Autumn MIST 2015

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Introduction

The Magnetosphere, Ionosphere and Solar-Terrestrial (MIST) community in the UK met at Burlington House on 27 November, for the 46th time. 81 people attended, ranging from PhD students to emeritus professors, to discuss a varied programme of research from the UK's MIST institutions.

After a discussion of the possible themes for the Autumn MIST meetings in the future, MIST Council eventually settled on the theme of 'Aurora: Earth to Exoplanets' for this year. Although it has been a decade since the last IMAGE observations, the community is currently in its tenth year with no available global auroral observations, great strides have been made in analysis and understanding of the aurora through smaller-scale measurements, both with spacecraft like the SSUSI instrument aboard DMSP, and ground-based measurements like all sky imagers and other specialist auroral instrumentation.

Auroral physics

The first session at this year's MIST meeting focused on the theme of the meeting, and as such comprised talks on auroral observations and auroral processes. As such, the keynote speaker was noted auroral physicist **Betty Lanchester**, formerly the head of the Space Environment Physics group at the University of Southampton. Aurorae are perhaps the most beautiful natural phenomenon visible with the naked eye and humanity has been fascinated with the eerie lights in the sky for hundreds, if not thousands, of years – but as well as being very beautiful, aurorae can tell us much, acting as a diagnostic for the magnetosphere of Earth and of other planets which have aurora (from Venus to Neptune). The first session was dedicated to talks which explored how the aurorae are generated and what information they yield.

The first talk was the keynote talk, and focused on multiscale processes of the aurora, using All Sky Imager (ASI) data to show observations of the twin-cell convection pattern and then asking how small-scale motions connect to the observed large-scale flows. Lanchester examined 'black aurora', which are structured gaps in the auroral emission observed from Earth. She showed observations from the Auroral Structure and Kinematics (ASK) instrument (Ashrafi, 2007) in support of the theory that the scattering of energetic particles into the loss cone is suppressed, resulting in high-energy gaps in the particle distribution. However, Lanchester pointed out that the cause of this suppression is an open question. ASK observations were presented which showed pulsations in the same region as the black aurora, and Reimei satellite data was used which showed the signature of black aurora coincident with pulsating aurora. More ASK observations followed, this time of flickering aurora, showing an inverse relationship between frequency and energy of the flickering. This is thought to be due to electromagnetic ion acoustic waves transferring energy to electrons via Landau damping. Lanchester also examined 'black aurora', which are structured gaps in the auroral emission observed from Earth, and showed ASK observations that support the theory that suppressed scattering of energetic particles into the loss cone results in high-energy gaps in the particle distribution, but that what causes this suppression is an open question.

Nadine Kalmoni, of the Mullard Space Science Laboratory (MSSL), spoke next about small-scale beads of auroral beads (bright spots of aurora lying along the onset arc) and their relation to substorms. She presented results from the THEMIS and MOOSE arrays of ASIs, showing that beads propagate both east and west, with the growth of the beads observed to be fastest at low wavenumbers and spatial scales also found to have an effect on growth rate, consistent with the idea that the shear flow ballooning instability is important in forming the beads. Kalmoni showed that the beads appear to be ubiquitous to all onset arcs and concluded with observations suggesting the electrons are accelerated by waves (Kalmoni et al, 2015)

Jenny Carter (University of Leicester) discussed auroral arcs extending into the polar cap, building on Carter et al (2015) by presenting a case study of two such transpolar arcs using IMAGE observations of the southern hemisphere combined with DMSP SSUSI observations of the northern hemisphere. She outlined the Milan model of transpolar arc formation in which a build-up of closed flux results in a transpolar arc, which predicts that strong azimuthal flows will be seen at the arc's footprint and that the footprint should be mirrored about the midnight meridian. The two arcs in the case study were found to be mirrored in the two hemispheres on either side of midnight (Figure 1) and SuperDARN observed strong flows, consistent with the predictions.

Moving from Earth further into the solar system, the next talk looked at auroral processes at Saturn, as **Joe Kinrade** (Lancaster University) presented auroral images from a 2014 Hubble Space Telescope (HST) campaign. The mean emissions showed features of the steady-state aurora, in which the dawn side had strong discrete emission at 20 kR but the dusk side was more diffuse. Current systems due to planetary period oscillation (PPO) were examined, showing suppression of auroral intensity of up to 40 kR, and the UV intensity in 2014 was found to be ordered by both northern and southern PPO phase.

Rebecca Gray (Lancaster University) moved to Jupiter, providing an overview of the Jovian magnetosphere and the plasma torus of the Jovian moon Io, which forms as a result of volcanic eruptions on Io. The plasma moves outwards due to centrifugal forces, distorting the magnetic field and resulting in field-aligned currents which drive the main auroral emissions. HST observations for a case study on 11 January 2014 showed a super-rotating polar spot; a bright and broadened main emission region; and equatorward emissions associated with injections of hot, sparse plasma. The spot was theorised to be formed deep in the tail (Figure 2), and the super-rotation possibly due to Dungey-like reconnection-driven inflow. Associated features in radio HOM and auroral power are observed prior to the event in support of this theory.

The final talk of the session was given by **Rosie Johnson** (University of Leicester), who examined the mid-to-low latitude region of Jupiter's ionosphere (which map equatorward of the Io plasma torus). The study aimed to verify whether this region is corotating; some authors have proposed high-velocity flows are present in this region (~20 km s^{-1}) due to observations of longitudinal asymmetries in emission intensity. CSHELL observations of H_3^+

emissions are used to observe these flows and calculate line-of-sight velocities in a Jovian rotational reference frame. No longitudinally localised bulge in the expected region was observed and the region was found to be corotating to within 0.5 km s^{-1}, indicating that there are no flows of the proposed velocity in this region.

Earth processes

The 'T' in MIST stands for terrestrial, and the second session was preoccupied with Earth-based observations and theory, with the talks starting on substorms and the central magnetotail, before moving to the magnetopause and dayside magnetosphere and finally down to the physics of the ionosphere. Understanding magnetic and plasma processes on Earth is important, partly because space weather and connected phenomena is recognised as a hazard by the Cabinet Office and can have a direct impact on the public, but also because understanding processes at Earth can lead to new insights into similar interactions through the rest of the solar system.

The first talk was given by **Sandra Chapman** (University of Warwick), who presented innovative work on a network analysis of magnetometers during a substorm using SuperMAG, a network of magnetometers throughout the northern hemisphere. Magnetometers, or nodes in the network, were defined to be 'connected' if the cross-correlation between their magnetic field line series exceeded a certain threshold; the number of connections and the number of connected nodes (the size of the network) were analysed throughout the substorm, yielding insight into the spatial structure (Dods et al, 2015).

Colin Forsyth (MSSL) spoke on SOPHIE, his new method of identifying substorm phases using the SuperMAG geomagnetic indices (SML/SMU), which measure the largest magnetic perturbations on the ground caused by westward and eastward currents flowing in the ionosphere. The time derivative of both indices is taken, and negative derivatives in SML above a threshold are identified as substorm expansion phases whereas positive derivatives in SML are identified as recovery phases. Enhanced convection events are identified and removed by comparison with the time derivative of SMU, and any point not identified is identified as a potential growth phase. Forsyth concluded that the SOPHIE expansion phase onsets matched the Frey list better than previous SuperMAG-based lists, and noted that the data is available either as supplementary material to Forsyth et al (2015) or by request.

Stephen Browett (University of Southampton) moved the session on from substorms to the effect of dayside reconnection on the tail, looking at the way in which IMF B_Y affects the value of B_Y during neutral sheet crossings in the magnetotail. Previous work has shown a relation, as it is a consequence of the interaction between the solar wind and the magnetosphere that the IMF BY component should 'penetrate' into the magnetotail; Browett presented an analysis of the time delay in the correlation between the IMF By component and the By component in the centre of the magnetotail (at low latitudes). Looking at the correlation as a function of time delay, two peaks are found; one at 1h 40m and the other at 3h (Figure 3). Browett suggested that a B_Z effect explained the two different peaks, noting that northward IMF may lead to a slower response from the tail.

Moving from the central magnetotail, **Katie Raymer** (University of Leicester) presented an analysis of crossings of the magnetopause over 17 years of Geotail data. Geotail has an apogee of 30 R_E and a perigee of 10 R_E. 7770 magnetopause crossings were identified and compared to a previous model of magnetopause position, and it was found that the predicted magnetopause positions were further from Earth than the observations. Raymer is working on a model which incorporates the amount of open flux and the strength of the ring current, to attempt to explain these discrepancies.

Tom Elsden (University of St Andrews) presented a model of the dayside magnetosphere, Ultra-Low Frequency (ULF) and magnetohydrodynamic (MHD) waves, with a simple waveguide model which uses a hydromagnetic box approach. This simulation matched the main features of observations made with Cluster and THEMIS, and the authors developed a new boundary condition to effectively drive the model with magnetic pressure, the main source of ULF waves (Elsden & Wright, 2015).

James Parker (Aberystwyth University) took the audience into the ionosphere, looking at the ionospheric trough (an area of low electron density between low and high latitudes) observed primarily in the F region. Parker outlined a method for modelling the trough, using GPS Total Electron Content (TEC) measurements as inputs to QinetiQ's Electron Density Assimilative Model (EDAM). The trough is seen between mid-afternoon and dawn MLT, with photoionization leading to higher densities at dawn. Results show that the trough moves to lower latitudes during higher geomagnetic activity (Figure 4), and this new technique has the potential to allow the trough to be monitored on a day-by-day basis, with more data to be utilised in the future.

Timothy David (University of Leicester) talked about the outflow of heavy ions from Earth's ionosphere. Data from the FAST spacecraft alongside the EISCAT Svalbard Radar and the SuperDARN radars were used to explore the dominant mechanisms of ion upwelling and the conditions during which outflow occurs. A local time variation in the flows was observed during summer (with a peak at noon) but not in winter, with higher Kp associated with higher flows. Observations indicated that the upwelling in the winter is velocity driven whereas in the summer it is density driven.

Solar physics and the solar wind

Although much work in the MIST community focuses on Earth, the 'ST' in MIST stands for 'Solar-Terrestrial' and so we must also examine phenomena sunward of the magnetopause. The first talk in the final session of the day was given by **Mike Lockwood** (University of Reading), who gave the keynote at last year's Autumn MIST. He returned to talk about sunspot numbers in this year's presentation, choosing to discuss the different sunspot series and what makes a series more or less believable than another. He talked about analysing the days with no sunspot observations, concluding that this analysis allows for the quality of the observer to be inferred; this is the underpinning of Usoskin et al (2016)'s new series.

Chris Chen (Imperial College) spoke on the definition of plasma instability thresholds using an analysis of multiple particle species, building on Chen et al (2014) by showing that by considering the dynamics of all major particle populations, the threshold of instability onset can be better defined. He used data from the WIND spacecraft, which spent much of its time in the solar wind, to show that the firehose instability, which was thought to be a proton instability, has a strong contribution from non-proton components. He also demonstrated that the fluid firehose and mirror instability thresholds constrain the distributions well, which suggests that these instabilities may be present in some form in the solar wind.

Peter Zelina (University of Central Lancashire) talked about Solar Energetic Particles (SEP), which are particles accelerated at the Sun by solar flares and coronal mass ejections. In particular, he focused on the heavy ion component of the SEP. Using data from a combination of near-Earth spacecraft, he showed that SEP heavy ion abundance ratios vary between different SEP events. Heavy ion SEP data can be used to probe the propagation and acceleration of the particles in the SEP event. The proton (X/H) ratio decay as a function of time shows a different profile to other heavy ion ratios.

Georgina Graham (MSSL) presented work examining the solar wind electron velocity distribution. There are three components of the distribution: the core, surrounding halo and the 'strahl'. The strahl component is highly field aligned. She demonstrated the importance of considering the effect of radial distance from the Sun on the pitch angle scattering rate (Figure 5), and showed Cassini data from its cruise phase that indicates the strahl is most likely totally scattered by the distance of Saturn's orbit.

Outer planets

Unfortunately, none of the letters in MIST stand for outer planets. However, the 'M' and 'I' between them cover the physics of magnetic interactions at the more distant members of our solar system. Much of what we have learned at the Earth informs our studies of the outer planets, whether it's to find similar features or to explore how the systems differ. Starting closest to Earth, **Ravindra Desai** (MSSL) talked about the plasma environment around Europa, a moon of Jupiter. He explored the relationship between positive and negative pick up ions and the generated ion-cyclotron waves. He showed pick up ion densities could be estimated from Galileo PWS data. These densities can be used to constrain mass loading estimates of the Europa plasma torus. Desai suggested that because this method probes the minority ion species, it might be used to investigate the possibility of a salt-rich sub-surface ocean of Europa.

Moving from the Jovian to Kronian system, and drawing parallels to Kinrade's talk in the morning session, **Greg Hunt** (University of Leicester) spoke about Planetary Period Oscillations (PPO) – the observation of field and particle perturbations of Saturn close to the planetary period, which are known to be different in the northern and southern hemispheres. The present model of two separate but interacting rotating current systems, one in each hemisphere (Hunt et al, 2015), has been successfully applied to reflect Cassini magnetometer and radio data. Hunt examined the local time effects of the two systems, showing that current profiles are similar between PPO dependent and independent currents. The Saturn Kilometric Radiation (SKR) is a measure of Field Aligned Current (FAC) strength and shows intensification at dawn. The model cannot account for this intensification as it predicts that the upward and downward FACs should cancel.

Staying at Saturn, **Sam Taylor** (MSSL) showed the results of an investigation that used Cassini ELS data to examine the photoelectron population around Enceladus, a moon of Saturn known for its icy plumes. He demonstrated that there are primary and secondary energy peaks in the electron spectra and that in the plumes, the ratio of the primary to secondary peak increases. This will allow the future analysis of ionization rates and distribution of neutrals around Enceladus, particularly in its plumes. Taylor also showed that modelling of photoelectron production and comparison with Cassini observations can provide an independent measure of the spacecraft potential.

The first talk of the conference dealt with phenomena which are very close to Earth, and the final talk was the one set at the furthest distance from us, as **Lars Mejnertsen** (Imperial College) demonstrated the power of global simulation and comparative magnetospherics in the far reaches of the solar system, where observations are sparse. At Neptune, the only data available is from the Voyager 2 flyby. Using a 3D resistive MHD model of Neptune's magnetosphere, he simulated the Voyager 2 flyby. During the flyby, the simulation showed evidence of dayside magnetopause reconnection as the planet rotated to face the solar wind pole on. This indicated that planetary rotation modulates reconnection at Neptune.

Summary

All in all, the day was packed with oral presentations after a huge number of submitted abstracts. Although this was the first year that a registration fee was levied, there was a very good attendance and the programme was well-received by attendees, with many people commenting on a day of exciting new developments in MIST science. To accompany the oral presentations, 22 posters were presented. Although none of the talks during the main session dealt with the inner planets, posters were presented on Mercury and Mars, as well as on Earth and the outer planets. MIST Council would like to thank the RAS for hosting the meeting, everyone who submitted an abstract, everyone who attended and everyone who said hello to us in the Walkers of St. James afterwards, where scientific discussion continued long into the evening.

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