MIST reunited

Emma Woodfield, Andy Smith and colleagues outline the research presented and discussed at the Autumn MIST meeting in November 2022

The first in-person Autumn MIST since the start of the Covid-19 pandemic was held in the Geological Society on 18 November 2022. It was a very successful hybrid meeting with 89 people attending in person and 24 online. The meeting was split into three oral sessions: planetary, solar and Earth-based presentations alongside two poster sessions to accommodate the very large number of abstract submissions to this thriving meeting.

The first session of the day collected a selection of planetary presentations. **Mark Lester** (University of Leicester) began the day by presenting Mars radar data from the MARSIS instrument on the MAVEN spacecraft during solar energetic particle (SEP) events. Using radar blackouts from MARSIS in the AIS mode (when it is a topside ionospheric sounder which also receives reflections from the surface) in conjunction with the MAVEN SEP particle instrument, Mark demonstrated the presence of a highly variable ionisation layer in the low-altitude atmosphere of Mars.

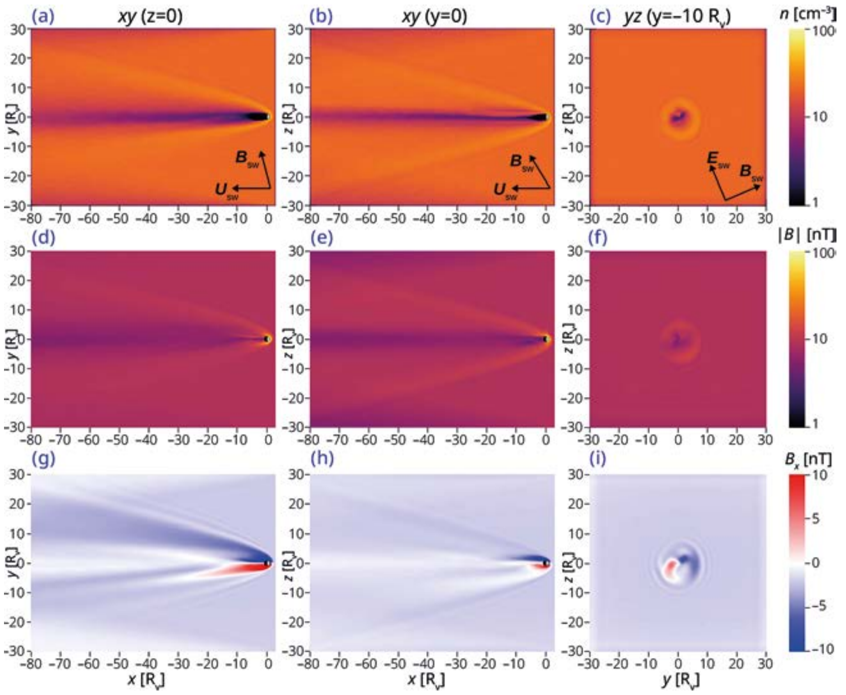
Katerina Stergiopoulou (University of Leicester) presented an investigation of the induced magnetotail at Venus using data from two flybys of the planet by ESA's Solar Orbiter spacecraft. Taking electron density and magnetic field measurements, Katerina compared these to hybrid simulations of Venus' magnetosphere using a model by Jarvinen and Kallio from Aalto University in Finland (figure 1). The comparison revealed times when the observed magnetic field vector was rotated away from the modelled vector and possible evidence of escaping plasma.

Charlotte Goertz (Northumbria University) took us on a tour of the diamagnetic cavity that occurs within the plasma environment around comets. Charlotte showed that these cavities, where the magnetic field strength is zero and no solar wind is observed, rather surprisingly sometimes contain protons, as shown by the Rosetta measurements of comet 67P/Churyumov-Gerasimenko. Having ruled out several other possibilities, Charlotte proposed that these protons can enter the cavity when the interplanetary magnetic field is parallel to the solar wind velocity.

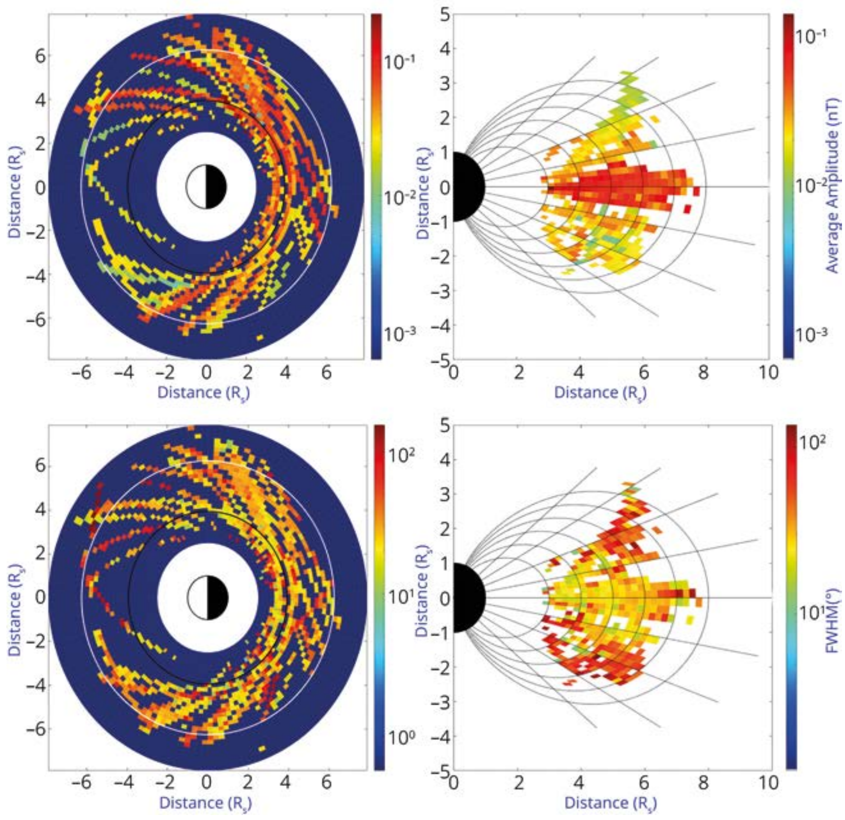
To finish the planetary session, **Cristian Radulescu** (University College London) presented findings on the distributions of pick-up ions at Saturn from Cassini data. These ions were recently neutral particles ejected by the moon Enceladus and have been 'picked up' by the fast-moving plasma in Saturn's magnetosphere. The evolution of the velocity distribution of these ions is related to the production of ion cyclotron waves. Analysing data between 4 and 6 Saturn radii (R_S) from the centre of the planet, Cristian found that the region of most intense ion cyclotron waves (centred on the equator) is co-located with the region of narrower ion pitch angle distributions and vice versa (figure 2).

Solar wind studies

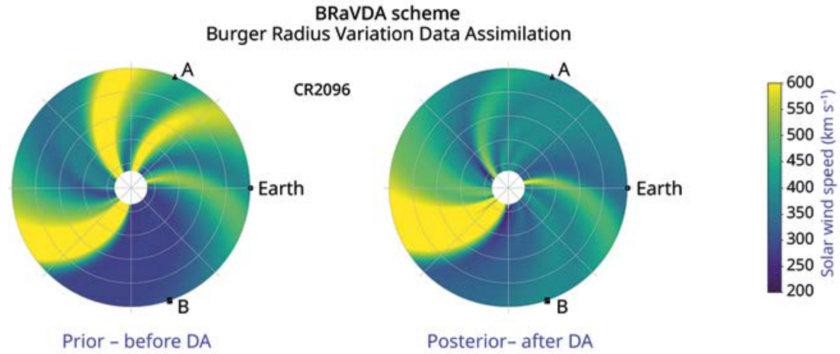
The second session began with **Harriet Turner** (University of Reading) looking at the use of real-time data in solar wind data assimilation. Noting the



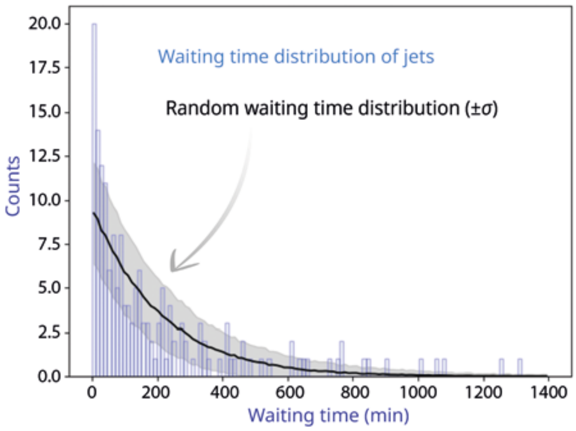
1 *Simulation results of the solar wind-Venus interaction from the global hybrid simulation RHybrid developed by Jarvinen and Sandroos at the Finnish Meteorological Institute (FMI). Solar wind density in XY, XZ and YZ VSO planes in (a)–(c), magnetic field magnitude in (d)–(f) and the X component of the magnetic field, BX, in (g)–(i).* (Reproduced from Figure 4 of Stergiopoulou et al., 2023, JGR, 128, 2)



2 *Cassini observations of ion cyclotron waves at Saturn showing the average amplitude (top row) and the full width at half maximum of the water group pick-up ion pitch angle distributions (bottom row).*



3 *Solar wind solution from the BRaVDA model using the simplified solar wind model HUX, initialised on 22/04/2010 for Carrington Rotation 2096 (22/04/2010 to 19/05/2010). The prior state (left) is that before the in situ data assimilation has taken place and the posterior state (right) is after the data assimilation. Indicated on both panels is the location of STEREO-A (A), Earth and STEREO-B (B) on 22/04/2010.* (Reproduced from Figure 1 of Turner et al. 2022, Space Weather, 20, 8)



4 *The waiting time distribution of reconnection exhaust jets in the solar wind (Preliminary data shown here, the updated version is in Fargette et al. 2023,* Astron. Astrophys.*, accepted)*

difference in the data between real-time and the cleaned-up science level data which appears some time later, Harriet showed that using the BRaVDA scheme (Burger Radius Variational Data Assimilation) with real-time data did not significantly worsen forecasts of the solar wind (figure 3). Harriet also showed that a future mission pairing of both an L5 and L1 monitor would improve forecasts of solar wind speed.

Next up, **Naïs Fargette** (Imperial College, London) described his work on the clustering of reconnection exhausts in the solar wind. Past observations have shown many reconnection jets at 1au but very few at 0.1au. Using Solar Orbiter data, Naïs set up an automatic detection algorithm and found 163 jets in a span of 24 days at 0.7au. Upon analysing the time in between jets, there was evidence of jets clustering together in time with the jets typically of short duration and low shear (figure 4).

Alina Bendt (Centre for Fusion, Space and Astrophysics, University of Warwick) investigated the use of wavelet decomposition on Solar Orbiter data to investigate turbulence in the solar wind. With non-gaussian probability distribution functions confirming turbulence, Alina found the scaling component was close to 3/2 but not fully in the inertial range. Fractal behaviour was evident in the kinetic range and multi-fractal behaviour in the inertial range.

In the penultimate talk of the session **Abid Razavi** (Mullard Space Science Laboratory) presented studies of interplanetary shocks. Abid showed examples of flat-top shock distributions, so named from their shape in the phase space density versus energy, from Solar Orbiter data. The shape of the distributions has implications for the energy dissipation at a shock. These case studies are the start of a larger statistical investigation.

In the final talk of the session, **Domenico Trotta** (Imperial College, London) presented analysis of particle acceleration at interplanetary shocks, focusing on upstream steep structures known as shocklets. A multi-spacecraft case study of a strong shock using observations from Solar Orbiter, Wind, THEMIS, DISCOVR and ACE shows the broad spatial extent of these phenomena upstream from the shock front.

Earth-based science

The final session of the day hosted talks focused on Earth-centred science from the MIST community. **Ciaran Beggan** (British Geological Survey, BGS) started the session by providing a description of how the BGS are increasing the number of locations at which observations of the magnetic field are made in the UK. Three new sites are being added to the current network of four existing magnetometers to dramatically improve the spatial coverage available. These stations now return high-quality magnetic variation data through the 4G network in near-real time, and improve our ability to monitor space weather.

Next, **Harley Kelly** (Imperial College, London) discussed how current understanding of the Kelvin-Helmholtz instability is based on simplified and unrealistic assumptions, partly because of the difficulty of measuring these data with spacecraft. Harley then described using GORGON MHD (MagnetoHydroDynamic) simulations to probe Kelvin-Helmholtz votices in global-scale 3D simulations. They located the structures by searching for pressure minima, and found more Kelvin-Helmholtz structures on the magnetopause, where they form tubular structures, than in the magnetotail.

Nonetheless, a complex series of phenomena occur in the Earth's magnetotail. Some of these are linked to magnetospheric substorms, which are a global cycle of energy storage and release that can be monitored in different data sets, using a range of techniques. **Christian Lao** (University College London) presented work comparing and contrasting the different databases of substorms that identify substorms through distinct methods. None of these competing catalogues agreed entirely with another, yet the time differences between them (when they agreed) was equal to the shortest time tested – suggesting that the events are near-simultaneous when the same event was recorded.

Gemma Bower (University of Leicester) then presented work investigating the formation and evolution of a type of auroral configuration known as 'Horse Collar Aurora'. This kind of auroral event was shown to occur during northward IMF (interplanetary magnetic field) conditions, with 11 events (out of 650) showing sufficient data to examine the auroral forms in more detail. In all cases the formation and motion of the aurora appeared to be governed by the sign of the IMF B_y component, as predicted by the Milan *et al.* (2020) model.

Following this, **Thomas Daggitt** (British Antarctic Survey, BAS) described their work exploring how the radiation belts – and the charged particles therein – interact with the ever-changing location of the magnetopause. When the magnetopause is compressed the radiation belts lose particles when and where they intersect. Thomas showed how existing analytical models of the magnetic field can predict this process on a large scale, but fail to do so during short-lived events where the magnetopause is compressed to within geosynchronous orbit. Further, there is a strong dependence on the magnetic local time of the observations, with satellites in similar but offset orbits encountering very different flux profiles (Daggitt *et al.* 2022).

Gareth Dorrian (University of Birmingham) then moved the focus of the session down to the Earth's ionosphere, discussing a new way to monitor ionospheric disturbances using the LOFAR (LOw Frequency ARray) radio telescope. This pan-European telescope is designed for radio astronomy, but by monitoring natural, consistent radio sources Gareth used it to understand the changing ionosphere through which received radio waves must travel. By monitoring different astrophysical sources it was possible to map where ionospheric disturbances existed and how they moved, results that were consistent with maps derived independently using GPS observations (figure 5).

The next talk returned to the radiation belts: **Shannon Killey** (Northumbria University) presented work using machine learning to diagnose the behaviour of relativistic electrons within the radiation belts. Shannon used a series of advanced methods to group similar types of radiation belt observations, allowing the isolation of when and where certain conditions manifest (figure 6). During the seven years of observations, five types of plasma conditions are found to dominate. One type, the 'butterfly'-shaped distribution is mainly seen at the edges of the belts, and is thought to represent regions where waves and particles are interacting, exchanging energy. Meanwhile during dynamic geomagnetic storms the type of conditions changes over time.

For the final talk of the session, **Ingrid Cnossen** (BAS) brought us to the upper atmosphere of the Earth, discussing predictions of the impact of climate change on the upper atmosphere and its consequences for space debris. Ingrid's simulations run from the present day through to 2070 and include the effects of solar and geomagnetic variability, along with changing trace gas (e.g. CO_2) emissions. These simulations show a long-term decrease in density of the upper atmosphere, with the knock-on effect that space debris will last for longer before burning up in the atmosphere. This amounts to 15% more debris by 2070 and indicates that there will be more frequent catastrophic collisions.

The success of the meeting means the MIST community has weathered the storms of the past few years. MIST council would like to thank the Geological Society for hosting us, and the Royal Astronomical Society for the continued support. Furthermore, we thank all attendees and presenters for contributing to an engaging and enjoyable meeting. ●

AUTHORS
This article was prepared on behalf of the MIST Council by **Emma Woodfield**, British Antarctic Survey, Madingley Road, Cambridge, UK; **Andy Smith**, Northumbria University, Newcastle, UK; **Thomas Daggitt**, British Antarctic Survey, Madingley Road, Cambridge, UK; and **Harriet Turner**, University of Reading, UK.
Contact: mist.council@gmail.com

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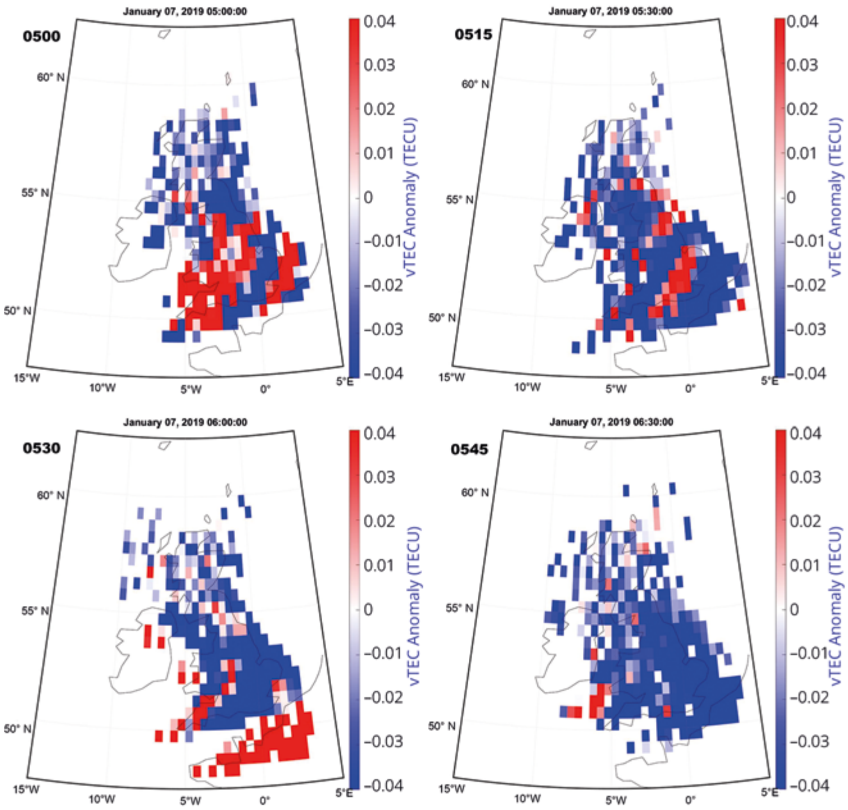
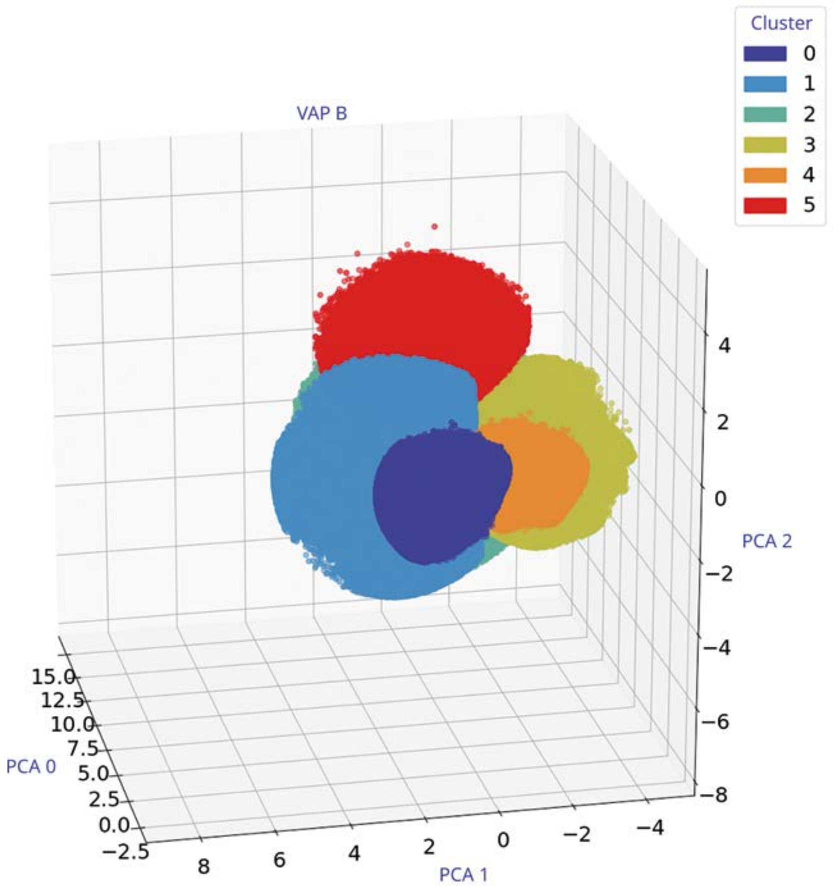
Milan S E *et al.* 2020 *Journal of Geophysical Research: Space Physics* **125(10)** e2020JA028567



5 *Global Navigation Satellite System Total Electron Content anomaly data, averaged to 30-min* (adapted from Figure 10 of Dorrian, G. et al., 2023, Space Weather, 21, e2022SW003198, with credit to David Themens, University of Birmingham).



6 *Seven years of Van Allen probe REPT data processed using an autoencoder neural network followed by principal component analysis to reduce the dimensionality of the data. This figure shows the clusters of similar plasma conditions that emerge from using K-means clustering on the reduced dimension data.*

Poster Presentations

In addition to the excellent oral presentations we had 37 outstanding posters shown across two sessions.

Joel Baby Abraham	Mullard Space Science Laboratory	*Radial Evolution and Energy Budget of Thermal and Suprathermal Electron Populations in the Slow Solar Wind from 0.13 to 0.5AU: Parker Solar Probe observations.*
Anasuya Aruliah	University College London	*Are thermospheric models overestimating mass density?*
Sarah Bentley	Northumbria University	*Radial Diffusion Benchmarking: Initial Conditions*
Shahbaz Chaudhry	University of Warwick	*Global dynamic network response of Pc2 waves to the 2015 St Patrick's day storm using SuperMAG and Intermagnet ground based magnetometers*
Joseph Eggington	Imperial College London	*Global Magnetospheric Modelling with Gorgon*
Omar El-Amiri	University of Warwick	*PIC Simulations of Electromagnetic Ion Beam Instabilities in Earth's Foreshock*
Amy Fleetham	University of Leicester	*AMPERE, GICs and the Electric Current of Geomagnetic Storms*
Colin Forsyth	Mullard Space Science Laboratory	*Potential observations from nanosatellites in ESA's D3S programme*
Laura Fryer	University of Southampton	*Global magnetotail configurations of simulated pressure pulses during northward IMF conditions.*
Imogen Gingell	University of Southampton	*Simulations of the decay of reconnected structures downstream of Earth's bow shock*
Sarah Glauert	British Antarctic Survey	*Theoretical loss timescales and pitch angle distributions for the radiation belts*
Adrian Grocott	Lancaster University	*SuperDARN observations of the two component model of ionospheric convection*
Rosie Hodnett	University of Leicester	*Harmonic Frequency Separation of Ionospheric Alfvén Resonances Observed at Eskdalemuir*
Lauren James	University of Reading	*Sensitivity of Model Estimates of CME Propagation and Arrival Time to Inner Boundary Conditions when Constrained by Spacecraft Data.*
Simon Joyce	University of Leicester	*Update on the Mars Express Active Ionospheric Sounder data processing*
Andrew Kavanagh	British Antarctic Survey	*DRivers and Impacts of Ionospheric Variability with EISCAT_3D (DRIIVE)*
Adrian LaMoury	Imperial College London	*Magnetopause reconnection and dynamics following the impact of magnetosheath jets*
Andrea Larosa	Queen Mary, University of London	*The interplay between magnetic switchbacks and solar wind turbulence in the inner heliosphere*
Harry Lewis	Imperial College London	*Generalised Ohm's Law in the Magnetosheath: Relative Contributions to Turbulent Electric Fields as Modified by Plasma Conditions*
Subir Mandal	British Antarctic Survey	*Understanding the Gravity Wave Activity in the Scandinavian Mesospheric Region as part of the MesoS2d Project*
Jack McIntyre	Queen Mary, University of London	*Parameters underlying the evolution of the magnetic field spectral index in the solar wind*
Tracy Moffat-Griffin	British Antarctic Survey	*MesoS2D:Mesospheric sub-seasonal to decadal predictability*
Michaela Mooney	University of Leicester	*Evaluating Auroral Forecasts Against Satellite Observations*
James Plank	University of Southampton	*Measures of Correlation Length at Quasi-Parallel and Quasi Perpendicular Shocks*
Catherine Regan	Mullard Space Science Laboratory	*Investigating the 2007 Global Dust Storm at Mars with Mars Express*
Jade Reidy	British Antarctic Survey	*Preliminary analysis of low altitude electron density measurements from EISCAT*
Sam Rennie	University of Leicester	*SuperDARN Observations of High-m ULF Waves*
Jasmine Sandhu	Northumbria University	*Exploring the complex response of ULF waves to plasmaspheric plumes*
Md Goribullha Shah	Queen Mary, University of London	*Multiband Whistler Mode Waves in the Earth's Magnetosphere: MMS Observations and Two-Fluid Plasma Simulations*
Julia Stawarz	Imperial College London	*The Evolution of Intermittency in the Solar wind During a Radial Alignment Between Parker Solar Probe and Solar Orbiter*
Gabriel Suen	Mullard Space Science Laboratory	*Solar Orbiter Observations of Switchback Dissipation Through Magnetic Reconnection*
Maria-Theresia Walach	Lancaster University	*Dusk-Dawn Asymmetries in SuperDARN Convection Maps*
Xueyi Wang	University of Warwick	*Wavelet analysis determination of scaling exponents and ranges in the magnetohydrodynamic range of solar wind turbulence seen by Parker Solar Probe*
James Waters	University of Southampton	*A Perspective on Substorm Dynamics Using 10 Years of Auroral Kilometric Radiation Observations from Wind*
Cara L. Waters	Imperial College London	*Calibration and Attitude Determination of the Inboard Magnetometer on the RadCube CubeSat*
Emma Woodfield	British Antarctic Survey	*The effect of Z-mode waves on the electron radiation belt at Jupiter.*
Sophia Zomerdijk-Russell	Imperial College London	*Assessing how BepiColombo will use Solar Wind Variability to Probe Mercury's Interior*