loss, and transport of radiation belt electrons during geomagnetic storms.
In this study, we quantify the changes and variability in storm-time radial diffusion coefficients. A statistical analysis of Van Allen Probes data is conducted to obtain measurements of ULF wave power spectral densities and estimated radial diffusion coefficients. A key result is global wave power enhancements observed during storm main phases, due to both external sources from solar wind driving as well as internal sources from coupling with ring current ions and from substorm activity. The increased wave power drives enhancements in diffusion coefficients by over an order of magnitude. A comparison to previous models shows important discrepancies, where the magnetic field diffusion coefficient is approximately 10 times larger than predicted. Overall, this study extracts the dynamics and variability of ULF wave activity during geomagnetic storms, and provides new storm-time radial diffusion coefficients for direct use in radiation belt simulations.

Poster session 2:

Jeffersson Andres Agudelo Rueda, Mullard Space Science Laboratory, University College London
Verscharen D; Wicks R T; Owen C J; Nicolaou G; Walsh A P; Zouganelis I; Germaschewski K; Vargas Dominguez S

Study of plasma bulk profiles along artificial-spacecraft trajectories through a 3D fully kinetic simulation of turbulent magnetic reconnection

Heating and energy dissipation in the solar wind remain important open questions. Turbulence and reconnection are two candidate processes to account for the energy transport to subproton scales at which, in collisionless plasmas, the energy ultimately dissipates. Understanding the effects of small scale reconnection events in the energy cascade requires the identification of these events in observational data as well as in 3D simulations. We use an explicit fully kinetic particle-in-cell code to simulate 3D small scale magnetic reconnection events as a result of anisotropic and Alfvènic decaying turbulence. We define a set of indicators to find reconnection sites in our simulation based on intensity thresholds. According to the application of these indicators, we observe the creation of reconnection events in the simulation domain. We select one 3D reconnection event and study its geometry as well as the profiles of plasma bulk quantities along realistic spacecraft trajectories passing near and through the reconnection event. We observe features consistent with observations of magnetic reconnection in the solar wind.

Oliver Allanson, Northumbria University
Watt, C E J; Allison, H J; Ratcliffe, H

Diffusion and advection during nonlinear electron-whistler interactions

Radiation belt numerical models utilize diffusion codes that evolve electron dynamics due to resonant wave-particle interactions. It is not known how to best incorporate electron dynamics in the case of a wave power spectrum that varies considerably on a 'sub-grid' timescale shorter than the computational time-step dt, particularly if the wave amplitude reaches high values. Timescales associated with wave growth rates are often very short, and typically $\ll$ dt. We use a kinetic code to study electron interactions with whistler-mode waves in the presence of a background plasma with thermally anisotropic components. For 'high' levels of anisotropy, wave growth via instability is triggered. Dynamics are not well described by the quasilinear theory when calculated using the average wave power. During the growth phase we observe strong diffusive and advective components, which both saturate as the wave power saturates at ~1nT. The advective motions dominate over the diffusive processes. The growth phase facilitates significant transport in electron pitch angle space via successive resonant interactions with waves of different frequencies. This motivates future work on the longer-time impact of very short timescale processes in radiation belt modelling, and on the indirect effects of anisotropic background plasma components on electron scattering.

Luke Barnard, University of Reading
Owens, M; Scott, C; de Koning, C

Ensemble CME Modeling Constrained by Heliospheric Imager Observations

Predicting the arrival of coronal mass ejections (CMEs) is one key objective of space weather forecasting. In operational space weather forecasting, solar wind numerical models are used for this task and ensemble techniques are being increasingly explored as a means to improve these forecasts. Currently, these forecasts are not constrained by the available in situ and remote sensing observations, such as those from the heliospheric imagers (HIs) on NASA's STEREO spacecraft. We show how HI observations can be used to improve the skill and reduce the uncertainty of ensemble predictions of CME arrival at Earth. Using the HUXt solar wind model, we produce 200-member ensemble hindcasts, perturbing the CME parameters from their best estimates. By comparing the trajectory of the modelled CME flanks with HI observations, we compute a weight for each ensemble member. Weighting the ensemble distribution of CME arrival times improves the skill and reduces the uncertainty of each studied event. For the four studied events, the weighted ensembles show a mean reduction in arrival time error of 20±4%, and a mean reduction in arrival time uncertainty of 15±7%. We discuss how this technique could be applied in operational space weather forecasting.

Sarah Bentley, Northumbria University
Stout, J; Bloch, T; Watt, C

Random Forest Models of Magnetospheric ULF Wave Power

We present a freely-available model of the power found in ultra-low frequency waves (ULF, 1-15 mHz) throughout Earth’s magnetosphere. Predictions can be compared to observations to test our understanding of magnetospheric dynamics, while accurate models of these waves are required for radiation belt modelling.

Our model is constructed using decision tree ensembles, which iteratively partition the given parameter space into variable size bins. Wave power is determined by physical driving parameters (solar wind speed vsw, magnetic field component Bz and variance in proton number density var(Np)) and spatial parameters of interest (magnetic local time MLT, magnetic latitude and frequency).

We explain why one cannot extract all physical processes from parameterised models such as this. Instead we iteratively consider smaller scale driving processes to examine magnetic local time asymmetries in ULF wave power. We conclude that the dawn-dusk asymmetry is probably due to the different radial density profile of the plasma combined with driving from magnetopause perturbations, while var(Np) does not represent power from external drivers. Nor does Bz, which likely represents power increases with substorms. Significant remaining uncertainty occurred with mild solar wind driving, suggesting that the internal state of the magnetosphere should be included in future.

Laura Bercic, Mullard Space Science Laboratory
Landi, S; Maksimovic, M

The interplay between ambipolar electric field and Coulomb collisions in the solar wind acceleration region

The solar wind protons are accelerated to supersonic velocities within the distance of 10 solar radii from the Sun, as a consequence of a complex physical mechanism including particle kinetic effects as well as the field-particle energy and momentum exchange. We use a numerical kinetic model of the solar wind, accounting for Coulomb collisions (BiCoP), and model a solar wind accelerated only by the ambipolar electrostatic filed (E) arising due to the difference in mass between electron and proton, and assuring quasi-neutrality and zero current. We study the effect of E, which was found to be on the order of Dreicer electric field (E_D) (Dreicer, 1959), on the resulting electron velocity distribution functions (VDF). The strahl electron radial evolution is represented by means of its pitch-angle width (PAW), and the strahl parallel temperature (T_s,||). Collisions were found to scatter strahl electrons below 250 eV, which in turn has an effect on the measured T_s,||. A slight increase was found in T_s,|| with radial distance, and was stronger for the more collisional run. We estimate that the coronal electron temperature inferred from the observations of T_s,|| in the solar wind, would be overestimated for between 8 and 15 %.

Aisling Bergin, Centre for Fusion, Space and Astrophysics, University of Warwick
Chapman, S C; Moloney, N R; Watkins, N W

Quantifying the statistical variation of return period, amplitude and duration of bursts in the AE index across successive solar cycles.

The overall level of solar activity, and the response at earth, varies within and between successive solar cycles. The AE index characterises this geomagnetic response at high latitudes and we consider non-overlapping 1 year samples at different solar cycle phases. We investigate bursts, that is, excursions above a fixed threshold in AE. We perform the first study of variation in burst statistics within and between the last four solar cycles. We find that, for bursts above 75th quantile thresholds, the functional form of the burst return period distribution is stable over successive solar maxima. The magnitude of 75th quantile threshold scales with overall solar cycle activity level. At solar maximum, the 75th quantile relates to events which exceed 160 - 350 nT. We will discuss burst statistics for solar cycle minimum and declining phases. Above the 75th quantile of observed data records, there exists an underlying functional form for the tail of statistical distribution which also does not change between successive solar cycles. These properties may be related via crossing theory. If the overall amplitude of the upcoming solar maximum can be predicted, our results may be used to estimate the upcoming distribution of event return times.

Nathan Case, Lancaster University
Hartley, D P; Grocott, A; Miyoshi, Y; Matsuoka, A; Imajo, S; Kurita, S; Shinohara, I; Teramoto, M

Inner Magnetospheric Response to the IMF By 2 Component: Van Allen Probes and Arase Observations

We utilise 17 years of combined Van Allen Probes and Arase data to statistically analyse the response of the inner magnetosphere to the orientation of the IMF By component. Past studies have demonstrated that the IMF By component introduces a similarly oriented By component into the magnetosphere. However, these studies have tended to focus on field lines in the magnetotail only reaching as close to Earth as geosynchronous orbit. By exploiting data from these inner magnetospheric spacecraft, we have been able to investigate the response at radial distances of < 7RE. When subtracting the background magnetic field values, provided by the T01 magnetic field model, we find that the IMF By component does affect the configuration of the magnetic field lines in the inner magnetosphere. This control is observed throughout the inner magnetosphere, across both hemispheres, all radial distances, and all MLT sectors. The ratio of IMF By to observed By residual, also known as the "penetration efficiency", is found to be ~0:33. The IMF Bz component is found to increase, or inhibit, this control depending upon its orientation.

John C. Coxon, University of Southampton
Fear, R C; Fryer, L J; Plank, J; Reidy, J A

Hot plasma in the magnetotail lobes shows characteristics consistent with closed field lines trapped in the lobes

We examine the magnetotail using data from the Hot Ion Analyzer on Cluster 1 during 2001--2009. We develop and utilise an algorithm in order to identify times during which Cluster 1 is in the magnetotail lobe but observes plasma which is hotter than our expectations of the lobe. We analyse the prevailing Interplanetary Magnetic Field (IMF) BZ conditions for our algorithm and a reference algorithm (with no particle energy criteria) and find that the periods we select are, on average, ~2 nT more towards northward IMF. Examining the temperature in the magnetotail for our periods shows that the morphology of the average temperature is consistent with the Milan et al. (2005) model of magnetotail structure during Northward IMF, in which closed field lines are prevented from convecting to the dayside, causing them and the plasma trapped on them to protrude into the magnetotail lobes.

Diego de Pablos, Mullard Space Science Laboratory (UCL)
Owen, C J; Long, D M; Valori, G; Harra, L K

Analysis of time-domain correlations between EUV and in-situ observations of coronal jets

The role of small-scale coronal eruptive phenomena in the generation and heating of the solar wind remains an open question. Here we investigate the role played by coronal jets in forming the solar wind by testing whether temporal variations associated with jetting in EUV intensity can be identified in the outflowing solar wind plasma.

This type of comparison is challenging due to inherent differences between remote-sensing observations of the source and in-situ observations of the outflowing plasma, as well as travel time and evolution of the plasma throughout the heliosphere. To overcome these issues, we propose a novel algorithm combining signal filtering, two-step solar wind ballistic backmapping, and Empirical Mode Decomposition.

We first validate the method using synthetic data, before then applying it to measurements from the Solar Dynamics Observatory, and Wind spacecraft. We find several time windows where signatures of dynamics found in the corona are embedded in the solar wind stream, at a time significantly earlier than expected from simple ballistic backmapping.

Elizabeth Donegan-Lawley, University of Birmingham
Elvidge, S E; Wood, A G; Dorrian, G D; Kjellmar, O

High latitude statistical modelling for scintillation of GNSS signals

The ionosphere is a plasma structured over a wide variety of scale sizes. Structures on a small spatial scale (tens of metres to tens of kilometres) can disrupt trans-ionospheric radio signals in the frequency range used by Global Navigation Satellite Systems (GNSS). These structures are driven by a number of processes such as time of day, season, solar cycle, geomagnetic activity, solar wind conditions, and geographic location. While the drivers of these structures are well understood, the relative importance of these is a more open question.

Generalised linear modelling has been applied to model the occurrence of scintillation of GNSS signals from the Galileo, GPS, and GLONASS satellite constellations. These signals were measured using a receiver located at Longyearbyen, Svalbard (78.2° N, 15.6° E).

The development and effectiveness of both a single model for an entire (24 hour) day, as well as four individual time-sector models representing dawn, noon, dusk, and midnight are presented. These models quantify the relative significance of each of the driving processes on the disruption of signals. A multivariate model has been used to determine which combination of processes best describes the observed variability, results are discussed.

Xiangcheng Dong, RAL Space, STFC, UK
Dunlop, M W; Wang, T Y; Trattner, K J; Russell, C T

In-situ Observation of Secondary Magnetic Reconnection Region Beside Ion-Scale Flux Rope at the Magnetopause

Flux transfer events (FTEs) are the flux ropes caused by unsteady reconnection at the magnetopause region, allowing the transportation of solar wind into the terrestrial magnetosphere. Due to the high-resolution plasma data and small separation of the four spacecraft Magnetospheric Multiscale (MMS) mission, the detailed plasma and field structure of ion-scale flux rope FTEs have been investigated. The formation mechanism of these ion-scale flux rope and its relationship with typical size FTEs are still outstanding questions. A series of evolving flux ropes in the reconnection exhaust region with size increasing from several ion-scales to the mesoscale have been observed while the secondary reconnection required for their magnetic flux growth has not been directly observed. Using high-resolution data from MMS, we report an in situ observation of a secondary reconnection electron diffusion region (EDR) beside the leading edge of an ion-scale flux rope at the magnetopause. Our observation of secondary reconnection beside the flux rope gives direct evidence that flux ropes can be created and evolved in the reconnection exhaust region.

Tom Elsden, University of Leicester
Wright, A N

Evolution of High-m Poloidal Alfven Waves in a Dipole Magnetic Field

We investigate how initially high-m, poloidal Alfven waves evolve using a numerical model solving the ideal, cold, linear magnetohydrodynamic (MHD) equations in a dipole coordinate system. The curved magnetic geometry provides a key difference between the poloidal and toroidal Alfven frequencies of any one field line. A polarisation rotation from poloidal towards toroidal predicted from the Cartesian box model theory still occurs, but now with the waves following contours of Alfven frequency, which moves the Alfven wave across field lines. The structure of these contours depends on the harmonic mode along the field line and the equilibrium. We find that the amplitude peak of the poloidal mode moves significantly radially outward in time. When the typically observed azimuthal phase motion of such waves is included, hodograms show a polarisation rotation from purely poloidal to a mixed poloidal/toroidal polarisation at all locations. Such features could be used to help interpret satellite observations of Pc4-5 poloidal ultralow frequency (ULF) waves in Earth's magnetosphere.

Tadhg Garton, University of Southampton
Jackman, C M; Smith, A W; Yeakel, K L; Maloney, S A; Vandegriff, J

Machine Learning Applications to Magnetospheric Reconnection Identification

Magnetic reconnection regularly occurs for planetary magnetospheres immersed in the variable interplanetary magnetic field (IMF) where nearby magnetic field lines of opposing polarity can breach and reform into a more stable structure. This continual process releases significant amounts of energy and allows mass to transfer about the planetary magnetosphere and between it and the solar wind. Within planetary magnetotails, signatures of these reconnection events can be identified in situ as characteristic deflections in the north aligned component of the local magnetic field. The most common approach to identifying these signatures is through manual and semi-automated means, however these methods are typically slow and heavily reliant on human verification. Here, we present a fully automated, machine learning model to identify signatures of reconnection with Cassini magnetic field measurements of Saturn's planetary magnetosphere. This model utilizes a previously created catalogue of Kronian magnetotail reconnections created using semi-automated identification by Smith et al., 2016 for training. Utilizing this method attains an event identification accuracy of 99% for the year of 2010, and a Heidke skill score of 0.84. From this model, a full catalogue of magnetic reconnection events in the Kronian magnetosphere across Cassini's lifetime (13 years) is now available.

Imogen Gingell, University of Southampton
Schwartz, S J; Eastwood, J P; Stawarz, J E; Burch, J L; Burgess, D; Ergun, R E; Fuselier, S; Gershman, D J; Giles, B L; Khotyaintsev, Y V; Lavraud, B; Lindqvist, P-A; Paterson, W; Russell, C T; Strangeway, R J; Torbert, R B; Wilder, F

Inverted Rope-like Structures in the Bow Shock's Transition Region

Observations of Earth's bow shock have shown that a disordered transition region can generate thin current sheets at ion and electron kinetic scales. Indeed, a recent survey of current sheets in the shock has shown that active reconnection occurs across the full range of shock parameters at Earth's bow shock. Furthermore, kinetic simulations have also shown that reconnection in the shock transition can generate magnetic islands and similar rope-like current structures. Using observations of Earth's bow shock by Magnetospheric Multiscale (MMS), we have identified several rope-like current structures embedded in the shock transition region. In each case the associated shock crossings also have observations of active magnetic reconnection. In contrast to typical models of flux ropes, several events exhibit an inverted structure for which the axial, core field is anti-parallel to the background. Using hybrid simulations, we show that inverted rope-like structures can be generated by instabilities of whistler waves in the shock foot. The structures then contract as they convect downstream. Using multi-spacecraft analyses to measure size and contraction rates of the inverted rope-like structures observed by MMS, we associate our case studies with different stages of the life of these structures as seen in simulations.

Adrian Grocott, Lancaster University
Walach, M-T

TiVIE: The Time-Variable Ionospheric Electric Field Model

We present a brief summary of a new model of the Time-Variable Ionospheric Electric field (TiVIE), derived from line-of-sight plasma velocity measurements from the Super Dual Auroral Radar Network (SuperDARN). Major improvements over existing models are achieved by the use of novel parameterisations that capture three major sources of time-variability of the coupled solar wind-magnetosphere-ionosphere system. The first source of variability relates directly to the time-dependence of the system to the upstream solar wind conditions, specifically the strength and orientation of the interplanetary magnetic field. The second source of variability relates to the storage and release of energy in the magnetosphere that is associated with magnetospheric substorms. The third source of variability relates to the different phases of geomagnetic storms. In this poster, we briefly outline the motivation for the model, and present results from an example scenario that illustrates some of the advantages of TiVIE over other models.

Richard Haythornthwaite, Mullard Space Science Laboratory, University College London
Coates, A J; Jones, G H; Wellbrock, A

Coupled Cation-Neutral-Anion Winds in Titan's Thermosphere/Ionosphere

Titan is a moon of Saturn with a thick extended atmosphere and large ionosphere. Pre-Cassini models of Titan predicted thermospheric winds of up to 60 m/s, however, from Cassini-Huygens and ALMA observations there have been indications of superrotation in the thermosphere/ionosphere, with speeds reaching up to 390 m/s. Previous studies through remote and insitu measurements have measured winds in one direction and either neutral or positive ions. However, in Titan's dense lower ionosphere; neutrals, positive and negative ions are collisionally coupled below 1300km, meaning that the three groups should be similarly affected by these winds.

Through a novel combined positive and negative ion study using Cassini CAPS data, these winds are studied as bulk flows of positive and negative ions perpendicular to Cassini's track through the ionosphere. These cross-track winds have not been previously measured and could have implications for other in-situ instruments aboard Cassini. Furthermore, through future combination with along-track winds, two dimensional wind vectors can be generated from in-situ measurements in the thermosphere. These measurements add to the understanding of high altitude winds at Titan, aiding future investigation into this dynamic system.

Greg Hunt, Imperial College London
Provan, G; Bradley, T; Cowley, S W H; Dougherty, M K; Roussos, E

The response of Saturn's dawn field-aligned currents to magnetospheric conditions during the Proximal Orbits

The Proximal orbits of the Cassini spacecraft during 2017 have given us the opportunity to examine the auroral field-aligned currents in the northern hemisphere dawn sector in relation to wider magnetospheric conditions. Here we will combine the results of three recent studies on the properties of the auroral field-aligned current, magnetospheric ring current and the overall compressional state of Saturn's magnetosphere due to solar wind conditions. Using these results, we will examine the response of the auroral field-aligned currents in combination with the magnetospheric ring current to compressions and expansions of the Saturnian magnetosphere. We will show that for a compression of Saturn's magnetosphere the current within in the downward current sheet, directed into the ionosphere, and located equatorward of the main auroral oval increases in strength with increasing total ring current. While the inverse relation occurs during an interval of quiet or expanded magnetospheric conditions. This response is akin to an Earth-like 'region 2' field aligned current within Saturn's dawn magnetosphere. We will discuss the position of this current in relation to the hot plasma population within the magnetosphere. We will also discuss the implications of these observations for Saturn's magnetospheric current systems and dynamics.

James Lane, Lancaster University
Grocott, A; Case, N A; Walach, M -T

Dynamics of Variable Dusk-Dawn Flow Associated with Magnetotail Current Sheet Flapping

We present Cluster spacecraft observations from 12th October 2006 of earthward convective magnetotail plasma flows. During a 4-minute interval, the azimuthal (v_parallel_y) component of the flows was observed to vary between dawnward and duskward. Combined observations of the upstream solar wind conditions from OMNI, and ionospheric convection data using SuperDARN, indicate a large-scale magnetospheric morphology consistent with positive IMF By penetration into the magnetotail. The dusk-dawn sense of the localised convective flows observed by Cluster disagrees with expectations based on current theories of Interplanetary Magnetic Field (IMF) By control of magnetotail asymmetries. Inspection of the in-situ Cluster magnetic field data reveals a flapping of the magnetotail current sheet and the presence of a localised By negative kink at the location of Cluster 1. Results from the curlometer analysis technique suggest that the dusk-dawn flow perturbations were being driven by the J x B force associated with the current sheet flapping. The direction of the flows seems consistent with removal of the localised By-negative kink from an otherwise globally By-positive twisted tail.

Emma Thomas, University of Leicester
Melin, H; Stallard, T S; Chowdhury, M N
Unearthing Uranus's Infrared Aurora
In 1986 we first detected the ultraviolet aurora across Uranus with Voyager II. Since then, we have had two re-detections (Lamy et al, 2012 and 2017) but never a confirmed observation in the infrared.

The aim of our research is to detect and produce an initial mapping of the infrared aurora at Uranus through H3+ emissions. This is achieved by using observational data from September 2006 with the Keck II Telescope. This dataset spans over a 6-hour period where emissions were detected with a 0.43x24^{o} slit, whilst Uranus measured 3.7^{o} in the sky. We present two spatial mappings of the Q1 and Q3 emission lines of H3+, from these we can calculate and successfully map H3+ ro-vibrational temperatures and ion column densities across a 121-degree longitudinal period.

Our results show broad intensity regions across Uranus which peak above estimated errors. In contrast we see no peaks in ro-vibrational temperature across these areas but instead find increased H3+ column densities (which occur close to or at these intensity peaks). The implications of these results suggest an increase in ionisation rates in the upper atmosphere, confirming that our results are the first observations of the infrared aurora at Uranus!

Dong Wei, Southern University of Science and Technology
Dunlop, M W; Dong, X C; Yang, J Y; Yu, Y; Wang, T;
Intense dB/dt variations driven by near-Earth Bursty Bulk Flows (BBFs): A case study
During geomagnetically disturbed times, geomagnetically induced currents (GICs) may flow in power systems and potentially cause damages. GICs are often produced when the surface geomagnetic field changes abruptly. However, there are few studies reporting GIC effects driven directly by bursty bulk flows (BBFs) in the inner magnetosphere. In this study, we investigate the characteristics and response of the magnetosphere-ionosphere system during the 7 January 2015 storm by using a multi-point approach which combines the space-borne measurements from Cluster and Swarm, and the magnetic observations from an array of ground stations. During the BBF interval, the magnetic footprints of Cluster and Swarm map to the same conjugate region near the magnetometer ground stations. Moreover, the added measurements from RBSP-B, GOES-15 and other 17 geomagnetic stations indicate that a large-scale Substorm Current Wedge (SCW) appeared in this conjugate region is a combined effect of multiple wedgelets due to multiple flow bursts. Also, the multi-point magnetic and current signatures occur with suitable time lags for BBF related effects. Our results provide direct evidence that the most intense dB/dt (and dH/dt) variations are associated with large-scale field-aligned currents driven by BBFs around a substorm onset.

Session 6:

Samuel Walton, University College London
Forsyth, C; Rae, I J; Sandhu, J K

The Relative Contribution of Enhancement and Loss to Global Variations in Relativistic Outer Radiation Belt Electrons

The relativistic (MeV) electron population in the outer Van Allen radiation belt is highly dynamic and typically linked to geomagnetic activity such as storms and substorms and ultimately driven by the interaction of the magnetosphere with the solar wind. The continuously shifting balance between acceleration and loss can dictate global, orders of magnitude changes in outer belt flux on hour to day timescales. However, the relative contributions of simultaneously occurring acceleration and loss, and variation of such, is highly complex and far from fully understood. Using a continuous 12-year dataset from the Proton Electron Telescope (PET) on board the Solar Anomalous Magnetospheric Particle Explorer (SAMPEX), we statistically examine spatial flux variations with geomagnetic activity on a global scale. We find that during heightened periods of geomagnetic activity, changes in electron flux are spatially dependent with observed enhancements inside L~3 and depletions inside of L~3. Furthermore, we find that the proportion of flux within the bounce loss cone increases relative to enhanced trapped flux in all regions. These new results reveal important changes in the balance of radiation belt acceleration and loss processes with geomagnetic activity.

Téo Bloch, University of Reading
Watt, C E; Owens, M J; Thompson, R L; Agiwal, O

Constraining the Location of the Outer Boundary of the Radiation Belts

Due to ever-increasing space-infrastructure and the implementation of electrical orbit raising, understanding Earth’s radiation belts has never been more important. Radiation belt models require an outer boundary to act as a time dependent source. Typically, the location of the boundary is determined by the availability of the spacecraft data used to quantify it, or it is chosen subjectively. As a source, it is important to accurately characterise this boundary to ensure that modelling efforts can most effectively forecast space-weather or most accurately represent the physics of the system.
We present a statistical location for the outer boundary, determined by applying machine learning techniques to electron distribution functions, derived from in-situ THEMIS observations of the differential electron flux about the magnetic equator. Our results suggest that the nominal boundary location is ~8.5 Earth Radii, a larger value than those used in most radiation belt models, though significant variability and a dawn-dusk asymmetry are present.

Alexander Lozinski, British Antarctic Survey, and University of Cambridge
Horne, R B; Glauert, S A; Del Zanna, G; Albert, J

Optimisation of a Steady State Radial Diffusion Model to Derive Diffusion Coefficients for the Proton Radiation Belt

Proton flux measurements from the Proton Telescope instrument aboard CRRES are used to drive a radial diffusion model of the inner proton belt at 1.1≤ L≤1.7. Our model utilises a physics-based evaluation of the cosmic ray albedo neutron decay (CRAND) source, and coulomb collisional loss driven by plasmaspheric density from the Global Core Plasma Model. We drive our model using time-averaged data at L=1.7 to calculate steady state profiles of phase space density, and optimise radial diffusion coefficients to fit data. This is first performed for a quiet period when the belt is near steady state. Additionally, we investigate fitting steady state solutions to time averages taken during active periods that exhibit limited deviation from steady state, demonstrated by CRRES measurements following the 24th March 1991 storm. We discuss how to make the optimisation process more reliable by excluding periods of variability in plasmaspheric density from time averages. Lastly, we compare our diffusion coefficients to those derived in previous work, including those derived for electrons from ground and in situ observations. We find higher diffusion coefficients are derived compared with previous work, but our estimates may be increased by uncertainty in inner zone plasmaspheric density.