Science Meeting for the Ireland-UK Europlanet Society Hub

Organizers: Prof. Nicholas Achilleos (UCL), Dr. Licia Ray (U. Lancaster) (I-UK Hub Committee Interim Chairs), Dr. Joanna Fabbri (UCL)

Date: Friday March 27, 2020
Venue: Royal Astronomical Society, Burlington House, London

Programme of Talks

Time	Speaker	Title
10:00-10:05	Nick Achilleos (UCL)	Introduction
10:05-10:15	Licia Ray (U. Lancaster)	I-UK Hub Survey
10:15-10:40	Anita Heward (Europlanet)	The Europlanet Society (Invited)
10:40-11:00	Fernando (U. Oxford)	Weird waveforms on Mars: scattering or atmospheric effects?
11:00-11:30		Coffee / Tea break
11:30-12:00	Lauren McKeown (Trinity College)	(Invited)
12:00-12:20	Wibisono (UCL/MSSL)	Temporal and Spectral Studies of Jupiter's X-ray Aurorae with XMM-Newton During a Compression Event Observed by Juno
12:20-12:40	Haythornthwaite (UCL/MSSL)	Fast and slow water ion populations in the Enceladus plume
12:40-13:00	Branduardi-Raymont (UCL/MSSL)	Imaging the Earth's magnetic environment in soft X-rays: SMILE
13:00-14:00		LUNCH – Catering provided for presenters
14:00-14:30	Emma Woodfield (BAS)	Wave-particle Interactions in the Radiation Belts (Invited)
14:30-14:50	Weigt (U. Southampton)	Current and future studies of Jupiter's X-rays with Chandra
14:50-15:10	Wiggs (U. Lancaster)	Hybrid Magnetospheric Modelling at the Outer Planets using Python
15:10-15:30	Desi (Imperial)	Particle-In-Cell simulations of the Cassini spacecraft within Saturn's ionosphere
15:30-16:00		Coffee / Tea break
15:55-16:25	Chowdhury	A Last Look at Saturn during Cassini's Grand Finale: Maps of H3+ emission, temperature and ion winds
16:25-16:55	Tsiaras	(Invited)
16:55-17:00	Achilleos	Closing Remarks

Posters: Arridge, Garton

ABSTRACTS

Time	Title, Author/s and Abstract
10:40-11:00	***Weird Waveforms on Mars: Scattering or Atmospheric Effects?*** **Benjamin Fernando** *(University of Oxford, Student), Kuangdai Leng (University of Oxford, Nicholas C Schmerr (University of Maryland College Park), Mark P Panning (NASA JPL), Eleonore Stutzmann (CNRS, Institut de Physique du Globe de Paris), Ludovic Margerin (Observatory Midi-Pyrenees), Nobuaki Fuji (Institut de Physique du Globe de Paris), Ceri Nunn (NASA JPL) Renee C Weber (NASA/NSSTC), William Bruce Banerdt (Jet Propulsion Laboratory), Domenico Giardini (ETH Zurich), Philippe Henri Lognonné (Université de Paris, Institut de Physique du Globe de Paris, CNRS), William T Pike (Imperial College London), Tarje Nissen-Meyer (University of Oxford*) Since landing in November 2018, InSight has revealed that Mars' seismicity is clearly different to Earth's. Two striking differences observed are the extremely long duration of the waveforms, which may last up to several minutes, and the unusual polarization of the ambient noise data, which is opposite to that seen on Earth. Explaining these features using conventional (terrestrial) source and structural properties is problematic, and hence high-frequency modelling is an invaluable tool for exploring whether these effects may arise from strong crustal heterogeneities or atmospheric processes. We explore these questions using the high-frequency modelling code AxiSEM3D.
11:30-12:00	TBD
12:00-12:20	***Temporal and Spectral Studies of Jupiter's X-ray Aurorae with XMM-Newton During a Compression Event Observed by Juno*** **Affelia Wibisono** *(UCL Mullard Space Science Laboratory)* It is now more than 40 years since it was discovered that Jupiter produces bright X-ray aurorae [Metzger et al., 1983]. There are two constituents to these emissions. Hard X-rays with energies above 2 keV are produced by precipitating electrons via bremsstrahlung radiation. Soft X-rays have lower energies and are due to charge exchange processes between precipitating ions and neutrals in Jupiter's atmosphere [e.g. Cravens et al., 1995; Branduardi-Raymont et al., 2007]. The origins of these ions are not very well understood - are they from the solar wind or from Io's volcanoes? Quasi-periodic pulsations in the auroral X-ray emissions have often been detected to have periods of tens of minutes [Gladstone et al., 2002] and the two poles don't always beat in sync with each other [Dunn et al., 2017]. It is currently unclear as to why Jupiter's X-ray aurorae should behave in this way but evidence suggests that wave-particle interactions may play a role. Juno's arrival at Jupiter in 2016 means that in-situ measurements of the jovian magnetosphere can be used to complement remote sensing data obtained by Earth-orbiting observatories such as XMM-Newton. Juno revealed that Jupiter's magnetosphere was compressed during XMM-Newton's June 2017 observation of the giant planet's X-ray aurorae. We created solar wind and iogenic plasma models to fit XMM-Newton's spectra of the aurorae and showed that for this

	observation, the iogenic model gave the best fit meaning that the precipitating ions originate from Io's volcanoes. We ran discrete wavelet and Fast Fourier transforms on the XMM-Newton lightcurve of the aurorae to reveal that during this observation the northern and southern aurorae were pulsating at the same time with the same period of ~23 minutes for 12.5 hours. This hints that the X-ray aurorae at both poles can also share the same driver.
12:20-12:40	***Fast and slow water ion populations in the Enceladus plume*** **Richard Haythornthwaite** *(UCL Mullard Space Science Laboratory)* Ion velocities have been measured during the Enceladus E3 and E5 flybys using the Cassini Plasma Spectrometer (CAPS) instrument on the Cassini spacecraft. Data from three sensors in the CAPS instrument has been examined from two flybys that occurred during 2008. Positive ion measurements from the CAPS Ion Beam Spectrometer and Ion Mass Spectrometer have been used to measure positive ion velocities. The CAPS Electron Spectrometer has been used to complement the positive ion findings with measurements of negative ion velocities. Two velocities for the positive ions are found, with the fast ions (2.3-5.8 km/s) originating from the high-speed neutral gas emission and slow ions (0.2-2.2 km/s) associated with the low-speed thermal gas emission from Enceladus. Negative ions were found to be near stationary or northerly travelling, implying a deceleration mechanism within the plume. A tentative detection of fast negative ions was also recorded for one of the flybys. These findings will aid in future modelling of plume dynamics.
12:40-13:00	***Imaging the Earth's magnetic environment in soft X-rays: SMILE*** **G. Branduardi-Raymont** *(MSSL/UCL) and the SMILE Team* It is a relatively recent discovery that charge exchange soft X-ray emission is produced in the interaction of solar wind high charge ions with neutrals in the Earth's exosphere; this has led to the realization that imaging this emission will provide us with a global and novel way to study solar-terrestrial interactions. Such imaging is one of the main objectives of SMILE (Solar Wind Magnetosphere Ionosphere Link Explorer), a joint space mission by ESA and the Chinese Academy of Sciences, which is under development and is due for launch in 2023. This presentation will introduce the scientific aims of SMILE, show simulations of the expected images to be returned by SMILE's Soft X-ray Imager for different solar wind conditions, and will discuss some of the techniques that will be applied in order to extract the positions of the Earth's magnetic boundaries, such as the magnetopause standoff distance.
14:00-14:30	***Understanding the Energetic Particle Environment around the Outer Planets: Wave-particle Interactions in the Radiation Belts.*** **Emma E. Woodfield** *(British Antarctic Survey)* The importance of wave-particle interactions in the dynamics of the terrestrial radiation belts has been known for many years, firstly as a scattering mechanism and in recent decades as a method of particle acceleration. Wave observations at the outer planets show many of the same features as at the Earth, whistler

	mode waves for example were observed as early as the Voyager 1 flyby of Jupiter in 1979. Fundamental plasma waves are present in these magnetospheres as expected from theory but the plasma conditions within which they exist vary significantly leading to different wave interactions dominating. I will present an overview of the current understanding of the contribution of wave-particle interactions to the radiation belts at Saturn and Jupiter and then focus on future directions inspired by the Europlanet meeting on moon-magnetosphere interactions.
14:30-14:50	***Current and Future Studies of Jupiter's X-rays with Chandra*** **Dale Michael Weigt** (University of Southampton) We present results of a jovian Chandra X-ray observation while Juno was near apojove and outline future avenues which can be explored from this dataset. Chandra observed for ~ 10 hours from 18:56 June 18th while Juno was on the dawn flank of the magnetosphere, close to the expected nominal position of the magnetopause. Using the closest magnetopause crossing from the Juno JADE and JEDI data, the magnetosphere was inferred to be compressed during the Chandra interval. A ~24-hour XMM-Newton observation overlapped the final ~ 5 hours of the 10-hour Chandra campaign, allowing both spatial and spectral X-ray analysis of Jupiter in tandem. We present light curves from Chandra; timing analysis of two significant quasi-periodic oscillations (QPOs) detected in the North polar region and map their magnetospheric origin using a flux equivalence model. We look at how we can explore any correlations between the morphology and timing variations of the X-ray hot spot to magnetospheric/solar wind conditions as well as looking at potential drivers for the pulsating emission. We compare our results to previous large statistical studies.
14:50-15:10	***Hybrid Magnetospheric Modelling at the Outer Planets using Python*** **Josh Wiggs** (University of Lancaster) Modelling planetary magnetospheres is essential to develop understanding of how these dynamic regions of space respond to forcing from both internal and external sources of mass, momentum and energy. Obtaining an exact solution for the governing equations describing these complex systems is very difficult. Therefore, simplified models are required for investigation. The size of planetary magnetospheres presents additional complications when creating models of them as important dynamics occur on spatial scales ranging from planetary radii down to the kinetic ion and electron levels. Such challenges are present in simulating bulk plasma transport in Jupiter's inner and middle magnetosphere, where plasma flows from Io's plasma torus radially outwards. The process of radial transport is attributed to the centrifugal-interchange instability, analogous to the Rayleigh-Taylor instability but with centrifugal force replacing gravity. A hybrid kinetic-ion/fluid-electron approach is taken to modelling these magnetospheric plasma flows. Hybrid techniques are able to capture large-scale flow dynamics as well as interactions between particles. Whilst most models of this type are written in C/C++ or Fortran, the aim in this project is to provide a Python codebase that allows for prototype physical effects to be examined before incorporation into an optimised implementation. Writing a version in a

	modern accessible language also has pedagogical value. The techniques utilised to construct a hybrid model in Python will be explored along with an examination of a series of physical benchmarks between model and analytical results.
15:10-15:30	***Particle-In-Cell Simulations of the Cassini Spacecraft within Saturn's Ionosphere*** **R. T. Desai,** Z. Zeqi, Y. Miyake, H. Usui, O. Shebannits (Imperial College) A surprising and unexpected phenomenon observed during Cassini's grand finale was the spacecraft charging to positive potentials in Saturn's ionosphere. Here the ionospheric plasma was depleted of free electrons with negatively charged ions and dust accumulating >90% of the negative charge density. In this paper, we perform a three-dimensional Particle-In-Cell study of the entire Cassini spacecraft immersed in plasmas representative of Saturn's ionosphere. The simulations reveal a number of complex features not apparent from the in-situ observations, such as electron-scale Alfvén wings, large electrostatic potentials beyond the Debye screening distance, and electron-scale vortices. Moreover, it is shown how the fast motion of the spacecraft within this highly magnetised environment results in the inertial ion currents dominating and that the large negative ion concentration, combined with the >1 negative ion to positive ion mass ratio, was able to drive Cassini to the observed positive potentials. The close agreement between the simulations and observations demonstrate the concept of using this technique to further constrain fundamental parameters relating to Saturn's ionosphere.
15:55-16:25	***A Last Look at Saturn during Cassini's Grand Finale: Maps of H3+ emission, temperature and ion winds*** **Nahid Chowdhury**, Tom Stallard (University of Leicester) In August 2017, as the NASA Cassini mission continued its final set of 'Grand Finale' orbits around Saturn, we carried out a series of ground-based observations of the planet's infrared auroral emissions using the Keck telescope at Mauna Kea, Hawaii. This unprecedented programme provided the first two-dimensional maps of Saturn's northern polar temperature and ion wind structure and was achieved by scanning the auroral region from Earth over the course of seven separate Cassini orbits, thus providing an incredibly high spectrally resolved view of the entire auroral region. The derived temperature maps show a thermosphere with highly localised hotspots, with temperatures varying by as much as 300 K spatially across the aurora on each night. However, there does exist an underlying temperature structure (once the seven nights of data are smoothed out) which broadly follows the H3+ emission brightness, with an apparent cooling at the pole. The ion wind images show highly localised and intricate ion wind flows across the auroral region, suggesting that past observations had smoothed out these small-scale jets, while likely indicating a combination of both local time and planetary frame ion flows. The seven-night average velocities provide a view of

	the overall local time flows, allowing us to map out the location of the core of co-rotating field lines (previously described as the “three-tier structure” in the literature) from noon to midnight across the pole of the planet. This talk will explore the thermal and ion wind structures observed by Keck, placing them in the context of solar wind conditions observed during the final stages of the Cassini mission. It will also reveal evidence of how Saturn’s ionospheric and thermospheric structures are controlled by changing solar wind conditions. This will then be followed by a look ahead to what ongoing investigations in the context of the planetary period oscillations intend to reveal about Saturn’s thermosphere-ionosphere-magnetosphere interaction at large.
Poster 1	***Tools for Giant Planet Studies*** **Chris Arridge** (Lancaster University) In this presentation I will present several open source tools that are useful for studies of the giant planets. “*Ikuchi*” is a JavaScript application for viewing the geometry of a planetary magnetosphere/planetary system with season and diurnal rotation. It is specifically designed for examining the peculiar configurations of Uranus and Neptune, but are applicable to any planet, including exoplanets. “*Badger*” is a Python/C++ toolkit for detailed manipulation of space plasma data. In particular it includes a forward modelling toolkit to model the electrostatic analysers. “*Humboldt*” is a Python toolkit for magnetic field modelling. I will also highlight a general need for database tools for planetary aeronomy cross-sections, similar in spirit to Chianti.
Poster 2	**Machine Learning Applications on Planetary Magnetotail Reconnection Classification** **Tadhg Garton**, Caitriona Jackman, Andrew Smith (University of Southampton) Magnetotail Reconnection is an energetic process which produces products like plasmoids. These products can be detected directly or indirectly (travelling compression regions, TCRs) by orbiting spacecraft. They are evidenced by deflections in the magnetic field. The presence of plasmoids and TCRs have typically been identified within magnetometer data by eye, or more recently through semi-automated methods such as in *Smith, et al.* (2015). The increased application of identification models has enabled the creation of significant catalogues of magnetotail reconnection events. To date, models of identification are sparse, within their infancy and still subject to scrutiny. Here, we investigate methods of identification of Saturnian magnetotail reconnection events in Cassini MAG data through bipartisan machine learning methods. This research primarily focuses on the application of simple feed forward neural network architecture into the identification of magnetotail reconnection.