National Astronomy Meeting 2019 Abstracts

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Active Region Laboratories (ActiveRegions)

Peter Wyper (Durham University)

C. R. DeVore (GSFC), S. K. Antiochos (GSFC)

Talk

A Numerical Simulation of an Active Region Periphery Helical Jet

Coronal jets are observed above minority polarity intrusions throughout the solar corona. Some of the most energetic occur on the periphery of active regions where the magnetic field is strongly inclined. These jets exhibit a non-radial propagation in the low corona as they follow the inclined field, and often have a broad, helical shape. We present a three-dimensional magnetohydrodynamic simulation of such an active region periphery helical jet. Free energy is injected into an initially potential field, creating a sigmoidal flux rope which eventually erupts to produce the helical jet. We find that the eruption results from a combination of magnetic breakout and an ideal kinking of the erupting flux rope. We discuss how the two mechanisms are coupled, and contrast our results with our previous simulations of coronal-hole jets.

Dylan Williams (Aberystwyth University)

Dylan Williams, Huw Morgan

Talk

Active longitudes and rotation rates: a large survey of active regions observed by AIA/SDO.

A large-scale survey of Active Regions (AR) has been carried out over approximately 8 years, or the entire SDO dataset. Using a 2-stage identification process all observed ARs are identified and tracked in 5 different EUV wavelengths (131, 171, 193, 211 and 304). This reduced set of data leads to several different avenues of research. This first study focuses on active longitudes (AL). Plotting the mean longitudinal positions of these ARs over the entire time period reveals several bands of increased AR frequency drifting faster than the Carrington rotation rate. These bands can last for several years, and are regions that host several distinct ARs over these long periods. Understanding ALs can lead to a better understanding of the production and transport of the magnetic field within the solar interior, and can contribute towards predicting increased space weather risk over long timescales.

Natasha Jeffrey (University of Glasgow)

Natasha L. S. Jeffrey

Invited

Active regions, the origin of solar flares, and a laboratory for studying particle acceleration

Solar active regions are sites of complex magnetic activity and the origin of transient events like flares, where magnetic energy is released and dissipated in the solar atmosphere. Flares are efficient particle accelerators, and prime laboratories for studying acceleration processes in astrophysics, with a high fraction of the released energy being carried by energetic particles. Over the last decade, our understanding of flare particle acceleration has been enhanced by multi-wavelength observations from X-rays to (E)UV to radio. However, many questions remain about how and where energetic particles are accelerated, and how different plasma environments (e.g., collisions, turbulence) affect the transport and observed properties of energetic particles. We anticipate that proposed missions with direct X-ray imaging capabilities (e.g. FOXSI) could probe high energy processes in active regions in unprecedented detail, while data from a new generation of observatories (e.g. Solar Probe/Solar Orbiter) will help to understand the connection between energetic particles at the Sun and those measured in situ in the heliosphere.

Thomas Williams (UCLAN)

Thomas Williams, Robert W. Walsh, Amy Winebarger, & the Hi-C team

Poster

Are We Now Fully Resolving Coronal Loops?

The High-resolution Coronal Imager (Hi-C) has been launched three times from White Sands Missile Range. The first launch (Hi-C 1), occurred on 11 July 2012 and during the 345 seconds of data acquisition, Hi-C 1 obtained the highest spatial resolution and highest cadence images of the EUV (19.3 nm) solar corona ever achieved. Those few minutes of data have thus far generated >25 refereed publications and is arguably one of the most scientifically successful sounding rocket payloads ever launched by NASA. Unfortunately, the second launch (Hi-C 2) did not result in any science data. On 29 May 2018, it was launched for a third time (Hi-C 2.1). On this occasion, 329 seconds of 17.2 nm data of target active region AR12712, was captured with a cadence of ~5.5s, and a plate scale of ~0.13x0.13 arcsec^2/pixel

In this study we investigate coronal strands as seen from Hi-C 2.1 and SDO/AIA 17.1 nm observations. We search for evidence of substructure within the strands which is not detected by AIA, and whether they are fully resolved by Hi-C 2.1. With the aid of Multi-Scale Gaussian Normalisation (MGN), strands from a region of low-emission which can only be visualised against the contrast of the darker, underlying moss are studied. A comparison is made between these low-emission strands with those from regions of higher emission within the active region.

Sandra Milena Conde Cuellar (Institute of Astronomy, Geophysics and Atmospheric Sciences, University of Sao Paulo - School of Mathematics and Statistics, University of St Andrews)

S. M. Conde (University of Sao Paulo- University of St Andrews), C. E. Cedea (Brazilian Center for Physics Research)

Talk

Coronal loops geometry and the physical description of their structure

There are several semi-empirical models to describe the structure of the solar atmosphere currently in the literature. These models help us to describe the distribution of the physical quantities along the coronal loops. However, the loop geometry influences the quantities values describing their physical structure, i.e., pressure and temperature. Thus, the accuracy in the determination of the loops geometry must be as high as possible. Here, we reproduce the loop geometry through extrapolation of magnetic field lines by using linear and nonlinear models and a method involving data from the STEREO and AIA instruments. The applicability of the last method is only for active regions at the limb of the solar disk. After that, we adjust several semi-empirical models to the loop shape obtained. We compare their incidence on the estimation of the physical parameters describing the loop structure.

James Threlfall (University of St Andrews)

J. Threlfall (University of St Andrews), A. W. Hood (University of St Andrews), E. R. Priest (University of St Andrews)

Poster

Flux Rope Formation Due to Shearing and Zipper Reconnection

Zipper reconnection has been proposed as a mechanism for creating most of the twist in the flux tubes that are present prior to eruptive flares and coronal mass ejections. In this contribution, I will describe our results from a simple initial numerical experiment on this new regime of reconnection, where two initially untwisted parallel flux tubes are sheared and reconnect to form a large twisted flux rope. I will expand on several aspects of this work which have already been published in Threlfall et al. 2018, Solar Physics, 293, 98. I will also explore more recent improvements to the model and how these changes affect our previous findings. Finally, I will also describe some of our (ongoing) attempts to expand this initial concept to include further additional flux tubes.

Sean Quinn (Queen's University Belfast)

S. Quinn (QUB), A. Reid (QUB), M. Mathioudakis (QUB), C. Nelson (University of Sheffield, QUB), S. Zharkova (Hull University)

Talk

How the Chromosphere responds to a flare-initiated Sunquake

Active region 12673 produced a number of solar flares in September 2017, including the largest of solar cycle 24, an X9.3 flare on September 6th. The presence of sunquakes produced by this flare has already been reported on by (Sharykin & Kosovichev, 2018), however using Ca II 8542Å data form the Swedish 1-m Solar Telescope (SST), a co-spatial and co-temporal chromospheric component of one of these sunquakes has been detected. In this presentation I will describe the analysis of such a response, using the co-alignment of SST and HMI LOS data, as well as using the spectroscopic capabilities of the SST to investigate the line profiles of the wavefronts created by the sunquake. Finally, I will discuss the use of the NICOLE inversion code in helping us understand the creation of such a chromospheric response.

Mykola Gordovskyy (University of Manchester)

M. Gordovskyy (University of Manchester), S. Shelyag (Deaking University), P.K. Browning (University of Manchester), V.G. Lozitsky (Kiev University)

Talk

Intrinsic photospheric magnetic field diagnostics using the Stokes V widths method

Magnetic field in the solar photosphere is inhomogeneous at scales as small as few kilometres. Observations with limited resolution yield the magnetic flux per pixel, rather than the actual (intrinsic) magnetic field. Usually, the intrinsic photospheric magnetic field is evaluated using the magnetic line ratio (MLR) method (see e.g. Smitha & Solanki 2017), which is reliable for moderate magnetic field values, but saturates above 1-2 kG. Gordovskyy et al. (2018) suggested an alternative method, based on measuring the widths of Stokes V peaks, which does not show saturation for stronger fields.
In this study, 3D MHD models of magneto-convection in the photosphere developed using the MURAM code and the NICOLE radiative transfer code are used to calibrate and test the SVW method for several classical magnetographic lines. We show that the SVW does not saturate for fields up to 2-3 kG and, unlike MLR, requires observations in minimum one spectral line, making it a very promising method for fast photospheric field measurements using the existing spectrapolarimetric data, as well as observation from the forthcoming optical solar instruments, such as DKIST.

Llŷr Humphries (Aberystwyth University)

L. Humphries (Aberystwyth University) (presenting), H. Morgan (Aberystwyth University)

Talk

IRIS observations of fan-shaped jets within a flaring Active Region

Preliminary results are presented of several “fan-shaped” jets within a flaring Active Region observed by IRIS and SDO/AIA. These jets occur at the edge of a sunspot and exhibit interesting dynamics such as demonstrating wave-like patterns during their phases of propagation on recession. Space-time plots have been produced across several channels, providing values for apparent speeds and accelerations. A spectral analysis of these jets was also conducted. Several mechanisms for explaining the observed dynamics of these jets are also proposed. These results are compared to those of Robustini et al. [1] and Reid et al. [2]. This study seeks to determine if a connection exists between these jets and foot-point

brightenings and/or flaring events. Determining a correlation (if any) between these small-scale Chromospheric events and characteristics changes of the low Corona will clarify the connection between these solar layers.

[1] Robustini et al. 2016, A&A 590, A57
[2] Reid et al. 2018, ApJ, 855, L19

Chris Smith (University of Manchester)

C Smith, M Gordovskyy and P Browning

Poster

Modelling emission of microwaves as a diagnostic of flares in twisted magnetic fields

Microwave emission is one of the most important sources of information about energetic electrons of non-thermal and hot thermal plasmas in solar flares. It is particularly valuable for observational diagnostics of flares in twisted coronal loops: while the polarisation can be used to evaluate the magnetic twist (Gordovskyy et al. 2017), loop oscillations, visible in microwave, can provide unique information about the magnetic relaxation and energy release process.
In this study, we use 3D MHD models of unstable twisted coronal loops (Gordovskyy et al. 2014) and the fast microwave code (Fleishman & Kuznetsov 2010) to investigate how the magnetic field evolution, as well as the dynamics of energetic electrons in the loop, affect intensity and circular polarisation of the microwave emission in the range 4-80 GHz. In particular, we investigate how the spatial distribution of circular polarisation, and the intensity and amplitude of the microwave oscillations change during the kink instability and the relaxation phases.

Patrick Antolin (University of St Andrews)

C. Froment (University of Oslo), P. Antolin (University of St Andrews), V. Henriques (University of Oslo), P. Kohutova (University of Oslo), L. Rouppe van der Voort (University of Oslo)

Talk

Multi-scale observations of thermal non equilibrium cycles in coronal loops

Active regions have been recently found to commonly host coronal loops that pulsate in EUV intensity with an incredibly precise period of several hours, lasting over several days. This feature is currently at odds with any 3D MHD modelling of active regions, since, for instance, it requires the debated concept of a loop to be well defined over a long period of time. Another common and enigmatic characteristic of active regions is the presence of material hundreds of times cooler in its atmosphere, falling along the loops in what is termed coronal rain. Both, EUV pulsations and coronal rain have been proposed as two aspects of the phenomenon of thermal non-equilibrium (TNE) in loops. TNE cycles are characterised by evaporation (heating) and condensation (cooling) phases, and are produced by highly stratified and quasi-steady, long duration heating in coronal loops. As such, they reflect specific spatiotemporal characteristics of the heating mechanism. In this work we report unique observations with SDO/AIA and SST/CRISP & CHROMIS that capture the extreme spatial scales covered by TNE processes. Within the same coronal loop bundle, we captured 6 hr-period coronal intensity pulsations in AIA, and coronal rain in chromospheric wavelengths of CRISP and CHROMIS, thus reinforcing the link between both phenomena. We present here the thermal analysis of the cycles as well as an extensive spectral characterisation of the rain clumps that allows us to measure precisely the chromosphere-corona solar atmospheric mass and energy cycle during TNE.

D. Shaun Bloomfield (Northumbria University)

KD Leka (NorthWest Research Associates & Nagoya University/ISEE), D.S. Bloomfield (Northumbria University) and the third International Flare Forecasting Comparison Team (various)

Talk

Performance Characteristics of Operational Flare Forecasting Systems

Solar flares can be considered initiating events for many Space Weather phenomena/impacts, and are directly tied to radiation storms and ionospheric-layer disruption. While solar flares

are perhaps not the direct cause of other serious Space-Weather impacts, they do serve as an identified initiation to the related solar- and heliospheric-based processes that more directly cause such problems. Predicting solar flares from active region observations has thus long been a well-defined and required operational product, now with several facilities world-wide providing operational forecasts to a variety of end users. Evaluating the performance of operational forecasting methods was the subject of a recent workshop held at Nagoya University Institute for Space-Earth Environmental Research through its Center for International Collaborative Research. Using a variety of quantitative metrics the team examined the overall performance, but more importantly we have sought to ask why certain methods and implementations perform better than others, and how to best evaluate this question in the first place. In this talk I will summarize the group's findings including performance differences resulting from both methodology and data, and especially highlight the findings that may improve operational forecasting in the future.

Christopher Prior (Durham University)

Prior C (Durham) MacTaggart D (Glasgow)

Invited

Photospheric geometry and the ability to gauge active region magnetic field structure during flux emergence

Flux emergence is a crucial source of complex magnetic field structure in the corona. State of the art simulations indicate emergence is a vital mechanism behind phenomena such as coronal heating, jets, flaring and CME's. Observationally the most reliable information on the magnetic field structure emerging into this region is through photospheric magnetograms (standard and vector). In comparing simulated and observational emerging magnetogram data there are often significant differences in the variation in magnetic field structure; primarily that the helicity input of observational data shows far more variation than the simulations (which often focus on idealised twisted flux rope emergence). In an attempt to characterise the variation in helicity input structure we have preformed simulations of mixed helicity flux rope structures emerging into the corona; this includes fields with helicity across varying spatial scales. One crucial aspect of this study was an attempt to characterise effect on the helicity input due to the variation in geometry of the simulation's photosphere, represented by a fixed density value. It is found this effect is significant, highlighting the fact that the ability of future missions such as DKIST to resolve the variation in field structure across the photosphere could have a critical impact on our ability to determine what kind of magnetic field structure the sun is transporting into its corona.

Andre Chicrala (Northumbria University)

A. Chicrala, D.S. Bloomfield

Poster

Poynting flux evolution in active regions

Evolution of solar active regions (ARs) is directly related to the occurrence of flares and coronal mass ejections. In this sense, changes in AR magnetic field can be used to unveil other relevant features like plasma flows in the region and vertical Poynting flux into the overlying atmosphere. Here, surface 3D vector magnetic field observations from SDO/HMI are studied with the differential affine velocity estimator for vector magnetograms (DAVE4VM) to recover 3D plasma flows in the photosphere. From these results, the evolution of vertical Poynting flux is presented over the lifetimes of several ARs that display differing Mt. Wilson magnetic classifications.

Silvia Dalla (University of Central Lancashire)

S. Dalla (University of Central Lancashire (UCLan)), G. de Nolfo (NASA GSFC), J. Giacalone (University of Arizona), A. Bruno (NASA GSFC), M. Battarbee (University of Helsinki), T. Laitinen (UCLan) and S. Thomas (UCLan, University of Reading)

Talk

Propagation of relativistic solar protons from solar eruptive events

Flare/Coronal Mass Ejection (CME) events originating in Active Regions can accelerate protons to relativistic energies. These particles may produce signatures at Earth detected by neutron monitors as Ground Level Enhancements (GLEs), as well as photon emission associated with interaction with solar plasmas, including gamma-ray emission. Interest in the acceleration and propagation of protons in the ~100 MeV - ~1 GeV energy range has been renewed by recent observations by PAMELA and FERMI LAT. While traditional proton propagation models used to interpret GLE events solve a spatially 1D focused transport equation, there is evidence that at relativistic energies 3D processes such as drift and heliospheric current sheet effects are important. By means of a 3D test particle model we integrate trajectories of relativistic solar protons through interplanetary space and show that the spatial extent of the event at 1 AU is larger than the footprint of the injection region near the Sun. We discuss the dependence of the number of times particles cross 1 AU on the polarity of the interplanetary magnetic field, for a given mean free path. The latter quantity is important when comparing gamma-ray flare data with SEP fluxes measured in space. We also simulate particle spectra and intensity profiles and compare them with PAMELA

observations for the GLE event of 2012 May 17.

Richard Grimes (Aberystwyth University)

R. Grimes, B. Pinter

Poster

Simultaneous Rotational Analysis of Complex Multi-Spot Sunspot Groups

The dynamics of sunspots are a visible manifestation of the evolution of the solar magnetic field and its interaction with photospheric plasma. Analysing sunspots and their surrounding environments thus helps us to understand the physics of the solar magnetic field. A new technique allows simultaneous analysis of multiple sunspot umbrae at different thresholds of intensity, giving new insight into the group behaviour of these spots in the context of their interior structure. This technique is applied to a complex sunspot group that are linked to flaring activity, observed by HMI/SDO in September 2014 (NOAA 12158), and shown by Bi et al (2016) to exhibit a partial reversal in rotation during the flare. The preliminary findings of this study are discussed and compared to the results of Bi et al (2016).

Observation of a reversal of rotation in a sunspot during a solar flare. Bi et al (2016) https://www.nature.com/articles/ncomms13798

Eddie Ross (University of Birmingham)

Eddie Ross (University of Birmingham), William J. Chaplin (University of Birmingham), Steven J. Hale (University of Birmingham), Rachel Howe (University of Birmingham), Yvonne P. Elsworth (University of Birmingham) Guy R. Davies (University of Birmingham)

Talk

Solar cycle measurements of lifetimes of active and ephemeral region flux

We use very high-cadence (sub-minute) observations of the solar mean magnetic field (SMMF), covering a period of more than 20 years, to constrain the lifetimes of active region (AR) flux and ephemeral region (ER) flux on the Sun.

The ARs give rise to a rotationally modulated signal in the SMMF observations, which manifests itself as Lorentzian-like peaks in the frequency domain, whose widths allow us to measure the lifetimes of AR flux. The ERs introduce a stochastic, red-noise-like signal in the

SMMF, whose fall off in power with frequency gives an estimation of the lifetimes of ER flux. We examine the relative contributions of ARs and ERs to the SMMF and provide an investigation into the evolution of the lifetimes with the solar activity cycle over the observational period.
The data used were collected by the Birmingham Solar-Oscillations Network (BiSON) node in Sutherland, South Africa since 1992.

Daniel Gass (University of Central Lancashire)

D. Gass (University of Central Lancashire), R.Walsh (University of Central Lancashire)

Poster

Using EUV SDO/AIA data to undertake a comprehensive survey of coronal limb loop width evolution over a solar cycle

NASA's SDO/AIA instrument has over ten years of continuous EUV observations of the solar atmosphere. Most AIA studies limit themselves to short time periods (or even single images) around specific events and as yet we have not properly exploited the full potential of this longitudinal dataset. As such, we risk missing possible long-term trends in a range observable features. However, given the quantity of data, advanced and appropriate data processing techniques (such as machine learning and automated feature tracing) need to be employed for long term trend evaluation of fundamental structures.
This work describes preliminary results from a multi-wavelength EUV coronal survey of limb loops, taken from ten years of AIA data created to investigate fundamental properties of these coronal structures. The data reduction, image enhancement (through a Multiscale Gaussian Normalisation (MGN) approach) and subsequent pattern recognition algorithms will be introduced. Coronal loop widths in particular will be analysed to investigate and quantify any potential correlation between the phase of the solar cycle and the energy distribution within the corona. Going forward, the role of machine learning within the project is likely to be significant and possible ways to address this are outlined.

Bridging the Disciplines of Galactic and Extra-galactic Archaeology (GalArchaeology)

Philipp Edelmann (Newcastle University)

P. V. F. Edelmann (Newcastle University, UK), R. P. Ratnasingam (Newcastle University, UK), M. G. Pedersen (KU Leuven, Belgium), D. M. Bowman (KU Leuven, Belgium), V. Prat (CEA Saclay, France), T. M. Rogers (Newcastle University, UK)

Talk

3D Simulations of Internal Gravity Waves in Massive Stars

Recent asteroseismological observations of stars with a convective core showed evidence of stochastically excited internal gravity waves (IGWs). IGWs are expected to effectively transport angular momentum and chemical species through the radiative envelope of the star. This has potentially large implications on the evolution of rotating massive stars. We present the first three-dimensional hydrodynamic simulations of the convective core and a large part of the radiative envelope of a main-sequence star. These show the self-consistent convective excitation and propagation of IGWs. The simulations show standing modes consistent with predicted f and g modes. Additionally we see a continuous signal at low frequencies (~30 μHz), which is caused by stochastically excited IGWs. The spectral energy distribution is different from predictions based on theoretical estimates. We compare these synthetic observables to actual photometric observations. We also give an overview on ongoing work on the effect of differential rotation and magnetic fields on IGWs.

Veronica Ferreiros Lopez (Lancaster University)

John Stott (Lancaster University), Andreas Koch (Heidelberg University)

Talk

Age-metallicity relation of the bulge globular cluster NGC6528

We present our comprehensive campaign to study stellar populations in the Galactic bulge using the well-established means of Strömgren photometry. To this end, we obtained photometry with the Hubble Space Telescope’s (HST) Wide Field Camera 3 and Advanced Camera for Surveys bands of the bulge globular cluster NGC 6528 in the filters F395N, F410M, F467M, and F547M. By using photometric metallicity sensitive indices, we were able to estimate the stellar metallicity of horizontal branch, red giant branch and main sequence stars. The age of the cluster was determined using Dartmouth isochrones. We also include an

estimation of the cluster's differential reddening. The main aim of our study is to test for the actual presence of a young, metal-rich population and identifying candidate metal-poor stars in the bulge, which ultimately lets us constrain the age range of the entire cluster population and its surrounding field.

Bill Chaplin (University of Birmingham)

W. J. Chaplin (University of Birmingham)

Talk

Asteroseismology

In this review talk I will give an overview of asteroseismology -- the study of stars by observation of their natural pulsations -- and discuss how this field is providing important results for Galactic Archaeology studies.

Chiaki Kobayashi (University of Hertfordshire)

Chiaki Kobayashi, Christopher Haynes, Fiorenzo Vincenzo, and Philip Taylor

Invited

Chemodynamical simulations of the Milky Way, early-type galaxies, and high-redshift star-forming galaxies

Chemodynamical simulation from cosmological initial conditions is a powerful tool for studying the formation and evolution of the galaxy in a cosmological context, as well as the origin of elements in the Universe.

Our chemodynamical simulation of a Milky Way type galaxy have well reproduced the frequency distribution of elements from O to Zn in the solar neighborhood and the spatial variation of alpha/Fe as a function of radius and latitude, consistent with recent galactic archaeology surveys. It can also constrain the origin of neutron-capture elements, where the contribution of magneto-rotational supernovae is equally or more important than neutron-star mergers, one of the gravitational wave sources.

With feedback from active galactic nuclei, it is possible to suppress star formation in massive galaxies as observed, and to reproduce the observed mass-metallicity relation of galaxies. The alpha/Fe ratios, however, are still lower than observed for early-type galaxies, and this observation can be used to improve our understanding of the feedback process.

For star-forming galaxies, we predict the evolution of CNO abundances instead, which can be used to constrain the formation timescales in disc galaxies in the JWST era.

Daniel Thomas (University of Portsmouth)

Daniel Thomas

Invited

Early-type galaxies

Early-type galaxies, in their apparent simplicity, keep challenging our understanding of galaxy formation and evolution. Despite being at the top of the LCDM food chain, their stellar population properties, chemical enrichment histories and gas fractions suggest surprisingly fast and homogeneous formation at early times followed by an uneventful evolution ever since. I will review recent developments in the study of stellar population and chemical enrichment properties of early-type galaxies, both from an observational and theoretical perspective.

Nic Scott (The University of Sydney)

N. Scott (University of Sydney), J van de Sande (University of Sydney)

Talk

Extragalactic thick disks and alpha enhancement

One of the key insights of Galactic Archaeology is the existence of a chemically distinct 'thick disk' component in the Milky Way. While similar thick disks have been identified photometrically in external galaxies, confirming a distinct chemical nature is tricky. We use a sample of edge-on disk galaxies observed with MUSE to search for chemically distinct components. Based on these results we consider how detailed studies of small samples can be applied to large spatially resolved galaxy surveys such as SAMI, Hector and MaNGA to allow statistical studies of extragalactic thick disks.

Soheil Koushan (International Centre for Radio Astronomy Research - The University of Western Australia)

A. Soheil Koushan (ICRAR - UWA) B. Simon P. Driver (ICRAR - UWA and The University of St. Andrews) C. Aaron S. G. Robotham (ICRAR - UWA) D. Luke J. Davies (ICRAR - UWA) D. Sabine Bellstedt (ICRAR - UWA)

Poster

Finding a new constraint on the Extra-galactic Background Light via WAVES input catalogue

The extragalactic background light (EBL) is defined as the total flux received today from all sources of photon production since the epoch of recombination. Understanding this form of energy is essential as it encodes all energy production pathways.

Here, we measure the energy output from discrete components in the universe, i.e. galaxies, using the input catalogue for the Wide Area VISTA Extragalactic Survey (WAVES, Driver et al. 2015) a deep spectroscopic campaign on 4MOST. We calculate galaxy number counts in 9 bandpasses (0.4 micron - 2.1 micron) and model the EBL contribution from these resolved extragalactic sources. We compare our results obtained from discrete integrated galaxy counts (IGL) to that measured from very high energy (VHE) astrophysics, which samples all photons. A comparison between our measurements and the total EBL from VHE represents the fraction of photons arising from diffuse components in the Universe, and provides an estimate of the total missing mass in galaxy samples.

Currently, the uncertainty in the IGL measurements is 20%, of which the most dominant component is caused by cosmic variance. This is comparable to the predicted difference between IGL and VHE measured. Adding data from the WAVES input catalogue which is the combination of the ESO VIKING+KiDS datasets covering ~1200 sq_deg of the extragalactic sky, are essential in reducing this error component. With significantly reduced errors the comparison between our IGL measurements and those derived from VHE will allow us to parameterise the total missing mass in galaxy samples for the very first time.

Joaquín García de la Cruz (Liverpool John Moores University)

Joaquín García de la Cruz, Marie Martig, Philip James. Liverpool John Moores University

Talk

Finding tracers of galaxy evolution in the age structure and kinematics of thick disks of galaxies.

We aim to find imprints that internal and external processes leave on the age structure and kinematics of thick disks of galaxies and could potentially be observed in the Milky Way and nearby galaxies. We analyse a sample of 30 galaxies simulated in their cosmological context, with a diversity of merger and gas accretion histories, strength of bar and spiral arms, disk morphologies, etc.
Inspired by the age gradient found in the Milky Way's geometric thick disk by Martig et al. 2016, this study explores the different evolutionary scenarios that could result in such age gradients. We find that, while most of our simulated geometric thick disks have radial age gradients, the shapes of the age profiles can vary quite a lot from galaxy to galaxy. Some galaxies show no age gradient in their thick disks, and those tend to be galaxies where thin and thick disks are very distinct structures.
We explore how the global thick disk arises from the superposition of stellar mono-age populations (MAPs), and we link the morphological and dynamical properties of MAPs with the global properties of the thick disk. Radial age gradients are produced by different degrees of flaring of MAPs, contributing stars of different ages at different radii and heights. We analyse the different processes that can produce flaring, finding clear imprints at z=0 of past mergers and flybys in MAPs. With this study, we establish links between the different evolutionary scenarios and the diversity of age structures in galaxies

Jianhui Lian (Institute of Cosmology and Gravitation)

Jianhui Lian, Daniel Thomas, Claudia Maraston

Poster

Galactic archeology: Milky Way merged with two gas-rich galaxies at ~8 and ~4 Gyr ago

Galaxy mergers are usually identified by asymmetry morphologies, such as tidal tail, or peculiar dynamics with predominant random motion instead of rotation. In fact, in addition to the influence on the morphology and dynamic properties, galaxy-galaxy merger events also affect chemical compositions of stars dramatically. In particular, stars formed during a gas-

rich merger tend to have lower iron abundance due to metal-poor gas accretion and enhanced alpha-to-iron abundance ratio because of the star burst triggered by the merging event. Recently, we identified two stellar populations in Milky Way with relatively young stellar age showing this peculiar chemical composition based on the SDSS/APOGEE survey. The two merger events occurred at ~8 (z~1) and ~4 (z~0.4) Gyr ago, respectively. Using a numerical chemical evolution model, we simulated the distribution of stars in [a/Fe]-[Fe/H] diagram predicted by the merger scenario. We found that the well-known alpha abundance dichotomy of stars in Milky Way could be well explained by the model involving gas-rich mergers. The first merger event occurred at z~1 triggered a star burst that forms the majority of the chemical thick disk stars observed today with [a/Fe]~0.3. In other words, our model suggests a merger origin of the thick disk in the Milky Way. The second merger at z~0.4 leads to the formation of young, alpha-enhanced ([a/Fe]~0.1) and iron-poor ([Fe/H]-0.3) stars in the thin disk which contributes to ~10% of the Milky Way disk in mass.

Mirko Curti (Kavli Institute for Cosmology - University of Cambridge)

Talk

Metallicity gradients in star forming galaxies: from the local Universe to the cosmic noon (and beyond...)

The spatial distribution of heavy elements within galaxies provides key informations on their star formation history and evolution.
In this talk, I will review the current observational status in the determination of metallicity gradients and chemical abundance patterns in star forming galaxies, both in the local Universe and at higher redshift.
I will try to put the main results in the context of the predictions of the latest chemical evolution models and simulations and discuss which progresses we might expect from forthcoming observational facilities and instrumentation.

Nimisha Kumari (University of Cambridge)

Nimisha Kumari, Bethan James, Mike Irwin, Ricardo Amorin, Enrique Perez-Montero

Talk

O/H-N/O:the curious case of NGC4670

The relation between nitrogen-to-oxygen ratio (N/O) and oxygen abundance (O/H) has been a topic of intense debate and discussion in both observing and modelling communities working on chemical evolution. I find an unusual negative relation between N/O and O/H within a blue compact dwarf (BCD) NGC 4670 using the integral field spectroscopic observations from the Gemini North Multi-Object Spectrograph (GMOS-N). This galaxy also shows a region of enhanced N/O coinciding with the a continuum region hosting wolf-rayet stars. I combine these data with large samples of star-forming galaxies from previous studies including BCDs, green peas and low-mass SDSS galaxies, and further explore the observed properties with chemical evolution models. Such studies are imperative to enhance our understanding of the nucleosynthetic origin of nitrogen, chemical enrichment and recycling processes in the interstellar medium; and hence shed light on several secrets of the chemical evolution of the Universe.

Michael Greener (University of Nottingham)

Michael Greener (University of Nottingham), Alfonso AragÃ³n-Salamanca (University of Nottingham), Michael Merrifield (University of Nottingham)

Poster

Spatially Resolved Extinction in MaNGA Spirals

Properties such as the star-formation rates and gas metallicities in star-forming galaxies are often derived from nebular emission lines. However, this light is strongly attenuated by dust within these galaxies. The work we are undertaking aims to accurately correct for the presence of this dust in MaNGA spirals, and measure its spatial distribution. In our sample of galaxies, we select regions where star formation is the principle source of line emission; and use the Balmer decrement as a diagnostic to quantify the dust extinction in each galaxy. We also compare extinction values derived from this dust with extinction due to the stellar populations in the MaNGA spirals. Preliminary analysis, which is presented in this poster, indicates that the ionised gas in predominantly star-forming galaxies exhibits significantly lower dust extinction than in AGN or LI(N)ER dominated ones; whereas the dust extinction measured from analysis of stellar populations is not significantly affected by the rate of star formation within a galaxy.

Richard Stancliffe (E.A. Milne Centre for Astrophysics, University of Hull)

R. J. Stancliffe (Hull)

Invited

Stellar Evolution Challenges for Galactic Archaeology

Stars are fundamental to galactic archaeology, both as sites of stellar nucleosynthesis and as unevolved 'fossils' preserving a chemical record of the galaxy at their time of formation. Both require a fundamental understanding of how stars work: how they transport material and the processes by which they synthesis isotopes. I will discuss some of the challenges facing stellar modellers, and how they can be addressed in an era where asteroseismology and multidimensional simulations can help to develop our understanding of what is going on deep within stellar interiors. I will highlight some of the nucleosynthesis that can happen at low metallicities -- in particular the so-called intermediate neutron capture process -- and how it impacts our understanding of the production of the elements in the early stellar generations.

Lewis Hill (University of Portsmouth)

Talk

Stellar parameter determination for MaNGA stars and population properties of MaNGA galaxies

The SDSS-IV/Mapping Nearby Galaxies at APO (MaNGA) survey will have collected spectra for ~10,000 nearby galaxies, and for 30,000 stars by 2020. To understand the evolution of these galaxies, one needs an accurate determination of stellar parameters for the empirical stars to be used in stellar population modelling. In this talk I will present results from a full-spectral fitting analysis of stellar spectra, comparing different methodologies and discussing the accuracy at which stellar parameters can be derived. I will then present the first results of applying these models to interpret MaNGA galaxy spectra and globular clusters with the full-spectral fitting code 'Firefly'. This scientific analysis will provide key insight into the physical processes that govern the formation and evolution of galaxies in the universe.

Claudia Maraston (Institute of Cosmology and Gravitation)

Claudia Maraston

Invited

Stellar Population models

Stellar population models import robust stellar physics into galaxy science by combining stellar evolution and model atmosphere theories and empirical calibrations. They are instrumental to determine the still poorly known process of galaxy formation and evolution, hence are connected to the main themes of the 'Bridging' session. In this talk, I shall review the state-of-art in the field.

Raphael Hirschi (Keele University)

Hirschi, R. (Keele Uni, Kavli WPI IPMU), Arnett, W. D. (Uni of Arizona), Meakin, C. (Karagozian & Case), Cristini, A. (Uni of Oklahoma), Georgy, C. (Uni of Geneva), Campbell, S. (Monash Uni), Scott, L. (Keele Uni), Kaiser, E. (Keele Uni)

Poster

Synergy between 3D and 1D simulations of stellar convection

Stars are complex objects involving many multi-dimensional processes like convection, rotation and magnetic fields. Ideally, we would like to model stars with 3D MHD simulations but it is unfortunately not feasible to simulate their entire evolution in 3D. We will thus always need 1D stellar evolution models to provide the necessary input for galactic chemical evolution and to study the cosmic impact of stars in general. In this talk, I will introduce a framework to develop synergy between 3D and 1D simulations, the so-called RA-ILES framework. I will end by presenting recent results obtained by applying this framework to convective boundary mixing, which is one of the most important uncertainties in the evolution of stars of all masses.

Jianhui Lian (Institute of Cosmology and Gravitation)

Daniel Thomas, Claudia Maraston

Talk

The origin of mass-metallicity relation and metallicity gradient in gaseous and stellar components of galaxies

The origin and cosmic evolution of the gas and stellar metallicity vs galaxy mass relations are a matter of hot debate. Usually, these relations are studied separately, and there is no comprehensive model that can explain both simultaneously. As the stellar metallicity carries information about the early epochs of chemical enrichment in galaxies, while gas metallicity reflects more recent evolutionary processes, the simultaneous study of both will set stringent constraints to galaxy formation and evolution across cosmic time. Here we show a unified chemical evolution model aiming at reproducing both relations simultaneously. As input data we use both integrated as well as spatially-resolved spectra from SDSS and SDSS-IV/MaNGA, with carefully derived stellar and gas metallicities. The stellar metallicity is found to be much lower than the gas metallicity, especially in low mass galaxies and at large radii. This suggests a dramatic cosmic metallicity evolution with very low metallicity at early times. Using a full chemical evolution model, we conclude that only two scenarios can reproduce gas and stellar metallicity simultaneously. One invokes a time-dependent metal outflow escape fraction with high fractions at early epochs. The other one must adopt a time-dependent IMF slope, in which a steeper IMF slope (i.e. more bottom-heavy IMF) in the lower-mass galaxies is needed at early times. This is the first time that the gas metallicity-mass and the stellar metallicity-mass relations including radial profiles within galaxies are successfully reproduced by a chemical evolution model.

Alison Laird (University of York)

A. Laird (University of York)

Invited

The role of nuclear physics in interpreting observations

Nuclear physics plays a critical role in galactic chemical evolution. To model abundances in stars and from supernovae it is vital to understand the relevant nuclear reaction rates and nuclear properties, such as masses and decay rates.
With hundreds of nuclei involved and thousands of possible reactions, the focus of both experimental and theoretical effort is on those cases which are needed to understand

observables, such as gamma- and X-ray fluxes, light curves, isotopic ratios in grains and some elemental abundances.
This review talk will outline recent progress in constraining key nuclear reaction rates which directly impact observables. Current challenges in the field will also be highlighted.

Simon Kemp (Instituto de Astronomia y Meteorologia, Universidad de Guadalajara)

Ernesto Perez Hernandez, Claudia Martinez Robles, Cristian Hinojosa

Poster

The unusual nature of the galaxy NGC 4488

NGC 4488 is an unusual small galaxy in the Virgo cluster which may be a face-on barred S0 galaxy with weak spiral arms or an edge-on disk galaxy with significant warping, or may even be a marger product with tidal filaments. We report on a photometric and spectroscopic study of this galaxy using the 2-1m telescope at San Pedro Martir, Baja California, Mexico, including colour maps and profiles, residual images, stellar population analysis and major axis velocity profile, and form conclusions on the nature of this galaxy.

Roberto Maiolino (University of Cambridge)

Invited

Understanding galaxy chemical evolution: prospects from high redshift studies

I will provide a review of our understanding of the chemical evolution of galaxies across the cosmic epocs based on recent multi-band observations at high redshift and also by discussing these results in the framework of theoretical models and cosmological simulations.
I will illustrate how the comparison between observations and models provides important constraints on the mechanisms responsible for galaxy formation and evolution.
I will discuss the open issues and the progress in this field expected from forthcoming and planned observing facilities, such as JWST, the ELTs, the next generation multi-object spectrographs, ALMA, SKA and SPICA.

C.Clare Worley (Institute of Astronomy, University of Cambridge)

Invited

Updates on Galactic Archaeology: New Data and Discoveries

Advances in Galactic Archaeology have been driven to new heights with the arrival of Gaia Data Release 2 and the release of impressive catalogues from large scale programmes such as RAVE, APOGEE, Gaia-ESO and GALAH.
I will review recent advances with a particular view to these key datasets that are now available and discuss the challenges still to be met by the community as the first light of the next generation of projects such as WEAVE and 4MOST draw near.

David Sobral (Lancaster University)

D. Sobral, T. Cornish, J. Matthee, WARP: A. Jenkins, F. Wragg, J. Butterworth, C. O'Neill, J. Edwards, J. Gough, LAMPSS: E. Worrell, N. Patel, K. Wresilo, J. Bagness, O. Bray, S. Dicker

Poster

WARP-LAMPSS: the Lancaster CaHK narrow-band surveys for metal poor stars in the halo of the Milky way

We will present the pilot results of the Lancaster deep CaHK narrow-band surveys for metal-poor stars in the halo of the Milky Way. We explore deep NB392 and CaHK data obtained with the INT and CFHT over several extra-galactic fields and combine them with the full deep multi-wavelength data to identify extremely metal poor stars down to [Fe/H]~-5. Our survey is able to identify very metal poor F, G and K type stars all the way to the edges of the galactic halo in multiple sight-lines for the very first time. We will present the best candidates for extremely metal poor stars, the number density distribution in terms of temperatures and metallicities in the halo, and also the metallicity distribution and gradients that we recover. Follow-up observations will allow to confirm and fully establish the very low metallicity of these halo stars, along with potentially confirming the best candidates as low metallicity record breakers.

Connecting MHD Wave Research from the Sun to the Magnetospheres (MHDWavesSTP)

Harry Manners (Imperial College London)

H. Manners (Imperial College London), A. Masters (Imperial College London)

Talk

A global survey of the spatial distribution of ultra-low-frequency waves with periods ~1-100 minutes in the Jovian magnetosphere

Ultra-low-frequency (ULF) waves of unknown origin have been observed throughout Jupiter's magnetosphere since the Pioneer era. The enormous Jovian magnetospheric cavity is capable of supporting magnetohydrodynamic waves of periods of order tens of minutes, with a widely reported range of ~1-100 minutes. Previous studies of such waves are scattered between different datasets and often focus on individual case studies, leaving the spatial distribution and source mechanisms of these waves an ongoing mystery.

We have performed a global survey identifying large-amplitude ULF wave events using magnetometer data from the Galileo spacecraft and several near-equatorial flyby missions. We found over 400 ULF wave events, consisting of a combination of compressional and Alfvénic wave packets. Compressional and Alfvénic events were often coincident in space and time, which may be evidence for the driving of global standing wave structures such as field-line-resonances. The results confirm that 15, 30- and 40-minute periods dominate the Jovian ULF wave spectrum, encompassing the entire range of periods reported in the established literature. Additionally, we present the first evidence for multiple harmonics in the equatorial plasma sheet. Events occurred predominately in the outer magnetosphere close to the magnetopause, supporting hypotheses that magnetospheric ULF wave power may be driven by Kelvin-Helmholtz instabilities and other large-scale compressive perturbations on the magnetopause.

Andrew Hillier (University of Exeter)

A. Hillier (Exeter), I. Arregui (IAC)

Talk

Approximate nonlinear solutions of MHD Kelvin-Helmholtz mixing and their applications

The Kelvin-Helmholtz instability is one that appears in many magnetized astrophysical and space systems including the solar atmosphere and the flanks of the magnetosphere. The instability in its nonlinear regime drives turbulence, and from that mixing and heating. Here we present mean-field solutions to the nonlinear MHD Kelvin-Helmholtz mixing problem, confirming their validity through 3D MHD simulations. We use these solutions to provide heating rates for Kelvin-Helmholtz instability heating of prominence threads, highlighting that as long as the shear velocities driving the instability are smaller than the coronal sound speed, then mixing effects dominate this interaction.

Ajay Tiwari (Northumbria University)

Richard J. Morton (Northumbria), Stephane Regnier (Northumbria), James A. Mclaughlin (Northumbria)

Poster

Damping of Propagating Kink Waves in the Solar Corona

Alfvénic waves have gained renewed interest since the existence of ubiquitous propagating kink waves were discovered in the corona. It has long been suggested that Alfvénic waves play an important role in coronal heating and the acceleration of the solar wind. To this effect, it is imperative to understand the mechanisms that enable their energy to be transferred to the plasma. Mode conversion via resonant absorption is believed to be one of the main mechanisms for kink wave damping and is considered to play a key role in the process of energy transfer. In this study, we examine the rate of damping of propagating kink waves in coronal loops observed using the Coronal Multi-channel Polarimeter (CoMP). In order to provide accurate estimates of damping lengths and quality factors for the waves, we discuss a suitable likelihood function for fitting models to the ratio of two power spectra obtained from discrete Fourier transforms. We compare this method with the previously used method of least-squares and highlight the limitations of least-squares. We are able to confirm earlier indications that the propagating kink waves are undergoing frequency dependent damping. Additionally, it is found that the rate of damping decreases, or equivalently the damping length increases, for longer coronal loops.

Tom Elsden (University of St Andrews)

Tom Elsden (University of St Andrews), Andrew Wright (University of St Andrews)

Poster

Fast Normal Modes and 3D FLRs of a Magnetospheric Waveguide

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

Jasmine Sandhu (MSSL, UCL)

J. K. Sandhu (MSSL, UCL), T. K. Yeoman (University of Leicester), M. K. James (University of Leicester), I. J. Rae (UCL, MSSL), M. Georgiou (UCL, MSSL), S. J. Wharton (University of Leicester)

Poster

Field Line Eigenfrequencies in the Terrestrial Magnetosphere: How do they vary during geomagnetic storms?

Standing Alfvén waves on geomagnetic field lines result in large scale resonant oscillations at frequencies determined by the magnetic field configuration and the plasma mass density distribution along the field. These oscillations are a fundamental mechanism for the transfer of energy and momentum within the magnetosphere.
By applying the cross phase technique to ground magnetometer observations, the eigenfrequencies of field lines can be directly measured. Magnetic field observations from the IMAGE and CARISMA ground magnetometer arrays are analysed, providing simultaneous coverage over a large range of L shells. The direct observations of eigenfrequencies are

compared to estimates of eigenfrequencies that are determined using magnetic field and mass density models with a time-of-flight technique.

For quiet geomagnetic conditions, we find that existing magnetic field and mass density models well describe the spatial variations in the observed eigenfrequencies. During storm times, magnetic field and mass density models suggest that the eigenfrequencies are depressed due to an enhanced ring current acting to weaken the inner magnetospheric field. The results are supported by direct observations of the eigenfrequencies, using both large scale statistical studies as well as case studies of geomagnetic storms. This global depression of field line eigenfrequencies has significant implications for the propagation of wave power throughout the magnetospheric system.

In these studies, we have demonstrated the capability of eigenfrequencies to provide a useful diagnostic for magnetic field and plasma conditions within the inner magnetosphere. In particular, during highly dynamic storm times, the eigenfrequencies unveil large scale magnetospheric changes.

Patrick Antolin (University of St Andrews)

P. Antolin (University of St Andrews), T. Van Doorsselaere (KU Leuven)

Poster

Influence of resonant absorption on the generation of the Kelvin-Helmholtz Instability

The inhomogeneous solar corona is continuously disturbed by transverse MHD waves. In the inhomogeneous environment of coronal flux tubes, these waves are subject to resonant absorption, a physical mechanism of mode conversion in which the wave energy is transferred to the transition boundary with the ambient corona. Recently, transverse MHD waves have also been shown to trigger the Kelvin-Helmholtz instability (KHI) due to the velocity shear flows across the boundary layer, and their continuous driving has been shown to lead to fully turbulent loops. In this work, we show that resonant absorption plays a key role in energising and spreading the transverse wave-induced KHI rolls all over the loop. This is shown by performing simulations of impulsively triggered transverse MHD waves in a loop that initially lacks a boundary layer. In the absence of this layer, the first unstable modes have high azimuthal wavenumber. A boundary layer is generated relatively late due to the mixing process of KHI vortices, which allows the late onset of resonant absorption. As the resonance grows, lower azimuthal wavenumbers become unstable, in what appears as an inverse energy cascade. The velocity shear from the resonance also triggers higher order azimuthal unstable modes radially inwards inside the loop and a self-inducing process of KHI vortices occurs gradually deeper at a steady rate until all the loop is covered by small-scale vortices. We can

therefore make the generalisation that all loops with transverse MHD waves become fully turbulent.

Valery Nakariakov (University of Warwick)

V.M. Nakariakov (University of Warwick)

Invited

Magnetohydrodynamic Oscillations in the Solar Corona and Earth's Magnetosphere: Towards Consolidated Understanding

Magnetohydrodynamic (MHD) oscillatory processes in different plasma systems, such as the corona of the Sun and the Earth's magnetosphere show interesting similarities and differences, which so far received little attention and remain underexploited. The consolidated understanding of MHD wave processes in the corona and magnetosphere opens up interesting perspectives for effective knowledge transfer and cross-fertilisation of these two research fields. We review several important topics, such as Alfv enic resonances and mode conversion; MHD waveguides, e.g. the magnetotail, coronal loops, coronal streamers; mechanisms for periodicities produced in energy releases during substorms and solar flares, possible drivers of MHD waves; and diagnostics of plasmas with MHD waves. The main attention is paid to the effects of the plasma non-uniformity.

Martin Archer (Queen Mary University of London)

M.O. Archer (Queen Mary University of London), H. Hietala (University of Turku), M.D. Hartinger (Space Science Institute), V. Angelopoulos (University of California Los Angeles)

Talk

Magnetopause Surface Eigenmodes: Direct observations and global implications

The abrupt boundary between a magnetosphere and the surrounding plasma, the magnetopause, has long been known to support surface waves. 45 years ago, Chen and Hasegawa proposed that the reflection of surface waves by the ionosphere might result in a standing wave or eigenmode of the magnetopause surface on the dayside. While many potential impulsive upstream drivers which might excite this mode exist, only recently has strong observational evidence of its existence been discovered, which we present.

Inspired by observational criteria for other MHD eigenmodes, we employ multipoint and polarisation observations using the THEMIS spacecraft at Earth. During a rare isolated magnetosheath jet event, we show that the broadband impulsive driver excited narrowband oscillations of the magnetopause location and associated magnetospheric ultra-low frequency waves. Through comparing the observations with theoretical expectations for several possible mechanisms, we conclude that the isolated jet excited the magnetopause surface eigenmode - like how hitting a drum once reveals the sounds of its normal modes.

Using global MHD simulations, we discuss the implications of this eigenmode on other MHD wave modes, energy propagation and radiation belt interactions throughout Earth's magnetosphere. Finally we discuss the possible existence of this mode at other planetary magnetospheres across the solar system.

David Southwood (Imperial College London)

David Southwood

Talk

MHD waves excited by twisting of a magnetised plasma column from below: Saturn and solar corona compared.

Saturn's magnetosphere is pervaded by MHD signals that are driven from the rotating upper atmosphere, deliver heat and angular momentum into the magnetosphere and have an azimuthal wave number, m = 1. The signals appear to share kink mode characteristics. We provide a simple theoretical argument as to where and why kink mode structure is preferred to Alfvén mode for momentum/energy transfer along a column where rotation is imposed from below as it is at Saturn. Observational results from the Cassini spacecraft have provided global information on magnetic structure and appear to provide backing for the idea presented but ideas should be relevant to other contexts including transmission of rotation from the solar surface into magnetic structures in the coronal.

Thomas Howson (University of St Andrews)

Thomas Howson, Ineke De Moortel, Jack Reid, Alan Hood

Poster

MHD Waves in Complex Magnetic Fields

Many previous studies have proposed the slow stressing of magnetic field and subsequent release of energy as a mechanism for maintaining the high temperature of coronal plasma. Whilst direct observational evidence of braided fields within the Sun's atmosphere remains elusive, if these models are representative, then we might expect significant field complexity to exist within coronal structures. Meanwhile, over the past 20 years, many observational studies have highlighted the abundance of wave power throughout the solar atmosphere. In this context, we present the results of three dimensional MHD simulations of propagating waves in complex magnetic fields. We discuss the observed wave dynamics, formation of small spatial scales and establish what may be inferred about the nature of the background plasma.

Daniel Johnson (UCLan)

G.J.J. Botha (Northumbria Univeristy), D. Johnson (UCLan), M.J. Weberg (NRL, USA), D.S. Bloomfield (Northumbria University), P.B. Kotze (SANSA, South Africa)

Poster

Periodicities in the solar wind during the C22-C23 and C23-C24 solar minima

The solar minima between cycles 22-23 and 23-24 were unusually long and quiescent. This makes then ideally suited for studying periodic behaviour in the solar wind. In situ measurements of the solar wind magnetic field, velocity, and helium and proton number densities are obtained from the ACE and WIND satellites at a cadence of one hour. A wavelet analysis is performed on the data, while a Fourier spectral analysis is performed separately on the fast and slow-moving components of the solar wind. The wavelet results show a signal at 27 days that is due to the synodic equatorial rotation rate of the Sun, together with higher frequencies due to the presence of coronal holes. The Fourier spectra capture higher frequencies, with a fundamental of typically 5.6 microhertz together with its associated overtones.

Andrew Wright (University of St Andrews)

A. Wright (University of St Andrews), T. Elsden (University of St Andrews)

Talk

Resonant Fast and Alfven Wave Coupling in 3D

Coupling of fast and Alfven MHD waves occurs naturally in nonuniform media such planetary magnetospheres and the solar corona. Until recently, theory and simulations of the resonant coupling process was confined to 2D. The real word is 3D in nature, and recently 3D simulations have shown that there unexpected features present in 3D that are totally absent in 2D. It is too early to say what the effect of a 3D perspective will have on understanding of coronal and magnetospheric waves, although the theory has already been used to explain the dawn-dusk asymmetry of Field Line Resonances in the Earth's magnetosphere. We shall briefly outline the 3D scenario and its novel features.

Samuel Wharton (University of Leicester)

S. J. Wharton, D. M. Wright, T. K. Yeoman, M. K. James, J. K. Sandhu

Poster

The Variation and Sources of Broadband Magnetospheric Resonance

The magnetosphere is a dynamic system full of ultralow frequency Alfven waves. These are perturbations of the magnetic field that guide energy along field lines, much like waves on a string. Alfven waves can be reflected by the ionosphere and hence standing waves are formed with a set of harmonic frequencies. These harmonic frequencies depend on the plasma mass density and magnetic field strength along the field line.

These harmonic frequencies can be measured by applying the cross-phase technique to ground-based magnetometers. This relies on the local magnetic field being driven by a broadband source of energy which excites the local field lines at their respective harmonic frequencies. Hence, measurement of these harmonic frequencies implies the presence of a broadband energy source.

Using ten years of magnetometer data, we have studied under what geomagnetic conditions the field lines will be excited. We find that the first and third harmonics are detected under different conditions and we are able to link each harmonic to a possible source of ultralow frequency wave energy. We also look at how the values of the harmonic frequencies change with these conditions. This can tell us about how the magnetospheric structure is changing.

COSMIC WEB: BRIDGING GALAXIES AND COSMOLOGY (COSMICWEB)

Chris Duckworth (University of St Andrews)

C. Duckworth (St Andrews)

Talk

Connecting the angular momentum content of the cosmic web to galaxy kinematics and dynamics

In Duckworth+19, we investigate the relationship of kinematically misaligned galaxies (difference in kinematic PA between stars and Halpha) with their large-scale environment, in the context of halo assembly history.. We investigate the relationship between distances to various cosmic web features and several proxies of halo formation time with present-time gas accretion rate seen in central MaNGA galaxies (https://arxiv.org/abs/1811.06408). I will also discuss the morphological dependence of kinematic misalignment and how comparison to IllustrisTNG could yield things such as merger rate and relaxation timescales. Finally, current work in IllustrisTNG will also be discussed, concerning how the anisotropy of the cosmic web imprints on the orbits of satellite galaxies moving around the central. To recover the anisotropy in these orbits, we take lessons learned from applications of JAM to stellar clusters and galaxies but with the idea of whole galaxies as tracers.

Tracey Friday (University of Central Lancashire)

T. Friday (University of Central Lancashire), R. G. Clowes (University of Central Lancashire), S. Raghunathan (University of Melbourne), G. M. Williger (University of Louisville)

Poster

Accidental deep field bias in CMB T x SNe z correlation

Evidence presented by Yershov, Orlov and Raikov showed that the cosmic microwave background (CMB) pixel-temperatures (T) at supernovae (SNe) locations tend to increase with increasing redshift (z). They suggest this correlation could be caused by the Integrated Sachs-Wolfe effect and/or by some unrelated foreground emission. We assess this correlation independently using Planck 2015 SMICA R2.01 data and, following Yershov et al., a sample of 2783 SNe from the Sternberg Astronomical Institute. Our analysis supports the prima facie existence of the correlation but attributes it to a composite selection bias (high CMB T x high SNe z) caused by the chance alignment of seven deep survey fields with CMB hotspots. These

seven fields contain 9.2 per cent of the SNe sample (256 SNe). Spearman's rank-order correlation coefficient indicates the correlation present in the whole sample (ρs = 0.5, p-value = 6.7 x 10-9) is insignificant for a sub-sample of the seven fields together (ρs = 0.2, p-value = 0.2) and entirely absent for the remainder of the SNe (ρs = 0.1, p-value = 0.6). We demonstrate the temperature and redshift biases of these seven deep fields, and estimate the likelihood of their falling on CMB hotspots by chance is at least ~ 6.8% (approximately 1 in 15). We show that a sample of 7880 SNe from the Open Supernova Catalogue exhibits the same effect and we conclude that the correlation is an accidental but not unlikely selection bias.

Benjamin Giblin (University of Edinburgh)

Benjamin Giblin, Matteo Cataneo, Ben Moews and Catherine Heymans

Talk

Accurate non-linear calibration in arbitrary cosmologies beyond LCDM

We present a general method to accurately predict the non-linear matter power spectrum of general extensions to the vanilla LCDM model. This approach requires only a suite of relatively inexpensive LCDM N-body simulations with initial conditions suitably modified, which can then be used as a training set for an emulator. By rescaling the predictions of our emulator with analytical halo model reactions, we can compute accurate non-linear matter power spectra for a broad class of beyond-LCDM cosmologies. We demonstrate the power of this approach with theoretically motivated modified gravity and massive neutrino paradigms, as well as artificial models featuring arbitrary deviations from LCDM. In all cases the emulator can reproduce the matter power spectrum with errors at the level of 1% or better deep in the highly non-linear regime. This work represents a significant step forward to limiting our reliance on expensive simulations, and gives viable means to test the validity of the standard cosmological model in the non-linear regime with the next generation of large-scale structure surveys.

Seshadri Nadathur (ICG, University of Portsmouth)

S. Nadathur (Portsmouth), P. M. Carter (Portsmouth), W. J. Percival (Waterloo), H. A. Winther (Portsmouth, Oslo), J. Bautista (Portsmouth)

Talk

Beyond BAO: improving BOSS cosmological constraints using voids

Spectroscopic galaxy redshift surveys provide a wealth of cosmological information, in particular measurements of the angular diameter distance, Hubble rate, and growth rate of structure. We present a new method of measuring these quantities through measurement of the anisotropic cross-correlation of galaxies with cosmic voids, allowing simultaneous fits for redshift space distortions and those from Alcock-Paczynski (AP) effect. Applied to CMASS data from the Baryon Oscillation Spectroscopic Survey (BOSS) at redshift 0.57, this method yields a measure of the AP parameter that is more precise than that from BAO by a factor of 3.5, and orthogonal degeneracy directions in parameter space. We show how combining this void information with traditional BAO and galaxy clustering methods reduces measurement errors in each variable by a factor of 2, equivalent to a massive increase in the effective survey data volume. We show that in combination with cosmic microwave background measurements, this gain in cosmological information significantly tightens constraints on alternative models of dark energy over those previously obtained.

David Sobral (Lancaster University)

D. Sobral (Lancaster), B. Darvish (Caltech), A. Paulino-Afonso (MPA)

Talk

Cosmic Web of Galaxies in the COSMOS Field: Different Quenching for Centrals and Satellites

I will present the results from our recent studies that aim to unveil the role of the cosmic web on the evolution of galaxies, focusing on the COSMOS field. We use a mass complete sample of galaxies with accurate photometric redshifts in the COSMOS field to construct the density field and the cosmic web to z=1.2, but I will also focus on an unique structure studied spectroscopically at z=0.84. The comic web extraction relies on the density field and breaks the density field into clusters, filaments, and the field. We show that at z0.8, the trend flattens out for the overall galaxy population and satellites. For star-forming (SF) galaxies only, the median SFR is constant at z>0.5 but declines by from the field to clusters for satellites and centrals at z0.5. We suggest that most satellites experience a rapid quenching mechanism as they fall from the field into clusters through filaments, whereas centrals mostly undergo a slow environmental quenching at z0.5 and a fast mechanism at higher redshifts. Our results highlight the importance of the large-scale cosmic web on galaxy evolution.

Yan-Chuan Cai (Institute for Astronomy , University of Edinburgh)

Talk

Discussion

Discussion

Violeta Gonzalez-Perez (Lancaster University)

Violeta Gonzalez-Perez, Weiguang Cui, Michaela Hirschmam, Johan Comparat, Prabhakar Tiwari, Carlton Baugh, Sergio Contreras, Andrew Griffin, Alexander Knebe, Cedric Lacey, Peder Norberg, Alvaro Orsi

Talk

Do emission line galaxies live in filaments?

Emission line galaxies (ELGs) are used in several ongoing and upcoming surveys (SDSS-IV/eBOSS, DESI, Euclid) as tracers of the dark matter distribution. Using two state-of-the-art galaxy formation models, we explore the large scale environment of [OII] emitters, which dominate optical ELG selections at z~1. Model [OII] emitters at 0.5z1.5 are selected to mimic the DEEP2, VVDS, eBOSS and DESI surveys. The mean halo occupation distribution for model central [OII] emitters can be described as the sum of an asymmetric Gaussian for disks and a step function for spheroids, which plateaus below unity. This is far away from the canonical step function assumed for mass selected samples. The different halo occupation distribution brings us to explore the large scale environment of [OII] emitters, in order to better bridge these galaxies with future cosmological analyses. For this purpose we classify the cosmic web into Voids, Sheets, Filaments and Knots using two algorithms. We use Vweb, a velocity-shear-tensor algorithm with a 0.1 threshold, and also Pweb, a tidal-tensor algorithm with a 0.01 threshold. The results from using both algorithms are consistent. The distribution of ELGs in the cosmic web is closer to that of samples with the same number density based on a star formation rate cut. Nevertheless, model ELGs are about 5\% more present in Sheets and thus, tracing better regions with lower densities.

Ulrike Kuchner (University of Nottingham)

U. Kuchner (U. Nottingham), A. AragÃ³n-Salamanca (U. Nottingham), M. Gray (U. Nottingham), F. Pearce (U. Nottingham), A. Aguerri (IAC), J. Mendez-Abreu (IAC), A. Rost (U. Nottingham, UN Cordoba)

Talk

Probing cosmic filaments around local clusters with WEAVE: The WEAVE Wide-Field Cluster Survey (WWFCS)

Filaments are ubiquitous in the Universe. Î›CDM-based cosmological simulations indicate that galaxy clusters sit at the nodes of these filaments. In order to trace the impact of structure growth via filaments on the galaxy population, we must therefore consider galaxies in groups and cosmic filaments well beyond the cluster’s virial radius.
At low redshifts, observations deliver high data quality, but the large area, combined with their lower contrast, means that these regions are largely unexplored. In response to these challenges, we have designed the WEAVE Wide-Field Cluster Survey (WWFCS) to map the filaments around local clusters spectroscopically out to ~5Rvir: We selected 20 well-studied clusters at z~0.05, which will be observed with the WEAVE instrument at the WHT. Given the high spatial sampling, and aided by dedicated auxiliary data, we predict to observe ~5000 galaxies over a broad range of masses (10^9 M⊙ M* 10^11.5 M⊙) per cluster structure. The survey is expected to have its first light in less than a year. To develop and test structure-finding methods, we are using the DisPerSE algorithm on simulations from the Three Hundred project. These are re-simulations of the 324 most massive galaxy clusters and their surrounding environment from the MultiDark 1Gpc/h simulation. With these full-physics simulations, we are able to compare filament networks based on Dark Matter particles, gas and galaxies. Crucially, we can model the relative importance of the various physical processes experienced in each environment in transforming galaxies.

Amira Val Baker (Hawaii Institute for Unified Physics)

N. Haramein (Hawaii Institute for Unified Physics), A. Val Baker (Hawaii Institute for Unified Physics)

Talk

Resolving the vacuum catastrophe: a generalized holographic approach

We address the ~122 orders of magnitude discrepancy between the vacuum energy density at the cosmological scale and the vacuum density predicted by quantum field theory.

This disagreement is known as the cosmological constant problem or the 'vacuum catastrophe'. Utilizing a generalized holographic model, we consider the total mass-energy density in the geometry of a spherical shell universe (as a first order approximation) and find an exact solution for the currently observed critical density of the universe. We discuss the validity of such an approach and consider its implications to cosmogenesis and universal evolution.

Weiguang Cui (IfA, University of Edinburgh)

Cui Weigaung (IfA, UE); Knebe, Alexander (UAM); et al.

Talk

The baryonic webs: a view from the cosmological hydrodynamic simulations

Observations showed that the baryonic matters (galaxies) are mostly distributed in the web-like structures at large scale. Dark matter simulations have also shown such distributions. Understanding the link between baryonic matter and dark matter at large scale can help us to understand the cosmology as well as galaxy evolution. Using a set of cosmological simulations (410 Mpc/h) with various baryon models, we classified the large-scale environments into knots, filaments, sheets and voids with two classification methods: Vweb (based on the shear tensor, Hoffman et al. 2012) and Pweb (based on the tidal tensor, Hahn et al. 2007). In this talk, I will present our recent studies (Cui et al. 2018, 2019) on the connection between baryons and dark matter, as well as their evolutions.

Rita Tojeiro (University of St Andrews)

Rita Tojeiro (University of St Andrews)

Invited

The galaxy-halo connection in the cosmic web

Galaxies and the halos in which they reside are intrinsically connected. That relationship holds information about important processes in galaxy and structure formation, and is key to unlocking the full statistical power of forthcoming redshift surveys and their cosmological analyses. In this talk, I will consider how the galaxy-halo connection might depend on its position within the cosmic web, highlighting recent and ongoing work in observations and in simulations.

Chris Davies (Institute for Computational Cosmology - Durham)

Christopher T. Davies, Marius Cautun, Baojiu Li

Talk

Universalities In Weak Lensing Peak Statistics

Weak Lensing Convergence Maps correspond closely to the projected matter field. Naturally, this makes them excellent probes of the Large Scale Structure of the Universe. Weak lensing peaks extracted from these maps offer complimentary statistics that can provide additional cosmological constraints. Furthermore, a significant amount of cosmological information is contained in peaks with small amplitudes, for which few models exist.
In this talk I will present a model for some universal properties in weak lensing peak statistics as a function of Omega_m and sigma_8. This is achieved by identifying a connection between the Peak Abundance and the Peak Two Point Correlation Function, which is able to describe the behaviour of small peaks. This model only requires a few free parameters, is robust to the choice of smoothing scale and is not significantly impacted by galaxy shape noise. I will then discuss how we can use this model to make predictions of the Peak Abundance and Peak Two Point Correlation Function to within a few percent.
The work developed here has a large range of applications, such as the fast generation of mock weak lensing peak catalogues. Cosmological constraints on Lambda CDM, Dark Energy, Modified Gravity, and the Neutrino mass sum can also be achieved with our model, which will be made possible with upcoming surveys such as Euclid and LSST.

Ryan Jackson (University of Hertfordshire)

Mr. Ryan Jackson Affiliations: University Of Hertfordshire, Garreth Martin Affiliations: University Of Hertfordshire, Sugata Kaviraj Affiliations: University Of Hertfordshire, Julien Devriendt Affiliations: University of Oxford, Clotilde Laigle Affiliatio

Poster

Unveiling the low-surface-brightness universe with New Horizon: Galaxy evolution in the low mass regime

Galaxy evolution studies have been dominated by objects that lie above the surface brightness (SB) limit of current wide surveys like the SDSS (23 mag/arcsec^2). However, hints of a much larger population of low-surface-brightness galaxies (LSBGs) have recently been discovered. State-of-the-art cosmological simulations, and new deep wide surveys, have begun to show that these galaxies might dominate the local number density, indicating that our current understanding of galaxy evolution is incomplete. We use New Horizon, a cosmological hydro-dynamical simulation, to quantify the origin of LSBGs. We show that the majority of galaxies occupy a fairly tight LSB locus in the SB vs stellar mass plane, which is invisible in past surveys. However, some galaxies scatter off this locus, and these are the ones that are visible in past datasets and on which our theoretical paradigm is predicated. Key to understanding galaxy evolution, therefore, is to understand both the formation of the LSB locus and the objects that lie off it. We show that on-locus LSB galaxies form more of their stellar mass at higher redshift. More intense supernova feedback and mergers at early epochs flatten their gas profiles. This gas then produces diffuse LSB galaxies. The off-locus population exhibits milder supernova feedback at high redshift, which enables them to progressively deepen their potential wells, continue to form stars more vigorously to later epochs, thus attaining high SBs that make them visible in past surveys. We make testable predictions for the next generation of deep-wide surveys, such as LSST.

Alexander Hill (Liverpool John Moore's University)

Alexander Hill (LJMU), Rob Crain (LJMU), Ian McCarthy (LJMU)

Talk

Using EAGLE to Investigate Intrinsic Galaxy Alignments in Radio Weak Lensing Surveys

The SKA opens up the novel possibility of conducting weak lensing studies with radio continuum emission, complementing and perhaps surpassing counterpart surveys in the

optical. A major systematic uncertainty for weak lensing is the intrinsic alignment (IA) of galaxies which, if unaccounted for, masquerades as a genuine cosmic shear signal. The recent advent of state-of-the-art cosmological simulations that accurately reproduce the key characteristics of the galaxy population has enabled an assessment of the expected IA signal. To date this work has focussed on the IA of galaxies as seen in the optical regime; I will discuss the extension of such assessments into the radio continuum regime using the EAGLE simulations of galaxy formation. Preliminary results indicate that the IA signal will be lower in radio surveys than their optical counterparts.

Jacob Crossett (University of Birmingham)

J. Crossett (University of Birmingham), S. McGee (University of Birmingham), T. Ponman (University of Birmingham), M. Ramos-Ceja (University of Bonn)

Talk

Witnessing galaxy group evolution using X-ray observations

We present results from the XXL and GAMA surveys investigating the evolution of galaxies in groups at different stages of formation. We compare the galaxy properties of optically selected groups with matched aperture X-ray photometry to test whether differences in the X-ray emitting gas are linked to differences in the group age or feedback history.

We find that galaxy groups with high X-ray luminosity contain a lower fraction of blue, star forming galaxies, when compared with low X-ray luminosity groups. The X-ray bright groups also have a more dominant, passive central galaxy, than seen in low X-ray luminosity groups. These results demonstrate that our group samples can separated by group formation time, allowing a comparison of environmental quenching mechanisms at different epochs.

Cultural and Archaeo-Astronomical Tools in the Digital Age (AstroTools)

Georg Zotti (Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology)

G. Zotti (LBI ArchPro)

Talk

4D Skyscape Simulation in Stellarium

Desktop planetarium programs have largely replaced the planisphere as favourite tool for a comfortable visualisation of the starry sky for every place and time on the Earth's globe. A popular program is the free and open-source Stellarium which delivers arguably the most visually realistic simulation of the night sky. Since 2010 the author is member of the Stellarium development team and is working on improvements that make this program more accurate for long-time simulations and applications in the context of cultural astronomy. The most important development was the introduction (together with students at TU Wien) of a 3D landscape and architecture rendering module which allows the study of the interplay of sky, landscape and architecture, orientation of buildings towards points of astronomical interest (e.g. solstice sunrise), and light and shadow interaction for sites of alleged astronomical use. Recently, even the temporal development of the building model can be studied, so that the time control of Stellarium also controls the architectural changes a monument may have undergone over centuries of use. Comparing photos with simulated views in a model created from laser scan data gives a very promising indicator that this method provides a reliable simulation.

For simpler applications, a panorama photograph can be created and carefully adjusted to act as “dependable proxy” of the real landscape horizon for single viewpoints. However, Stellarium is not perfect yet. Users should be aware of a few remaining shortcomings, and also in general of pitfalls when dealing with the simulations of historical sky views.

Daniel Turner (Nottingham Trent University)

Daniel Turner, Daniel Brown

Talk

Archaeoastronomy Survey Work on Arbor Low

Some ancient sites within their landscape context, in the UK and beyond Stonehenge, allow for interesting links to be made with the sky experienced above them as exemplified for example for a standing stone at Gardom's Edge in the Peak District. To explore in more depth possible alignments or inter-visibilities a three-dimensional landscape model must be used in conjunction with a reliable planetarium program simulating the sky at appropriate times in the past. Stellarium as a free planetarium software offers this opportunity.

This presentation is a progress report of ongoing work on the prehistoric site of Arbor Low in the Peak District National Park, UK, used as a case study to explore the sky experience using Stellarium. This location presents a curiously meandering possible avenue connecting the main stone circle with the older burial both located on a hill ridge (http://www.arborlowenvironsproject.org/). The varying local horizon when proceeding along this avenue offers a rich source to investigate possible sites connection with the sky. The presentation will draw upon local survey data taken both with theodolite and camera as well as three-dimensional landscape models and its representation and interpretation within Stellarium. This work builds upon already existing experience with Stellarium and the opportunity it then offers to illustrate issues related interpreting local horizons and visualising it in innovative ways. This current case will in future offer a real-world scenario to test for the impact of more realistic refraction, extinction, proper motion and precession models upon astronomical interpretation.

Georg Zotti (Ludwig Boltzmann Institute)

G. Zotti (Ludwig Boltzmann Institute)

Talk

Workshop: Stellarium: How to add to my landscape

In this little workshop Georg Zotti will explore how you can create a panorama photograph of your own observing site and configure it for use in Stellarium.

G Zotti is co-developer of Stellarium and expands its applications mostly in archaeoastronomy.

Please bring your own laptop computers with multi-core CPU:

Windows 7, Windows 10, or a current Linux system.
(Mac use is also OK, but no Mac-specific help can be given, sorry.)

Please come with the following installed programs:
Stellarium 0.19.0 or 0.19.1
Hugin 2019.0.0
GIMP or Photoshop.

Current Developments in Numerical Astrophysics (NumericalAstro)

Linh Le Phuong (Northumbria University)

L. Le Phuong (Northumbria University), S. Shelyag (Deakin University), G. J. J. Botha (Northumbria University), J. A. McLaughlin (Northumbria University)

Poster

A 2D two-fluid MHD code to model partially-ionised plasma: calibration and a future benchmark

In the lower solar atmosphere, there exists partially-ionised plasma and such an environment changes significantly the dynamics of the plasma-to-magnetic-field interaction. Appropriate numerical treatment of this requires a more complex description than single-fluid magnetohydrodynamics (MHD) can provide.
A 2D two-fluid MHD code is developed to simulate partially-ionised plasma. The code is validated through various standard tests to demonstrate a high level of accuracy and stability. These tests include the Sod-shock tube test in hydrodynamics, and the Brio-Wu shock and Orszag-Tang vortex test in MHD. To calibrate the two-fluid code, we benchmark against a 1D slow-mode MHD shock, known as the switch-off shock. Furthermore, we initiate the Orszag-Tang vortex test in the two-fluid setting, and present the results as a future benchmark test for 2D two-fluid tests.

Jamie Quinn (University of Glasgow)

J. Quinn (University of Glasgow)

Talk

An Implementation of Anisotropic Viscosity in LaRe3D

Due to the complexity of anisotropic viscosity, it is often ignored in models of the solar corona. If included, the traditional viscous model takes the form of the Braginskii viscous stress tensor. Though this captures the main physics, it is complex to implement numerically and these implementations poorly revert to isotropic behaviour in regions of weak magnetic field. To investigate the potential importance of anisotropic viscosity in MHD instabilities, an implementation of an anisotropic viscous stress tensor has been developed, based on a physically motivated interpolation between the isotropic and strong-field parallel Braginskii stress tensors, hence the term 'parallel-isotropic switch'. This is implemented in the

Lagrangian-Remap MHD code, LaRe3D, and verified.
Results show excellent agreement between the parallel-isotropic model and the Braginskii model in high-resolution tests. The model is currently being used to assess the importance on the nonlinear dynamics of the kink instability in solar coronal conditions.

Arjen Tamerus (University of Cambridge)

S. Yurchenko (UCL), A. Tamerus (University of Cambridge), Jeffrey Salmond (University of Cambridge)

Talk

Distributed memory supercomputing to calculate high temperature line lists for large polyatomic molecules in TROVE

TROVE, part of the ExoMoL project, is an application for predicting the spectral signatures of polyatomic molecules important for exoplanet atmospheres. TROVE has been extensively used to produce line lists for a larger number of polyatomic molecules of key atmospheric importance, including NH3, CH4, H2CO, H2CS, PH3, SbH3, HOOH, HSOH, CH3Cl, BiH3, CH3F, C2H2, C2H4, PF3, SO3, AsH3. The program is highly optimised for massive intensities calculations (tens of billions of transitions) required for high temperatures (i.e. covering high rotation-vibrational excitations).
TROVE was originally developed to make use of large shared-memory supercomputers, but current architectures for cost-efficient supercomputing make use of large numbers of commodity nodes in a distributed-memory configuration. In order to tackle cutting-edge, high-memory problems on the current generation of DiRAC supercomputers, it was necessary to implement support for distributed memory parallelism in the application code. In collaboration with PI Dr Yurchenko and members of the DiRAC RSE team at the university of Cambridge, we developed an MPI-parallel version of TROVE which parallelises over multiple commodity compute nodes. Additionally we implemented parallel file I/O through MPI-IO to make use of fast distributed file systems like Lustre, enabling significantly higher I/O bandwidth.
With this distributed memory port of TROVE, the scaling limits of shared-memory systems are avoided, making it possible to compute line lists for larger polyatomic molecules and model higher temperatures that were previously not easily achievable. By exposing additional compute and I/O resources, we experience performance increases leading to a significant reduction in time-to-solution.

Franziska Schmidt (UCL)

Franziska Schmidt (UCL), Florian Kirchschlager (UCL), Erica Fogerty (LANL), Antonia Bevan (UCL), Felix Priestley (UCL), Michael Barlow (UCL)

Talk

Hydrodynamic Simulations of Supernova Remnants: Dust Destruction by the Reverse Shock

Sub-millimetre observations of galaxies at redshift z > 6 have revealed dust masses of up to 1e8 solar masses. Such systems are too young for significant dust enrichment by asymptotic giant branch stars and core-collapse supernovae (CCSNe) have been suggested as possible alternative dust producers. This is supported by the recent discovery of dust in young remnants of such supernovae using Herschel.
Once formed, the dust grains in the remnant are subjected to various erosion processes such as sputtering and grain-grain collisions due to the reverse shock generated by interactions between ejecta and circumstellar material. This can result in either the complete destruction of the grains or a size reduction.
In this study, we present the Dusty Grid model which allows us to incorporate the dust and the dust destruction mechanisms directly into the MHD code AstroBEAR which we use to simulate the conditions within the remnant. Our simulation setup is an extension of the Cloud Crushing model by Silvia et al. (2010) featuring a collection of dense gas clumps embedded in a less dense ambient medium through which a shock propagates. As the shock travels through the computational domain, it collides with the clumps and accelerates, compresses and heats the gas contained within. The dust is then subjected to dust processing routines that result in a redistribution of grain sizes.

Rowan Smith (University of Manchester)

Rowan Smith

Talk

Introducing the Cloud Factory: Zooming in to molecular cloud scales in Galaxy simulations.

I present a new suite of AREPO simulations that resolve individual molecular clouds down to ~0.1 pc scales while they are embedded within a Spiral Galaxy. We tie our resolution scheme to tracer particles injected into the gas so that individual regions can be resolved to arbitrarily high levels without neglecting the galactic context. Our simulations include a time-dependent chemical model, gas self-gravity, the ISRF and gas self-shielding, magnetic fields, sink particles, supernova feedback, and photo-ionisation from sinks. Using an analytic Milky-Way like spiral potential as our base, we turn on these effects step-by-step in a series of simulations to create a laboratory for testing the physics of the ISM and star formation from kpc scales to cold cores.

The molecular clouds formed in our galaxy scale simulations consist of networks of velocity coherent filaments, as seen in observations. In regions with high turbulence from supernova feedback the filaments within the clouds are shorter and less aligned than those in more quiescent regions dominated by the galactic potential. Stars form in all cases, but are more likely to form at the junctions of filaments in the feedback dominated case.

Tim Cunningham (University of Warwick)

Pier-Emmanuel Tremblay, Bernd Freytag, Hans Ludwig, Detlev Koester

Talk

Investigating Convective Overshoot in White Dwarf Atmospheres with CO5BOLD

White dwarfs are frequently observed (25%-50%) to have heavy metals in their atmosphere, a phenomena which is mostly explained by the accretion of rocky planetesimals from the evolved planetary systems which they host. For the atmospheres of white dwarfs with effective temperatures 15000K the process of atmospheric energy transfer becomes dominated by convection, rather than radiation, keeping metals suspended in the atmosphere for much longer times. Conventionally, calculations of the mixed mass in the convection zone are performed using the 1D mixing length theory, but recent studies have necessitated the inclusion of convective overshoot into these models. This non-linear boundary effect, which requires multi-dimensional simulations to be properly characterised, can significantly increase the inferred accreted mass.

Using the 3D radiation-hydrodynamics code, CO5BOLD, in a grid-based implementation, we are modelling the convective behaviour of hydrogen atmosphere white dwarfs. In particular, we are probing the temperature range 11400K - 18000K where convection is existent, yet confined to a region small enough to allow modelling of the full vertical extent of the convective and overshoot layers. We will present the first 3D simulations of degenerate stars with passive scalar particles that provide a statistical characterisation of the macroscopic diffusion of metals in the overshoot layers, below the convection zone. Our results suggest that macroscopic diffusion, driven by convective overshoot, decays over several pressure scale heights beneath the unstable layers, leading to an increase in mixed mass of up to 2.5 orders of magnitude.

Aoife Curran (ICC, Durham University)

Aoife Curran (ICC, Durham), Adrian Jenkins (ICC, Durham), Carlos Frenk (ICC, Durham), Azadeh Fattahi (ICC, Durham)

Talk

Investigating the tidal evolution of small dark matter subhaloes in N-body simulations of Milky Way type galaxies

Recent work by van den Bosch et al. has suggested that tidal disruption in N-body simulations of dark matter subhaloes may be strongly affected by numerical effects. However, many of these simulations were performed with an unrealistic distribution of orbits in a static potential. In this work, we aim to examine the tidal evolution of small dark matter substructures in more realistic conditions. Using the merger trees from the Aquarius simulations, we obtain the distribution of infall times and the orbits for all subhaloes. Rather than integrating these subhalo orbits within a static, analytical potential, we use a halo expansion code (HEX) (Lowing et al.), which approximates the potential of a simulated halo using a basis function expansion. HEX allows us to recreate the potential of the Aquarius halo and to replay the orbits of the subhaloes, substituting the original subhaloes with model subhaloes. This makes it possible to quickly and easily test the effect that varying the parameters of the simulation has on the tidal evolution of the substructure. We are particularly interested in what occurs at the centre of these subhaloes and whether numerical effects have a significant effect on the overall population of subhaloes.

Poster presenters

Cheryl Lau, Linh Le Phuong, Edward Snowdon

Talk

Lightning Talks by Poster Presenters

1."Stellar rotation formalisms of gamma Doradus stars from gravity-mode period spacings"; Cheryl Lau (York), id.352
2."A 2D two-fluid MHD code to model partially-ionised plasma: calibration and a future

benchmark"; Linh Le Phuong (Northumbria), id.321
3."Spectroscopic Analysis of Gamma Doradus Variables"; Edward Snowdon (York), id.192

Raphael Hirschi (Keele University)

Hirschi, R. (Keele Uni, Kavli WPI IPMU), Arnett, W. D. (Uni of Arizona), Meakin, C. (Karagozian & Case), Cristini, A. (Uni of Oklahoma), Georgy, C. (Uni of Geneva), Campbell, S. (Monash Uni), Scott, L. (Keele Uni), Kaiser, E. (Keele Uni)

Talk

RA-ILES framework: developing synergy between 3D and 1D simulations of stellar interiors

Stars are complex objects involving many multi-dimensional processes like convection, rotation and magnetic fields. Ideally, we would like to model stars with 3D MHD simulations but it is unfortunately not feasible to simulate their entire evolution in 3D. We will thus always need 1D stellar evolution models to provide the necessary input for galactic chemical evolution and to study the cosmic impact of stars in general. In this talk, I will introduce a framework to develop synergy between 3D and 1D simulations, the so-called RA-ILES framework (Arnett+2018: ArXiv1810.04653). I will end by presenting recent results obtained by applying this framework to convective boundary mixing, which is one of the most important uncertainties in the evolution of stars of all masses.

Edward Snowdon (University of York)

E. Snowdon (University of York)

Poster

Spectroscopic Analysis of Gamma Doradus Variables

Spectroscopic analysis of stars and other targets is often a complex and challenging task. New software pipelines have been utilised to streamline this process while still retaining the validity and precision of results. This has been done with iSpec, a software package that bundles a variety of models within a user-friendly interface. Applying these methods to data collected from the Mount John Observatory in New Zealand, allows the chemical abundances, atmospheric characteristics and other parameters of the targets to be determined. The study focuses on the relatively recent stellar classification of Gamma Doradus variables in the hope

of shedding further light on the nature of these stars and allowing them to be more readily distinguished from other categories of variable.

Cheryl Lau (University of York)

C. Lau, E. Brunsden

Poster

Stellar rotation formalisms of gamma Doradus stars from gravity-mode period spacings

Gamma Doradus stars are A-F type main sequence stars which pulsate in high-order non-radial gravity modes. These modes uniquely probe the deep stellar interior and reveal the properties of the near-core region. The period spacing patterns of g-mode pulsations have been successfully used as observable indicators to constrain the surface-to-core rotation for individual stars. Pulsation frequencies of gamma Doradus stars are comparable to their rotation frequencies and hence their oscillations are strongly coupled with the effects induced by rotation. Various theoretical formalisms have been introduced to describe interior rotation by applying approximations to the physics of stellar oscillations, in particular, the treatment of the Coriolis force and centrifugal effects. We investigate the ability of g-modes to differentiate between two different rotation formalisms using a grid of 1D stellar models computed with the MESA evolution code. The code simulates the adiabatic oscillations of gamma Doradus stars and provides the period spacings for each model. With detailed analysis on the grids we can evaluate the extent to which the two rotation formalisms are distinguishable in observational data. This will allow us to improve seismic modelling for rotating gamma Doradus stars and extend our capabilities to trace the interior stellar structure.

Mark Wilkinson (University of Leicester)

Mark Wilkinson

Invited

The DiRAC HPC Facility

The DiRAC HPC facility is the primary provider of state-of-the-art computing resources for the STFC theory communities in astronomy, cosmology, nuclear and particle physics. In order to maximise the science output of the facility, it is vital that our software is able to exploit the

full processing power of the latest computing hardware. To achieve this, DiRAC supports a team of Research Software Engineers. I will present examples which demonstrate that this is an efficient way to drive scientific research forward, allowing researchers to focus on their science while using the skills of specialist software engineers to optimise their software and improve its portability and sustainability. I will describe how DiRAC projects have benefitted from access to Research Software Engineering expertise to modernise and optimise their science codes, and how such collaborations has reduced time-to-science. I will also discuss how early access to next generation architectures is helping us to plan for the deployment of DiRAC-3 systems.

EDUCATION, OUTREACH AND ENGAGEMENT: WHAT ARE THEY AND WHAT WORKS? (EDUOUTRCHENGAGE)

Sophie Murray (Trinity College Dublin, The University of Dublin)

Ã‰ine Flood [1,2], Peter T. Gallagher [3,1], Sophie Murray [2,3], Laura A. Hayes [2,4], Pearse Murphy [1,3], Ciara Maguire [1,3], Aoife Ryan [1,3]; [1] I-LOFAR Education Centre, Birr Castle, Birr, Co. Offaly, Ireland. [2] School of Physics, Trinity Colleg

Poster

Astronomical Midlands: Engaging Rural Communities in Ireland with Radio Astronomy

The Irish Midlands has a rich heritage in astronomy, a fact that is not well known in this region of higher than average unemployment and low uptake of post-secondary education. We have therefore embarked on a regional engagement project - the Astronomical Midlands (AstroLands) - which uses the recently constructed Irish Low Frequency Array (I-LOFAR; lofar.ie) radio telescope and I-LOFAR Education Centre at Birr Castle in the Irish Midlands to connect with students, teachers and members of the public in local, rural communities in the Midlands. In this presentation, we will describe our three key initiatives: Space4Exploration: Developing an engaging, inspirational, and multi-use space in the I-LOFAR Education Centre; Space4Students: Day-long and week-long camps at the I-LOFAR Education Centre to run during school terms and holidays for students aged 10 to 14; Space4Teachers: Create and run Continuous Professional Development workshops for primary and secondary school teachers based around the Irish National Junior Certificate (12-15 year olds) theme of Earth and Space. With these programmes our ambition is to inspire and support teachers, students and the general public to engage with the science and engineering of LOFAR.

Emily Drabek-Maunder (Royal Observatory Greenwich)

Emily Drabek-Maunder (Royal Observatory Greenwich), Brendan Owens (Royal Observatory Greenwich)

Poster

Astronomy and Islam

The Royal Observatory Greenwich has been working with the New Crescent Society to develop a programme to engage people who use a lunar calendar in their daily lives with the science of the Moon. Our Astronomy and Islam Mornings are held before the predicted sighting of the next new crescent Moon and consist of a monthly planetarium show followed by a practical demonstration to learn how to sight the new crescent. The planetarium shows cover a variety of topics, from the science behind the new crescent visibility, discoveries by key scientific figures from the past, differences in constellations and historical instruments built for navigation and prayer.

Emily Drabek-Maunder (Royal Observatory Greenwich)

E. Drabek-Maunder, B. Owens, T. Kerss, Royal Observatory Greenwich

Poster

Bringing observing back to Royal Observatory Greenwich with the Annie Maunder Astrographic Telescope (AMAT)

The Annie Maunder Astrographic Telescope (AMAT) officially had its first light in June 2018 at the Royal Observatory, making Greenwich a working astronomical observatory for the first time in 60 years. Named after the famous Irish astronomer and mathematician who worked as a 'lady computer' at the Observatory, the purpose of the AMAT is to communicate astronomy to schools and the public alike using astrophotography as well as tours and live streams that allow people to ask the astronomers direct questions. AMAT consists of a suite of four telescopes that can image everything from high resolution images of Solar System objects (e.g. the Sun, Moon and planets) to distant nebulae and galaxies at different wavelengths. These images will also be used to support astrophysics research and planning is in progress for developing astrophysics research projects for undergraduates.

Andrew Newsam (Liverpool John Moores University)

A. Newsam (Liverpool John Moores University), S. Habergham-Mawson (Liverpool John Moores University)

Talk

Developing and assessing two-way engagement with an online resource

The National Schools' Observatory (NSO) has been successfully supporting STEM education in schools and helping to enhance the appreciation of STEM in school students for a numbers of years. However, in common with many web-based resources, the interaction with our users has been quite one-sided, with resources and content we provide being used by teachers and students, but with little two-way discussion, except during testing of new resources and formal evaluation. However, in the last couple of years, we have been developing a range of ways to increase interaction with both teachers and students, including enhanced social media activity, collaborative projects, out-of-school activities and competitions. Here we will report on some of the successes and failures, and lessons learnt from our initial evaluation.

Fraser Lewis (National Schools' Observatory (LJMU) & Faulkes Telescope Project)

Fraser Lewis - National Schools' Observatory (LJMU) & Faulkes Telescope Project

Poster

Developing Astronomy Projects Using the IBSE (Inquiry Based Science Education) Format

I will present details of two online teacher-free IBSE activities created for the National Schools Observatory. These are project style resources on exoplanets and open clusters, containing background information and real astronomical data.
I will outline our plans to create several further resources and reflect on the successes and difficulties encountered so far.

Kierann Shah

Talk

Discussion

Discussion

Rebecca Smethurst (University of Oxford)

Talk

Engaging on YouTube: Lessons learnt from 9 months of creating content

In October 2018, the "Dr Becky" YouTube channel was born. The aim was to engage and inspire people with astronomy topics, presented with the usual academic narrative but at a high school Physics level. With the recent results suggesting that people are engaging with scientific falsifications on YouTube, such as the Flat Earth Theory, it is important that more scientists are visible on this platform. Topics of videos on the "Dr Becky" channel range from a monthly roundup of astronomy news, to explaining unsolved mysteries in Physics, and to how 110 years worth of results culminated in allowing us to state that every galaxy contains a supermassive black hole at its centre. As of March 2019, the channel has 14,500 subscribers and 315,000 total video views. In this talk, I will outline my lessons learnt navigating the world of click bait, comments and the YouTube algorithm to engage as many people as possible with current astronomy results.

Becky Parker (IRIS)

B. Parker (IRIS)

Invited

Engaging schools in cutting edge research

The Institute for Research in Schools (IRIS) makes cutting edge research projects open to school students and their teachers. We do this by making data accessible to schools and also by lending out kits. We support schools across the country and many teachers find our research programmes reinvigorating CPD for them.

We have national programmes on space science, astrophysics, particle physics, chemistry, environmental science, antibiotic resistance, engineering, wellbeing and genomics. The talk will outline opportunities to get involved or develop similar approaches with local and regional schools based on research.

Gregory Brown (Royal Observatory Greenwich)

G. Brown (Royal Observatory Greenwich), D. Patel (Royal Observatory Greenwich)

Talk

From concept to completion: a case study in producing a successful outreach programme

Designing effective outreach sessions isn't easy. Coming up with an original premise is hard enough, let alone taking it from a moment of inspiration to a full-fledged programme. But while every programme is different, with its own unique challenges to face, there are some issues that are common to all: providing an engaging experience, pitching content at an appropriate level, covering relevant curriculum links and dealing with the issues associated with equipment and resources.

At the Royal Observatory Greenwich we run a successful outreach programme providing exciting practical demo-filled Science Theatre Shows to students from KS1 all the way to Post-16, covering multiple topics in the fields of Physics and Astronomy. In this talk, using the recent development of our Moon-themed shows as a case study, I'll talk about the process for the design, implementation and evaluation of our shows. I'll also discuss how our Teacher Forum provides a connection to the very people we are building our shows for, how this helps in our development and evaluation, and how we attempt to strike a balance between spectacle, content and ease of presentation.

Martin Archer (Queen Mary University of London)

M.O. Archer (Queen Mary University of London)

Talk

How to undertake a programme of deep research-based engagement with schools and evaluate it

School students rarely experience science in the same way as researchers and educational research has highlighted the limited impact of typical STEM outreach interventions. However, to address this there are a number of growing efforts for school students to undertake independent project work with direct links to current scientific research.

Queen Mary University of London's Physics Research in School Environments (PRiSE) programme is one such example. Aimed at 14-18 year olds, the programme currently consists of four projects whereby students and teachers are supported by active researchers. 50 diverse London schools have participated in these 6-month long projects thus far.

We present our template for these projects and their evaluation that can easily be adopted

by other institutions. The programme has shown the significant benefits such experiences have on both students and teachers, such as increased confidence and skills development. Furthermore, developing and delivering these projects can also impact upon researchers giving new context to their research topic and, in a small number of cases, producing novel and unexpected scientific results. We finally highlight elements of good practice and the support available to apply this template to your own research area within your institution.

George Bendo (Jodrell Bank Centre for Astrophysics)

George Bendo

Poster

Introducing the General Public to FITS Images

Although fully-processed astronomical images in FITS format as well as the tools to work with these files are publicly available, neither most educators nor the general public are aware of the existence of these data or how to access them. Through work with secondary school and university undergraduate students, I have developed a series of activities that teach people how they can download astronomical FITS files and perform quantitative analyses with these data. I have written an introduction to using the DS9 image viewer aimed at a very broad audience, and I have also developed several lab scripts, including different versions for secondary school and for university students. These scripts not only teach students about astronomical concepts such as stellar ages and metallicities, the Kennicutt-Schmidt law, and the expansion of the universe but also explain how to make photometric and spectroscopic measurements. These materials are available online as a general teaching resource, and I am continually working to expand the materials available.

Becky Parker (IRIS)

Becky Parker (IRIS), Laura Thomas (IRIS), Olivia Johnson (STFC)

Poster

IRIS Webb Telescope Project Student Poster 1

The Institute for Research in Schools (IRIS) helps schools to provide opportunities for their students to undertake original research using existing datasets. This poster shows the results of work on the Webb: Cosmic Mining project, in which students have used data from the Spitzer Space Telescope to identify potential targets for the James Webb Space Telescope.

The project was scoped by IRIS in collaboration with the UK Astronomy and Technology Centre.

Laura Thomas (IRIS)

Becky Parker (IRIS), Laura Thomas (IRIS), Olivia Johnson (STFC)

Poster

IRIS Webb Telescope Project Student Poster 2

The Institute for Research in Schools (IRIS) helps schools to provide opportunities for their students to undertake original research using existing datasets. This poster shows the results of work on the Webb: Cosmic Mining project, in which students have used data from the Spitzer Space Telescope to identify potential targets for the James Webb Space Telescope. The project was scoped by IRIS in collaboration with the UK Astronomy and Technology Centre.

Becky Parker (IRIS)

B. Parker (IRIS), IRIS students

Poster

IRIS Webb Telescope Project Student Poster 3

The Institute for Research in Schools (IRIS) helps schools to provide opportunities for their students to undertake original research using existing datasets. This poster shows the results of work on the Webb: Cosmic Mining project, in which students have used data from the Spitzer Space Telescope to identify potential targets for the James Webb Space Telescope. The project was scoped by IRIS in collaboration with the UK Astronomy and Technology Centre.

Jake Morgan (Jodrell Bank Centre for Astrophysics, University of Manchester)

Jake Staberg Morgan, Naomi Asabre Frimpong and the Jodcast Team (all JBCA)

Poster

Keep on Jodding: The Jodcast at 13

The Jodcast was established by astronomy PhD students and postdocs of the Jodrell Bank Centre for Astrophysics, University of Manchester since 2006. It is a bi-monthly podcast which aims to inform the public about latest astronomy research results, to motivate young people and students to pursue careers in science and to make astronomy plain and understandable to all.

As part of this update, we present the results of a listener survey conducted in 2016. The result show a listener demographic that is overwhelmingly white, male and well-educated, with many listeners holding at least a Bachelor's degree in a scientific field. The average listener age is 55, and they are typically keen amateur astronomers, with many owning their own telescopes. The majority of our listeners are UK-based, with North America being the second-most represented.

Recent accomplishments include hosting a Jodcast Live episode at Jodrell Bank Observatory (JBO), attended by more than 50 people, and securing a permanent studio space. More Live outings are planned for the Bluedot Festival 2019 and the inaugural Manchester Podcast Festival in October 2019, in order to reach a wider and more diverse audience. The show is keen to represent the changing face of professional astronomy, and has covered astronomy-adjacent issues such as open access, the representation of women in STEM fields and science policy and communication. With these, the show is well placed to "Jod On" for the foreseeable future.

Adriana Cardinot (National University of Ireland Galway)

Adriana Cardinot (NUI Galway), Andy Shearer (NUI Galway)

Poster

Making Space Programme - Using arts to engage the community with astronomy

The twenty-first century has brought increased attention to science, leading to enhanced research in all areas of science including astronomy education. Astronomy plays a crucial in understanding the world around us, in strengthening science education and in enhancing public science literacy. It also has a unique power to engage a diverse community with science due to its universal appeal, to inspire wonder at all ages and to resonate uniquely with human questions about our place in the universe. However, astronomy should not be limited to this, as it has an interdisciplinary nature, which enables multiple career trajectories in science. The RAS funded Making Space Programme (MSP) is an astronomy outreach project that aims to bridge the gap between under-represented groups (socially, economically and educationally disadvantaged) and astronomy. Guided by the Universal Design for Learning (UDL) principles, we aimed at creating an environment in which everyone regardless of their background or previous knowledge could benefit from our activities.

We developed new approaches that combine astronomy and arts in order to tackle misconceptions and to promote astronomy by presenting the content in ways that make the learning accessible to everyone. Initial findings have shown that our activities have a significant potential to engage meaningfully diverse learners with astronomy and participants were highly positive about our approaches. During our presentation, we will share the approaches that we have developed so far along with ideas on how it can be used to communicate astronomy.

Martin Yates (Beal High School)

Martin Yates

Talk

Teaching Astronomy to the new curriculum

At Beal High School we offer GCSE Astroinomy - but not as a timetabled subject, rather as an extra-curricular activity via our Astronomy Club. This enables us to engage and capture the imagination of all our students without necessarily putting them under pressure for yet another public exam. However the new syllabus is proving a challenge - and we would like to share with conference delegates our ideas, techniques, successes and failures with it. We are also very keen to involve students beyound GCSE. We have a thriving sixth form Astronomy Cliub, and we would also like to share our experiences of teaching Astronomy to these highly motivated, high performing future scientists!

Megan Argo (University of Central Lancashire)

M. Argo (UCLan)

Talk

We Share the Same Moon: Science through Storytelling

We Share the Same Moon is a unique collaboration between astrophysicist Megan Argo and storyteller Cassandra Wye, with the aim of bringing together creativity and science in both formal and informal learning contexts, and of promoting cultural understanding through the use of sky lore stories from every culture represented in British society. It will help children, parents and teachers understand why science is important, and will reach a significant audience at a young age. With the close involvement of teachers in partner schools we are developing, testing and evaluating fully-accessible educational resources linking stories and science, and delivering public and schools workshops around the country. Currently in the pilot phase, the project is bringing to the UK for the first time the native American sky-lore storytelling tradition of teaching science through story. I will showcase some of our work so far, and the early evaluation of our resources from pilot sessions carried out to date.

Daniel Brown (Nottingham Trent University)

Daniel Brown (NTU)

Talk

Writing Skyscapes - Capturing engagement to offer engagement

Exploring the heavens above is usually associated with astronomy. This is a branch of science that is seen to engage the public easily, offer potential for outreach and can be an ideal background to develop science education on. Ensuring the different aspects of education, engagement and outreach are carried out successfully and impactful is more challenging when focusing upon projects that focus upon cultural astronomy. This area specifically deals with astronomy in a cultural context as well as societies and peoples interaction with the sky. Running projects in this specific field is highly interdisciplinary and inherently engaging communities. As a result, distinction between outreach and engagement start to become more fluid.

In this presentation we will be presenting an ongoing NTU Global Heritage project "Writing Skyscapes" that works with creative and critical writers to capture our current engagement with the sky. It includes a writing workshop at unique locations (including caves, rock art, and ice age landscapes) challenging our modern views of the sky. It engages, develops and re-engages the general public with an art exhibition of sky motivated imagery and writing.

Throughout our project the engagement and outreach aspect will be captured in various ways to illustrate reach and impact. These include hard data but also creative expressions. Overall, this talk will reflect upon how impact assessment and engagement then becomes a cyclic and recursive process that never ends.

Electrodynamics and energetics of the ionosphere-thermosphere system (IonosThermos)

Michael Kosch (Lancaster University)

M.J. Kosch (Lancaster University) and S. Nnadih (University of Cape Town

Talk

Estimating electron energy and electric field within sprites

Sprites are a gas discharge phenomenon in the mesosphere powered by the charge moment change from large lightning strikes within major convective thunderstorms. Typically, only 0.1% of all lightning strikes produce a sprite. Bright optical emissions of nitrogen appear around 40-90 km altitude for 10s of milliseconds. These may be observed by naked eye but are rarely reported. The phenomenon was predicted in 1925, first recorded in 1989 and first observed in South Africa in 2016. Here, the sprite occurrence rate is such that in less than one week more sprites are observed than in a whole decade in Europe. We use ground-based night-vision TV cameras fitted with optical filters to estimate the electron energy (which is of order 5 eV), and from this the electric field (which is of order 100 V/m), within a sprite.

Anasuya Aruliah (University College London)

A.L.Aruliah (UCL), I.McWhirter (UCL), D.G.Johnson (UCL), A.Apsit (UCL)

Talk

FPI and EISCAT radar observations of large upwellings and downwellings in the polar cap upper thermosphere

Mesoscale density structures in the polar regions are poorly represented by empirical atmospheric models used in satellite orbit determination. In particular they do not allow for heating from electrical currents generated by the solar wind-magnetospheric dynamo in the auroral regions. Heating causes upwelling of the denser air. On either side of a heating region there is downwelling as the atmosphere relaxes back to a normal state. Physics-based models are better able to represent the meso-scale structures, but are far too slow to be useful for near-instantaneous orbit prediction. Two nights are presented here as case studies to indicate the size of vertical winds and the horizontal extent of up and downwelling regions for geomagnetically quiet and active conditions. Long-lived up/downwellings have been observed by Fabry-Perot Interferometers measuring the vertical winds at Svalbard. Simultaneous measurements by the EISCAT Svalbard Radar have shown electron density enhancements and, in particular, field-aligned plasma flow driven by the neutral winds, consistent with large up/downwelling. We also used the UCL Coupled Middle Atmosphere Thermosphere (CMAT2) model to estimate the changes in density from a localised heat source, representative of auroral plasma flows. Finally we present initial results from the PHOENIX CubeSat which was one of the QB50 constellation of CubeSats launched in the summer of 2017. PHOENIX carries a miniaturised mass spectrometer, with the aim to provide the first in-situ mass spectrometer measurements since the two Dynamics Explorer spacecraft in the late 1970s- early 1980s.

Daniel Billett (Lancaster University)

D. D. Billett (Lancaster University), K. Hosokawa (University of Electro-Communications Japan), A. Grocott (Lancaster University), J. A. Wild (Lancaster University), A. L. Aruliah (University College London), S. Taguchi (Kyoto University), Y. Ogawa (Natio

Talk

Multi-instrument Observations of Dayside Ion-Neutral Coupling in the Auroral Zone

Recent research into F-region ion-neutral coupling has shown a stark increase in strength of the ion drag force due to ionisation brought about by the aurora. During auroral activity, mesoscale thermospheric winds are able to respond to changes in the ionospheric plasma drift on the order of minutes as opposed to hours. This has implications for the amount of energy deposited into the atmosphere via Joule heating, as well as the amount of atmospheric drag imposed on low Earth orbiting satellites. In this study, we present the first observations of dayside neutral winds under the influence of poleward moving auroral forms. We additionally use data from the Super Dual Auroral Radar Network (SuperDARN) and EISCAT Svalbard Radar (ESR) to compare ion drag response times before and after the auroral forms start, along with resultant Joule heating rates.

David Price (University of Southampton)

D. Price (University of Southampton), D. Whiter (University of Southampton)

Talk

Observations of Joule heating associated with an auroral arc above Svalbard

We present results that indicate the existence of two distinct neutral heating processes associated with a discrete auroral arc over Svalbard: a heavily asymmetric temperature increase, observed over a large altitude range, directly adjacent to the arc structure on its poleward edge only; and a varying temperature increase, seen within the arc itself, constrained to a narrow altitude range close to the mesopause. By utilising a range of observations and new analysis methods we are able to measure the atmospheric temperature profile, over auroral altitudes, at unprecedented temporal and spatial scales. The University of Southampton's Auroral Structure and Kinetics (ASK) instrument and the ESR (EISCAT Svalbard Radar) are used to measure precipitating particle energies and fluxes for the event in question. These parameters are used as an input to the Southampton ionospheric model to retrieve N2 volume emission rate profiles for the duration of the event. The University's complementary instrument HiTIES (High Throughput Imaging Echelle Spectrograph) records high resolution emission spectra of the aurora, which are then fit with a synthetic N2 spectra, generated with the modeled N2 volume emission rate profiles and a library of trial temperature profiles. The application of this technique allows us to produce a time series of best fit neutral temperature profiles and thus to distinguish between temperature changes due to variation in emission altitude and those due to localised heating associated with the arc’s electrodynamics.

Maria-Theresia Walach (Lancaster University)

M.-T. Walach (Lancaster University), A. Grocott (Lancaster University)

Talk

SuperDARN observations during geomagnetic storms, geomagnetically active times and enhanced solar wind driving

The Super Dual Auroral Radar Network (SuperDARN) was built to study ionospheric convection at Earth and has in recent years been expanded to lower latitudes to observe ionospheric flows over a larger latitude range. This enables us to study extreme space weather events, such as geomagnetic storms, which are a global phenomenon, on a large

scale (from the pole to magnetic latitudes of 40 degrees). We study the backscatter observations from the SuperDARN radars during all geomagnetic storm phases from the most recent solar cycle and compare them to other active times to understand radar backscatter and ionospheric convection characteristics during extreme conditions and to discern differences specific to geomagnetic storms and other geomagnetically active times.
We show that there are clear differences in the number of measurements the radars make, the maximum flow speeds observed and the locations where they are observed during the initial, main and recovery phase. We show that these differences are linked to different levels of solar wind driving.
We also show that when studying ionospheric convection during geomagnetically active times, it is crucial to consider data at mid-latitudes, as we find that during 19% of storm-time the equatorward boundary of the convection is located below 50 degrees of magnetic latitude.

Sean Elvidge (University of Birmingham)

S. Elvidge (University of Birmingham), L. Nugent (University of Birmingham)

Talk

The Key Thermospheric Parameters for Ionospheric Forecasting

Comprehensive, global and timely specifications of the Earth's ionosphere are required to ensure the effective operation, planning and management of a diverse range of systems impacted by space weather. Whilst much work has gone into accurate 'nowcasting' of the ionosphere our ability to forecast it is still limited. Since the ionosphere-thermopshere is such a strongly coupled system the only way to accurately forecast the ionosphere is to forecast the thermosphere.
The University of Birmingham is developing the Advanced Ensemble electron density (Ne) Assimilation System (AENeAS), a physics-based DA model of the coupled ionosphere-thermosphere system. AENeAS uses state-of-the-art mathematical techniques (the local ensemble transform Kalman filter) to assimilate data and to estimate covariances between the thermosphere and ionosphere. This allows the model to be self-consistently updated when ingesting data.
As well as describing how to estimate the thermosphere in a data assimilation model (when the primary source of data is ionospheric measurements), this paper explores the relative impact of the different species, winds and temperatures in the thermosphere on their ability to forecast the ionosphere. The results of this analysis can be used to inform future data collection missions with the eventual aim of providing accurate and actionable operational forecasts of the ionosphere.

ENGAGING THE PUBLIC AND SCHOOLS WITH SCIENCE THROUGH THE SOLAR SYSTEM (ENGAGEMENTSTP)

Anne Buckner (University of Leeds)

A. Buckner (University of Leeds), S. Lumsden (University of Leeds), R. Oudmaijer (University of Leeds), E. McNeill (University of Leeds), K. Johnston (University of Leeds)

Poster

A HOLOtta fun: explaining astrophysics using 3D holograms

"Illusion is the first of all pleasures" – Voltaire

Astronomical topics are intrinsically abstract and typically only 2D telescope images available as visual aids to explain complex ideas, which can greatly hinder their comprehension by people outside academia. For this reason we created an innovative schools workshop program which not only projects astronomical objects as giant 3D holograms, but allows the participants to watch astrophysical processes happen right in front of their eyes. The use of 3D holograms is a powerful, innovative approach to explain complex topics in an easy-to-understand format. They are inherently inspiring, engaging and capture participants imaginations. In this talk we will demonstrate how holograms are a cheap, easy and highly effective way to communicate astrophysical research.

Robert Walsh (University of Central Lancashire)

R.W. Walsh, C. Canovan, A. Rinsler

Poster

Blackpool PIER (Physics: Inspire, Engage, Research)- an illuminating, longitudinal study in low science capital engagement

The seaside resort of Blackpool, Lancashire holds a unique place in the affections of UK holidaymakers. In 2018 alone, over 16M for visited its iconic landmarks of the Blackpool Tower and Pleasure Beach, followed in autumn by the unique Blackpool Illuminations. However, soaring deprivation measures reveal a different resort. The percentage of pupils achieving good school exit exam grades is declining and is substantially below the UK average (40% compared to 65% nationally). It is estimated that in certain wards only 12% of young people will enter higher education. Blackpool is a prime example of a region with exceptionally “low science capital”.

This work describes preliminary results of an ambitious three-year longitudinal public engagement programme within the resort funded by the Science and Technology Facilities Council; Blackpool PIER. Two main engagement strands will be outlined.
Firstly, the programme works with a specific cohort of young people and consists of school visits and community events plus trips to specialised outreach facilities at UCLan, all with a focus on astronomy and astrophysics engagement. An overall aim is to inspire the group through activities that increase their exposure to and enhance their confidence in engaging with science and technology.
Secondly, plans will be outlined for an innovative solar physics-themed art installation to be premiered in the resort in Autumn 2019. Part-funded by STFC, "SUN" is a 7m diameter, suspended sphere with internal laser projection of NASA's SDO EUV imagery, forming a unique, 360-degree "shining" presentation of our closest star.

Martin Archer (Queen Mary University of London)

M.O. Archer (Queen Mary University of London)

Poster

Breaking out of the echo chamber by thinking outside of the box

Now more than ever has it become apparent (particularly online) that people tend to engage with that which aligns with their pre-existing beliefs, perceptions and interests. This is known as the echo chamber effect. This highlights that our typical public engagement may chiefly be reaching those already engaged with science and that we need to find ways of breaking out of the scientific echo chamber so that the work we do is made accessible to a diverse range of people.
Here I present one approach through YouTube (both with the BBC and my own personal channel) by creatively applying concepts within space plasma physics research to popular movies and television series, interests of mine outside of science. From starting points such as Star Wars, Marvel, Rick and Morty, and Black Mirror we can communicate aspects of our research such as magnetic confinement, reconnection, plasmoids, and planetary atmospherics amongst many others. Through analytics I show that audiences have overwhelmingly been drawn to this content because of the areas of popular culture and not the science. Therefore, through thinking laterally about our science we can attract those who might not actively engage with us otherwise.

Ciaran Beggan (British Geological Survey)

Ciaran Beggan (British Geological Survey), Steve Marple (Lancaster University)

Poster

Building a Raspberry Pi magnetometer network for schools in the UK

As computing and geophysical sensor components have become increasingly affordable over the past decade, it is now possible to design and build a cost-effective system for monitoring the Earth's natural magnetic field variations, in particular for space weather events.
Modern fluxgate magnetometers are sensitive down to the sub-nanoTesla (nT) level, which far exceeds the level of accuracy required to detect very small variations of the external magnetic field. When the popular Raspberry Pi single-board computer is combined with a suitable digitiser it can be used as a low-cost data logger. We adapted off-the-shelf components to design a magnetometer system for schools and developed bespoke Python software to build a network of low-cost magnetometers across the UK.
We describe the system and software and how it was deployed to schools around the UK. We show the results recorded by the systems from September 2017, one of the largest geomagnetic storms of the current solar cycle.

John Coxon (University of Southampton)

J. C. Coxon (Southampton), A. W. Smith (MSSL/UCL)

Poster

Engaging the public and schools with the Southampton Planeterrella

The Southampton Planeterrella is a modern reimagining of the original terrella created by Kristian Birkeland to explore his theories of solar-terrestrial physics. This recreation allows us to capture the public’s interest due to its spectacular nature. From there, we can engage the public with the history, the foundational science and the cutting edge of MIST science. In our initial engagement programme we have engaged over 4000 people and over 50 schools. In this poster, we share some vital statistics from our engagement programme and look at how we could improve our engagement and our evaluation, as well as what we could do to engage the public with auroral and space weather research in the future.

Richard Morton (Northumbria University)

Richard Morton, Carol Davenport, James McLaughlin, Joe Shimwell, Johnathan Sanderson, John Woodward (Northumbria University)

Talk

Imagining the Sun and Exploring Extreme Environments

Over the last 3 years, the Solar Physics Group and NUSTEM at Northumbria University have ben developing a programme for sustained engagement with schools in the North East. The hope is that we will be able to influence the attitudes of young people with regards to enjoyment and attainment in STEM subjects, and also raise the likelihood of their participation in STEM subjects at A-level and STEM careers. In particular, we have been focusing on working with schools whose students typically have low science capital. In 2016 we undertook a 1-year pilot project called Imagining the Sun (funded by an STFC Small Outreach Award), working with local artists and poets to deliver mixed outreach sessions, involving physics and art or poetry. The project reached over a thousand children and we undertook surveys of both primary and secondary school children to assess the impact of the interactions. During the talk, I will discuss the project delivery, how we undertook the surveys and what we learned. I will then discuss the latest incarnation of the programme, Exploring Extreme Environments (funded by an STFC Nucleus Award), which develops upon our pilot project and will be delivered over the next 3 years.

James McLaughlin (Dr)

McLaughlin, James A.; Boothroyd, Lynda G.; Philipson, Peter M.

Poster

Impact arising from sustained public engagement: A measured increase in learning outcomes

[based on McLaughlin+ 2018, Research for All, 2, 244; doi:10.18546/RFA.02.2.04]

This presentation details the impact arising from a sustained public-engagement activity with sixth-form students (16- to 17-year-olds) across two further education colleges during 2012/13. Measuring the impact of public engagement is notoriously difficult. As such, the engagement programme followed closely the recommendations of the National Co-ordinating Centre for Public Engagement (NCCPE) and their guidance for assessing Research Excellence Framework 2014 (REF2014) impact arising from public engagement with research.

The programme resulted in multiple impacts as defined by REF2014 under 'Impacts on society, culture and creativity'. Specifically: the beneficiaries' interest in science was stimulated; the beneficiaries' engagement in science was improved; their sciencerelated education was enhanced; the outreach programme made the participants excited about the science topics covered; the beneficiaries' awareness and understanding was improved by engaging them with the research; there was tentative evidence of an improvement in AS-level grades; there was indirect evidence of an improvement in student retention. These impacts were evidenced by the user feedback from the sixth-form students collected from 50 questionnaires (split 16 and 34 across the two further education colleges), as well as testimonies from both the teachers and individual participants. This article will be of interest to anyone looking at how to evidence that public engagement has produced impact, in particular with regards to impact arising from a sustained public-engagement activity.

Poster presenters

Martin Archer, Ciaran Beggan, Anne Buckner, John Coxon, Geraint Jones, Helen Mason, James McLaughlin, Richard Morton, Robert Walsh

Talk

Lightning Talks by Poster Presenters

1. Martin Archer - Breaking out of the echo chamber by thinking outside of the box
2. Ciaran Beggan - Building a Raspberry Pi magnetometer network for schools in the UK
3. Anne Buckner - A HOLOtta fun: explaining astrophysics using 3D holograms
4. John Coxon - Engaging the public and schools with the Southampton Planeterrella
5. Geraint Jones - Astrojots - Explaining space & its exploration with cartoons
6. Helen Mason – SunSpaceArt
7. James McLaughlin - Impact arising from sustained public engagement: A measured increase in learning outcomes
8. Richard Morton - SOLARNET - Building Public Engagement Capacity in the European Solar Physics Community
9. Robert Walsh - Blackpool PIER (Physics: Inspire, Engage, Research)- an illuminating, longitudinal study in low science capital engagement

William Dunn (UCL/MSSL, Harvard-Smithsonian)

W. Dunn (UCL/MSSL, Harvard-Smithsonian), J. Holdiship (UCL), L. Offer (RAS, UCL), M. Niculescu-Duvaz (UCL), T. James (UCL), R. Meyer (UCL), J. Smutna (Imperial), A. Francis (UCL/MSSL), K. Putri (UCL/MSSL), F. Hardy (UCL), H. Andrews (UCL), M. Rickard (UCL

Talk

Original Research By Young Twinkle Scientists (ORBYTS)

ORBYTS partners PhD students and Post-docs with schools in order to give teenagers (particularly those from under-represented backgrounds) the opportunity to contribute towards active space research. We have grown through word of mouth, from 1 school when we launched in 2015-2016 to 20+ researcher-school partnerships in 2018-2019 (~100s of school students). So far, this has lead school students to produce 4 publications in scientific journals (and we hope to add another 4 publications this year). Every school undertaking the programme in 2017-2018 asked to continue in 2018-2019 and we receive exceptional feedback from teachers and students alike. Logistically, the programme works as follows: after a launch event at a University, science researchers visit their partner schools fortnightly for 2 terms to have school students contribute to active research. At the end of these terms the schools present their work at our ORBYTS conference. Research topics so far have included: exoplanets, molecular spectroscopy, surface features of Mars, stellar formation, planetary aurorae, high redshift galaxies and more (depending on the research interests of the researcher). Our preliminary evaluation is suggesting that ORBYTS is having very positive impacts on student's aspirations, STEM knowledge and perceptions of 'who a scientist is' - addressing some of the chronic diversity challenges that physics faces. Based on this, we are very interested in partnering with more schools and researchers, to scale this impact to more students, and to work with other outreach/engagement groups to continue to develop our best practice and maximise our positive impact on.

Maria-Theresia Walach (Lancaster University)

M.-T. Walach (Lancaster University), D. Whitworth (Manchester University)

Talk

Outreach via existing platforms: “I’m a Scientist, Get me out of here!”

“I’m a Scientist, Get me out of here!” is a web-based outreach platform, produced by Mangorolla CIC, where school pupils from varying backgrounds, locations, and scientific knowledge can interact directly with scientists via web-based interfaces, such as a scheduled group-chat and a messaging board.

It is organised as a competition where scientists compete for student votes by answering their questions in order to win £500 for an outreach project.
In March 2019 we took part and became finalists competing against each other, so we have first hand experience into using knowledge about space weather, space in general, brown dwarfs and planetary science as a primary catalyst to spark interest. As it is a text-based outreach platform, the student engagement is different to more traditional methods, however the impact and reach is high. Furthermore, we show how the experience is comparatively low-effort for scientists to take part in, but valuable due to its reach as after taking part in "I'm a Scientist", students say they are more likely to study science post-16, and more likely to look for a job in science.

Helen Mason

Helen Mason, Martin Archer, Jasmine Sandhu, Robert Walsh, Stephanie Yardley

Talk

Panel discussion

Researchers from UKSP and MIST with a range of experience in public engagement will discuss a number of themes raised by the community. These might include how to get involved, their experiences so far, and any tips or good practice they've learnt along the way. If you would like to pose a question for discussion, please email hm11@damtp.cam.ac.uk by 15 June to add it to the pool.

Richard Morton (Northumbria University)

R. Morton (Northumbria)

Poster

SOLARNET - Building Public Engagement Capacity in the European Solar Physics Community

It is estimated that more than 600 scientists are actively involved in Solar Physics research in Europe. SOLARNET (funded by the European Commission under Grant Agreement number 824135) aspires at integrating: all group of scientists with complementary expertise in observational techniques, instrumentation, theoretical astrophysics, numerical simulations and modelling; the major European research institutions, research infrastructures, and data repositories in the field of high-resolution solar physics. As part of this large-scale network, we are aiming to build capacity in the SOLARNET community through Public Engagement training, and share best practice in effectively utilising outreach to engage and educate, engendering changes in attitudes - both amongst consortium members and the general public. In collaboration with experts in public engagement and science communication from NUSTEM at Northumbria University, we are designing a series of workshops in order to achieve this, which will be delivered in the next couple of years. Here, we discuss in detail some of the goals and methodology of the planned training.

Helen Mason (University of Cambridge)

H. Mason (University of Cambridge)

Poster

SunSpaceArt

The STFC funded SunSpaceArt project brings together scientists and visual artists to work in schools, with teachers and children, at upper primary and lower secondary levels. Through these creative STEAM (STEM + Art) activities the children have produced original, imaginative and beautiful art that communicates a deeper understanding of the Sun, solar system and 'Our Place in the Universe'. "Today I loved this lesson because the science and art inspired me" (student)

Sophie Murray (Trinity College Dublin)

S. A. Murray (TCD, DIAS), P. A. Higgins, D. Perez Suarez (UCL), P. T. Gallagher (DIAS), and the Sunspotter and Zooniverse Teams

Talk

Sunspotter: Solar Physics in the Classroom

Sunspotter.org was part of the Zooniverse collection of web-based citizen science projects. The scientific aim of the project was to establish the true relationship between sunspot complexity and solar flares, a topic constantly under discussion within the solar physics community. Citizen science was the perfect way to trawl through the huge datasets of sunspot observations to help this investigation, getting the general public to organise sunspot images in order of how complex they looked via a web-browser interface. Beyond the scientific results of the project, Sunspotter also became an invaluable tool for outreach related to solar physics and space weather. The activities undertaken throughout the project duration will be presented, particularly how it was used in the classroom, as well as lessons learned along the way.

Gabby Provan (University of Leicester)

G. Provan (University of Leicester, Jenny Carter (University of Leicester)

Invited

The importance of public engagement in higher education

Over the past fifteen years we have been involved in numerous public outreach activities, presenting auroral science to a wide range of audiences using a number of different tools. Here we will draw on our own experiences to examine public engagement by researchers in the MIST and the UKSP community; looking at purpose, people, process and evaluation. We will investigate the motivation and inspiration of researchers to engage in outreach activities. Next we will examine how to identify different audiences, including current efforts to widen participation in science, and the importance of parental involvement. We will present several engagement processes from different universities, and discuss stories of involvement and lessons learnt. We will finish by discussing how to best evaluate your engagement activity and examine the role of REF impact case studies in increasing the profile of public engagement in the university sector. Throughout the talk we will be discussing our involvement in Leicester's many engagement activities, including the Planetarrella, the Planetarium, SMILE-related events, and the University's A-level revision club. We will include discussion of a recent programme with the Somali Community Parents Association, which aims to link student-led activities with the wider community through a Space Celebration event. The overall aim is to motivate and inform your approach to public engagement and to assess its value.

EQUALITY, DIVERSITY, AND INCLUSION (EQUALITYDIVERSITY)

Fran Bagenal (University of Colorado)

F. Bagenal (University of Colorado)

Talk

Demographics of Astrophysical, Planetary and Space Sciences

For the past 25 years or so I have been digging into the demographics of our field. I guess it is the scientist in me. But I also find that the numbers can challenge our assumptions about what is shaping the demographics of our field. In this regard, it is useful to look at the demographics of scientific fields in different countries. Which country would you guess to have the highest percentage of PhDs in physics awarded to women? It's probably not a country that comes to mind. Then there is the usual assumption that the numbers must be getting better with time. Did you know that the percentage of US physics bachelors degrees awarded to women has been dropping for the past 15 years? But it is not just the gender issues that matter. Key questions for our scientific fields are whether our education systems providing sufficient people with appropriate training and whether our research institutions can maintain a healthy workforce pipeline. In this presentation I will review the numbers, offer some reflections, and outline some potential local actions that could change the demographics of the physical sciences.

Anuradha Damale (UKSEDS)

A. R. Damale (UKSEDS), A. C. O'Brien (University of Glasgow), H. B. Thiemann (The Open University)

Talk

Diversity in Student Space Activities in the United Kingdom

UKSEDS (UK Students for the Exploration and Development of Space) is the UK's national student space society, connecting students and young professionals to opportunities, advice, and experience in the space sector.
The UK Space Agency's aim is for the UK to make up 10% of the global sector by 2030. To meet this goal, a larger and more diverse workforce is needed. It is widely acknowledged that diverse workforces in industry lead to greater innovation and productivity.
We analysed the demographic data we gathered at the National Student Space Conference 2019. We compared this data to the UK census, as well as to the space workforce in the UK (e.g. the RAS demographics survey of 2016 and Engineering UK's 2018 report), finding that

delegates were significantly more diverse than the sector as a whole. 22.6% of NSSC delegates declared their sexuality as homosexual/gay, bisexual or other, compared to 18% of the permanent workforce, and 18.3% of NSSC delegates identified as Black, Asian, Mixed or Other, compared to 6% of permanent workforce respondents to the RAS survey.
We aim to investigate why NSSC attracted a more diverse cohort than the sector at large, and are continually and reflexively working on making all our activities as inclusive as possible. Subsequently, we aim to improve opportunities and remove barriers for underrepresented groups in the next generation of the space sector, whilst setting an example of best diversity and inclusion practice for the sector.

Chris Arridge (Department of Physics, Lancaster University)

C.S. Arridge (Lancaster University)

Talk

If we’re not snowflakes, why are we more likely to suffer poor mental health?

(Trigger words: self-harm; depression; anxiety; suicide) 'Billie is a bright, hard-working PhD student but feels like an imposter and doesn’t "fit in". Her supervisor emails her at midnight, 7am, 10.30am, and at 3pm demands to know why she hasn’t replied yet. She presented a poster at her first conference. Someone said it was incremental and meaningless, but another thought it was amazing and asked for a preprint. Billie ruminates about the word "incremental". Everyone uses it at journal club. The gregarious student next to her got lots more attention, even though his poster was just an advert for work he hadn’t done yet. Her social media is full of posts from people having a great time at the conference; but she’s overwhelmed and has to go back to her hotel at the end of each day. Billie cuts herself. Everyone tells Billie that she must publish, so she skips the next conference to finish her paper and it’s published in Nature Astronomy. It hasn’t been cited yet. A postdoc says that’s because she didn’t present it at the conference she missed. Her office-mates think she’s weird for wearing long sleeves in July. Billie’s supervisor rips her ideas to shreds, even though she was working on them whilst missing her Mum’s birthday. Billie is lonely and isolated. Is there any wonder that she’s sitting at on her bed with two packs of paracetamol?' In this talk I will discuss mental health, personality and stigmatisation through the lens of modern research cultures.

Vinesh Maguire-Rajpaul

Organisers of the EDI parallel session, plus speakers from the session

Talk

Panel discussion

An opportunity for session attendees to pose questions to a panel including the speakers from the session, and to have an open-ended discussion on issues relevant to equality, diversity and inclusion.

Jane Greaves (Cardiff University)

J. S. Greaves (Cardiff University)

Talk

Prestige bias in allocation of telescope time?

Research has shown that gender and nationality can affect the award of time to use telescopes, in systems that are supposed to be fair and transparent. Motivated by anecdotal suggestions, I investigated whether being on the time awarding committee could also influence outcome (work published in Res. Notes AAS 2 203). For a major telescope facility with entirely open data on membership and time awards, I found that gender was again a factor in success - but being on the committee had an effect ten times larger. Proposers tripled their chances of getting telescope time by being on the committee, compared to periods both before and after. My original hypothesis was that being seen at a high-level meeting created an unconscious bias, i.e. an impression that the proposer must be a high-level scientist. However, the magnitude of the effect may suggest more powerful biases are at work - discussion of what is going on, how better to investigate it, and solutions for more fairness are thus highly welcome outcomes for this talk.

Stephen Wilkins (University of Sussex)

S. Wilkins (Sussex)

Talk

Representation in Physics Higher Education

Quantifying exactly how undergraduate participation in physics represents elements of the UK's population is a key step in ultimately making it representative. By combining data from the Higher Education Statistics Authority (HESA) and the Office for National Statistics (ONS) we have quantified how representative the undergraduate population in physics and other STEM disciplines are in terms of ethnicity, gender, socio-economic background, and regional domicile. This analysis reveals that various groups are significantly under-represented in physics despite actually being over-represented in higher education overall and even across the STEM disciplines.

Ashley Spindler (University of Hertfordshire)

Talk

Social Capital and its Role in Community Building, Social Justice and Allyship

Social Capital, as a concept in philosophy and sociology, is defined as an individual's ability to affect their community. This ability comes from an individual's access to social resources, such as people and public spaces, the relationships among those resources, and the impact relationships have on those resources. In the context of social justice, equality and diversity, a person's Social Capital can be understood as their ability to affect the thinking of those around them to improve the life and working conditions of marginalised groups. In this talk, I will discuss the theoretical underpinnings of social capital, provide examples of how social capital can be used in the context of allyship for marginalised groups, and finally discuss dangers presented by the accumulation and monopolisation of social capital.

Vivienne Wild (University of St Andrews)

V. Wild, A. Kohnle, P. Miles, K. Mavor (Schools of Physics and Astronomy, and Psychology and Neuroscience, University of St Andrews)

Talk

The impact of gender on the student experience of physics undergraduates

The female:male ratio on the integrated Physics Masters (MPhys) programme at the University of St Andrews is significantly lower than on our bachelors (BSc) programme. A higher fraction of women are leaving Physics early on, representing the start of the 'leaky pipeline', where more women than men drop out of STEM subjects while progressing up the career ladder (Ivie, 2013; UK science select committee, 2014). The MPhys:BSc gender discrepancy is thought to be a country-wide problem, however, the cause(s) remain unknown. Constructs such as self-efficacy and sense of belonging have been identified as strong predictors of career intentions and persistence in physics (e.g. Hazari, 2010) and STEM more generally (e.g. Lewis, 2017). However, more work is needed to understand the underlying mechanisms by which these constructs, alongside institutional culture and practice, might impact participation, achievement and persistence in physics. During Summer 2017 we designed a survey using validated standardized items from the literature to test four psychological constructs that may play a role in why female physics students leave the course early. Survey constructs were chosen based on known or hypothesized variation with gender, their likelihood to affect academic performance and career intention and documented interventions allowing improvements. During September 2017 and April 2018 we collected survey responses from around 400 undergraduates (~35% of students are female), in all years 1-5 of the physics course. Responses were linked to grade and gender information. I will present the preliminary results from this ongoing study.

Rachael Livermore

Rachael Livermore

Talk

Unenforced Policies as a Leak in the Pipeline

In recent years there has been increasing focus on policies to deal with bullying and harassment in astronomy. Despite numerous high-profile cases, it remains vanishingly rare for those found guilty of breaching these policies to face meaningful consequences. This frequently leaves the affected parties with no choice but to leave astronomy, and since they are disproportionately members of marginalised groups, this effect contributes to the leaky pipeline. I will discuss the ways that the culture of astronomy prioritises the careers of bullies and harassers over those of their victims, how survivorship bias has excluded the narratives of those who ultimately leave the field, and what steps can be taken to plug this leak in the pipeline.

EXPLOSIVE ENERGY RELEASE IN THE SOLAR ATMOSPHERE (SOLARATMOS)

Thomas Rees-Crockford (Northumbria University)

T. Rees-Crockford (Northumbria University), E. Scullion (Northumbria University), D.S. Bloomfield (Northumbria University), S.-H. Park (Nagoya University)

Talk

2D and 3D Kinematic Analysis of an Ideal-MHD Prominence Eruption

We carry out multi-dimensional kinematic analysis of a prominence eruption in order to characterise the role of eruptive ideal-MHD instabilities. Using SDO/AIA and STEREO/EUVI-A we reconstruct the leading edge of the prominence in 3D, as observed between 26-Feb-2013 20:30:00 UT and 27-Feb-2013 05:45:00 UT. We use a novel semi-automated, dual, edge detection method to precisely detect the leading edge and create height-time profiles from SDO/AIA image sequences in He II 30.4 nm, to analyse the kinematics of erupting plasma along radial slits intersecting the leading edge coordinates. Constraining the power index parameter of fitted functions characterizing the linear and non-linear phases of the eruption, we investigate a set of fits of the eruption profile across all slits and identify the best fit in order to compare different eruption mechanisms. We also parameterise the onset time of the acceleration phase in order to confine the start time of the torus instability. For the first time, 3D kinematic analysis has identified a significant delay in the onset time of the acceleration phase together with a corresponding critical height at which acceleration starts to occur, as a function of position along the leading edge, which is in remarkable agreement with the determination of the critical height according to the decay index governing the torus instability.

Daniel Johnson (University of Central Lancashire)

Daniel Johnson (University of Central Lancashire)

Poster

Coronal Mass Ejection Energy Approximations

Sunspot rotation is believed to inject energy into active region magnetic fields. Active regions are observed to release energy via extreme events such as solar flares and coronal mass ejections (CMEs hereafter) that can have significant effects on the Earth and heliosphere. To establish a link between energy injection by sunspot rotation and energy ejection via eruptive

events, a robust method of defining energy transport must be established. Energy ejection by CMEs is investigated here. Whilst solar flares release electromagnetic energy at the event site, CMEs carry a range of dynamic energies away from the Sun (e.g. thermal energy, kinetic energy, magnetic energy and potential energy). These energies evolve as the CME propagates and therefore snap-shot measurements of energy does not necessarily determine the long-timescale properties of the CME. Accurate measurements are often computationally expensive and slow, making a statistical analysis of sunspot rotation and CME events difficult using high accuracy approximations. This work aims to investigate the accuracy of approximating energetic properties of CMEs using existing catalogued kinematic data. CMEs are analysed using an optical flow method to determine plane-of-sky projected velocity fields, additionally projected mass fields are determined using Thompson scattering theory. This allows the determination of CME kinetic and gravitational potential energy. These values are then compared to approximations derived using catalogued data to determine any discrepancy between the two, and whether any simple scaling can be used to correct for this.

John Armstrong (University of Glasgow)

J. Armstrong (University of Glasgow), L. Fletcher (University of Glasgow/University of Oslo), C. Osborne (University of Glasgow)

Poster

Deep learning as a tool for chromospheric flare imaging

Deep learning is a subset of machine learning which utilises deep neural networks (networks with more than one hidden layer) to learn how to perform a task without being explicitly programmed to do so. Machine learning (and deep learning) has seen a rise in popularity in the last several years with many of the techniques being applicable to solar physics if used in the correct way. Here, I aim to discuss the fundamentals of how deep neural networks operate and how this can be used to automate laborious tasks and approximate functions which can lead to faster analysis tools. I will discuss the use of deep learning as an alternative for seeing correction in flare observations through the use of autoencoders and the application of such a model to the 6th September 2017 X9.3 flare. Finally, I will talk about the possibilities of using instance segmentation learning for flare ribbon tracking in H? and Calcium ?8542 and the physics we can explore by doing so.

Eduard Kontar (University of Glasgow)

E. P. Kontar (University of Glasgow), Natasha L. S. Jeffrey (University of Glasgow), A. Gordon Emslie (WKU, USA)

Talk

Energetics of solar flare explosive energy release

Solar flare hard X-ray (HXR) spectroscopy serves as a key diagnostic of the accelerated electron spectrum. However, the standard approach using the collisional cold thick-target model poorly constrains the lower-energy part of the accelerated electron spectrum, hence the overall energetics of the accelerated electrons and consequently the flare energetics are typically constrained only to within one or two orders of magnitude. In this talk, I will discuss the development and application of a physically self-consistent, warm-target approach that involves the use of both HXR spectroscopy and imaging data. The approach allows an accurate determination of the electron distribution low-energy cutoff, and hence the electron acceleration rate and the contribution of accelerated electrons to the total energy released, by constraining the coronal plasma parameters. Using a solar flare observed in X-rays by RHESSI, we demonstrate that using the standard cold-target methodology, the low-energy cutoff (hence the energy content in electrons) is essentially undetermined. However, the warm-target methodology can determine the low-energy electron cutoff with ~7% uncertainty at the 3σ level, hence it permits an accurate quantitative study of the importance of accelerated electrons in solar flare energetics.

Lianne Fyfe (University of St. Andrews)

L. E. M. F. Fyfe (St Andrews), I. De Moortel (St Andrews), T. Howson (St Andrews)

Talk

Establishing Observational Signatures of Coronal Heating Mechanisms

Closing the gap between observations and numerical models is a critical step in helping us to identify the mechanism(s) responsible for coronal heating. Through the use of forward modelling, we can transform the model results into synthetic emission data, allowing us to compare models and observations in a meaningful way. We present the results of numerical simulations investigating the braiding of two coronal magnetic flux tubes. Using forward modelling, we infer if there are any observational signatures associated with this particular model's heating mechanisms. We discuss the evolution of synthetic intensities and Doppler velocities in order to predict observables which would highlight the existence of such

processes in the Sun's atmosphere. Analysing such results from multiple heating models will allow us to identify characteristics of energy release in the solar corona.

Iain Hannah (University of Glasgow)

I. G. Hannah

Invited

Explosive energy release in the flares of Solar Cycle 24

We are now at the end of cycle 24, which since late 2008 has given us many new examples of the explosive energy release in flares. This is the rapid process in which energy is liberated in the solar atmosphere to accelerate particles, heat material and produce bulk motions. The multi-wavelength signatures of flares have been studied in great detail using existing and new ground and space-based telescopes, driving theoretical developments to quantify the underlying physical processes. Although our understanding of these mechanisms has progressed over the last solar cycle, questions of how, why and where explosive energy release occurs remains a fundamental and long-standing problem in solar physics. In this talk, I will recap some of the advances made in understanding solar flares of all sizes during the last solar cycle, and the new opportunities that exist in the coming cycle 25.

Pearse C. Murphy (Trinity College Dublin and Dublin Institute for Advanced Studies (DIAS))

Pearse C. Murphy (TCD/DIAS), Pietro Zucca (ASTRON), Eoin P. Carley (TCD/DIAS), Peter T. Gallagher (DIAS/TCD)

Poster

Interferometric imaging of Type III bursts in the solar corona

The size of radio emission sources at the plasma frequency in the solar corona is thought to be fundamentally limited by scattering off of random density inhomogeneities. Radio interferometers such as the LOw Frequency ARray (LOFAR) have been increasingly used to study radio bursts in the solar corona over the last number of decades. Observations with LOFAR's tied-array imaging technique suggest that the source sizes of Type III radio burst emission is limit by coronal scattering. However, it has yet to be determined whether source sizes observed with tied-array imaging are a result of this fundamental limit or an effect due to interpolation used in that imaging mode.

LOFAR interferometric imaging gives another measure of source size and its resolution can be much finer. Here, an interferometric dataset of a Type IIIb burst (a Type III burst showing frequency striations) observed with an 86 km baseline is analysed. We show that despite a sub arc minute resolution coronal source sizes are significantly larger than expected from analysis of fine structure in the burst spectrum further supporting the theory of scattering being the limiting factor in coronal radio observations.

Aaron Peat (The University of Glasgow)

A. Peat (University of Glasgow), N. Labrosse (University of Glasgow), A. S. Rodger (University of Glasgow), B. Schmieder (Observatoire de Paris)

Poster

Joint Prominence Observation with ALMA, SDO/AIA, and IRIS.

We present the first full Atacama Large Millimeter Array (ALMA) observation of a solar prominence from observing cycle 4 in band 3 (84-116 GHz), with simultaneous observations from the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) in 171Å, 193Å, 211Å, and 304Å; and the Interface Region Imaging Spectrograph (IRIS) in C II (1330Å), Si IV (1400Å), and Mg II (2796Å). The prominence was located in the South West of the Sun and appeared to have no major large scale evolution over the ALMA observation period. However, at the end of the ALMA observation period we observe a small scale plasma structure extending from the top of the prominence towards the solar limb. This is seen rather faintly in ALMA, but easily seen in 304Å from SDO/AIA and C II and Mg II from IRIS/SJI. The SDO/AIA and IRIS observations extend beyond the ALMA observing window and confirm this evolution. This structure is seen to reach the solar limb in 304Å and C II and Mg II.

Chris Osborne (University of Glasgow)

C. M. J. Osborne (University of Glasgow), J. A. Armstrong (University of Glasgow), L. Fletcher (University of Glasgow)

Talk

Learning to Invert a Solar Flare Atmosphere with Invertible Neural Networks

During a solar flare, it is believed that reconnection takes place in the corona followed by fast energy transport to the chromosphere. The resulting intense heating strongly disturbs the chromospheric structure, and induces complex radiation hydrodynamic effects. Interpreting the physics of the flaring solar atmosphere is one of the most challenging tasks in solar physics. I will present a novel deep learning approach, an invertible neural network, to understanding the chromospheric physics of a flaring solar atmosphere via the inversion of observed solar line profiles in Hα and Ca II λ8542. Our network is trained using flare simulations from the 1D radiation hydrodynamics code RADYN and then applied to an observation of an M1.1 solar flare taken with SST/CRISP instrument. The inverted atmospheres obtained from observations provide physical information on the electron number density, temperature and bulk velocity flow of the plasma throughout the solar atmosphere ranging from 0-10 Mm in height. The density and temperature profiles appear consistent with the expected atmospheric response, and the bulk plasma velocity provides the gradients needed to produce the broad spectral lines whilst also predicting the expected chromospheric evaporation from flare heating. We conclude that we have taught our novel algorithm the physics of a solar flare according to RADYN and that this can be confidently used for the analysis of flare data taken in these two wavelengths. This algorithm can also be adapted for many inverse problems whilst providing extremely fast results. The network is open source and freely available.

David C. L. Millar (University of Glasgow)

D. C. L. Millar (University of Glasgow), L. Fletcher (University of Glasgow)

Poster

Mapping oscillations in the flaring chromosphere with CRISP

Quasi Periodic Pulsations (QPP) are intensity fluctuations which are observed during solar flares. The emergence of these pulsations and their characteristic periods of oscillation can reveal physical processes underlying the flare activity.

Recent observations in EUV have suggested that flare energy deposited in the lower solar atmosphere can excite the chromosphere's resonant ~3-minute oscillations. Presented here is a study into the response of the chromosphere to an M-class solar flare (2014-09-06) using ground based imaging and spectroscopy from the CRISP instrument at the 1-m Swedish Solar Telescope. Lightcurves from the chromospheric spectral lines Hydrogen-alpha and Calcium II 8542 have been investigated using Fourier power and wavelet analysis to create 2-D maps of oscillatory behaviour around the flare footpoints and a large sunspot before and after the flare brightening. These 2-D maps have been created across the width of both spectral lines, allowing a range of heights in the solar atmosphere to be studied.

Jack Reid (University of St Andrews)

J. Reid, A. W. Hood, P. J. Cargill, C. E. Parnell, C. D. Johnston

Poster

MHD Avalanches and the Heating of the Solar Corona

Parker's nanoflare model is one possible mechanism for heating the solar corona. The suggestion is that coronal loops may be heated through the release of magnetic energy in multiple, small-scale events.

Our work aims to show that the continuous driving of the coronal magnetic field, by identified photospheric velocities, can result in a magnetohydrodynamic (MHD) 'avalanche', a succession of multiple, reconnection-triggered heating events.

Using three-dimensional MHD simulations, we simulate the formation, twisting, and disruption of magnetic threads within a coronal loop, and determine the distribution of heating produced. Instability and the subsequent formation of strong current layers supports a 'bursty' sequence of localized heating events, consistent with concepts of impulsive heating, associated with nanoflares, and giving a seeming 'background' level of heating. The heating derived from this simulation is then used to investigate the thermal evolution of the plasma along the magnetic field. It is shown that the heating from this MHD avalanche may be capable of maintaining realistic coronal temperature and density.

James McLaughlin (Northumbria University)

McLaughlin, J. A.; Nakariakov, V. M.; Dominique, M.; JelÃ-nek, P.; Takasao, S.

Poster

Modelling Quasi-Periodic Pulsations in Solar and Stellar Flares

Solar flare emission is detected in all EM bands and variations in flux density of solar energetic particles. Often the EM radiation generated in solar and stellar flares shows a pronounced oscillatory pattern, with characteristic periods ranging from a fraction of a second to several minutes. These oscillations are referred to as quasi-periodic pulsations (QPPs), to emphasise that they often contain apparent amplitude and period modulation. In this presentation, we will review the current understanding of quasi-periodic pulsations in solar and stellar flares. In particular, we will focus on the possible physical mechanisms, with an emphasis on the underlying physics that generates the resultant range of periodicities. These physical mechanisms include MHD oscillations, self-oscillatory mechanisms, oscillatory reconnection/reconnection reversal, wave-driven reconnection, two loop coalescence, MHD flow over-stability, the equivalent LCR-contour mechanism, and thermal-dynamical cycles. We will also provide a histogram of all QPP events published in the literature at this time. The occurrence of QPPs puts additional constraints on the interpretation and understanding of the fundamental processes operating in flares, e.g. magnetic energy liberation and particle acceleration. Therefore, a full understanding of QPPs is essential in order to work towards an integrated model of solar and stellar flares.

Jack Jenkins (Mullard Space Science Laboratory - UCL)

J.M. Jenkins, M. Hopwood, P. Démoulin, G. Valori, G. Aulanier, D.M. Long, L. van Driel-Gesztelyi

Talk

Modelling the Effect of Mass-draining on Prominence Eruptions

Quiescent solar prominences are observed to exist within the solar atmosphere for up to several solar rotations. Their eruption is commonly preceded by a slow increase in height that can last from hours to days. This increase in the prominence height is believed to be due to their host magnetic flux rope transitioning through a series of neighbouring quasi-equilibria before the main loss-of-equilibrium that drives the eruption. Recent work suggests that the removal of prominence mass from a stable, quiescent flux rope is one possible cause for this change in height. Here we present a simple model to quantify the effect of "mass-draining" during the pre-eruptive height-evolution of a solar flux rope. The flux rope is modeled as a

line current suspended within a background potential magnetic field. We first show that the inclusion of mass, up to 1e12 kg, can modify the height at which the line current experiences loss-of-equilibrium. Next, we show that the rapid removal of mass prior to the loss-of-equilibrium can allow the height of the flux rope to increase sharply and without upper bound as it approaches its loss-of-equilibrium point. This indicates that the critical height for the loss-of-equilibrium can occur at a range of heights depending explicitly on the amount and evolution of mass within the flux rope. Finally, we demonstrate that for the same amount of drained mass, the effect on the height of the flux rope is up to two orders of magnitude larger for quiescent than for active region prominences.

Craig Johnston (University of St Andrews)

C. D. Johnston (University of St Andrews) & S. J. Bradshaw (Rice University)

Poster

Modelling the Evaporative Response to Explosive Energy Release in Coronal Loops

We present the results of field-aligned simulations of the coronal plasma response to explosive heating events. During these events, an increase in the coronal density occurs because the increased coronal temperature leads to an excess downward heat flux that the transition region (TR) is unable to radiate. This creates an enthalpy flux from the TR to the corona. The density increase is often called chromospheric evaporation. Sufficiently high resolution of the TR is essential in numerical simulations in order to obtain the correct coronal density (Bradshaw & Cargill, ApJ, 2013). If the resolution is not adequate, then the downward heat flux jumps over the TR and deposits the heat in the chromosphere, where it is radiated away. Bradshaw & Cargill showed that with an under-resolved TR major errors occur in simulating the coronal density evolution. Therefore, we propose that the TR should be treated using an adaptive thermal conduction approach that broadens any unresolved parts of the atmosphere. We show that this method, referred to as TRAC, successfully removes the influence of numerical resolution on the coronal density response to heating while maintaining high levels of agreement with fully resolved models. When employed with coarse spatial resolutions, typically achieved in multi-dimensional MHD codes, the peak density errors are less than 3% and the computation time is three orders of magnitude faster than fully resolved field-aligned models.

Kristopher Cooper (University of Glasgow)

K. Cooper (University of Glasgow), I. Hannah (University of Glasgow), H. Hudson (University of Glasgow, University of California Berkeley), B. Grefenstette (California Institute of Technology), S. Krucker (University of Applied Sciences and Arts Northwest

Poster

NuSTAR observations of a repeatedly microflaring solar active region

We present several microflares from a recently emerged active region, AR12721, that were observed on 2018 September 9-10. Using both the Nuclear Spectroscopic Telescope Array (NuSTAR) and the Solar Dynamics Observatory's Atmospheric Imaging Assembly (SDO/AIA) the temporal, spatial, and spectral evolution of the microflares can be studied to determine the energy released, and the associated heating of the solar atmosphere. NuSTAR is an astrophysical X-ray telescope, with direct imaging spectroscopy providing a unique sensitivity for observing the Sun above 2.5keV. The active region microflares were below GOES A1 equivalent level, and the X-ray emission observed by NuSTAR peaks several minutes earlier than the EUV emission seen by SDO/AIA. From the NuSTAR X-ray spectra, we find that the temperature in some of the microflares reached up to 8MK but even at the time of peak emission the microflares are clearly multi-thermal.

Sarah Matthews (UCL-MSSL)

Sarah A. Matthews (UCL-MSSL), Louise K. Harra (UCL-MSSL)

Talk

Particle acceleration and the evolution of non-thermal line broadening in a solar flare

Stochastic particle acceleration by wave turbulence is one of the proposed mechanisms by which charged particles can be accelerated to high energies during solar flares, with the turbulence assumed to be generated during the primary energy release process. The role of Alfvén wave turbulence in the acceleration of protons and the broadening of soft X-ray lines was explored by Alexander & MacKinnon (1992) and applied to gamma-ray flares by Alexander & Matthews (1994). In this scenario, the peak of the line broadening corresponds to the peak wave flux, which precedes the peak in the hard X-ray and gamma-ray emission. This is observed to be the case in many HXR flares (e.g. Alexander et al., 1998; Harra, Matthews & Culhane, 2001). More recently, Kontar et al. (2017) compared the turbulent kinetic energy density derived from Hinode EIS observations with the non-thermal electron

energy inferred from RHESSI observations, concluding that in the flare studied there was a substantial reservoir of turbulence, the decay of which correlated well with the production of accelerated electrons. Here, we expand on this previous work by exploiting EIS sit-and-stare observations to examine the evolution of the wave energy density at high cadence and at multiple temperatures to further quantify the link between turbulence and electron acceleration.

Qian Xia (Northumbria University)

Q. Xia (Northumbria University), V. Zharkova (Northumbria University)

Talk

Particle Acceleration and Their Diagnostics in 3D Reconnecting Current Sheets with Magnetic Islands

Magnetic reconnection is an important mechanism to release magnetic energy in various events on the Sun and in the heliosphere and to generate energetic particles by the reconnection electric field in the vicinity of the X-nullpoint. We investigate acceleration of the protons and electrons from the ambient plasma dragged into a current sheet by magnetic diffusion process using PIC approach. We explore the role of the polarisation electric field induced by accelerated particles on their parameters with coalescent and squashed magnetic islands. Particle energy spectra and pitch-angle distributions in current sheets with single and multiple X-nullpoints are presented for different magnetic topologies, magnitudes of magnetic field, proton-to-electron ratios, ambient plasma densities and magnetic island shapes. The simulate parameters are compared with the observations of energetic particles in the solar atmosphere and the heliosphere.

Qian Xia (Northumbria University)

Q. Xia (Northumbria University), V. Zharkova (Northumbria University)

Poster

Particle acceleration in magnetic reconnection processes formed during CME eruption

Particle acceleration during magnetic reconnection has been extensively studied with numerical methods, such as test-particle and particle-in-cell simulations. Several particle acceleration mechanisms have been identified from the fluid and kinetic modelling of

magnetic reconnection phenomenon. Recent kinetic studies have identified a curvature drift along the reconnecting electric field (perpendicular to the reconnecting current sheet) as an important particle acceleration mechanism. This mechanisms becomes important for particle acceleration region at MHD scale in large volumes of interacting magnetic structures. In this study, we apply the test-particle approach to a global MHD simulation, using 3D ARMS code, which was used to simulate the onset and eruption of CMEs events from the corona base up to ~ 2 solar radii. The model simulations discover a few current sheets where particles can be accelerated: in the front of the coronal mass ejection (breakout current sheet) and the current sheet below the flux rope leading to a flare. We explore the difference of particle acceleration at difference locations and show the energetic particle distribution in two different scenarios describing the characteristics of energetic particles at the macroscopic MHD scale.

Valentina Zharkova (University of Hull)

S.Zharkov (Hull, UK), S.A.Matthews (MSSL/UCL,UK), V.V.Zharkova (Northumbria, UK), M.G.Druett (Stockholm, Sweden), C.Macrae (Hull, UK), I.E. Damasch (Brussles, Belgium)

Talk

Radiative and seismic signatures of the 6 September 2017 flare: observations versus simulations

In this paper we describe observational and simulated properties of emission and sunquakes generated by the largest 9.3 X-class flare of the current cycle on September 6, 2017. We analyse the events and their coronal and photospheric impacts using helioseismic techniques and HMI/SDO data supplemented by atmospheric observations from GOES, RHESSI, KONUS, AIA/SDO and Hinode. We also use observations of high resolution H-alpha emission by Swedish Solar Telescope, Lyman alpha observations by Lyra/PROBA and white light (WL) emission. The radiative signatures were simulated for Balmer hydrogen and Paschen (WL) emission using full NLTE radiative transfer models for hydrogen applied to hydrodynamic atmospheres heated by particle beams. We compare the emission contributions functions and seismic responses of flaring atmosphere heated by particle beams in this flare with that of the flare of 6 September 2011 generated at the maximum and minimum of solar activity. We evaluate energies and momenta delivered to the solar surface and interior and search for possible mechanisms of sun quake generation in each case. We show that despite the both events were accompanied by the sun quakes they exhibit strikingly different characteristics. This comparison allows us to derive the important properties of energy and particle transport in flaring atmospheres at the different phases of solar activity.

Mykola Gordovskyy (University of Manchester)

M. Gordovskyy, P.K. Browning (University of Manchester)

Poster

Reduced kinetic modelling of magnetic reconnection in non-neutral Harris sheet

Kinetic models of magnetic reconnection in the solar corona are usually limited to small spatial scales and short time scales. The spatial resolution is determined by the Debye length, while the time step is determined by the fundamental plasma frequency. As the result, it is not practically possible to consider realistic spatial and temporal scales. The goal of this study is to develop an approximate self-consistent, partially-kinetic computational approach - the reduced kinetics (RK) - for modelling strongly magnetised plasma with parameters relevant for the solar corona (Gordovskyy et al. 2019). This is done by combining the drift-kinetic description of particle motion along the magnetic field with MHD treatment of particle transport perpendicular to the magnetic field.

In order to test this new approach we develop a 2D RK model of magnetic reconnection and particle acceleration in Harris current sheet with strong guiding field. We compare the results of RK simulations with the Hall-MHD model of the same current sheet configuration. The developed RK model is also used to examine the effect of electron-ion separation due to strong guiding field, which has been predicted by some test-particle and particle-in-cell models (Zharkova & Gordovskyy 2004, Wood & Neukirch 2005, Siversky & Zharkova 2009).

Ryan French (UCL Mullard Space Science Laboratory)

French, R. J. (UCL MSSL), Matthews, S. A. (UCL MSSL), Long, D. M. (UCL MSSL), Van Driel-Gesztelyi, L. (UCL MSSL), Kuridze, D. (Aberystwyth University), Morgan, H. (Aberystwyth University), Harra, L. K. (UCL MSSL)

Poster

Searching for Signatures of Plasma-Sheet Instabilities during the September 10th 2017 Flare

Magnetic reconnection is the process at the heart of global energy release in the standard eruptive flare model. However, observed energy release timescales in solar flares are much faster than those predicted by reconnection models, which therefore do not account for key physical processes in the onset of fast reconnection. One such process is that of instabilities, which can lead to the production of Alfven waves and plasma turbulence. Alfven waves are undetectable through intensity observations, as they are incompressible and result in no intensity modulation. However, they are in principle detectable through non-thermal velocity measurements. In this study, we use observations of the September 10th 2017 flare from the Extreme ultraviolet Imaging Spectrometer (EIS), Swedish Solar Telescope (SST), Coronal Multi-channel Polarimeter (CoMP) and the Expanded Owens Valley Solar Array (EOVSA). By combining these unique spectroscopic observations and magnetic field measurements, we will be able to quantify the time-varying relationship between Alfven wave speed and non-thermal velocity. This will enable us to identify signatures of plasma-sheet instabilities in the September 10th 2017 flare.

Stephane Regnier (Northumbria University)

S. Regnier (Northumbria University)

Talk

Statistics of Nanoflares in quiet-Sun Magnetic Fields: Tangential Discontinuities

Parker's nanoflare model (1987) is widely used to describe the heating of the corona. However, the model is viable only if the number of events is large and covers the whole solar sphere. Klimchuk (2015) argued that more than 100,000 current sheets should exist in an active region to produce a sufficient heating of the corona up to 1 MK. In order to validate Klimchuk's model, we study the dynamics of a quiet-Sun region observed by Hinode/SOT. From a potential field model, we derive the existence of tangential discontinuities, signatures of current sheets. We obtain that, at a given time, there exists a large number of tangential discontinuities that have potentially a free energy of pico- to nano-flare energy. The current sheets are located in the photosphere and chromosphere, but just a small number of current sheet is located in the corona where the topology of the magnetic field is less tangled/twisted. The density of current sheets is constant in time. This analysis supports Klimchuk's argument regarding Parker's model, and also predicts energy releases at the picoflare scale.

Giulia Murtas (University of Exeter)

Giulia Murtas (University of Exeter), Andrew Hillier (University of Exeter)

Talk

Study of coalescence instability in chromospheric partially ionised plasmas

Magnetic reconnection is a recurring process taking place in various layers of the solar atmosphere, and plays a fundamental role in driving heating and explosive dynamics. However, unlike the processes occurring in fully-ionised coronal plasmas that have been subjects of extensive studies, still little is known about how magnetic reconnection develops in partially ionised plasmas of the lower atmosphere. In this talk I will investigate the role of partial ionisation on reconnection through the study of the coalescence instability. In a single-fluid MHD approach, this instability forms a turbulent reconnecting current sheet by driving plasmoid interaction, and is a key process that leads to fast reconnection without the addition of further anomalous resistivity terms. I will present my plasmoid simulations, focusing on the current distribution solved for a two-fluid model of the chromosphere, and then show how this new current distribution changes the dynamics of the coalescence process and the development of fast magnetic reconnection.

Chris Nelson (Queen's University Belfast / University of Sheffield)

C. J. Nelson et al.

Invited

Understanding Small-Scale Magnetic Reconnection In The Solar Atmosphere

It is now well known that magnetic reconnection can take place throughout the solar atmosphere on a variety of spatial and temporal scales. Recent breakthroughs in the analysis of the smallest examples of magnetic reconnection (currently observed) in the solar atmosphere has been facilitated by the development of state-of-the-art instrumentation (such as the CRisp Imaging SpectroPolarimeter [CRISP] and the Interface Region Imaging Spectrograph [IRIS]), which are capable of sampling the lower solar atmosphere on scales close to 100 km. These instruments allow us to observe the evolution of reconnection events in exquisite detail and provide information about the local magnetic field during the reconnection itself. In this talk, we will review our current understanding of small-scale explosive reconnection events in the solar atmosphere including Ellerman bombs (EBs), IRIS

bursts (IBs), and Quiet-Sun Ellerman-like Brightenings (QSEBs). The specific observational signatures of these events, and their general properties, will be presented before their links to cancelling bi-poles in the solar photosphere will be discussed. We will also investigate one of the key questions currently puzzling both observers and modellers in the small-scale reconnection community: How do EBs (which form at temperatures below 10000 K) and IBs (which appear to have temperatures of between 20000 K and 80000 K) form at the same spatial locations? Is this evidence of multi-thermal reconnection, or plasmoids, or reconnection at different heights in the solar atmosphere projected onto each other on 2-d plane? Finally, we will present a brief overview of recent modelling efforts.

Jack Jenkins (Mullard Space Science Laboratory - UCL)

J.M. Jenkins, M. Hopwood, P. Démoulin, G. Valori, G. Aulanier, D.M. Long, L. van Driel-Gesztelyi, J. Carlyle

Poster

Understanding the Role of Mass Within Prominence Eruptions

We combine observations of a partial filament eruption on 11 December 2011 with a simple line-current model to demonstrate that including mass is an important next step for understanding solar eruptions. Observations from the Solar Terrestrial Relations Observatory-Behind (STEREO-B) and the Solar Dynamics Observatory (SDO) spacecraft were used to remove line-of-sight projection effects in filament motion and correlate the effect of plasma dynamics with the evolution of the filament height. The two viewpoints enable the amount of mass drained to be estimated, and an investigation of the subsequent radial expansion and eruption of the filament. We use these observational measurements to constrain a line-current model and quantitatively demonstrate the important role that the presence and draining of mass has in the lead-up to solar eruptions. Specifically, we show that the balance of magnetic and gravitational forces acting on the line-current is increasingly sensitive to mass perturbations as it approaches its loss-of-equilibrium. Finally, we conclude that the eruption of the observed filament was restrained until 15% of the mass had drained from the structure.

GAIA DATA RELEASE 2: CONTENTS, ACCES AND USE (GAIA)

Abi Chown (University of Bath)

A. Chown (University of Bath), V. Scowcroft (University of Bath)

Poster

3D maps of the Magellanic Clouds using Classical Cepheids

Variable stars, such as Classical Cepheids, have been used for over one hundred years as probes for determining astronomical distances; these distances can be used to map out the three-dimensional (3D) structure of nearby galaxies. Exploiting the effect that moving to the mid-infrared has on Cepheid magnitudes and light curves, we can now map our nearest galaxies in 3D at fidelities never before achievable. Combining data from the OGLE-IV catalogue with mid-infrared photometry from the Spitzer Space Telescope, ~5000 fundamental mode Cepheids are being used to trace the 3D structure of the Magellanic Clouds, two dwarf galaxies in orbit around the Milky Way. An automated photometry pipeline has been developed to obtain precise mean magnitudes and light curves for Cepheids in the Magellanic System. These mean magnitudes are used to produce a mid-infrared period-luminosity (PL) relation, with the zero point calibrated using Gaia parallaxes of Cepheids. As a result, we can produce distance measurements accurate to 5% for individual Cepheids. These detailed maps are being used to probe the geometric and chemical structure of the Magellanic Clouds as well as their interaction and dynamical histories. Future inclusion of RR Lyrae stars will allow us to also trace the old stellar population of the system. With the increased precision expected from future Gaia data releases, this project will combine Gaia's astrometric solution with our precise 3D position measurements to further constrain the past trajectories of these galaxies.

Giorgia Busso (Institute of Astronomy, University of Cambridge)

G. Busso (Institute of Astronomy, University of Cambridge)

Talk

Access to Gaia DR2 from the ESA Archive

This presentation will give a short introduction to the Gaia archive present and run through a number of data queries utilised in the Gaia DR2 science performance papers.

Nigel Hambly (Institute for Astronomy, University of Edinburgh)

N. Hambly (Institute for Astronomy, University of Edinburgh)

Talk

API access with Python to the Gaia DR2 data

This presentation will demonstrate interactive analysis of the Gaia DR2 data from the desktop of python notebooks, via the Gaia DR2 API.

Nigel Hambly (Institute for Astronomy, University of Edinburgh)

N. Hambly (Institute for Astronomy, University of Edinburgh)

Talk

Gaia Data Release 2 and outlook for Gaia DR3

This presentation will give an overview of the Gaia Data Release 2, and look ahead to future releases, including the Gaia Early Data Release 3 scheduled for 2020, and the full Gaia Data Release 3 in 2021. The presentation will also discuss in detail the Gaia DR2 astrometric data and discuss a range of known issues related to this data.

Nigel Hambly (Institute for Astronomy, University of Edinburgh)

N. Hambly (Institute for Astronomy, University of Edinburgh), G. Busso (Institute of Astronomy, University of Cambridge), G. Seabroke (MSSL, University College London)

Talk

Participant Question and Answer

The session presenters will address Gaia DR2 queries raised by the session participants.

Giorgia Busso (Institute of Astronomy, University of Cambridge)

G. Busso (Institute of Astronomy, University of Cambridge), M. Taylor (University of Bristol), N. Hambly (Institute for Astronomy, University of Edinburgh)

Talk

Participant Question and Answer

The session presenters will address data usage queries raised by the session participants.

Friedrich Anders (University of Barcelona)

F. Anders, A. Khalatyan, C. Chiappini, A. Queiroz, C. Jordi

Poster

Precise photo-astrometric distances, extinctions, and stellar parameters for 150 million stars in Gaia DR2

Combining the precise parallaxes and optical photometry delivered by Gaia's second data release (DR2) with the photometric catalogues of Pan-STARRS1, 2MASS, and AllWISE, we compute Bayesian distances, extinctions, and stellar parameters (effective temperatures, gravities, metallicities, and masses) for stars brighter than G=18. Because of the wide wavelength range used, our results substantially improve the accuracy and precision of the Gaia DPAC results using Gaia DR2 alone. We achieve a median precision of 6% in distance and 0.17 mag in V-band extinction at G=14, degrading towards fainter magnitudes (15% and 0.20 mag at G=16; 30% and 0.25 mag at G=17). The results are carefully evaluated and flagged, and will be released through the ADQL query interface of the Gaia mirror at AIP (gaia.aip.de), and temporarily as binary tables. As first applications, we provide extinction maps as a function of distance, distance- and extinction-corrected colour-magnitude diagrams, and extensive kinematic maps of the Galaxy. Our results also serve to assess targeting strategies of the future 4MOST spectroscopic surveys. The produced catalogue may potentially be of interest for a number of existing and future projects within the institute.

George Seabroke (Mullard Space Science Laboratory (MSSL), University College London (UCL))

G. Seabroke (MSSL, UCL), M. Cropper (MSSL, UCL)

Poster

Radial velocities in Gaia DR2

Gaia DR2 includes radial velocities from its Radial Velocity Spectrometer (RVS) for the first time. In Gaia DR2, these are available for 7,224,631 stars, making it the largest radial velocity catalogue ever published and the first all-sky radial velocity map from a single instrument. We will present the UK's important role in Gaia's RVS, the spectroscopic processing required for Gaia DR2 and the properties and validation of the resulting radial velocities. Science highlights based on Gaia DR2 radial velocities will be briefly reviewed. The RVS limiting magnitude of Gaia DR2 is Grvs = 12 mag (V = 13 mag for a Solar-type star), which will be extended to Grvs = 14 mag (V = 15 mag for a Solar-type star) in Gaia DR3. Gaia DR3 radial velocities are expected for 30 million stars to be released in 2021.

George Seabroke (MSSL, University College London)

G. Seabroke (MSSL, University College London)

Talk

Radial Velocity data in Gaia DR2

This presentation will present the spectroscopy data in the Gaia DR2, highlight usage of this data and also discuss a range of known issues related to the data.

Giorgia Busso (Institute of Astronomy, University of Cambridge)

G. Busso (Institute of Astronomy, University of Cambridge)

Talk

The Photometric content of Gaia DR2

This presentation will present the photo and spectrophotometric data in the Gaia DR2, highlight usage of this data and also discuss a range of known issues related to the data.

Derek Ward-Thompson (UCLAN)

G Fleming, J Kirk, D Ward-Thompson

Poster

The two 'horns' of Taurus as seen by GAIA-DR2

We present a study of the GAIA-DR2 data for the Taurus molecular cloud, cross-matched against the Spitzer Taurus Catalogue, and find extremely interesting trends in distance and proper motion space. The results are currently embargoed, but will be divulged at NAM.

Mark Taylor (University of Bristol)

M. Taylor (University of Bristol)

Talk

Use of Gaia DR2 data from TOPCAT

This presentation will demonstrate interactive analysis of the Gaia DR2 data using the TOPCAT tool.

Galaxy Clusters in the next decade (GalClusters)

Martin Bourne (IoA/KICC, University of Cambridge)

M. A. Bourne

Talk

AGN jet feedback in realistic cluster environments

Feedback in the form of powerful jets plays an important role in galaxy cluster evolution, where the large lobes of relativistic plasma they inflate are critical in regulating the heating and cooling of the intracluster medium (ICM). However, the modus operandi of communicating the mechanical energy of the jets isotropically to the ICM remains an open question. Given the large dynamic range in the processes governing AGN feedback and its interaction with the ICM, attempting to simulate all of the relevant scales is a formidable task. I will discuss jet feedback simulations using the moving-mesh code AREPO.The method relies upon a super-Lagrangian refinement technique that provides vastly improved resolution near the SMBH while allowing courser resolution on larger scales. The technique means we can launch jets on relatively small scales and capture their propagation and evolution to large distances (~100 kpc). I will present results from our most recent works in which we investigate jet evolution in realistic cluster environments. Using our novel method we launch very high-resolution jets into fully cosmologically evolved zoom simulations of galaxy clusters at both high- and low-redshifts, for a range of jet powers. I will discuss how and where the feedback energy is deposited in the ICM, turbulence driving (or lack thereof), as well as the role ICM weather has on distributing the energy. Additionally I will present mock X-ray observations in order to compare with real systems, including comparisons to Hitomi observations of the Perseus cluster.

Roan Haggar (University of Nottingham)

R. Haggar (Nottingham), M. Gray (Nottingham), F. Pearce (Nottingham), A. Knebe (UAM, Spain)

Talk

Backsplash galaxies in simulations of clusters

The majority of galaxies are found in groups or clusters, meaning that an understanding of galaxy clusters is crucial in studying galaxy evolution, large-scale structure formation and cosmology. This work utilises The Three Hundred Project, a suite of 324 hydrodynamical re-simulations of galaxy clusters, to investigate the properties and time evolution of galaxies which are members of clusters. In particular, we focus on the 'backsplash population' - these are galaxies which have previously passed within the virial radius of a cluster, but now reside outside of the cluster, beyond its virial radius. We show that a significant fraction of all galaxies found in the vicinity of a cluster are backsplash galaxies, but that this fraction varies between clusters. This has important implications for observations of cluster outskirts, as galaxies within the same region may have notably different histories. For example, galaxies passing through a cluster are likely to have experienced strong ram pressure stripping, and so may have different halo gas contents to galaxies infalling for the first time. The effects of the dynamical state of a cluster on its backsplash population are also discussed.

Inigo Zubeldia (IoA, University of Cambridge)

I. Zubeldia (IoA, Cambridge), A.D. Challinor (IoA/DAMTP, Cambridge)

Talk

Cosmological constraints from Planck galaxy clusters with CMB lensing mass bias calibration: revisiting the Planck cluster sample

As demonstrated by Planck, galaxy clusters detected via the Sunyaev-Zel'dovich (SZ) effect offer a powerful way to constrain cosmological parameters such as Omega_m and sigma_8. Determining the absolute cluster mass scale is, however, difficult, and some recent calibrations have yielded cosmological constraints in apparent tension with constraints in the LambdaCDM model derived from the power spectra of the primary CMB anisotropies. In this talk I will present a new cosmological analysis of the galaxy clusters in the Planck MMF3 cosmology sample with a CMB lensing calibration of the cluster masses (Zubeldia & Challinor, in prep.). In this analysis we find Omega_m =0.33±0.02, sigma_8=0.76±0.04, and 1-bSZ=0.71±0.10, where the mass bias factor 1-bSZ relates cluster mass to the SZ mass that appears in the X-ray-calibrated cluster scaling relations, thus finding no evidence for tension with the Planck primary CMB constraints on LambdaCDM model parameters.

David Turner (University of Sussex)

D. Turner (University of Sussex)

Talk

FCtrlA: Automated hydrostatic masses of XCS galaxy clusters

FCtrlA is an XMM Cluster Survey (XCS) pipeline that aims to automatically measure hydrostatic masses for a large percentage of our cluster catalogue. This will result in the largest set of

hydrostatic cluster masses ever created, allowing us to achieve unparalleled constraints on cluster mass observable relations (MOR).
Measuring a very well constrained MOR will support precision cluster cosmology in future missions such as eROSITA, LSST, and Athena.

Judith Croston (Open University)

J. Croston, J. Ineson, M. Hardcastle

Talk

Finding galaxy groups with new radio surveys

Even in the era of eROSITA, EUCLID and LSST, the galaxy group regime will remain difficult to probe beyond the local Universe. I will discuss the prospects of using new radio surveys, including the LOFAR Two-Metre Sky Survey (LoTSS), to find and characterising galaxy groups at 1z2. Our method is based on an improved knowledge of particle content and hydrodynamics for morphologically regular powerful radio galaxies, which are known preferentially to inhabit galaxy groups, and has the potential to provide information about the baryon distribution in low-mass haloes at high redshifts, complementary to traditional cluster-finding methods.

Francesca Pearce (University of Manchester)

Francesca Pearce (University of Manchester), Scott Kay (University of Manchester), David Barnes (MIT), Richard Bower (Durham University), Matthieu Schaller (Leiden University)

Talk

Hydrostatic mass estimates of massive galaxy clusters

Using a set of 45 massive galaxy cluster zoom simulations, run with both the EAGLE and BAHAMAS models, we have looked at the effect of changes in the underlying SPH flavours (e.g. increased mixing), and sub-grid physics (e.g. changes in feedback mechanisms) on hydrostatic mass estimates when using mock X-ray data and a proxy for an SZ signal. We have also seen how including the non-thermal pressure in the calculation of mass leads to a less biased result.

Reese Wilkinson (University of Sussex)

Talk

Machine Learning in the XMM Cluster Survey

With the incoming of Big Data surveys such as LSST and eRASS^D, the ability for astronomers to "eye-ball" potential clusters in xray and optical datasets is becoming less feasible. I will discuss the tools developed to create 30,000+ classifications of SDSS and DES X-ray galaxy clusters, and the uses and development of machine learning tools in the XMM Cluster Survey (XCS).

Myles Mitchell (Institute for Computational Cosmology, Durham University)

M. A. Mitchell (ICC, Durham University), B. Li (ICC, Durham University), C. Arnold (ICC, Durham University), J.-h. He (School of Astronomy and Space Science, Nanjing University)

Talk

Preparing unbiased tests of gravity for next-generation cluster surveys

Galaxy clusters provide a powerful means to probe modifications to general relativity, which can offer a theoretical explanation for the late-time cosmic acceleration. However, cluster observable-mass scaling relations, the halo concentration and the dynamical mass are all affected by the presence of extra gravitational forces. Unless properly accounted for, these effects can lead to biased measurements of the cluster mass, thereby limiting the potential constraining power of upcoming cluster surveys in tests of gravity. I will outline a new framework for testing gravity which aims to provide unbiased constraints of modified gravity models from Sunyaev Zel’dovich (SZ) and X-ray cluster counts, and other cluster observables. Focusing on a popular f(R) model of gravity, I will present recent quantitative models for the enhancement of the dynamical mass and the concentration which have been calibrated by employing a large set of N-body simulations. Both models depend only on a simple combination of the background scalar field and the redshift, irrespective of the f(R) gravity model parameters. Finally, I will propose a novel procedure to recalibrate mass scaling relations from Î›CDM to f(R) gravity for SZ and X-ray cluster observables, which we will test using full-physics hydrodynamical cluster simulations.

Weiguang Cui (IfA, University of Edinburgh)

Cui Weigaung (IfA, UE); Knebe, Alexander (UAM); Yepes, Gustavo (UAM); Pearce, Frazer (UN); Power, Chris (ICRAR, UWA); Dave, Romeel (IfA, UE);et al.

Talk

The Three Hundred project: a large catalogue of theoretically modelled galaxy clusters

In this talk, I will introduce the 300 galaxy cluster project, which includes over 300 galaxy clusters from a MultiDark simulation. These clusters regions (radius 15Mpc/h) are re-simulated by different hydro-simulation codes. Further, we also have the cluster catalogue in the same zoom-in regions from three different Semi-Analytical Models, which were run for the parent MultiDark simulation. I will present the whole dataset, briefly discuss our findings in several different aspects and encourage people to use this catalogue by showing its potentials.

Behzad Ansarinejad (Durham University)

Behzad Ansarinejad (Druham), David Murphy (CASU), Tom Shanks (Durham), Nigel Metcalfe (Durham)

Talk

The VST ATLAS galaxy cluster catalogue: a progenitor to future cluster surveys of the southern sky

Exploiting the recently completed VST ATLAS survey covering ~4700 deg^2 of the southern sky, we create a galaxy cluster catalogue using the ORCA red-sequence cluster detection algorithm and obtain photometric redshifts for these clusters using the ANNz2 algorithm. Based on follow-up multi-object spectroscopy observations with EFOSC2, we obtain redshifts and velocity dispersions for 30 Planck Sunyaev-Zel'dovich clusters with no previous optical counterparts, which were detected in the VST ATLAS cluster catalogue. Similarly, VLT FORS2 was used to obtain redshifts and velocity dispersions for 3 high-z cluster candidates without previous optical detections. These new observations provide a major step in alleviating the current significant discrepancy between the Planck CMB+BAO estimate of $\sigma 8 = 0.83 \pm 0.015$ and that from evolution of cluster mass function, $\sigma 8 = 0.75 \pm 0.015$. Furthermore, we perform cross-correlation analysis of the cluster catalogue with the Planck CMB temperature map to provide new constraints on dark energy via the integrated Sachs-Wolfe effect. We then study magnification bias in the cross-correlation of the VST ATLAS cluster and quasar catalogues

providing constraints on cosmological parameters including Ω0 and σ8, complimentary to those obtained from other weak lensing analyses based on cosmic shear. Most importantly, due to it's large coverage of the southern sky the VST ATLAS cluster catalogue can serve as a valuable asset in providing targets for deeper spectroscopic observations as part of the 4MOST clusters survey, as well as follow up X-ray observations with eROSITA allowing for improved multi-wavelength calibrations of the cluster mass function.

Callum Bellhouse (University of Birmingham)

Talk

Untangling Jellyfish: Studying Ram-Pressure Stripped Galaxies with MUSE and GASP

The evolution of galaxies has, for many years, been known to be driven by a combination of internal and environmental processes. Spectacular examples of environmental quenching at play are so-called "jellyfish" galaxies, whose asymmetric morphologies are suggestive of intense ram-pressure stripping. I will demonstrate the power of MUSE IFU data in characterising properties and kinematics of jellyfish galaxies, and also present the most interesting results so far from the GASP (GAs Stripping Phenomena in galaxies with MUSE) program.

Alberto Acuto (Astrophysics Research Institute, Liverpool John Moores University)

Acuto Alberto (Astrophysics Research Institute,Liverpool John Moores University), McCarthy Ian (Astrophysics Research Institute,Liverpool John Moores University)

Talk

Using cosmological hydro simulations to improve the halo model with an eye to large-scale structure emulators

Upcoming surveys (such as LSST, Euclid, eROSITA, CMB-S4 etc.) will require robust and accurate theoretical predictions for the distribution of matter on large scales, so that these surveys can constrain the standard model of cosmology and to test its possible extensions. Cosmological hydrodynamical simulations can, at least in principle, provide such predictions, but the task is too computationally demanding at present to simulate the full cosmological landscape.

The halo model formalism is an attractive alternative, given the speed at which the predictions can be generated. In fact, the halo model formalism makes use of simple mass-redshift dependent functions (that strongly depends on the chosen cosmology) to trace several LSS observables without running various simulations. However, it suffers from well-known issues in the non-linear regime and the handling of the complex physics of galaxy formation.

Here we present some interesting results from a project that aims to characterise and improve the performance of the halo model by making detailed comparisons to the BAHAMAS suite of cosmological hydrodynamical simulations and real observations (Planck, SPT, ACT, DES etc). We explore how well the halo model performs at recovering several cosmological probes like the true Sunyaev-Zel'dovich, weak lensing, and X-ray auto- and cross-correlation functions and make physical adjustments to the halo model to better reproduce the simulations.

GALAXY-BLACK HOLE CO-EVOLUTION: OBSERVATIONAL AND THEORETICAL PERSPECTIVES (GALBLACKHOLES)

Emily Ferris (University of Leicester)

E. Ferris (University of Leicester) , A. Blain (University of Leicester)

Poster

Spectroscopy and black hole masses of extreme IR and radio selected WISE galaxies.

Ultra-luminous AGNs selected by combining mid-IR WISE and NVSS radio data, radio-WISE galaxies are a rare and extreme population of highly-obscured galaxies with young, compact radio jets exciting their ISM. Dominated by extreme mid-IR warm dust emission, they are radiatively efficient and with potentially merging morphologies, may represent an unknown and key phase in quasar evolution.

We have observed 27 of these radio-WISE galaxies using VLT instruments X-shooter and ISAAC at excellent seeing. We present NIR spectroscopy of these extremely luminous sources with bolometric luminosities of 10^47 erg/s across a wide redshift range of z = 0.88 - 2.85. Requiring multiple component models to produce acceptable fits for the emission line asymmetry, we measure 7 Hβ, 15 [OIII]λ5007 and 14 Hα lines. Using the broad [OIII]λ5007 emission lines we calculate lower limit black hole masses of log(M_BH) = 8.2 - 9.5 M_sun with corresponding host masses of log(M_Host) = 10.7 - 12.0 M_sun assuming black hole-host co-evolution. Using detected or simulated Balmer lines, we use the Cardelli (1989) extinction law to measure the visual extinction of our sources. Our results suggest these galaxies are extremely obscured and with a mean lower limit of Av = 4.7 magnitudes, extinction will increase our masses by two orders of magnitude in extreme cases.

Shown to be supermassive, ultra-luminous and highly obscured, radio-WISE galaxies are a rare and unique galaxy population. We aim to uncover a deeper understanding of the role these extreme galaxies play in wider quasar evolution.

Romeel Davé (University of Edinburgh)

R. Davé (Edinburgh), N. Thomas (UWC), D. Anglés-AlcÃ¡zar (Simons Foundation)

Talk

Black Hole-Galaxy Co-Evolution in the Simba Simulation

The recent Simba cosmological galaxy formation simulation uniquely includes torque-limited black hole growth, along with bipolar jet and X-ray black hole feedback, providing a state of the art alternative to canonical cosmological simulations that employ Bondi accretion and thermal feedback. We present results for the evolution of supermassive black holes in Simba, examining both the physical nature of the accretion process and the relationship to their host galaxies as governed by AGN feedback. We highlight potential multi-wavelength observational probes that can be used to constrain black hole growth modes and associated feedback models, particularly discussing the additional information provided by upcoming radio observations with the MIGHTEE survey on MeerKAT.

Rebecca Smethurst (University of Oxford)

C. Lintott (Oxford), B. Simmons (Lancaster)

Talk

Constraining the inflow rates to secularly growing AGN

We present narrow band imaging of the [OIII] 5007 Å component for 12 disk-dominated galaxies hosting luminous, unobscured AGN with spectrally confirmed outflows. These massive galaxies' formation histories are dominated by secular processes and thus provide a unique opportunity to study how inflows from secular processes fuel significant growth of black holes in the absence of significant mergers. We have constrained this contribution from secular processes by using the luminosity and extent of the [OIII] 5007 Å outflow in the narrow band images to measure the rate of mass loss in outflows from the central AGN of these disk-dominated galaxies. By combining these measurements with spectroscopically derived data constraining the black hole accretion rates, we have placed a limit on the total inflow rate to the centre of these galaxies. This technique offers the promise of directly measuring the black hole growth that is occurring in present-day systems evolving solely via secular evolution.

Brendan Webster (The Open University)

B. Webster (Open University), J. Croston (Open University), B. Mingo (Open University)

Talk

Jet Feedback in a new sample of Galaxy Scale Jets from the LOFAR Two Metre Sky Survey

Using the unparalleled sensitivity and high angular resolution of the LOFAR Two-Metre Sky Survey (LoTSS), we are now able, for the first time, to conduct a systematic study of low-luminosity radio AGN within the local universe. The recent first data release from the LoTSS project contains ~300,000 sources in an area of sky covering 424 square degrees which represents 2% of the final survey area. The LoTSS survey is more than an order of magnitude more sensitive than FIRST whilst being sensitive to emission at the same resolution on both small and extended scales. Dubbed Galaxy Scale Jets (GSJ), I will present my discovery from amongst the LoTSS DR1 dataset of a substantial population of physically small, low luminosity radio-loud AGN. Small, low-luminosity sources such as these are important because they are far more numerous than the large, powerful radio sources typically studied and their cumulative effects upon cosmic evolution is much less well-understood. The few existing studies of sources similar in size to GSJ have revealed X-ray detected shocks, providing some of the only known evidence for the direct effects of feedback on galaxy scales (as opposed to cluster scales in the larger sources). I will describe the methods used to find these objects along with their typical radio and host properties. I will also present the first study of the energetic impact of feedback from this previously unknown galaxy-scale jet population and their implications for galaxy evolution.

Daniel Asmus (University of Southampton)

D. Asmus (University of Southampton), S. F. Hoenig (University of Southampton), M. Stalevski (Observatory of Belgrade), P. Gandhi (University of Southampton)

Talk

Kilo-parsec scale dusty outflows in AGN revealed by high-angular resolution infrared observations

In this talk, we show how high-angular resolution observations can efficiently disentangle the infrared emission from AGN and star formation in local galaxies, and thus, allow us to study the dust structures of both separately, as well as their interplay. Until recently, the mid-

infrared emission of AGN was thought to predominantly originate from a toroidal obscuring structure. However, our new observations reveal that the mid-infrared is dominated by emission from the polar regions of the AGN, reaching up to kilo-parsec scales in some objects. The most likely explanation for this is a powerful dusty wind that, thanks to the large intersection of the dust particles for optical/IR radiation, can efficiently be driven by radiation pressure, both from primary emission of the accretion disk and internal reprocessing. We will review the current evidence for such dusty winds in AGN and present new deep high-angular resolution mid-infrared observations of a local AGN sample to test the ubiquity of this phenomenon. Then, using the full sample of all AGN with resolved polar dust emission, we will compare the observations to our newly developed 3D radiative transfer models of a physically and observationally motivated AGN dust structure and show that both SEDs and morphologies can be well explained. Finally, we discuss whether these dusty winds could be an important ingredient for AGN feedback onto the host galaxies, something that we will be able to fully assess with JWST in the near future.

Brooke Simmons (Lancaster University)

B. Simmons, R. Smethurst, C. Lintott, J. Shanahan, I. Garland

Talk

Merger-free quasars and secular black hole-galaxy co-evolution

Recent observational and theoretical studies indicate that merger-free accretion processes can fuel supermassive black hole growth up to quasar strengths and cumulatively dominate the growth of both galaxies and supermassive black holes in the Universe. We have identified a sample of nearby (z 0.25) luminous AGN growing in host galaxies whose lack of significant classical bulges indicate a growth history over the past ~10 Gyr free of significant mergers. From a Hubble Space Telescope imaging survey of 100 of these systems we have separated nuclear emission from galaxy light and determined galaxy structural parameters, including bulge- and pseudobulge-to-total ratios and bar lengths and strengths. Combining these parameters with multi-wavelength data (infrared to X-ray) and black hole mass estimates from single-epoch broad-line spectra, we examine the co-evolution of black holes and galaxies in the merger-free regime as a function of these galaxy properties and compare the results to those from galaxies with histories including major galaxy mergers. This sample offers insights into how important the dynamical history of the baryonic components of galaxies are to the co-evolution of galaxies and black holes.

Jessica Craig (Lancaster University)

J.E.M. Craig (Lancaster University), B.D. Simmons (Lancaster University)

Talk

Minor Gravitational Interactions as Contributors to Supermassive Black Hole Growth

It is known that most galaxies contain supermassive black holes at their centres. Early research suggested a link between galaxy mergers and supermassive black hole growth; however, more recent results indicate there may be additional important pathways to SMBH growth, such as merger-free processes and very minor interactions. We investigate SMBH growth in disk-dominated galaxies with no history of mergers that may be gravitationally interacting, but not merging, with nearby companions. We identify companions within 500 kpc of these merger-free AGN host galaxies and determine the level of gravitational interaction. We then compare the distribution of gravitationally interacting companion galaxies between the disk-dominated sample and a control sample. We additionally compare the two samples' environments by using measurements from a well-studied group catalogue. We find that disk-dominated AGN host galaxies have fewer very close (r 350 kpc) companions but an increase in more distant (350 r 500 kpc) companions compared to the control sample. This suggests SMBH growth in merger-free galaxies may be triggered by high-velocity 'fly-by' interactions.

Joao Calhau (Lancaster University)

Joao Calhau (Lancaster University), David Sobral (Lancaster University)

Talk

On the X-ray activity of typical and luminous Ly α emitters from z ~ 2 to z ~ 6 : evidence for a diverse, evolving population

We present the study of ~4000 Lya-alpha emitters (LAE) in the COSMOS field, selected across z=2.2-6 and their black hole activity. We use stacking to probe the X-ray activity of LAEs beyond the detection limits of current X-ray surveys and compare our results with similar analyses done to lower redshift (z=0.4-2.2) H-alpha emitters (HAE). The total AGN fraction (8.5% of LAEs) shows evidence of declining with increasing redshift and of a correlation between the AGN fraction and Ly-alpha luminosity. This behaviour is observed for both Radio and X-ray AGN. X-ray luminosity grows with Ly-alpha luminosity for sources detected directly in the X-ray surveys, suggesting that Ly-alpha is tracing the BHARs of these galaxies. We detect no clear relation of Ly-alpha luminosity with radio luminosity or spectral index. We detect no X-ray emission from the stacking of X-ray undetected LAEs, indicating BHARs of less than 0.08 Msolar/yr, while upper limits from stacking in the Radio and FIR show SFRs comparable to those measured directly from H-alpha and Lyman-alpha line luminosities (SFRs of ~7-20 Msolar/yr). Our results show the BHAR/SFR ratio of SF galaxies follows the evolution of SFRD closely for z=0.4-2.23 but we cannot claim the BHAR of SF galaxies follows SFRD for higher redshifts. Furthermore, comparing our results to our previous study of H-alpha selected galaxies at lower redshifts reveals that our sample has SFRs bellow HAEs and that LAES may have higher black hole-to-galaxy growth ratio than HAEs.

Megan Argo (University of Central Lancashire)

M. Argo, J. Coppola, E. Currell, Z. Clegg (UCLan) et al

Poster

Searching for intermediate mass black holes in NGC3310

Intermediate-mass black holes are theoretically predicted but observationally elusive. They are potentially the seeds of supermassive black holes in the early universe, and yet conclusive evidence for them is proving exceedingly difficult to obtain. The nearby face-on spiral galaxy NGC3310 has hosted many supernovae in recent history, and recent Chandra observations have shown a group of strong off-nuclear x-ray sources that are coincident with radio emission seen in archival radio observations with VLA and MERLIN. Their luminosity, spectrum and off-nuclear location make these sources excellent IMBH candidates. To investigate this possibility, we used combined EVN/e-MERLIN observations at both 1.4 and 5 GHz to look for compact radio emission and evidence of jet activity. I will show the results of our ongoing investigations and the potential implications for IMBH parameter space.

Andrew Worsley (University of London)

Poster

Solving Galactic Black Hole Co Evolution, and the Physics of CDM using Dynamic Advanced Newtonian gravity (DNAg)

The co evolution of galaxies and the presence of black holes is important in the understanding of the larger scale structure of the Universe. Equally well, the connection between dark matter (CDM) and galactic formation is not fully explained. Using conventional gravity there also appears to be infinite time dilation at the event horizon, which means that theoretically matter cannot enter the black hole, particularly the central supermassive black hole, in the lifetime of galaxies. Here we deconstruct the equations used in the formulation of classical GTR. This gives a dynamic form of Newtonian advanced gravity termed DNAg, which resolves a number of problems in gravity. Firstly, it does not offer infinite time dilation at the event horizon. By the same token it is possible to explain the presence of dark matter at the centre of the galaxy in addition to that in the galactic halo. Equally, it is able to explain the overall presence of cosmological dark matter in the formation of galaxies. Moreover, it predicts the results of black hole merges and gravitational wave studies. Importantly, it offers further future predictions for black hole physics, which will be readily testable using the newly commissioned event horizon telescope.

Chiaki Kobayashi (University of Hertfordshire)

Chiaki Kobayashi and Philip Taylor

Talk

Stellar originated SMBHs in cosmological simulations

Feedback from stars and active galactic nuclei (AGN) is the most important process in galaxy formation and evolution. In our cosmological hydrodynamical simulations, we introduced a new AGN model, where super-massive blackholes (SMBHs) originate the first stars with only ~100-1000 Msun, contrary to the merger products in other models. We also have chemical and thermal feedback from core-collapse supernovae (Type II supernovae and hypernovae), Type Ia supernovae, and asymptotic giant branch stars.

As a result, we can reproduce many observations well, including cosmic star formation rates, blackhole mass-galaxy mass relation, size-mass relation, mass-metallicity relations of galaxies, and radial metallicity gradients within galaxies.

With our method, it is possible to have SMSHs in bulge less galaxies or in dwarf galaxies. We also predict that the blackhole mass-galaxy mass relation does not evolve as a function of time, and SMBHs evolve along the relation.

Mikkel Kristensen (University of Hull)

M. Kristensen (University of Hull), K. Pimbblet (University of Hull), S. Penny (University of Portsmouth)

Talk

The Feeding Habits of Galaxies

Galaxies are dynamical objects that evolve and mature over time where both internal and external processes can change the composition and structure of them. Low-mass galaxies constitute an unrivalled sample to determine the effect of these processes due to their typically pristine gas, stellar, and structural components.

The hierarchical structure formation theory is often invoked to explain the origin of the galaxies and AGNs we see today, and this work test the early stages of this process. We assemble a sample of 6,615 low-mass galaxies from the NASA Sloan Atlas with AGN characteristics in an attempt to determine their cosmological histories and the importance of environment as an AGN trigger.

We find that the fraction of low-mass galaxies exhibiting AGN activity is comparable to regular galaxies (~2-5%), and that they tend to be in denser environments than non-AGN galaxies. However, using a WHAN diagram to select AGNs rather than BPT shows no environmental differences between active and regular galaxies. We discuss the implications of these findings.

Max Wallis (Buckingham University (retired))

Trevor W. Marshall, Max K. Wallis (Buckingham University)

Poster

The galactic centre as a degenerate matter shell

We explore modelling of super-massive galactic centres as horizon-less objects of degenerate neutron/proton/electron matter with no central singularity or surface-of-separation. Stable solutions to the radially-symmetric Einstein-Hilbert equations (Tolman form) have matter distributed in a shell of Schwarzschild scale (Rg), whose interior contains intense gravitational field energy. A typical solution for the SgrA* galactic centre (Rg =12 Gm) is a shell of radius 1.2 Rg, density peaking at 154 tonnes/cm3 and shell width 73 km. At such densities, the neutron fluid description is only marginally valid, with a fraction of the neutrons decaying to a proton and electron. We follow Weinberg's analysis to obtain a modified Equation of State. This shows the fringes of the shell would be mainly Fermi gas of protons/electrons, with a transitional density of 29 tonne/cm3. Our galactic centre body is thus a hybrid between neutron- and electron- degenerate matter, while larger galactic centres have lower density

shells and can be termed Supermassive White Giants (SWGs) analogous to traditional White Dwarfs. The trajectory of a test-particle entering the shell penetrates to a finite distance and then returns outwards, which is one indicator of stability. Matter accreted onto the shell would be quickly turned into degenerate ‘white dwarf’ material.

David Sobral (Lancaster University)

D. Sobral (Lancaster), J. Matthee (ETH), B. Darvish (Caltech)

Poster

The nature of luminous Lyman-alpha emitters: maximal dust-poor starbursts and highly ionizing AGN

Deep narrow-band surveys have revealed a large population of faint Lyman-alpha (Lya) emitters (LAEs) in the distant Universe, but relatively little is known about the most luminous sources. I will present the results of the follow-up of a large sample of luminous LAEs at z~2-3 found with panoramic narrow-band surveys over five independent extragalactic fields (~4x10^6 Mpc^3 surveyed). We use WHT/ISIS, Keck/DEIMOS and VLT/X-SHOOTER to study these sources using high ionisation rest-frame UV lines. Luminous LAEs at z~2-3 have blue UV slopes, high Lya escape fractions and span five orders of magnitude in UV luminosity, covering the parameter space occupied by galaxies, faint and more typical AGN. Many (70%) show at least one high ionisation rest-frame UV line such as CIV, NV, CIII], HeII or OIII], typically blue-shifted by ~100-200 km/s relative to Lya. Overall, 60+-11% appear to be AGN dominated, and at L>10^43.3 erg/s and/or MUV-21.5 virtually all LAEs are AGN with high ionisation parameters and close to solar metallicities. Those lacking signatures of AGN (40+-11%) have lower ionisation parameters and are apparently metal-poor sources likely powered by young, dust-poor "maximal" starbursts. Our results show that luminous LAEs are a diverse population and that 2Lâˆ— and 2xMâˆ— mark an extremely sharp transition in the nature of LAEs, from star formation dominated to AGN dominated.

Kevin Pimbblet (University of Hull)

Y. Gordon (Manitoba), K. Pimbblet (Hull), S. Kaviraj (Herts), M. Owers (Macquarie), C. O'Dea (Manitoba), M. Walmsley (Oxford), S. Baum (Manitoba), J. Crossett (Birmingham), A. Fraser-McKelvie (Nottingham), C. Lintott (Oxford), J. Pierce (Sheffield)

Talk

The Role of Galactic Mergers in the Evolution of Weakly Accreting Radio AGN

The triggering mechanism for weakly accreting radio-loud active galactic nuclei (AGN) is an open question. In this work we exploit deep imaging from the Dark Energy Camera Legacy Survey (DECaLS) to assess the role of past and ongoing mergers in the evolution of 282 Low Excitation Radio Galaxies (LERGs) at z4 sigma excess of LERGs with stellar masses 10^11 Msol undergoing such interactions. As this represents the lower end of our LERG stellar mass distribution, we hypothesise that these are recently triggered AGN that will evolve into high-excitation radio galaxies. Additionally, we see no evidence that minor mergers, a theorised fuel supply for LERGs (e.g. Kaviraj 2014), are involved in LERG triggering, with consistent minor merger rates found amongst LERGs and control galaxies. Furthermore, in the cluster environment, we observe a ~4 sigma deficit of LERGs experiencing minor merger relative to their control sample. This raises the possibility that in this dense environment a delicate equilibrium is required to fuel a LERG (consistent with the cooling flow hypothesis, e.g. Tremblay et al. 2016), which may be disrupted by even lower impact merger activity.

Eve North (Cardiff University)

Eve V. North, Timothy A. Davis, Martin Bureau, Michele Cappellari, Satoru Iguchi, Lijie Liu, Kyoko Onishi, Marc Sarzi and Mark D. Smith

Talk

The WISDOM from molecules about Galaxy-black hole co-evolution

Galaxy-black hole co-evolution is a crucial part of our modern theories of galaxy evolution. Our understanding of this vital process is hindered, however, by a lack of direct dynamical black hole mass measurements. The use of molecular gas as a tracer of the gravitational field in a galaxy has been used to make several direct super-massive black hole mass measurements. With fewer morphological biases than previous methods, and the possibility of pushing towards high redshift observations, this method has the potential to advance our understanding of the evolution of supermassive black holes and their hosts. In this talk I will

present the latest results from the mm-Wave Interferometric Survey of Dark Object Masses (WISDOM). I will show that the molecular gas method can probe the same material as megamasers, deep in the molecular torus, clearly resolving the Keplerian increase in rotational velocities close to the black hole and providing high precision black hole mass measurements. I will support this with tests conducted on a simulated galaxy, which allow us to identify the strengths (and observational limitations) of the molecular gas method.

Weiguang Cui (IfA, University of Edinburgh)

Cui Weigaung (IfA, UE); Romeel Dave (IfA, UE); et al.

Talk

Understanding the scatter in Black Hole - galaxy scaling relations

Using the state-of-art cosmological hydrodynamic simulation -- Simba (Dave et al. 2019), we studied the scatter in the Black Hole - galaxy scaling relations. We try to link this scatter with different galaxy properties and seek to understand its origin by tracking the accretion history of the host Black Hole and the galaxy formation history.

GRAVITATIONAL WAVES & MULTIMESSENGER ASTRONOMY (GRAVWAVES)

Daniel Williams (University of Glasgow)

D Williams, (University of Glasgow), IS Heng (University of Glasgow), J Gair (University of Edinburgh), JA Clark (Georgia Institute of Technology) B Khamesra (Georgia Institute of Technology)

Poster

A binary black hole waveform generator trained on numerical relativity waveforms

Most methods for extracting signals and parameter estimation for gravitational wave signals from compact binary coalescences require prior knowledge of the signal morphology. This prior information is obtained from numerical relativity simulations which are both expensive and time-consuming to produce. Consequently, only a small region of the overall signal parameter space has been probed. We present a method, based on Gaussian process regression informed by numerical relativity waveforms, which is capable of placing a prior probability distribution over the entire precessing binary black hole merger parameter space. This allows us to produce interpolated waveforms with an associated measure of the interpolation uncertainty across the entire parameter space.

Rachel Gray (University of Glasgow)

Gray, R. and the LIGO-Virgo Collaboration

Talk

A Statistical Constraint on the Hubble Constant Using the Latest Gravitational Wave Detections

The field of gravitational wave cosmology opened up with the detection of the binary neutron star merger GW170817, alongside its electromagnetic counterpart. It is currently understood that many detections, in particular binary black holes, are not expected to be accompanied by electromagnetic counterparts. To this end, we have developed a method of statistically inferring the Hubble constant using compact binary mergers in combination with galaxy catalogues to provide the complementary redshift information. I discuss details of this method and present the latest Hubble constant results from the LIGO-Virgo Collaboration using events from GWTC-1 (Gravitational Wave Transient Catalog 1).

Rob Eyles (University of Leicester)

R. A. J. Eyles (University of Leicester), P. T. O'Brien (University of Leicester), R. L. C. Starling (University of Leicester)

Poster

An unusual transient following GRB 071227

We present X-ray and optical observations of the short duration gamma-ray burst GRB 071227 obtained using Swift, Gemini South and the Very Large Telescope. We use image subtraction to identify an optical transient in the r, i and z bands at ~0.26 days before becoming undetectable in subsequent epochs. We find that an extrapolation of the X-ray power law underpredicts both the flux and slope of these optical detections and that the excess is inconsistent with other afterglow mechanisms, such as reverse shocks or a coupled X-ray optical flare as suggested in the case of GRB 050724. We instead find that the most plausible explanation for this excess is the presence of an additional emission component and explore the possibility that this additional component is consistent with a kilonova candidate.

Fergus Hayes (University of Glasgow)

F. Hayes (University of Glasgow), I. S. Heng (University of Glasgow), D. WIlliams (University of Glasgow), J. Veitch (University of Glasgow)

Talk

Analysing Beaming Profiles of Short Gamma-Ray Bursts using Gravitational Waves

GRB170817A had the weakest observed emission of any short gamma-ray burst (sGRB). It is postulated that either SGRBs can be intrinsically weaker than previously thought, that GRB170817A was viewed off-axis, or that SGRBs have some non-uniform energy distribution within the jet. Determining the true beam profile would explain the dimness of GRB170817A, as well as give insight into the astrophysics behind the jet formation. This is achievable with the promise of coincident gravitational wave and sGRB detections in the future, bolstered by the development of future generation detectors. A number of models with different beam profiles have been proposed, including Gaussian, structured power-law and top-hat beams. We have been working on an analysis to allow for model comparison between the different profiles, as well infer the underlying model parameters. Another approach is to infer the beaming profile without assuming a model, but instead use a Gaussian process prior, allowing for a non-parametric analysis. This talk will focus on how we can use future events to

determine the most favourable beam profile, and how many events would be necessary before the models can be discerned with significance. The talk will also outline our ongoing work with the non-parametric case and discuss how it could give us an unbiased perspective on the astrophysics of binary neutron star merger.

Gregory Chappell (The University of York)

A, Gregory Chappell, The University of York.

Poster

Frequency and Mode analysis of Gamma Doradus Variables

Stars pulsate throughout their lifetime and these pulsations are the best way to investigate certain aspects of the star, such as the fundamental physics in the stellar interior. These pulsations are analysed through the movement of spectral lines with time. The changes in the line profile correlate directly to the variations in Doppler shifts on the stellar surface as the star expands and contracts. Stars pulsate either radially (where the star expands and contracts around its equilibrium by altering its radius to maintain its spherical shape) or non-radially (where some parts of the stars surface move inwards as other parts move outwards). These pulsations can be defined by different modes.

Gamma Doradus stars pulsate in a unique way. The restoring force of these stars is gravity and the origin of the pulsations mean they propagate very deep into the star and characterising these pulsations gives information about the internal stellar structure. It’s extremely important to categorise as many of these pulsating stars as possible to eventually develop a complete stellar model.

This poster will present the frequency and mode analysis of two Gamma Doradus variables, HD 139095 and HD 48501, and the line profile analysis of a third Gamma Doradus, HD 197541.

Patricia Schmidt (University of Birmingham)

Patricia Schmidt (University of Birmingham)

Invited

Gravitational-Wave Transients of Compact Binary Mergers observed by LIGO and Virgo: Status & Prospects

The first and second observing runs of Advanced LIGO and Virgo between 2015 and 2017 have seen confident gravitational-wave detections from eleven compact binaries, including one neutron star merger, firmly establishing the field of gravitational-wave astronomy. In this talk,

I will summarise the results from two matched-filter searches as well as one unmodelled transient search, present estimates of the source properties and discuss the implications for merger rates of compact binaries. Finally, I will discuss prospects for the third observing run.

Phil Evans (University of Leicester)

P.A. Evans (University of Leicester)

Invited

High-energy electromagnertic counterparts of gravitational wave signals

For many years the coalsence of a binary neutron star has been seen as the most promising phenomenon to be detected by both gravitational wave and electromagnetic emission. Such events are also believed to be the progenitors of short gamma-ray bursts (GRBs); however, since the GRB emission is beamed a GRB is only expected to be detected from a narrow range of observing angles, thus the probability of observing a short GRB coincident with a GW event was thought to be low. As it turned out, the first binary neutron star merger detected by Advanced LIGO-Virgo, GW 170817, was accompanied by a short burst of gamma-rays, GRB 170817A, detected by the Fermi-GBM. While superficially a 'short gamma-ray burst', this event does not match the simple models of such phenomena, either in its prompt gamma-ray emission or the later X-ray, optical or radio evolution. In this talk I will review some of the results and analysis of GW 170817 and consider both the questions and challenges this raises for the O3 observing run of Advanced LIGO-Virgo.

Max Wallis (BCAB Buckingham University (retired))

Max K. Wallis and Trevor W. Marshall (Buckingham University)

Poster

Modelling the neutron star merger remnant in GW170817 as a supra-massive neutron star

The unique observation of the merging of a neutron star pair, seen as the gamma-ray burst coinciding with the gravitational wave-pulse and broad-band afterglow emissions plus a pulsar-like relativistic jet, has led to interpreting the product as a 2.7-2.8 $M_{\odot}$ neutron star rather than the ‘expected’ black hole. The mass derives from gravitational wave pulse GW170817 from the binary neutron star merging on 17 August 2017, which implies both premerger neutron stars had ~1.4 M⊙ masses   We model the structures of 1.4 and 2.8 M⊙ neutron stars as stationary solutions of the radially symmetric Tolman equations, in which the mass density peaks on the MG/c2 scale. The 2.8M⊙ star's density profile is tending towards a shell with a central hole. The densities we find are well within the hyperon limit on neutron matter. The 2.8M⊙ star breaches the Tolman-Oppenheimer-Volkoff (TOV) limit, but we do not invoke the exotic physics of some modelling.   Relatively little mass was ejected and little energy shed in gravitational waves during the 2017 event. The merging process therefore conserved both the nucleonic mass and the gravitational energy - this implies the mass defect is a constant fraction of the nucleonic mass, though fractional mass defect generally increases with mass. Our modelling confirms that a stable solution for 2.8 M⊙ does exist for a range of merging neutron stars of ~1.4 M⊙. However, in some cases a significant fraction of the mass would have to be ejected to reach an energetically stable configuration.

Jonathan Thompson (Cardiff University)

Jonathan Thompson (Cardiff University), Edward Fauchon-Jones (Cardiff University), Sebastian Khan (MPI Hannover), Francesco Pannarale (Sapienza University), Tim Dietrich (Nikhef), Mark Hannam (Cardiff University)

Poster

Phenomenological Models of Neutron Star Black Hole Binaries

The potential detection of gravitational wave signals from neutron star black hole (NSBH) binary mergers is poised to provide a deeper insight into the complex physics underlying the structure of neutron stars. The morphology of an NSBH waveform may range widely from completely disruptive coalescences, similar to the waveforms of binary neutron star mergers such as GW170817, to signals with minuscule tidal disruption almost indistinguishable to those produced during binary black hole mergers. We present recent developments and improvements that have been made to past phenomenological modeling of NSBH waveforms, with applications for the current LVC gravitational wave detectors and an eye toward next-generation detectors.

Andrew Worsley (London University)

Poster

Predicting Gravitational Wave Emissions and the Physics of Black Holes using Dynamic Advanced Newtonian gravity (DNAg)

The detection of gravitational waves has been enormously successful in confirming gravity. However, some problems remain with gravity, not least that dark matter (CDM) is not explained. There are also infinite singularities in black holes. Additionally in conventional gravity there appears to be infinite time dilation at the event horizon, which means that matter cannot enter the black hole in the lifetime of the Universe Here we deconstruct the equations used in the formulation of classical GTR. This gives a dynamic form of Newtonian advanced gravity termed DNAg, which resolves a number of problems in gravity. Firstly, it obviates the infinite density singularities, and it does not offer infinite time dilation at the event horizon. By the same token it is possible to explain the presence of dark matter contribution made by black holes. Equally, it is able to explain the presence of the bifurcation of gravitational wave signals from black hole mergers Moreover, it can explain the frequencies of the gravitational waves and their ratios. Importantly, it offers future predictions for black hole physics, which will be readily testable using the newly commissioned event horizon telescope.

Vaibhav Tiwari (Cardiff University)

Vaibhav Tiwari, Stephen Fairhurst

Talk

Prospect of precession astronomy for gravitational wave source population

The first gravitational wave observations have provided us with unprecedented information about the nature and population properties of compact binaries. Precision astronomy with gravitational waves will however require hundreds and thousands of such observations. One may ask about the number of such observations that will be required to measure a specific property of the population, or in general how many observations will be required to measure the mass, spin and redshift distribution of these systems. In this talk I will explore this topic along with the timeline that is required to achieve the objectives.

Tom Kimpson (Mullard Space Science Laboratory, UCL)

T.Kimpson (UCL), K.Wu (UCL), S.Zane (UCL)

Talk

Pulsar Timing in Extreme Mass Ratio Binaries

The detection of a pulsar in a tight, relativistic orbit around a supermassive or intermediate mass black hole - such as those in the Galactic centre or in the centre of Globular clusters - would allow for precision tests of general relativity in the strong-field, non-linear regime. I will present a fully general relativistic framework for the calculation of the theoretical time-frequency signal from a pulsar in such a system. This model will provide an accurate theoretical basis, applicable to the strong-gravity regime, to then compare with observations in order to test fundamental physics.

David Tsang (University of Bath)

D. Tsang (University of Bath)

Talk

Resonant Shattering Flares: Multimessenger Probes of Neutron Star Physics

Resonant Shattering Flares (RSFs) are expected to occur during the inspiral phase for some NS-NS and NS-BH mergers. They result from the resonant tidal excitation of the NS crust-coreinterface mode fracturing the crust and sparking a relativistic pair-photon fireball, emitted seconds before the merger.

RSFs are prompt, bright, and isotropic, allowing potential detection and triggering from well beyond the LIGO-horizon and may be an important source for detectable electromagnetic counterparts to GW mergers. When a GRB is present, they appear as pre-cursors to the main flare, while for off-axis systems they should appear as isolated under-luminous GRBs with extremely short duration. RSFs will depend on the age and magnetic evolution of neutron stars, as they require sufficient surface magnetic field to mediate the energy release.

I will discuss the physics and detectable emissions for RSFs compared to other counterparts, in NS/NS and NS/BH mergers, as well as estimates of the number of expected RSFs compared to possible orphan events.

Gavin Lamb (University of Leicester)

Gavin Lamb, Shiho Kobayashi

Poster

Reverse Shocks in the Relativistic Outflows of GW detected Neutron Star Mergers

The afterglows to gamma-ray bursts (GRBs) are due to synchrotron emission from shocks generated as an ultra-relativistic outflow decelerates. A forward and a reverse shock will form, however, where emission from the forward shock is well studied as a potential counterpart to gravitational wave detected neutron star mergers the reverse shock has been neglected. Here, we show how the reverse shock contributes to the afterglow from an off-axis and structured outflow. The reverse shock will be observable as a brightening feature in the rising afterglow at radio frequencies for bursts at 100Mpc and systems inclined 30 degrees (or ~5 times the core opening angle for θ=6 degrees) at ~1-10 days post-merger. For structured outflows, enhancement of the reverse shock by a strong magnetic field within the outflow is required for the emission to dominate the afterglow at early times. Early radio imaging of a reverse shock could reveal the presence of a strong magnetic field associated with the merger remnant.

Ronaldas Macas (Cardiff University)

R. Macas (Cardiff University) on behalf of LIGO-Virgo collaboration

Talk

Search for Gravitational Waves Associated with Gamma-Ray Bursts During the Second Advanced LIGO-Virgo Observing Run

Gamma-ray bursts (GRBs) are one of the most violent phenomena in the universe. They are generally divided into two categories: short-duration bursts created by a collision of two compact sources such as binary neutron stars; and long-duration bursts that are powered by the core collapse of rapidly rotating massive stars. We expect GRBs to be intrinsically linked to gravitational-wave (GW) emission, providing an opportunity for multimessenger astronomy. In this talk, I will present results from targeted GW searches associated with GRBs during the second Advanced LIGO-Virgo observing run. We have analyzed 42 (98) GRBs with modeled (unmodeled) searches and found no candidates other than GW170817. I will briefly discuss the case of GW170817-GRB170817A,

as well as results for non-detections: analysis of subthreshold GRB population and lower bounds on the median source distance for various scenarios of GW emission. Finally, I will discuss the implications of these results for source rates and future observing runs.

Benjamin Gompertz (University of Warwick)

B. Gompertz (Warwick), Andrew Levan (Nijmegen), Nial Tanvir (Leicester), J. Hjorth (Copenhagen), S. Covino (INAF), P. Evans (Leicester), A. Fruchter (STScI), C. Gonzalez-Fernandez (Cambridge), Z. Jin (PMO), J. Lyman (Warwick), S. Oates (Warwick), P. O'Bri

Talk

The Diversity of Kilonova Emission in Short Gamma-Ray Bursts

The historic first joint detection of both gravitational-wave and electromagnetic emission from a binary neutron star merger cemented the association between short gamma-ray bursts (SGRBs) and compact object mergers, as well as providing a well-sampled multi-wavelength light curve of a radioactive kilonova (KN) for the first time. Here, we compare the optical and near-infrared light curves of this KN, AT2017gfo, to the counterparts of a sample of nearby (z 0.5) SGRBs. Although at similar epochs AT2017gfo appears fainter than every SGRB-associated KN claimed so far, we find three bursts where, if the reported redshifts are correct, deep upper limits rule out the presence of a KN similar to AT2017gfo by several magnitudes. Combined with the properties of previously claimed KNe in SGRBs this suggests considerable diversity in the properties of KN drawn from compact object mergers, despite the similar physical conditions that are expected in many NS-NS mergers. We find that observer angle alone is not able to explain this diversity, which is likely a product of the merger type (NS-NS versus NS-BH) and the detailed properties of the binary (mass ratio, spins etc.). Ultimately, disentangling these properties should be possible through observations of SGRBs and gravitational-wave sources, providing direct measurements of heavy element enrichment throughout the universe.

Dan Ryczanowski (University of Birmingham)

D. Ryczanowski (University of Birmingham), G. P. Smith (University of Birmingham), M. Bianconi (University of Birmingham)

Talk

The effectiveness of source-based strong-lens searches in the context of lensed gravitational waves

In the early 2020s the rate of detection of strongly-lensed gravitational waves will approach and soon surpass ~1 per Earth year. On a similar timescale, LSST will begin surveying the Southern sky and will thus provide a data stream within which to search for electromagnetic (EM) counterparts to lensed GW sources (irrespective of any lensing effects). It is important to consider how to optimise such a search for EM counterparts to GW sources, and in particular whether/how to go about building up our knowledge of the population of lensing galaxy clusters to facilitate that search. Conventional lens searches utilise EM observations of lensing phenomena (such as bright arcs) caused by background galaxies or quasars. This strategy relies on a chance alignment between a source and the strong-lensing cross-section of a lens, and on the lensed source being detectable. Such a source-based search could therefore miss an unknown and potentially large fraction of the lens population that is relevant to the lensing of GWs. I have developed an analytic model to estimate the fraction of lenses that source-based lens searches will miss as a function of the lens mass, concentrating on the galaxy group and cluster mass range. I will present the details of the model, an application of it to an LSST-like survey, and discuss its implications for the potential first detection of lensed GWs.

Soheb Mandhai (University of Leicester)

S. Mandhai (University of Leicester), N. Tanvir (University of Leicester), G. Lamb (University of Leicester), A. Levan (University of Warwick), D. Tsang (University of Bath)

Talk

The Rate of SGRBs in the Local Universe

Following the faint gamma-ray burst, GRB 170817A, coincident with a gravitational wave-detected binary neutron star merger at d~40 Mpc, we consider the constraints on a local population of faint short duration GRBs (defined here broadly as T904 s). We review proposed low-redshift short-GRBs and consider statistical limits on a d≤200 Mpc population using Swift/Burst Alert Telescope (BAT), Fermi/Gamma-ray Burst Monitor (GBM), and Compton

Gamma-Ray Observatory (CGRO) Burst and Transient Source Experiment (BATSE) GRBs. Swift/BAT short-GRBs give an upper limit for the all-sky rate of 4 y-1 at d200 Mpc, corresponding to 5% of SGRBs. Cross-correlation of selected CGRO/BATSE and Fermi/GBM GRBs with d100 Mpc galaxy positions returns a weaker constraint of ≤12 y-1. A separate search for correlations due to SGR giant flares in nearby (d11 Mpc) galaxies finds an upper limit of 3 y-1. Our analysis suggests that GRB 170817A-like events are likely to be rare in existing SGRB catalogues. The best candidate for an analogue remains GRB 050906, where the Swift/BAT location was consistent with the galaxy IC0327 at d~132 Mpc. If binary neutron star merger rates are at the high end of current estimates, then our results imply that at most a few percent will be accompanied by detectable gamma-ray flashes in the forthcoming LIGO/Virgo science runs.

Robert Farmer (University of Amsterdam)

R. Farmer (University of Amsterdam), M. Renzo (University of Amsterdam), S. E. de Mink (University of Amsterdam), P. Marchant (Northwestern University), S. Justham (University of the Chinese Academy of Sciences, University of Amsterdam)

Talk

What can we learn about stellar astrophysics from LIGO/VIRGO?

With the detection of 40-50msun binary black holes (BH) from LIGO/VIRGO, and if we assume they come from stellar sources, then what can we learn about their progenitors? Massive stars are expected to undergo pulsational pair instabilities leading to a core collapse supernovae (PPISN) leaving behind BH's in the mass range detected by LIGO/VIRGO. More massive stars are expected to be completely disrupted in a pair instability supernovae (PISN), leaving no remnant. The boundary between these fates sets the second black hole mass gap. In this talk I will show how the location of the second black hole mass gap can be used to constrain stellar astrophysics by understanding the progenitors of the binary black holes. This can be achieved even without detailed knowledge of the environment in which the black holes formed, as I will show how the second black hole mass gap is independent of the host environment. I will show how the maximum mass black hole LIGO/VIRGO is sensitive to uncertain nuclear reaction rates, and how we can then use the maximum mass to constrain the nuclear reaction rates.

Impact of astronomy: ideas, inventions and people (AstroImpact)

Charlie Jeynes (University of Exeter)

C. Jeynes (University of Exeter), F. Wordingham (University of Exeter), L. Moran (University of Exeter), T. Harries (University of Exeter)

Talk

Applying an astrophysics modelling tool to improve the diagnosis and treatment of cancers using theranostic nanoparticles

The University of Exeter is home to the TORUS Monte Carlo code that has been used to model a wide variety of astrophysical radiative transfer phenomena. Tim Harries and team have recently extended this code to include the transfer of light through biological tissue. Here I discuss applying and modifying (ARC)-TORUS for 'Theranostic' applications for this STFC 'innovation' Fellowship.

Theranostics is an exciting new avenue in medicine that seeks to combine diagnostic and therapeutic techniques as a single treatment, with the most immediate applications in cancer therapy. Theranostics are generally based around nanoparticles that both act as imaging agents as well as in a therapeutic capacity.

Many hurdles remain before theranostic technology is seen in the clinic. Critical to its success is the concentration of the theranostic within the tumour, and subsequent 'killing dose' that it receives once an external energy source (e.g. Near-Infra-Red light) is applied.

Computational modelling is a crucial tool to quickly and cheaply simulate likely scenarios (e.g. theranostic concentrations in tumours and irradiation doses) in which good imaging contrast can be achieved while subsequent treatment gives acceptable tumour control.

Using ARC-TORUS, we present an optimization of treatment for skin cancers infused with NIR light absorbing gold nanorods, as a showcase for how Monte Carlo modelling can be used to inform experiments, enabling translation to theranostic use in clinical practice.

James Blake (University of Warwick)

A. James Blake (Warwick), B. Paul Chote (Warwick), C. Don Pollacco (Warwick)

Talk

Applying Astronomical Techniques to Space Situational Awareness

In the predawn of so-called mega-constellations, it is becoming more important than ever to closely monitor the near-Earth environment. A dangerous blend of break-ups, collisions and hardware disposal has generated a significant population of artificial debris, posing a threat to existing assets. Although methods of active debris removal are currently being tested, we are still some way off a viable solution. In the meantime, regular monitoring is essential to protect active satellites and ensure they manage to steer clear of potentially mission-fatal collision courses. At Warwick, we are utilizing existing astronomical instrumentation to characterize the debris population and obtain diagnostic data for space assets. We have conducted a survey of faint geosynchronous debris using the 2.54 m Isaac Newton Telescope, uncovering an interesting sample of objects tumbling in and out of the limiting magnitude within a single exposure. Alongside this, we are in the process of accumulating a database of light curves for target satellites. For the relatively rapid passes of low Earth orbit satellites, we utilize the super-wide field of SuperWASP-North on La Palma, an array of eight cameras historically used to detect exoplanets via the transit method. In the case of geosynchronous satellites, we instead make use of a 0.36 m Rowe-Ackermann Schmidt astrograph to obtain the light curves. We give an overview of these projects as part of an ongoing program to apply astronomical tools and techniques within the developing field of Space Situational Awareness.

Claire Burke (Liverpool John Moores University)

C.Burke, S.N. Longmore, J. Veitch-Michealis, P.R. McWhirter, S. Wich, O. McAree, M.F. Rashman

Talk

Astro-ecology: using astrophysics to help save the world

The world is currently facing the huge challenges of climate change, plastic pollution, industrial and domestic waste pollution, and the unintended impacts of natural resource exploitation by humans on the environment. As a result 60% of wildlife has disappeared over the past 30 years; putting us in the 6th mass extinction event in the history of life on Earth (the 5th being the end of the dinosaurs). We're also in an era where we have unprecedented potential to understand and address these challenges - and the need to do so has never been more urgent.

By applying techniques from astrophysics, computer science, machine learning, engineering and other technical disciplines, the astro-ecology research group are helping to address these challenges. Working in collaboration with conservationists, ecologists and environmental groups, we are building drone-based remote sensing systems to give us an unprecedented view on our planet. By applying the multi-wavelength approach often taken in astrophysics, we can monitor endangered animals more efficiently, catch poachers, and find people in need of rescue at sea or in disaster areas. We are also building systems to combat climate change by locating underground fires (a larger source of carbon than the global transport sector), and address environmental pollution through drone-based spectroscopy. I will give an overview of the project and discuss how we can use astrophysics to solve real world problems.

Christopher Frohmaier (Institute of Cosmology and Gravitation, University of Portsmouth)

C. Frohmaier (ICG), M. Smith (University of Southampton), N. Pareek (KCH)

Talk

Establishing connections between transient astronomy and cardiovascular medicine

Entering the era of LSST and SKA, astronomers are at the forefront of the "Big Data" revolution, and while many of our analysis techniques may seem astrophysically focussed, their applications can be far-reaching. Recently, the UK Government outlined a grand challenge as part of its Industrial Strategy to revolutionise the NHS. Their vision will use “AI and big data” to meet the needs of an “ageing society”. The role of AI and big data analysis in healthcare is clear: it has the potential to provide more accurate decisions faster, reducing cost and improving patient outcomes. Motivated by this challenge, and recognising the skill set of astronomers, we have developed a collaboration with the School of Cardiovascular Medicine & Science at King’s College Hospital (KCH). Out of Hospital Cardiac Arrest (OOHCA) occurs in over a quarter of a million patients each year and presents a major public health challenge. The rate of coronary artery disease in patients with OOHCA is high, but the current technique to guide the provision of an emergency coronary angiography remains a poor predictor of a culprit coronary artery lesion. Using Random Forest and Boosted Decision Trees, as currently deployed in many astronomical classification tasks, we demonstrate significantly improved predictions of a culprit coronary artery lesion in a large sample of OOHCA patients. In this talk, I will present both the results from our study and areas of cardiology in which astronomers may be able to contribute.

Mathew Smith (University of Southampton)

M. Smith (University of Southampton), C. Frohmaier (ICG; University of Portsmouth), R. Matin (OUH)

Talk

MoleGazer: equating melanoma with stellar explosions

Able to detect and classify new events in real time, large astrophysical transient surveys routinely map the night sky with unprecedented accuracy. However, the techniques developed to detect stellar explosions need not only be used in astronomical contexts.... Here, I will introduce, motivate and outline a real world example of how the methods used every day by astronomers can be utilised in a totally different area of science: medical research. Joining transient science, machine learning and clinical expertise from institutes across the UK (Southampton, Portsmouth, Oxford, Cambridge, UCL, Birmingham, Leeds and CR:UK) we have developed a technique inspired by astronomy that will be applied to full body photography in a proof-of-concept study to detect and track the evolution of skin lesions. Combining astronomy and clinical expertise, this project is just the beginning: this framework could ultimately lead to the early detection of skin cancer.

Chris Brunt (University of Exeter)

Chris Brunt (University of Exeter), Malcolm Kitchen (Met Office)

Talk

Three-Dimensional Mapping of Atmospheric Humidity via Interferometry of Aircraft Navigational Broadcasts

I will describe a joint project involving the University of Exeter and the Met Office that aims to acquire real-time, low-cost, high-volume measurements of atmospheric humidity to inform numerical weather forecasts. Commercial air traffic broadcast radio signals that encode their GPS-determined position, speed, and heading, along with data physical data such as in situ pressure and temperature. Angle-of-arrival interferometry of these signals can also yield a measure of humidity, as the deviation of observed elevation angle from predicted elevation angle is due to refraction, which in turn is affected by humidity (at the level of a few tens of percent of the normal stratification-induced refraction). I will describe a prototype system deployed currently at the University of Exeter, and look forward to a planned network of interferometers deployed on the Met Office radar towers across the UK.

LINKING THE SUN TO THE HELIOSPHERE – THE SOLAR ORBITER MISSION (SOLARORBITER)

James Pickering (Aberystwyth University)

J.pickering(Aberystwyth University), H.Morgan(Aberystwyth University)

Talk

An efficient method for Differential Emission Measure analysis of large datasets.

A new two-stage method has been developed that greatly increases the computational efficiency of estimating DEMs from multi-channel EUV image data. The first stage can process a thousand DEMs per second on a standard desktop computer, and is simple in concept and implementation. The resulting DEMs are smooth, positive, and shown to replicate model DEMs reliably when tested on synthetic data. The second stage is a data gridding method, based on the realisation that many regions within EUV data of the low solar corona share similar measurement values, and thus give similar DEMs. Once a database of DEMs has been created, the gridding method allows millions of DEMs (i.e. a full-resolution AIA image set) to be produced in a few seconds. Whilst packaged as a two-stage method, the gridding method is in principle compatible with any other DEM-estimating routine. Given the large amount of data produced by AIA/SDO, and consideration of future observations such as EUI and SPICE onboard Solar Orbiter, this new method is timely, and will enable large-scale studies of the evolution of DEMs in different solar regions over time.

Valentina Zharkova (University of Northumbria)

V. Zharkova (Northumbria, UK), Russia), S. Shepherd (Bradford University, UK), S. Zharkov (Hull University, UK) and E. Popova (Institute of the Earth Physics, Russia)

Talk

Baseline magnetic field oscillations, its effect on the visible solar activity and terrestrial temperature

In this talk we will explore the eigen vectors and a summary curve of the solar magnetic field on a millennium timescale obtained from the full disk magnetograms with Principal Component Analysis and symbolic regression approach. Extrapolation of the summary curve of solar magnetic field in the past 3000 years confirms the past eight grand cycles of 350-400-years superimposed on 22 year-cycles caused by beating effect of the two dynamo waves

generated by dipole magnetic sources in the two layers of the solar interior. Temporal variations of the dynamo waves are modelled for dipole sources with the two-layer mean dynamo model with meridional circulation. Additionally e expand the summary curve back to 100000 years to discover the baseline oscillations related to the solar inertial motion. Possible effects of the baseline oscillations of solar magnetic field on the terrestrial temperature will be also discussed.

David Stansby (Imperial College London)

D. Stansby (Imperial College London) D. Perrone (Imperial College London), L. Matteini (LESIA, Observatoire de Paris), T. Horbury (Imperial College London)

Invited

Diagnosing solar wind origins using in situ measurements in the inner heliosphere

Both Solar Orbiter and Parker Solar Probe (PSP) will take extensive measurements of the solar wind inside 1 AU, but they will not be the first: in the 1970s and 80s the Helios spacecraft made comprehensive in situ measurements of the solar wind. I will present recent work using a re-analysis of the Helios data showing three distinct categories of solar wind can be identified inside 0.8 AU. Using physical arguments each of these three categories can be associated with distinct solar sources (ie. coronal holes, active regions, and small transient structures). Although speculative, this provides a new tool that can be used in association with other methods to link the Sun to the heliosphere. I will finish by briefly discussing how in situ measurements from PSP and Solar Orbiter will be used to further understand sources of the solar wind.

Hui Fu (RAL space & Shandong university, China)

Fu, Hui; Madjarska, Maria S.; Li, Bo; Xia, Lidong; Huang, Zhenghua

Poster

Helium abundance and speed difference between helium ions and protons in the solar wind from coronal holes, active regions, and quiet Sun

Two main models have been developed to explain the mechanisms of release, heating, and acceleration of the nascent solar wind, the wave-turbulence-driven (WTD) models and

reconnection-loop-opening (RLO) models, in which the plasma release processes are fundamentally different. Given that the statistical observational properties of helium ions produced in magnetically diverse solar regions could provide valuable information for the solar wind modelling, we examine the statistical properties of the helium abundance (AHe) and the speed difference between helium ions and protons (vαp) for coronal holes (CHs), active regions (ARs), and the quiet Sun (QS). We find bimodal distributions in the space of AHe and vαp/vA (where vA is the local Alfvén speed) for the solar wind as a whole. The CH wind measurements are concentrated at higher AHe and vαp/vA values with a smaller AHe distribution range, while the AR and QS wind is associated with lower AHe and vαp/vA, and a larger AHe distribution range. The magnetic diversity of the source regions and the physical processes related to it are possibly responsible for the different properties of AHe and vαp/vA. The statistical results suggest that the two solar wind generation mechanisms, WTD and RLO, work in parallel in all solar wind source regions. In CH regions WTD plays a major role, whereas the RLO mechanism is more important in AR and QS.

Allan Macneil (University of Reading)

A. Macneil (University of Reading), M. Owens (University of Reading), M. Lockwood (University of Reading)

Talk

Inverted Flux and Sunward Strahl Electrons in the Inner Heliosphere

The heliospheric magnetic field (HMF) exhibits local inversions, in which the field ‘bends back’ upon itself. Candidate mechanisms to produce these inversions include various configurations of upstream interchange reconnection; either in the heliosphere, or in the corona where the solar wind is formed. As such, explaining the source of these inversions, and how they evolve in time and space, is a crucial step towards explaining the origins of the solar wind; a key science goal of Solar Orbiter. Locally-inverted HMF can be identified by the inward (i.e., sunward) streaming of so-called ‘strahl’ electrons. The strahl is a suprathermal population of electrons, which typically propagates away from the Sun as a field-aligned beam. We examine whether the velocity distributions of inward-propagating strahl exhibit different properties to those of outward strahl, as a result of their alternative path through the heliosphere. To do so, we perform a statistical analysis contrasting the properties of inward and outward-propagating strahl observed by the Helios spacecraft, over heliocentric distances spanning ~0.3â€”1 AU. We find a range of differences in properties between inward and outward strahl populations, and also in how these populations evolve with heliocentric distance. We evaluate these findings in the context of the formation and evolution of inverted HMF, and the strahl populations themselves. We also suggest how our results may be extended by Solar

Orbiter, which will make improved observations of the solar wind strahl, over a greater range of heliocentric distances than the Helios spacecraft.

Diego de Pablos (UCL Mullard Space Science Laboratory)

de Pablos, D. (UCL MSSL); Long, D.M. (UCL MSSL); Harra, L, K. (UCL MSSL); Owen, C. J. (UCL MSSL))

Poster

Investigating likely source regions and dynamical signatures of the solar wind through observations and modelling

One of the main high level scientific questions of the Solar Orbiter mission is how the Sun creates and controls the heliosphere. A deeper understanding of the origin of the Slow Solar Wind is essential to start tackling this question. With Solar Orbiter, it will be possible to observe the Sun with high spatio-temporal resolution using instruments with active region sized fields of view. Effective target selection is therefore essential for studies of the origin of the Solar Wind that is later measured in-situ. Here, we use in-situ particle measurements taken at L1 (ACE, WIND) to then simulate the trajectory and time taken by the plasma up to the point where it ceased to co-rotate with the Sun and started expanding radially. We can then use these estimates to identify the relevant images taken by remote sensing spacecraft (Hinode, SDO, STEREO). Photospheric observations are then used to constrain a coronal magnetic field model, and the magnetic field lines which are connected to the point at the source surface are tracked down to the solar surface. The variability in the measured intensity of the region around the footpoints will then be compared to the observed variability present in the in-situ datasets. This will enable us to correlate features observed at the Sun during their emission and the properties of the associated particle populations measured at L1.

Lloyd Woodham (MSSL, UCL)

L. D. Woodham (MSSL, UCL), R. T. Wicks (MSSL UCL & IRDR, UCL), D. Verscharen (MSSL, UCL & SSC, UNH), C. J. Owen (MSSL, UCL), B. A. Maruca (UD), B. L. Alterman (UM)

Talk

Investigating solar wind fluctuations using magnetic helicity: Implications for Solar Orbiter and Parker Solar Probe Science

The solar wind is a highly-dynamic plasma supporting waves, instabilities, shocks and turbulent fluctuations over a broad range of scales. In-situ measurements of the solar wind provide unparalleled insights into these fundamental plasma processes, making it an excellent laboratory to better understand the flow of energy in other collisionless astrophysical plasmas.

We analyse over a decade of solar wind magnetic field and ion moment data from the Wind spacecraft to investigate the nature of solar wind fluctuations at ion-kinetic scales. We use a novel technique to recover wavevector information of these fluctuations using magnetic helicity. For the first time, we separate parallel- and perpendicular-propagating fluctuations with respect to the local mean magnetic field. We find that parallel-propagating fluctuations arise from Alfvén-ion cyclotron and parallel firehose instabilities driven by unstable proton temperature anisotropy and ?-particle drifts. In addition, we show that kinetic Alfvén wave-like fluctuations dominate the helicity signal of perpendicular-propagating fluctuations, consistent with an anisotropic turbulent cascade. These results imply that there is significant processing of energy by kinetic instabilities in the solar wind, which must be included to correctly model the global thermodynamics of expanding astrophysical plasmas. The method we employ here will be especially useful for Solar Orbiter and Parker Solar Probe science - by probing kinetic-scale fluctuations in the outer corona and how they evolve with increasing heliocentric distance, we can diagnose the processes thought to be crucial for the formation and acceleration of the solar wind.

Paolo Pagano (University of St Andrews)

P, Pagano (University of St Andrews), S. L. Yardley (University of St Andrews), D. H. Mackay (University of St Andrews)

Talk

Magnetic field connectivity during Coronal Mass Ejections

One of the key goals of Solar Orbiter is to link in-situ and remote sensing data in order to study the connection between the inner solar atmosphere and the solar wind. With this regard, it will be crucial to have accurate and precise reconstructions of the solar magnetic field in order to identify which location on the solar surface the location of the spacecraft is connected to. A number of force-free models have been put forward and these will probably address this challenge for most of the observational time, i.e. when the solar corona slowly evolves. At the same time, as some observational campaigns will focus on solar eruptions and coronal mass ejections, it is key to understand how this connectivity changes during these violent and disruptive events when most of the force-free field assumptions stop being valid. We will present a global MHD simulations of a study case, the CME from Dec, 30th 2014. In this work, we use a snapshot of a global magnetofrictional simulation as the eruptive initial condition of a MHD simulation that covers the whole solar corona until 4 Rsun. We find that the simulation reproduces most of the observable features and we address how the magnetic field connectivity between the external boundary of the MHD simulation and the solar surface is affected by the CME propagation.

Megan Maunder (University of Exeter)

Miss Megan Maunder (University of Exeter), Dr Claire Foullon (University of Exeter)

Poster

Multi-Spacecraft Investigation of High-Latitude Interplanetary Coronal Mass Ejections

Interplanetary Coronal Mass Ejections (ICMEs) are key drivers of space weather throughout the heliosphere and the better understanding of these phenomena can ultimately help in improving space weather forecasting. The launch of Parker Solar Probe and the imminent launch of Solar Orbiter will provide new observations of the solar high-latitudes in the coming years associated with the end of solar cycle 24 and rise of solar cycle 25. The forward-reverse shock pairs associated with the over-expansion of ICMEs are uniquely observed at high heliospheric latitudes, related to the fast speed streams from solar polar coronal holes. Whilst

the distribution of high-latitude ICMEs is solar cycle dependant and this special class of ICMEs has been more frequently observed near solar minimum some have been observed near solar maximum. Thus these missions provide a new and unique opportunity to further explore the dynamic and plasma properties of these phenomena. We present preliminary observations of high-latitude ICMEs using the complementaries of available multi-spacecraft observations, and in preparation for the new missions.

Anthony Yeates (Durham University)

A. R. Yeates

Invited

Non-potentiality of the solar corona and why it matters

Reconstructions of the coronal magnetic field will be critical for both the science and operation of Solar Orbiter. But many of our existing tools rely on potential field models where the electric currents in the corona are neglected. In this talk, I will argue that physical models predict the presence of large-scale currents, with associated free magnetic energy. Their presence may change both the open magnetic flux and the topology of the heliospheric magnetic field (the sector structure). Accounting for these effects requires time-dependent magnetic field modelling, and I will present some results from recent efforts in this direction.

Luca Franci (Queen Mary University of London)

L. Franci (Queen Mary University of London, London, United Kingdom), E. Papini (University of Florence, Florence, Italy), G. Lapenta (Katholieke Universiteit Leuven, Belgium), P. Hellinger (Astronomical Institute, CAS, Prague, Czech Republic), C. H. K. Ch

Talk

Numerical simulations of kinetic plasma turbulence in the low beta regime: interpreting and predicting spacecraft observations

We present numerical results from high-resolution hybrid and fully kinetic simulations of plasma turbulence, following the development of the energy cascade from large magnetohydrodynamic scales down to electron characteristic scales. We explore a regime of plasma turbulence where the electron plasma beta is low, typical of environments where the ions are much hotter than the electrons, e.g., the Earth’s magnetosheath and the solar corona, as well as regions downstream of collisionless shocks. In such range of scales, recent theoretical models predict a different behaviour in the nonlinear interaction of dispersive wave modes with respect to what is typically observed in the solar wind. We also extend our analysis to scales around and smaller than the electron gyroradius, where hints of a further steepening of the magnetic and electric field spectra have been recently observed by the NASA's Magnetospheric Multiscale mission, although not yet supported by theoretical models. Our numerical simulations exhibit a remarkable quantitative agreement with recent observations by MMS in the magnetosheath, allowing us to investigate simultaneously the spectral break around ion scales and the two spectral breaks at electron scales, the magnetic compressibility, and the nature of fluctuations at kinetic scales. Moreover, they will allow us to provide very timely predictions for present and future observations by NASA's Parker Solar Probe and ESA's Solar Orbiter missions.

Timo Laitinen (Jeremiah Horrocks Institute, University of Central Lancashire)

T. Laitinen (Jeremiah Horrocks Institute, University of Central Lancashire), S. Dalla (Jeremiah Horrocks Institute, University of Central Lancashire)

Talk

Pathlengths of Solar Energetic Particles in heliospheric turbulence

Solar Energetic Particles (SEPs) propagate through turbulent heliospheric medium before being observed with in situ instruments in the interplanetary space. In order to connect the SEPs to the other characteristics of the related solar eruption, we must deconvolve the effect of the turbulent magnetic fields on the SEP propagation from the observations. Recent studies suggest that the SEP propagation across the mean Parker spiral interplanetary magnetic field, primarily caused by turbulent meandering of magnetic field lines, may significantly affect the temporal evolution of the observed SEP events. A question so far unanswered is how the meandering affects the length of the path the particles travel along, from Sun to the observing spacecraft. The pathlength is critical for comparing the timing of SEP observations to remote sensing observations. So far, SEP transport models only consider propagation along the mean Parker spiral field. In this presentation, we consider the turbulent meandering of magnetic field lines as random walk around closed magnetic islands inherent in plasma turbulence. We introduce a characteristic length scale that describes the meandering, and use this length scale to estimate the effect of the turbulent meandering on SEP path lengths. We present the dependence of the pathlengths on the location of the observing spacecraft, and discuss how the Solar Orbiter, together with spacecraft at 1 au, can be used to constrain the SEP source locations and and injection times.

Andrzej Fludra (STFC Rutherford Appleton Laboratory)

A. Fludra (STFC), M. Caldwell (STFC), A. Giunta (STFC), T. Grundy (STFC). S. Guest (STFC), S. Sidher (STFC)

Poster

Science goals of the SPICE EUV spectrometer for the Solar Orbiter mission

SPICE is a high resolution imaging spectrometer for the Solar Orbiter mission, observing in extreme ultraviolet wavelength bands 70.4 - 79.0 nm and 97.3 - 104.9 nm. The instrument has been built by an international consortium led by STFC Rutherford Appleton Laboratory. We summarise the instrument performance and describe how SPICE will address the key science goals of Solar Orbiter by providing the diagnostics of the physical state and composition of the plasmas in the solar atmosphere, in particular investigating the source regions of the solar wind outflows and ejection processes which link the solar surface and corona to the heliosphere. SPICE spectra include lines from elements such as H, C, N, O, Ne, Si, Mg, S, Ar and Fe. By observing intensities of selected lines and line profiles, SPICE will derive temperature, emission measure, flow velocity and elemental abundances for the plasmas in the temperature range from 10,000 K to 10MK. Several bright lines in the SPICE range permit high-cadence observations of plasma dynamics in the upper chromosphere and the lower transition region to study flows, oscillations and transient brightening events. We also identify intensity ratios of elements with a low First Ionization Potential (FIP) to high-FIP elements, suitable for creating maps of low/high FIP abundance ratios and establishing connectivity to in-situ observations. SPICE can also study the coronal heating, and contribute to studies of transient ionization and non-equilibrium processes in the transition region.

Christopher Owen (UCL/Mullard Space Science Laboratory)

C.J. Owen (UCL/MSSL) and the International SWA Consortium

Poster

Solar Orbiter: The Solar Wind Analyser Investigation

The baseline launch date for Solar Orbiter is less than a year away. This mission will explore inner heliosphere to determine the links between activity in the magnetic field-dominated regime of the solar corona and their consequences in the particle-dominated regime of the interplanetary medium. These links will be revealed by making observations of the Sun with a complement of powerful, high-resolution optical instruments, together with those from

state-of-the-art instruments which sample, in situ, the properties, dynamics and interactions of ï¬elds and particles in the near-Sun heliosphere. These plasma and field instruments also have high temporal resolutions, and offer unique possibilities for resolving plasma kinetic processes in the solar wind at small scales.

To achieve the mission science goals, high-cadence measurements of 3D velocity distribution functions of solar wind electron, proton and alpha particle populations are required, together with abundant heavy ions such as O6+ and ion charge states such as Fe9+ or Fe10+. These measurements will be made by the Solar Wind Analyser (SWA) suite, which is part funded and led by the UK (P.I. Institute: UCL/MSSL).

Given the planned February 2020 launch, it is perhaps timely to remind the community of the opportunities that Solar Orbiter will bring. In this poster we brieï¬‚y review the mission science goals related to the in situ exploration of the inner heliosphere. We discuss the SWA sensors, the data products we expect to return and the operations planning which will ensure we meet the science goals.

Stuart Bale (Imperial College/UC Berkeley)

S. D. Bale and the PSP/FIELDS team

Talk

Some first results from the FIELDS instrument on the Parker Solar Probe mission

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

Eamon Scullion (Northumbria University Newcastle upon Tyne)

E. Scullion (Northumbria University), H. Morgan (Aberystwyth University), H. Lin (IfA University of Hawaii), J. McLaughlin (Northumbria University)

Poster

SULIS: Solar cUbesats for Linked Imaging Spectropolarimetry

Determining the 3D magnetic field of the solar corona is key to answering fundamental questions about the true nature of solar atmospheric heating and solar eruptive events driving space weather at Earth. SULIS will be a flagship UK-led space science mission, which will lead a step-change in our understanding of the key physics of the Sun-Earth environment, through innovative UK-built 11U CubeSat (small-satellite) technology with industrial partnership. SULIS is now listed as 1 or 5 high priority, large-scale, fundable, solar system projects by STFC Science and Executive Board. SULIS consists of 3 pairs of formation flying coronagraphs, with one pair in a High Earth Orbit (HEO), whilst the other two pairs enter 1 AU STEREO-like Earth orbits, ahead-of and behind Earth, over a 5-year mission lifetime. SULIS will answer important questions about the 3D evolutionary properties of the magnetic field of the solar corona, at remarkably high cadence (~1-min), in order to determine the potential geo-effectiveness of Coronal Mass Ejections (CME's) at the earliest opportunity, as well as, tracking of CME's to determine their 3D kinematics. SULIS will compliment operational space weather missions, through exploring the science underpinning space weather sources, in order to establish better forecasting systems in future.

Pete Riley (Predictive Science Inc. (PSI))

Pete Riley (PSI), Jon A. Linker (PSI), Cooper Downs (PSI), and Ronald M. Caplan (PSI)

Poster

The Open Flux Problem II: Polar Fields

Global models of the extended solar corona, driven by observed photospheric magnetic fields, generally cannot reproduce the amplitude of the measured interplanetary magnetic field at 1 AU (or elsewhere in the heliosphere), often underestimating it by a factor of two or more. Some modelers have attempted to resolve this "open flux" problem by adjusting what they believe to be errors in the estimates of the photospheric field values. Others have simply multiplied interplanetary values by some correction factor to match 1 AU values. Here, investigate whether this "missing" flux can be explained by a source of largely unobserved, concentrated bundles of flux in the photosphere at latitudes too high to be adequately resolved by ground-based observatories or Earth-based spacecraft. Using potential field

source-surface and magnetohydrodynamic models, we demonstrate that this additional polar flux can (at least partially) resolve the open flux problem, without generating any new observational discrepancies. The upcoming joint ESA/NASA Solar Orbiter mission should be able to support or refute this idea.

Hamish Reid (University of Glasgow)

H. Reid (University of Glasgow), E. Kontar (University of Glasgow)

Talk

The speed and spatial expansion of solar energetic electron beams: simulations and LOFAR observations

Solar type III radio bursts contain a wealth of information about electron dynamics. They provide the best remote sensing diagnostics of electron beams escaping from the Sun and can simultaneously provide parameters of the solar corona and solar wind plasma they travel through. Studies routinely use type III bursts to estimate the bulk velocity of escaping electron beams from the Sun. However, the motion of different regions of an electron beam (front, middle and back) have never been systematically analysed before. We present our electron beam dynamics results which utilise both the high-resolution LOFAR observations and numerical simulations of escaping solar electron beam propagation through the solar corona. We show how type III frequency drift rates have rise times decay times, driven by electron beam speeds being faster at the front of the beam and slower at the back. The difference in speed naturally elongates the beam in space. The energy density of electron beams strongly dictates their speed and expansion, and produces type IIIs with higher peak brightness temperatures. Higher background plasma temperatures also increase beam speeds, particularly at the back of the beam. Our radial predictions can be tested by the upcoming in situ measurements made by Solar Orbiter and Parker Solar Probe.

Mayur Bakrania (Mullard Space Science Laboratory, UCL)

M. Bakrania (MSSL), I. J. Rae (MSSL), D. Verscharen (MSSL), A. Walsh (ESAC), A. Smith (MSSL), T. Bloch (Reading University), C. Watt (Reading University), G. Graham (ESAC)

Talk

Using Big Data Techniques to Classify Solar Wind Electron Populations

Solar wind electron velocity distributions at 1 au consist of three main populations: the thermal (50 eV) population called the core and two suprathermal (~50-1000 eV) populations called halo and strahl. The core and halo are quasi-isotropic populations, whereas the strahl travels along the interplanetary magnetic field (IMF) and can be observed in either the parallel or antiparallel magnetic field direction.

Using spin averaged electron data from the Cluster PEACE instruments, we analyse differential energy flux vs. both energy and pitch angle to classify these electron populations. Initially, we train supervised learning algorithms on these three classifications in order to categorise the entire dataset. Subsequently, we use unsupervised algorithms to independently classify these distributions, enabling us to perform comparisons between the two methods.

We find high accuracies in determining whether there exists a dominant population in any given distribution, with both supervised learning and unsupervised learning methods showing very similar results. We also assign probabilities to distributions with multiple populations. By characterising the three electron populations dependent on solar wind parameters, with the verification of machine learning techniques, we can show a difference in breakpoint energies between core/halo and core/strahl populations.

We discuss our results in the context of potential scattering mechanisms for solar wind electrons.

Machine Learning in Astrophysics (MachineLearning)

Mike Walmsley (University of Oxford)

M. Walmsley (Oxford), L. Smith (Oxford), C. Lintott (Oxford), Y. Gal (Oxford).

Talk

Bayesian CNN and Active Learning: Probabilistic Morphology on Galaxy Zoo

For regression tasks, CNN typically provide only point estimates with no uncertainty, leading to overconfident predictions and limiting the scientific value of such methods.
We show that Bayesian CNN and generative label models can be combined to predict posteriors over all regression targets. This approach is highly general, with potential applications including fast radio burst detection and strong lensing mass estimation.
We apply this approach to Galaxy Zoo, predicting posteriors for the exact (as opposed to majority) responses of citizen scientists. We show that these posteriors are well-calibrated and hence are reliable for practical use in galaxy evolution research.
By predicting posteriors, we can identify which subjects would, if labelled, be most informative for our model (active learning). Using our Galaxy Zoo posteriors, we simulate iteratively requesting citizen scientist responses and retraining our model. We show that active learning significantly improves model performance given limited citizen scientist effort. This will allow researchers to classify morphologies in new surveys of any size on a timescale of weeks.

Friedrich Anders (University of Barcelona)

F. Anders, T. Cantat-Gaudin

Talk

Combining dimensionality reduction and clustering techniques to find new open clusters

Gaia's data second release (DR2) has completely changed our knowledge of the Galactic open star cluster population. Using machine learning techniques, hundreds of new open clusters have been discovered, while thousands of previously suspected clusters have been shown to be asterisms. Using Gaia DR2, we test the usefulness of a combined dimensionality reduction+clustering approach to detect groups of comoving stars, and estimate the number of new clusters that can be re-/discovered with Gaia DR2 using different statistical methods.

Ben Moews (Institute for Astronomy, University of Edinburgh)

Ben Moews and Romeel Dave

Talk

Deep-learned baryons: Hybrid emulators for high-speed cosmological simulations

While cosmological dark matter-only simulations relying solely on gravitational effects are comparably fast to compute, baryonic properties in simulated galaxies require complex hydrodynamical simulations that are computationally costly to run. To solve this issue, we merge an extended version of the equilibrium model, an analytic formalism describing the evolution of the stellar, gas, and metal content of galaxies, into a deep learning framework and retrieve fully Bayesian posteriors for baryon cycling parameters. In doing so, we are able to recover more properties than the analytic formalism alone can provide, creating a high-speed hydrodynamical simulation emulator that populates galactic dark matter halos in N-body simulations with baryonic properties. Our results demonstrate that this novel hybrid system enables the fast completion of dark matter-only simulations by accurately mimicking full hydrodynamical suites of choice, offering an orders-of-magnitude acceleration of commonly deployed simulations in cosmology.

Patricia Schady (University of Bath)

P. Schady

Talk

Introduction to the Session

We will introduce the session, provide motivation and background, and discuss logistics.

Chris Lovell (University of Sussex)

C. C. Lovell (University of Sussex), Viviana Acquaviva (City University New York), Peter A. Thomas (University of Sussex), Kartheik G. Iyer (Rutgers), Eric Gawiser (Rutgers), Stephen M. Wilkins (University of Sussex)

Talk

Learning the Relationship between Galaxy Spectra and their Star Formation Histories

I will present a new method for inferring galaxy star formation histories (SFH) using machine learning methods coupled with two cosmological hydrodynamic simulations, EAGLE and Illustris. We train Convolutional Neural Networks to learn the relationship between synthetic galaxy spectra and high resolution SFHs. To evaluate our SFH reconstruction we use Symmetric Mean Absolute Percentage Error (SMAPE), which acts as a true percentage error in the low-error regime. On dust-attenuated spectra we achieve high test accuracy (median SMAPE = 12.0%). Including the effects of simulated experimental noise increases the error (13.2%), however this is alleviated by including multiple realisations of the noise, which increases the training set size and reduces overfitting (11.4%). We also make estimates for the experimental and modelling errors. To further evaluate the generalisation properties we apply models trained on one simulation to spectra from the other, which leads to only a small increase in the error (~16%) and recovers the input star forming sequence. We apply each trained model to SDSS DR7 spectra, and find smoother histories than in the VESPA catalogue. This new approach complements the results of existing SED fitting techniques, providing star formation histories directly motivated by the results of the latest cosmological simulations.

Bogdan Matuszewski (University of Central Lancashire)

B. Matuszewski

Talk

Machine learning: What? How? When? - and should I care anyway?

With continued advances in mathematical modelling, ever increasing computational power and the recent unprecedented explosion of very large datasets, most notably in medicine and astronomy, the growth in automated data analysis is unavoidable (e.g. consider Pan-STARRS 1.6 petabytes data, or reported hundreds of hours of video uploaded to the YouTube servers every minute). Without the deployment of machine learning techniques, handling rapidly growing data volumes may not be possible.

The talk will focus on the fundamentals of machine learning with key ideas and terminology explained. It will include machine learning taxonomy and explain briefly relevant concepts of artificial intelligence, data mining, pattern recognition and computer vision. The focus will be on a broad overview of key methodologies, including: supervised, semi-supervised, unsupervised, active and reinforced-learning and their use in classification and regression problems. Essential concepts of: training, validation and testing data subsets; machine learning algorithm evaluation methodologies and metrics as well as fundamental limitations and frequent misconceptions will be mentioned. The talk will include some historical background as well a discussion of the recent state-of-the-art. A representative sample of discriminative and generative machine learning techniques will be briefly explained, including: k-nearest neighbors, mixture models, support vector machines, random forests, and deep learning frameworks.
A small number of practical examples, including astronomical data, will be provided to succinctly illustrate the key machine learning concepts.

James Pearson (University of Nottingham)

J. Pearson (University of Nottingham), N. Li (University of Nottingham), S. Dye (University of Nottingham)

Talk

Practicalities of strong gravitational lens modelling using convolutional neural networks

Strong galaxy-galaxy gravitational lensing is the distortion of the paths of light rays from a background galaxy into arcs or rings as viewed from Earth, caused by the gravitational field of an intervening foreground lens galaxy. Lensing provides a useful way of investigating the properties of distant galaxies and the early Universe, but to do so requires accurate modelling of the lens' mass profile. Conventionally this is done through relatively slow parametric techniques to work out the mass profile parameters. However, over the next few years new surveys will produce images of tens of thousands of gravitational lenses, so a more efficient method is needed to cope with such a large dataset.
In this work, we focus on the use of machine learning to develop a fast, automated approach to predict mass profile parameters straight from lens images, through training a convolutional neural network. Such a network can carry out the complex task of modelling strong lens systems with similar accuracy to parametric techniques but millions of times faster. We investigate a number of practicalities faced when modelling real image data, such as how network performance depends on the inclusion of lens galaxy light and the degree to which adding colour information improves the accuracy of predicted lens model parameters. The

network's effectiveness is examined for images simulated to match the imaging characteristics of the Large Synoptic Survey Telescope and Euclid, predicting how well surveys conducted with these facilities will enable direct retrieval of lens model parameters.

Téo Bloch (University of Reading)

Téo Bloch (University of Reading), Clare Watt (University of Reading), Mathew Owens (University of Reading), Leland McInnes (Tutte Institute for Mathematics and Computing)

Talk

Solar Wind Classification: Methods of Applying Unsupervised Machine Learning

Unsupervised machine learning provides an under-utilised set of tools for increasing the objectivity associated with scientific investigation and discovery. We present two new solar wind origin classification schemes developed using a variety of the techniques available. The schemes aim to classify solar wind into three types: coronal hole wind, streamer belt wind, and 'unclassified' which does not fit into either of the previous two categories. The classification schemes are created using non-evolving solar wind parameters, such as ion charge states and composition, measured during Ulysses' three fast-pass latitude-scans. The schemes are subsequently applied to the whole of the Ulysses and ACE datasets. Given the choice of parameter type, the scheme is grounded in the physical properties of the solar source regions. Furthermore, the techniques used are selected specifically to reduce the introduction of subjective biases. We demonstrate significant 'best case' disparities (7% - 18%) with the traditional "fast" and "slow" solar wind determined using speed thresholds.

Sebastian Turner (Liverpool John Moores University)

S. Turner (LJMU), M. Siudek (IFAE, Barcelona), A. Pollo (National Centre for Nuclear Research, Warsaw), S. Salim (Indiana University)

Poster

Synergies between low- and intermediate-redshift galaxy population classifications revealed with unsupervised clustering

Machine learning approaches will be crucial for the analysis of galaxy populations in the impending era of big data in astronomy. M. Siudek et al. (2018) tested an unsupervised clustering algorithm on a sample of ~50000 galaxies from VIPERS, which has a comparable

statistical fidelity to local surveys like SDSS, but at z~1, when the Universe was half its current age and the global star formation rate was much higher than at present. Clustering was conducted using 13 features: spectroscopic redshift, and SED-fit-derived photometry in 12 bands from UV to IR, ensuring that information across the full wavelength coverage of VIPERS was used. The 11 clusters that were found reveal substructure to the common two- (red/blue) or three- (red/green/blue) class view of the galaxy population.
Using the Fisher Expectation-Maximisation algorithm, we compare these intermediate-redshift clusters with clusters found in a low-redshift sample of ~500000 galaxies with a view to understanding the cosmic evolution of the galaxy population, in terms of these clusters, since z~1. The low-redshift sample is derived from GSWLC, itself based on the SDSS MGS, and we cluster using the same 13 features as for the intermediate-redshift sample. The clusters in this low-redshift sample are systematically offset from those of the intermediate-redshift, but also exhibit differences in the substructure in comparison with the intermediate-redshift sample, suggesting an evolving balance of evolutionary processes. Advantages of the algorithm, which operates in a discriminative latent subspace of the observed 13-dimensional feature space, will also be discussed.

Sebastian Turner (Liverpool John Moores University)

S. Turner (LJMU), I. Baldry (LJMU), P. Lisboa (LJMU), S. Longmore (LJMU), C. Collins (LJMU), R. Crain (LJMU)

Talk

Testing a cosmological galaxy simulation with unsupervised clustering

The use of computer simulations enables astrophysicists, traditionally limited in their study of the Universe to the analysis of real observations, to conduct numerical experiments in model Universes and thereby test theories of astrophysics. The results of such numerical experiments must, though, be assessed against real observations in order to establish whether the input theories apply to the real Universe. Previous comparisons of galaxy simulations and observations have generally considered only one or two features at a time (e.g. galaxy stellar mass functions, star formation main sequences). The use of an unsupervised clustering approach invites a comparison that considers several more features, ensuring all relevant aspects of galaxy formation and evolution are captured concurrently. Our work represents the first time that simulations and observations have been compared in this way.
We present results from a comparison of simulated and observed galaxies via the use of the k-means unsupervised clustering algorithm, guided by an evaluation framework that identifies stable clustering outcomes. Simulated galaxies are taken from the EAGLE hydrodynamical cosmological simulations, and observed galaxies are taken from the GAMA

survey. We ensure a consistent feature selection between simulations and observations: stellar mass, specific dust mass, specific star formation rate, size, and morphology. We establish the broad similarity of clustering structure in both simulated and observed galaxies 5-dimensional feature spaces, and discern the more detailed differences between these clusters, and determine the extent to which we can use the simulated clusters to make inferences about the observed clusters.

Matthew Chan (Lancaster University)

Matthew Chan

Talk

The search for Galaxy Clusters with Deep Learning

Galaxy clusters are the largest known gravitationally bound systems in the Universe, studying clusters allows us to understand the evolution of galaxies in extreme environments and determine cosmological parameters of the Universe. Current methods of identifying and examining clusters are gravitational lensing, Sunyaev-Zeldovich (SZ) technique, X-ray emission and red sequence fitting. The main difficulty in searching for clusters at any wavelength is distinguishing between foreground and background objects along the line-of-sight, that can increase the number of false detections. We present a new method in the search for clusters in wide-field optical imaging data, such as SDSS. This uses a state-of-the-art probabilistic deep learning technique that can generalize well to differentiate clusters from other objects and determine their basic properties. Since there is an abundance of labelled data of identified clusters from previous classifications in publically available catalogues, we do not need to rely simulated data. This means we can keep our training data as reliable as possible, which is advantageous for our deep learning model. Eventually we will apply our deep learning model to future upcoming redshift surveys such as LSST that will probe deeper into the unexplored parts of the Universe. The benefits of using a deep learning model is that it can quickly and efficiently mine large datasets performing analysis as accurate and reliable as a human, which means astronomers can minimize the time spent on data processing, leaving more time for scientific interpretation.

Hongming Tang (Jodrell Bank Centre for Astrophysics, the University of Manchester)

A. Hongming Tang (JBCA) B. Anna Scaife (JBCA) C. J.P. Leahy (JBCA)

Poster

Transfer learning for radio galaxy

In the context of radio galaxy classification, most state-of-the-art neural network algorithms have been focused on single survey data. The question of whether these trained algorithms have cross-survey identification ability or can be adapted to develop classification networks for future surveys is still unclear. One possible solution to address this issue is transfer learning, which re-uses elements of existing machine learning models with different applications. Here we present radio galaxy classification based on a 13-layer Deep Convolutional Neural Network (DCNN) using transfer learning methods between different radio surveys. We find that our machine learning models trained from a random initialization achieve accuracies comparable to those found elsewhere in the literature. When using transfer learning methods, we find that inheriting model weights pre-trained on FIRST images can boost model performance when re-training on lower resolution NVSS data, but that inheriting pre-trained model weights from NVSS and re-training on FIRST data impairs the performance of the classifier. We consider the implication of these results for future radio surveys being planned for next-generation radio telescopes such as ASKAP, MeerKAT, and SKA1-MID.

Magnetohydrodynamic Waves and Instabilities in the Solar Atmosphere in the High-Resolution Era (SolarMHDWav)

Hendrik-Jan Van Damme (University of St Andrews)

H.-J. Van Damme, I. De Moortel, P. Pagano

Poster

Chromospheric evaporation due to phase mixing of Alfvén waves

Observational evidence has shown that waves are ubiquitous in the solar corona. As such, the role of wave-based heating mechanisms is attracting increased attention. In particular, phase mixing of Alfvén waves has been proposed as a possible mechanism to accelerate the dissipation of wave energy.

Using MHD simulations, we consider a 2D magnetic strand in hydrostatic equilibrium as a model for a coronal loop, and we investigate chromospheric evaporation due to heating by phase mixing of Alfvén waves. We implement a continuous, sinusoidal driver that generates propagating Alfvén waves along the loop. Due to the non-uniform density profile, these Alfvén waves dissipate through phase mixing and increase the temperature in the boundary of the loop. In this study, we investigate whether this leads to chromospheric evaporation and whether the subsequent change in the local coronal density is sufficient to alter the phase mixing process.

David Pascoe (KU Leuven)

Poster

Coronal Loop Seismology Using Kink Oscillations in Loops with Wide Inhomogeneous Layers

The transverse structure of coronal loops plays a key role in the physics but the small transverse scales can be difficult to observe directly. For wider loops the density profile may be estimated by forward modelling of the transverse intensity profile. The transverse density profile may also be estimated seismologically using kink oscillations in coronal loops. The strong damping of kink oscillations is attributed to resonant absorption and the damping profile contains information about the transverse structure of the loop. However, the analytical descriptions for damping by resonant absorption presently only describe the behaviour for thin inhomogeneous layers. Previous numerical studies have demonstrated that this thin boundary approximation produces poor estimates of the damping behaviour in loops with wider inhomogeneous layers. Both the seismological and forward modelling approaches suggest loops have a range of layer widths and so there is a need for a description of the damping behaviour that accurately describes such loops. We perform a parametric study of the damping of standing kink oscillations by resonant absorption for a wide range of inhomogeneous layer widths and density contrast ratios, with a focus on the values most relevant to observational cases. We describe the damping profile produced by our numerical simulations without prior assumption of its shape and compile our results into a lookup table which may be used to produce accurate seismological estimates for kink oscillation observations.

Matthew Allcock (University of Sheffield)

Matthew Allcock (University of Sheffield), Noemi Zsamberger (University of Sheffield), Daria Shukhobodskaia (University of Sheffield), Robert Erdelyi (University of Sheffield)

Poster

Diagnosing the Alfven speed in asymmetric fibrils using solar magneto-seismology

We present the first application of a magneto-seismology technique using the MHD theory of asymmetric waveguides. By applying the recently developed Amplitude Ratio Method to chromospheric fibrils, we are able to estimate the local Alfven speed, which has previously been nearly impossible to determine given the observational challenges to directly measure the magnetic field. Solar magneto-seismology (SMS) diagnostics is carried out by approximating the boundaries of the chromospheric dark fibrils using Gaussian fitting, then taking the ratio of the measured maximum amplitudes of each boundary oscillation. This amplitude ratio provides a proxy of the internal magnetic field strength of the fibril as a waveguide and is exploited using a numerical inversion scheme. Five fibrils are analysed as a proof of concept. Their internal Alfven speeds are estimated and agree well with previous studies, demonstrating the powerful diagnostic applicability of SMS to asymmetric MHD waveguides.

Michaël Geeraerts (KU Leuven)

Michaël Geeraerts, Tom Van Doorsselaere

Poster

Effect of electrical resistivity on the damping of fast and slow sausage modes

The effect of electrical resistivity on the damping of fast and slow magnetosonic waves is studied analytically. First, we briefly analyse the simple case of an infinite homogeneous cartesian plasma and look at how it affects the damping time of the wave. In a second, more complicated case we look at axisymmetric modes of a cylindrical flux tube with a discontinuous profile in the equilibrium density, plasma pressure and magnetic field (representative for a pore in the solar photosphere e.g.). Analytical dispersion relations are found in both cases under the assumption of very small electrical resistivity, which converge to the corresponding dispersion relation from the ideal case when taking the limit of a vanishing electrical resistivity.

Paolo Pagano (University of St Andrews)

P, Pagano (University of St Andrews), R. Morton (Northumbria University), I. De Moortel (University of St Andrews)

Poster

Effect of the coronal loop density structure on the efficiency of wave heating

Observations of coronal loops have revealed ubiquitous transverse velocity perturbations and estimates have shown that these perturbations carry a significant amount of energy, possibly sufficient to sustain the million degree solar corona.
More recently, a clear power spectrum for these transverse oscillations has been identified providing clear indication of how much energy can be extracted from propagating waves. At the same time, MHD models still do not explain how this energy can be efficiently converted and the indications coming from the models suggest that the direct dissipation of waves is not a sufficiently efficient mechanism to heat the solar corona.
The damping of transverse waves can be understood in terms of coupling of the transversal modes (kink) with azimuthal modes (Alfvén) in the inhomogeneous boundaries of the loops, which is also the region where the energy conversion is most efficient. In this work we investigate the role of the density structure of the loop, i.e. the region with density

enhancement, in the efficiency of the wave heating mechanism. Using 3D non-ideal MHD simulation with a driver that simulates the observed power spectrum of transverse waves, we focus on two different loop structure; a traditional cylindrical one where a dense interior region exists along the whole loop length and another one where there is no interior regionÂ and the density enhancement extends only until a certain length along the loop.

Alexander Prokopyszyn (University of St Andrews)

Mr A. P. K. Prokopyszyn, Prof A. W. Hood, Prof I. De Moortel

Poster

Estimating the Heating Rate of Standing Alfven Waves

Phase mixing of standing Alfven waves has long been considered a possible candidate for coronal heating. In this study, we estimate the heating rate associated with phase mixing of standing Alfven waves. We use a 2.5D model and approximate the transition region as a perfect discontinuity, which allows us to obtain analytic solutions. The model builds on analytic work of previous authors by allowing an arbitrary factor of wave energy, R, to reflect and, 1 - R, to transmit through the transition region. We find that for ideal plasma, with R 1, the wave energy in the corona always grows to a maximum value. Even for ideal plasma, the cross-field gradients converge to a finite value which means an upper bound for the cross-field gradients and hence the heating rate can be calculated. From this, we are able to derive a formula which might be useful for calculating the parameter space under which wave heating could be negligible or non-negligible.

Chloe Sumner (Aberystwyth University)

C. Sumner (Aberystwyth University), Dr Y. Taroyan (Aberystwyth University)

Poster

Impact of plasma inflow on magnetic twists during prominence formation

Solar prominences are sheets of relatively cool and dense plasma which extend into the corona and have their feet within the photosphere. Forming in filament channels above polarity inversion lines found in the photosphere, prominences are magnetically suspended flux ropes. The origins of twist in prominence structures are investigated through modelling the inflow of plasma material during their formation, and considering the impact of torsional

Alfvén waves which are ubiquitous to the system.

As a first step in this investigation, the linear domain has been considered in order to ascertain the conditions under which any potential twisting might be amplified within the system. This is achieved through analysis within which a flux tube is adopted with a time-dependent inflow, whilst equations of motion and induction are combined to describe the evolution of small scale linear twists experiencing magnetic perturbations. Analytical solutions are derived in terms of the hypergeometric function, which allow us to investigate the growth of the perturbations.

Finally, a numerical approach is adopted and compared with the analytical approach. For the numerical analysis, the governing equations are solved for given initial conditions that replicate a small amplitude torsional Alfvenic pulse. The evolution of the pulse for given initial and boundary conditions is investigated over time within the simulated prominence flux rope to explore the conditions in which an expected twisted structure can evolve.

Thomas Rees-Crockford (Northumbria University)

T. Rees-Crockford (Northumbria University), E. Scullion (Northumbria University), D.S. Bloomfield (Northumbria University), S.-H. Park (Nagoya University)

Poster

Investigating the magnetic Rayleigh Taylor instability in a prominence with SST observations and supporting 3D MANCHA simulations

Understanding the magnetic field properties of prominence flux ropes, as a function of radial height from the solar surface, is important with regard to determining their eruption mechanism. Direct measurement of magnetic fields in prominences is highly challenging and observations are limited, however, new insights can be achieved through a combination of the kinematic analysis of high resolution observations together with supporting simulations. Here, we carry out kinematic and spectral analysis of prominence plumes in H-alpha 656.28 nm and Ca II 854.2 nm, as observed by the SST on 6th June 2014, to statistically characterize their dynamic properties (such as 3D flow velocity vectors, widths, lengths, lifetimes). We then designed a set of by advanced 3D MHD simulations of the Rayleigh Taylor instability (performed by MANCHA incorporating ambipolar diffusion) to explore the role of the magnetic field in the development of the prominence plumes, constrained by the observed properties. Constraining the simulations with the observed properties allows us to define a narrow range of applicable magnetic field properties (inclinations and strengths) that satisfy the observed plume within the observable limits and, therefore, the magnetic sub-structure of this prominence flux rope.

Poster Presenters

Hendrik-Jan Van Damme (St Andrews), David Pascoe (KU Leuven), Matthew Allcock (University of Sheffield), Michaël Geeraets (KU Leuven), Paulo Pagano (St Andrews), Alexander Prokopyszyn (St Andrews), Thomas Rees-Crockford (Northumbria), Simon White (Warwic

Talk

Lightning Talks by Poster Presenters

1. Chromospheric evaporation due to phase mixing of Alfvén waves, Hendrik-Jan Van Damme (St Andrews), id 445
2. Coronal Loop Seismology Using Kink Oscillations in Loops with Wide Inhomogeneous Layers, David Pascoe, (KH Leuven), id 536
3. Diagnosing the Alfven speed in asymmetric fibrils using solar magneto-seismology, Matthew Allcock (University of Sheffield), id 371
4. Effect of electrical resistivity on the damping of fast and slow sausage modes, Michaël Geeraets (KU Leuven), id 404
5. Effect of the coronal loop density structure on the efficiency of wave heating, Paulo Pagano (St Andrews), id 318
6. Estimating the Heating Rate of Standing Alfven Waves, Alexander Prokopyszyn (St Andrews), id 472
7. Investigating the magnetic Rayleigh Taylor instability in a prominence with SST observations and supporting 3D MANCHA simulations, Thomas Rees-Crockford (Northumbria), id 409
8. MHD Wave Coupling in the Solar Atmosphere, Simon White (Warwick), id 278
9. Multi-wavelength observations of 4 homologous global coronal waves, David Long (MSSL), id 204
10. Impact of plasma inflow on magnetic twists during prominence formation, Chloe Sumner (Aberystwyth), id 477
11. Random excitation of decay-less transverse oscillations of coronal loops, Andrei Afanasev (KU Leuven), id 159
12. Thermodynamic Evolution of a Coronal Loop, Erin Goldstraw (St Andrews), id 448
13. Transverse Wave-Induced Kelvin-Helmholtz Rolls in Spicules, Patrick Antolin (St Andrews), id 197

Simon White (University of Warwick)

Simon J. White, Erwin Verwichte

Poster

MHD Wave Coupling in the Solar Atmosphere

The strongly magnetised nature of the solar atmospheric plasma allows for the propagation of a diverse range of magnetohydrodynamic (MHD) waves. Of particular interest is the study of wave propagation within the coronal loops, plasma structures ubiquitous to the solar atmosphere. The study of which is primarily motivated by the explanation of the coronal heating problem and is a key element in wave-based heating models of the corona and in understanding space-weather relevant dynamics such as flares and CMEs. There have been numerous observations which provide evidence for the existence of both fast standing MHD waves [1] and slow propagating and standing MHD waves [2]. These oscillations are commonly observed following an eruption event. [3] Slow wave propagation at the loop footpoints has also been observed [4], which are driven by dynamics or heating from below, but in large loops this may also be due to coupling to transverse oscillations.[5] Here we investigate the evolution of transverse waves and the coupling of these waves to the lower atmosphere. These investigations are performed on loops with a large plasma beta, where the coupling effects are amplified. This is done Numerically for both the single interface and slab geometry, where the slab geometry should better describe the dense plasma loop. These simulations also provide a useful guide to possible future observations of the mode coupling within the solar atmosphere.
[1] Aschwanden, M. J., de Pontieu, B., Schrijver, C. J., & Title, A. M. 2002, Sol. Phys., 206, 99 [2] De Moortel, I. 2009, Space Sci. Rev., 149,65 [3] Aschwanden, M. J., Fletcher, L., Schrijver, C. J., & Alexander, D. 1999a, ApJ, 520, 880 [4] De Moortel, I. 2009, Space Sci. Rev., 149, 65 [5] Verwichte, E., Foullon, C., & VanDoorsselaere, T. 2010, ApJ, 717, 458

Noemi Kinga Zsamberger (The University of Sheffield)

Noemi Kinga Zsamberger, Matthew Allcock, Daria Shukhobodskaia, Robert Erdelyi

Talk

MHD waves in multi-layered waveguides

We present a family of multi-layered asymmetric waveguide models as a generalisation of the classical (symmetric) slab configuration and demonstrate their wide range of applications using high-resolution solar observations.
Diagnosing the solar atmospheric plasma is one of the major challenges in solar physics.

Magnetohydrodynamic (MHD) waves, by means of applying the methods of solar magneto-seismology (SMS), provide a powerful tool to diagnose the solar plasma in a range of MHD waveguides e.g. from small magnetic bright points (MBPs), pores to large structures like prominences. Here, we present the framework of a new model to describe MHD wave propagation. Namely, we employ a family of asymmetric Cartesian waveguide models that can better capture the structured solar atmosphere. We describe a general multi-layered, stationary MHD waveguide and its asymmetric (externally magnetic and non-magnetic) one-slab special cases. Additionally, we investigate the effect of one or more steady bulk flows on the dispersion and stability of MHD waves in an asymmetric magnetic slab system. With the recent and ongoing developments in high-resolution solar observations, each of these models can be utilised to describe different features in the solar atmosphere, such as elongated MBPs, light walls, fibrils, prominences, and CME flanks. We show a sample of these applications and demonstrate how the SMS diagnostic power of waveguide asymmetry can be utilised in these structures.

David Long (UCL-MSSL)

David M. Long (UCL-MSSL), Jack Jenkins (UCL-MSSL), Gherardo Valori (UCL-MSSL)

Poster

Multi-wavelength observations of 4 homologous global coronal waves

Freely-propagating global waves in the solar atmosphere are commonly observed using Extreme UltraViolet passbands (EUV or “EIT waves”), and less regularly in H-alpha (Moreton-Ramsey waves). Despite decades of research, joint observations of EUV and Moreton-Ramsey waves remain rare, complicating efforts to quantify the connection between these phenomena. We present observations of four homologous global waves originating from the same active region between 28-30 March 2014 and observed using both EUV and H-alpha data. Each global EUV wave was observed by the Solar Dynamics Observatory, with the associated Moreton-Ramsey waves identified using the Global Oscillations Network Group (GONG) network. Each global wave exhibits high initial velocity and strong deceleration in each passband studied, with the EUV wave kinematics exceeding those of the Moreton-Ramsey wave. The density compression ratio of each global wave was estimated using both differential emission measure and intensity variation techniques, with both indicating that the observed waves were weakly shocked with a Mach number slightly greater than one. This suggests that, according to current interpretation, the global coronal waves were not strong enough to produce Moreton-Ramsey waves, indicating an alternative explanation for these observations. Instead, we conclude that the evolution of the global waves was restricted by the surrounding coronal magnetic field, in each case producing a downward-angled wavefront propagating towards the north solar pole which perturbed the chromosphere and was observed as a Moreton-Ramsey wave.

Andrew Hillier (University of Exeter)

A. Hillier (Exeter), V. Polito (Harvard-Smithsonian CFA)

Talk

Observations of a flow instability driven by dynamic prominence motions

Prominences are incredibly dynamic across the whole range of their observable spatial scales, with observations revealing gravity-driven fluid instabilities, waves, and turbulence. With all these complex motions, it would be expected that instabilities driven by shear in the fluid motions contained in the prominence body would develop. However, evidence of these have been lacking. Here we present the discovery in a prominence, using observations from the Interface Region Imaging Spectrograph (IRIS), of a shear flow instability, a mode of the Kelvin-Helmholtz instability that makes streams of fluid develop serpentine patterns, driven by transonic motions in the prominence body. This finding presents a new mechanism through which we can create turbulence from the flows observed in quiescent prominences. The observation of this instability in a prominence highlights their great value as a laboratory for understanding the complex interplay between magnetic fields and fluid flows that play a crucial role in a vast range of astrophysical systems.

Callum Boocock (Queen Mary University London)

C.Boocock, D.Tsiklauri

Talk

Resistive 3D MHD simulations of the enhanced phase mixing of torsional Alfvén waves in axisymmetric exponentially divergent coronal structures

Resistive MHD simulations are used to validate analytical models for the enhanced phase mixing of torsional Alfvén waves in exponentially divergent coronal structures such as those found in coronal loop footprints and coronal holes. The 3D MHD simulations use an axisymmetrical exponentially divergent potential magnetic field embedded in a stratified atmosphere with a high density flux tube at its centre. Torsional Alfvén waves are driven from

the 'photospheric' lower boundary and undergo phase mixing at the tube boundary where there is a transverse gradient in Alfvén velocity. The results corroborate the analytic solutions in WKB approximation (Ruderman M.S. & Petrukhin N.S. A&A, 620 (2018), A44), and show that 3D geometry effects can significantly enhance phase mixing. Moreover 3D MHD simulations are also performed beyond WKB approximation. The simulation results also show that the effects of phase mixing propagate radially outwardly from the tube boundary as a series of torsional Alfvén modes that are continuously out of phase. Peculiarly this result is shown to be true whether a divergent field or a constant uniform magnetic field is used and a similar result is also shown for shear Alfvén waves. Finally the relative dissipation due to this enhanced phase mixing is discussed with reference to the scale height of the magnetic field divergence and density stratification, the frequency of the Alfvén waves and the viscosity/resistivity of the corona.

Erin Goldstraw (University of St Andrews)

Erin E. Goldstraw and Alan W. Hood

Poster

Thermodynamic Evolution of a Coronal Loop

Slow convective motions inject energy into the coronal magnetic field. Under suitable conditions this stored energy can be released as heat in the corona. One mechanism for this is reconnection, which can be triggered by the tearing instability.
In order to model the plasma response to this heating, thermodynamic processes need to be considered.
Full MHD simulations of a coronal loop, driven at its footpoints are considered. Initially, the magnetic field evolves through sequences of equilibria, then a symmetry breaking perturbation results in the development of the tearing mode. Optically thin radiation and thermal conduction are included to investigate the effect of thermodynamic processes on the system.

Patrick Antolin (University of St Andrews)

P. Antolin (University of St Andrews), D. Schmit (Catholic University), T. M. D. Pereira (University of Oslo), B. De Pontieu (LMSAL), I. De Moortel (University of St Andrews)

Talk

Transverse Wave-Induced Kelvin-Helmholtz Rolls in Spicules

In addition to their jet-like dynamic behavior, spicules usually exhibit strong transverse speeds, multi-stranded structure, and heating from chromospheric to transition region temperatures. In this work we first analyze Hinode and IRIS observations of spicules and find different behaviors in terms of their Doppler velocity evolution and collective motion of their sub-structure. Some have a Doppler shift sign change that is rather fixed along the spicule axis, and lack coherence in the oscillatory motion of strand-like structure, matching rotation models, or long- wavelength torsional Alfvén waves. Others exhibit a Doppler shift sign change at maximum displacement and coherent motion of their strands, suggesting a collective MHD wave. By comparing with an idealized 3D MHD simulation combined with radiative transfer modeling, we analyze the role of transverse MHD waves and associated instabilities in spicule-like features. We find that transverse wave induced Kelvin-Helmholtz (TWIKH) rolls lead to coherence of strand-like structure in imaging and spectral maps, matching some observations. The rapid transverse dynamics and the density and temperature gradients at the spicule boundary lead to Mg II k and Ca II H source functions maxima at the boundary, potentially allowing IRIS to capture the KHI dynamics. Twists and currents propagate along the spicule at Alfvénic speeds, and the temperature variations within TWIKH rolls, produce the sudden appearance/disappearance of strands seen in Doppler velocity and in Ca II H intensity. However, only a mild intensity increase in higher-temperature lines is obtained, suggesting there is an additional heating mechanism at work in spicules.

Julia M. Riedl (KU Leuven)

J.M. Riedl , T. Van Doorsselaere , and I. C. Santamaria

Talk

Wave modes excited by photospheric p-modes & mode conversion in footpoints of coronal loops

Waves are ubiquitous in the solar corona and there are indications that they are excited by photospheric p-modes. However, it is unclear how p-modes in coronal loops are converted to

sausage modes and transverse (kink) modes, which are observed in the corona. We aim to investigate how those wave modes are excited in the lower corona by photospheric acoustic waves. We build 3D magnetohydrostatic loop systems with different inclinations spanning from the photosphere to the lower corona. These atmospheres are then simulated with the MANCHA code, where we perturb the equilibrium with a p-mode driver at the bottom of the domain. By splitting the velocity perturbation into components longitudinal, normal, and azimuthal to the magnetic flux surfaces we can study the wave behavior. Depending on whether the driver polarization has a component perpendicular to the flux tubes or not, we find that both kink and deformed sausage waves or only sausage waves are excited. In addition, we calculate a wave conversion factor from acoustic to magnetic wave behavior by taking the ratio between the mean magnetic energy flux and the sum of the mean magnetic and acoustic energy flux and compare it to a commonly used theoretical conversion factor. We find that between magnetic field inclinations of 10Â° to 30Â° those two methods lie within 40%. For smaller inclinations the absolute deviation is smaller than 0.1.

MAPPING THE INFLUENCE OF MAGNETOSPHERE-IONOSPHERE INTERACTIONS ON THE SURFACE MAGNETIC FIELD AND GROUNDED INFRASTRUCTURE (GROUNDMAG)

Jim Wild (STFC-UKRI and Beihang University)

J.-Y. Yang (School of Space and Environment, Beihang University, 100191, Beijing, China), M. W. Dunlop (STFC-UKRI, Chilton, Oxfordshire, OX11 0QX, UK (m.w.dunlop@rl.ac.uk), M. Freeman, N. Rogers, J. A. Wild, J. Rae, J.-B. Cao, H. LÃ¼hr, C. Xiong

Poster

Correlation analysis of field-aligned currents measured by Swarm

The orientation of field-aligned current sheets (FACs) can be inferred from dual-spacecraft correlations of the FAC signatures between two or more Swarm spacecraft (A and C), using the maximum correlations obtained from sliding data segments. Statistical analysis of both the correlations and the inferred orientations shows clear trends in magnetic local time (MLT) which reveal the behaviour of both large and small scale currents. The maximum correlation coefficients show distinct behaviour in terms of either the time shift, or the shift in longitude between Swarm A and C for various filtering levels. The low-latitude FACs show the strongest correlations for a broad range of MLT centred on dawn and dusk, with a higher correlation coefficient on the dusk-side and lower correlations near noon and midnight. The current sheet orientations are shown to broadly follow the mean shape of the auroral boundary for the lower latitudes corresponding to Region 2 FACs and that these are most well-ordered on the dusk side. Together with these correlation trends, individual events have also been sampled by higher altitude spacecraft in conjunction with Swarm (mapping both to region 1 and 2), showing that two different domains of FACs are apparent: small-scale (some tens of km) which are time variable and large-scale (>100 km) which are rather stationary. We investigate further how these FAC regimes are dependent on geomagnetic activity, focusing on high activity events. The trends found here for different activities are compared to effects seen in the ground magnetometer signals (dH/dt).

Ciaran Beggan (British Geological Survey)

J. Huebert; C.D. Beggan; G.S. Richardson; T.P. Martyn; A.W.P. Thomson (British Geological Survey)

Poster

Differential Magnetometer Measurements in the UK High-Voltage Power Grid for the Validation of GIC Modelling in Space Weather Research

Extreme space weather events can have severe effects on satellites and other technology in orbit, but also pose risks to ground-based infrastructure like high voltage (HV) transformers, railways and gas pipelines through the induction of geomagnetically induced currents (GICs). Modelling GICs requires knowledge about the source magnetic field and the electrical conductivity structure of the Earth to calculate the electric fields generated during enhanced geomagnetic activity.
The electric field in combination with detailed information about an electrical network's topology and resistance parameters enable the derivation of GICs flowing in HV power lines. Directly monitoring of GICs at the ground neutral in substations is possible using a Hall probe, but scarcely implemented. Therefore, we have used the differential magnetometer method (DMM) to measure GICs at six sites in the UK power grid. The setup of the DMM includes the installation of two fluxgate magnetometers, one directly under a HV power line (400 kV) affected by GICs, and one as a remote site further away a few hundred metres away. The difference in the recorded magnetic field between the instruments allows for the inference of GICs in the line, via the Biot-Savart law, during geomagnetically enhanced periods. Data from several storm events during 2018 and 2019 are presented. These show a good match to Hall probe measurements available from one transformer site in Scotland. Comparing the measured GIC at the DMM sites to the computed ones will allow us to validate the UK model, and to monitor GICs in real-time.

Lauren Orr (University of Warwick)

L.Orr, S.C.Chapman, J.W.Gjerloev

Talk

Directed network analysis of the substorm ionospheric current system and timings, using SuperMAG ground-based magnetometer data

We quantify the spatio-temporal evolution of the substorm ionospheric current system utilising the full set of 100+ SuperMAG ground based magnetometers. We use this magnetometer data to construct dynamical directed networks for the first time. If the canonical cross-correlation between vector magnetic field perturbations, observed at two magnetometer stations, exceeds an event and station specific threshold, they form a network connection. The time lag at which cross-correlation is maximal determines the direction of propagation or expansion of the structure captured by the network connection. If spatial correlation reflects ionospheric current patterns, network properties can test different models for the evolving substorm current system. This analysis has been used to compare 86 isolated substorm events, chosen based on nightside ground station coverage. We obtained the timings for, a consistent picture in which the classic substorm current wedge (SCW) forms. A current system is seen pre-midnight following the SCW westward expansion. Later, there is a weaker signal of eastward expansion. Finally, there is evidence of post-substorm convection. The effectiveness of this methodology and the resulting sequence of substorm current system evolution will be discussed.

Mike Hapgood (RAL Space)

Mike Hapgood (RAL Space)

Talk

Short, Sharp and Vicious - the Great Storm of 15 May 1921

The severe space weather event of 13-16 May 1921 produced spectacular technological impacts, including destructive fires at telecommunications facilities in Sweden and the US, and damage to transatlantic cables. It included severe geomagnetic variations and spectacular aurora reported at many locations around the world. As a result, a wealth of information is available in scientific journals, newspapers, and other sources, enabling us to construct a timeline of the event. This shows that a series of large CMEs bombarded Earth during this period. The first CMEs may have prepared the way for latter intense activity, clearing density from the region between Sun and Earth, and energizing Earth’s magnetosphere. Thus, a

subsequent CME could travel more quickly and thus drive even more energy into the already active magnetosphere. This CME arrived late on 14 May, driving a series of very intense substorms early on 15 May, leading to strong geoelectric fields and the spectacular technological effects. However, some effects, attributed in media reports to space weather, were probably coincidental with the storm, and due to more prosaic faults. The timeline of the 1921 event, including the confusion caused by prosaic faults, can be used to construct scenarios for use today by policy-makers and emergency managers planning how to reduce the adverse impacts of future space weather events.

Andrew Kavanagh (British Antarctic Survey)

A. J. Kavanagh (BAS), Y. Ogawa (NIPR)

Poster

Small scale variability in ionospheric electric field and conductance: contributions to GIC.

Geomagnetically Induced Currents (GIC) are driven by variations in the ionospheric electric currents, which in turn are enhanced by space weather activity. These currents are a convolution of the structure of the electric field and Pedersen and Hall conductivities in the ionosphere and there is evidence that the meso-scale structure of the currents is important in terms of the rate of change of the surface horizontal magnetic field (dH/dt), relevant to hazardous GIC.

We use data from the European Incoherent Scatter (EISCAT) radar in northern Norway to derive estimates of the local electric field and conductance and consider how they vary in relation to each other and how that variability influences dH/dt, as measured by local magnetometers. Understanding how these parameters influence GIC will provide information on the meso and small spatial scale response to space weather events.

Andy Smith (MSSL/UCL)

A. W. Smith (MSSL/UCL), I. J. Rae (MSSL/UCL), C. Forsyth (MSSL/UCL), M. P. Freeman (BAS)

Talk

The Contribution of Sudden Compressions to the Rate of Change of the Surface Magnetic Field in the UK

Rapid changes in the surface geomagnetic field can induce potentially damaging currents in conductors on the ground; this is a critical consideration for the operation of power networks.

In this work we investigate how sudden compressions (SCs), associated with sharp increases in solar wind dynamic pressure, impact the (one minute) rate of change of the horizontal magnetic field (R) recorded by three UK based ground stations.
We find that though SCs last for a very small fraction of the total time, up to 10% of the most extreme R is accounted for at the lowest latitude station. At higher latitudes the proportion is much lower at approximately 1%.
Sudden compressions are also related to other magnetospheric phenomena, geomagnetic storms for example. We explore how the distribution of R changes over time following sudden compressions. We find that the probability of observing large R is greatly enhanced for 3 days after a SC. In the 24 hours following a SC it is 10 times more likely than normal to observe a rate of change of 100nTmin-1. Additionally, between 80 and 95% of data (depending on station) over 50nTmin-1 is recorded within three days of a SC. Further, subdividing the sudden compressions into sudden storm commencements (SSCs) and sudden impulses (SI), shows that SSCs in particular are related to much larger R.
These results suggest that accurately predicting sudden compressions is important to identify intervals during which the UK power network is at risk from GICs.

Neil Rogers (Lancaster University)

N. C. Rogers, J. A. Wild, and E. Eastoe

Talk

The Directional Statistics of Extreme Geomagnetic Field Variations

Understanding the statistics of large and rapid changes in the horizontal component of the geomagnetic field (dB/dt) is important in modelling the probabilities of geomagnetically induced currents (GIC) in ground infrastructure. In a study of |dB/dt| measured at 125 magnetometers worldwide over several decades, extreme value theory (Coles, 2001) was used to predict the magnitudes of such events for return periods up to 200 years. These were modelled as a function of geomagnetic latitude, magnetic local time, season, solar activity, and the orientation of the interplanetary magnetic field. Patterns of occurrence relate closely to the known statistics of ionospheric and magnetospheric current systems associated with Sudden Commencements, Pc5 ULF waves, and auroral substorm onsets.
Directionality is an important consideration when assessing the risk of GICs affecting long cables and networks. We have therefore examined the directional statistics of the field fluctuations, drawing on methods developed for other environmental datasets (extreme sea currents, wind speeds, etc.). The modal directions of dB/dt are associated with the principal current systems driving the field fluctuations and also depend on the time-scale (dt) of the fluctuation.

Reference:
S. Coles, An introduction to Statistical Modeling of Extreme Values, Springer-Verlag London ltd, 2001.

Carl Haines (University of Reading)

C. Haines (University of Reading), M. Owens (University of Reading), L. Barnard (University of Reading), M. Lockwood (University of Reading)

Talk

The variation of geomagnetic storm duration with intensity

Space weather impacts on grounds infrastructure are expected to increase primarily with geomagnetic storm intensity, but also storm duration. It is therefore important to understand the degree to which these storm characteristics are correlated. We use the recent recalibration of the long-running aa index, aa_H, to analyse the relationship between geomagnetic storm intensity and storm duration over the past 150 years, further adding to our understanding of the climatology of geomagnetic activity. Using a threshold approach to storm definition, we find that more intense storms have longer durations, as expected, and that the distribution of durations for a given intensity is approximately log-normal. On this basis, we provide a method for probabilistically predicting storm duration given its peak intensity and test this against the aa_H data set. By considering the average profile of storms we show that activity becomes less recurrent on the 27-day timescale with increasing intensity.

John Coxon (University of Southampton)

J. C. Coxon (Southampton), R. M. Shore (British Antarctic Survey), M. P. Freeman (British Antarctic Survey), R. C. Fear (Southampton), S. D. Browett (Southampton), A. W. Smith (MSSL/UCL), D. K. Whiter (Southampton), B. J. Anderson (JHUAPL)

Talk

Timescales of Birkeland currents driven by the IMF

Effective forecasting of space weather conditions allows us to better predict geomagnetic effects on Earth. However, a key part of this is knowledge of the timescales on which solar wind-magnetosphere-ionosphere coupling operates. To this end, we obtain current densities from AMPERE and IMF By and Bz from OMNI for March 2010. For each AMPERE spatial co-ordinate, we cross-correlate current density with By and Bz, finding the maximum correlation

for lags up to 360 minutes. The patterns of maximum correlation contain large-scale structures that have similar morphologies to the average current density separated by clock angle.
This novel approach enables us to see statistically the timescales on which information is electrodynamically communicated to the ionosphere after magnetic field lines reconnect at the magnetopause and in the magnetotail. Application of this technique, especially in future work focusing on timescales in case studies and specific event types, will greatly inform our knowledge of how magnetosphere-ionosphere coupling affects conditions on the ground.

Jim Wild (Lancaster University)

J.A. Wild (Lancaster University)

Poster

Using dissolved gas analysis data to assess the impact of geomagnetic activity on UK power station transformers

Previous studies have presented evidence of geomagnetically induced currents (GIC) damaging high voltage transformers within electricity transmission grids to the point of failure [e.g. Gaunt & Coetzee, 2007]. In the UK, National Grid has estimated that during an extreme space weather event, two large transformers could be catastrophically damaged, leading to disconnection from the transmission grid for potentially two to four months [Oughton et al., 2018]. Consequently, much research focuses on the modelling and measurement of potentially damaging GIC flowing through grid transformers. However, only a small fraction of UK grid transformers are equipped with GIC monitoring sensors. The resulting scarcity of data presents challenges to our understanding of the impact of differing levels of geomagnetic disturbance on infrastructure assets, and to the validation of grid models that might offer a forecasting capability. However, almost all transformers include dissolved gas analysis (DGA) sensors that monitor the status of the unit's coolant oil to detect indicators of stress or damage. We therefore present the results of a preliminary study, in which DGA data from a number of UK power station transformers between 2010-15 are analysed with respect to geomagnetic activity.

C.T. Gaunt & G. Coetzee (2007), Transformer failures in regions incorrectly considered to have low GIC-risk, 2007 IEEE Lausanne Power Tech, 10.1109/PCT.2007.4538419.

E.J. Oughton et al. (2018), A risk assessment framework for the socioeconomic impacts of electricity transmission infrastructure failure due to space weather: an application to the United Kingdom, Risk Analysis 10.1111/risa.13229.

Lisa Rosenqvist (Swedish Defence Research Agency)

L. Rosenqvist and T. Fristedt (Swedish Defence Research Agency), A. P. Dimmock (Swedish Institute of Space Physics) , D. Welling (University of Texas at Arlington) , M. Smirnov (LuleÃ¥ Technical University) , E. Yordanova (Swedish Institute of Space Phys

Invited

Verification of the GIC-SMAP modelling framework and assessment of the potential to predict extreme geomagnetically induced currents in Sweden

A proof-of-concept modelling capability that incorporates a detailed 3-D structure of Earth's electrical conductivity in a GIC estimation procedure has been developed (GIC-SMAP) and verified based on GIC measurements in northern Sweden. However, 3-D modelling show that southern Sweden is exposed to stronger electric fields due to a combined effect of a low crustal conductivity and the influence of the surrounding coast effect. Earlier studies have also shown that the Swedish power grid is especially vulnerable to GICs in the southern parts. This study utilizes GIC measurements recently conducted in collaboration with Svenska KraftnÃ¤t on a power line in southern Sweden to verify the GIC-SMAP modelling framework in this region. After verification the model is used to quantify the hazard of severe GIC by applying historic recordings of strong geomagnetic disturbances to the GIC-SMAP modelling framework. Moreover, we predict the GIC in the power line based on the modelled magnetic disturbance during the St. Patricks storm in March 2015 by the Space Weather Modelling Framework (SWMF). This event included a rapid, high magnitude localized magnetic disturbance over Scandinavia and is used to investigate the GIC prediction capability of current state-of-the art solar- and magnetospheric models due to its potential hazard of driving extreme GICs.

MOONS: THE NEXT GENERATION SPECTROGRAPH FOR THE VLT (MOONS)

Adam Carnall (Royal Observatory Edinburgh)

A. C. Carnall, R. J. McLure, J. S. Dunlop, V. Wild, F. Cullen

Talk

Inferring the physical parameters of high-redshift galaxies from MOONS data

The transformative quality and quantity of MOONS spectroscopy will allow us to extend truly statistical studies of subtle galaxy physical properties out to high redshift. In order to take full advantage of these data it is important to develop correspondingly superior analysis techniques, moving beyond index measurements to obtain stronger constraints through full spectral fitting. In this talk I will introduce the BAGPIPES spectral modelling and fitting tool, which allows the user to fit complex models to spectroscopic data within a fully Bayesian framework. Crucially, BAGPIPES also allows for the modelling and fitting of systematic uncertainties arising from instrumental and atmospheric effects. I will demonstrate the use of BAGPIPES to analyse data from VANDELS, a uniquely deep, recently completed spectroscopic survey, designed to obtain high-SNR continuum spectroscopy for ~2000 galaxies from 1 z 7. In particular I will present the first science results from the VANDELS quiescent sample at 1.0 z 1.3. We consider the trend in mean stellar age with stellar mass, recovering a strong downsizing trend of ~1.5 Gyr per decade in stellar mass, in agreement with similar studies at lower redshifts. This is a strong observational constraint on feedback models in numerical simulations, and we demonstrate that the downsizing trend at z=1 is insufficiently strong in both Simba and IllustrisTNG. We also consider how galaxies which undergo quenching events move across the UVJ diagram towards the red sequence, and hence explore the relationship between the green-valley, post-starburst and quiescent populations.

Roberto Maiolino (University of Cambridge)

Invited

MOONS: project overview, current status and high-z science

MOONS is the next generation multi-object optical/near-IR spectrograph for the ESO Very Large Telescope, which will enable astronomers to obtain simultaneously spectra of 1,000 targets in the spectral range between 0.65um to 1.8um, hence exporing an uncharted

territory in terms of statistics, sensitivity and wavelength coverage .
I will provide an overview of the project by describing the detailed its capabilities as well as the expected performance of the instrument.
I will also give a quick overview of the current status of the project.
Finally, I will provide an overview of the main science cases for what concerns the extragalactic surveys, while an overview of the Galactic science cases will be given in a separate presentation within the same session.

Oscar Gonzalez (UKATC)

MOONS Galactic Science Team

Talk

The MOONS survey of the reddened Milky Way

MOONS technical specifications, powered by the 8.2m telescope aperture of the VLT, make it the ideal workhorse to map the stellar populations of highly reddened regions of the Milky Way such as the Galactic plane and young star clusters. In this presentation, I will describe the plans of our MOONS Galactic survey, currently in its design stage. I will describe its complementary nature with other Galactic archaeology surveys, highlighting the wide range of science cases that can be addressed from MOONS mapping the southern disk and bulge at low Galactic latitudes.

Vivienne Wild (University of St Andrews)

V. Wild, D. Maltby, O. Almaini, L. Taj Aldeen, A. Carnall

Talk

The star formation histories of rapidly quenched galaxies at z~1

I will present the detailed star formation histories of ~40 z~1 galaxies with strong Balmer absorption lines indicating recent and rapid quenching of star formation. High quality VLT spectra and multiwavelength photometry, combined with state-of-the-art bayesian model fitting, provide tight constraints on physical properties such as the age and strength of the starburst, and fraction of old stars. A large fraction are consistent with being single-epoch burst events with peak star formation rates consistent with sub-mm galaxies. This data provides a perfect example of the quality of science that will be possible at 0.8z1.8 in the MOONS reference survey where the prevalence and global importance of rapid quenching of star formation in building the red sequence we see today is much debated.

OPEN SESSION ON MAGNETOSPHERIC, IONOSPHERIC AND SOLAR-TERRESTRIAL PHYSICS (MISTGENERAL)

Shannon Jones (University of Reading)

S. Jones (University of Reading), C. Scott (University of Reading), R. Highfield (Science Museum), C. Lintott (University of Oxford)

Poster

A subjective ranking of the visual complexity of coronal mass ejections

The Heliospheric Imagers on board NASA's twin STEREO spacecraft show that coronal mass ejections (CMEs) can be incredibly complex structures. To explore this complexity, we created a citizen science project, in collaboration with the Science Museum, where participants were shown pairs of CME images and asked to decide which appeared to be the most complicated, or complex. We then ranked all the CMEs in order of complexity. This complexity ranking revealed a surprising result; that the annual average complexity values follow the sunspot cycle. Here we present our findings and investigate the factors which cause a CME to be classified as 'more complex'.

Gareth Chisham (British Antarctic Survey)

G. Chisham (British Antarctic Survey)

Poster

An adaptive high-latitude co-ordinate system for ionospheric empirical models and climatologies

Empirical models and climatologies of polar ionospheric processes and variations are crucially important components of ionospheric space weather applications. Such models allow the tracking of ionospheric plasma density enhancements such as polar patches, which can disrupt and attenuate radio communications through the ionosphere, or allow the estimation of Joule heating, which increases the atmospheric drag on low-Earth orbiting satellites. One common feature in the development of previous empirical models is that measurements have been combined and averaged on fixed co-ordinate grids. However, there are significant differences between the dominant processes within the polar cap, the auroral oval, and equatorward of the auroral oval. These boundaries are in continual motion due to the shifting nature of the auroral oval in response to changes in the outer magnetosphere. As a consequence, models that are developed by combining and averaging data in fixed co-

ordinate grids heavily smooth the variations that occur near the boundary locations. The goal of this work is to aid researchers seeking to use adaptive, high latitude coordinates, based on auroral oval boundaries, in their studies. These include expanding the existing database of IMAGE FUV open-closed field-line boundaries (OCBs) to include equatorward auroral oval boundaries and details of how to convert between adaptive, high-latitude coordinates (with either only an OCB, or both an OCB and equatorward auroral boundary) and geographic or geomagnetic coordinates.

Téo Bloch (University of Reading)

Téo Bloch (University of Reading), Clare Watt (University of Reading), Mathew Owens (University of Reading), Leland McInnes (Tutte Institute for Mathematics and Computing)

Poster

Applying Unsupervised Machine Learning to Solar Wind Classification

We present a new solar wind origin classification scheme developed independently using unsupervised machine learning. The scheme aims to classify solar wind into three types: coronal hole wind, streamer belt wind, and 'unclassified' which does not fit into either of the previous two categories. The classification scheme is created using non-evolving solar wind parameters, such as ion charge states and composition, measured during Ulysses' three fast-pass latitude-scans. The scheme is subsequently applied to the whole of the Ulysses and ACE datasets. Given the choice of parameter type, the scheme is grounded in the physical properties of the solar source regions. Furthermore, the techniques used are selected specifically to reduce the introduction of subjective biases. We demonstrate significant 'best case' disparities (minimum 7%, maximum 18%) with the traditional "fast" and "slow" solar wind determined using speed thresholds.

Steve Milan (University of Leicester)

S. E. Milan, H. Sangha, J. A. Carter (University of Leicester, UK), B. J. Anderson, L. Paxton (JHU/APL, USA)

Poster

Auroral and field-aligned current signatures associated with substorms and steady magnetospheric convection

The terrestrial auroras are in large part produced by the field-aligned currents (FACs) that transmit stress from the magnetosphere to the ionosphere as a consequence of solar wind-magnetosphere-ionosphere coupling. Substorms and steady magnetospheric convection events, as important modes of magnetospheric response to the SW-M-I interaction, produce characteristic signatures in the FACs and auroras. In this study we employ measurements of FACs from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) and the auroras from the Defense Meteorological Satellite Program (DMSP) SSUSI instrument to investigate the differences and similarities in morphology and dynamics produced by impulsive and steady magnetotail reconnection, and discuss the relationship between these two modes of coupling.

Adrian Grocott (Lancaster University)

A. Grocott (Lancaster), J. N. Delaney (Lancaster), and M.-T. Walach (Lancaster)

Poster

Azimuthal fast flows in the nightside ionosphere: interplanetary magnetic field, auroral activity and latitude dependencies

Dawn-dusk asymmetries in the ionosphere may be controlled by the interplanetary magnetic field or by internal magnetospheric processes. We investigate this control by inspecting the occurrence of fast azimuthal flows in the nightside ionosphere, using an 18-year database of ionospheric radar data. We find that 80% of the flows display the expected IMF By dependence, that is, eastward for By > 0 and westward for By 0. This rises to 87% when considering only those nightside flows above 62 degrees magnetic latitude, dropping to 44% when considering only the lower-latitude flows. We compare these occurrence distributions to the IMF clock angle, auroral electrojet index (AE), and total ionospheric transpolar voltage (Vpc), and find that the By-dependent flows tend to occur during weak solar wind driving, when the IMF is moderately northward, the AE index is low (AE 100Â nT) and the transpolar voltage is modest (Vpc 50Â kV). When the convection pattern expands to the mid-latitudes

under stronger driving conditions the flows become predominantly westward, irrespective of IMF By. We suggest that this is due to the effects of processes in the inner magnetosphere that are intrinsically asymmetric, such as the Harang discontinuity and sub-auroral polarisation streams (SAPS), overriding any IMF By influence on the convection pattern morphology. We also find some evidence to suggest that intervals of non-IMF By controlled fast flows persist for longer (up to 120 mins) than the By-dependent flows (up to 60 mins).

Harneet Sangha (University of Leicester)

H. Sangha, S. E. Milan, J. A. Carter, A. R. Fogg, B. J. Anderson, H. Korth, L. J. Paxton

Poster

Bifurcating Region 2 Currents Associated with Substorms

We use the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) to study the variability of the magnetosphere-ionosphere (MI) field-aligned currents (FACs) associated with substorms. We report on a new phenomenon that has been observed with AMPERE: the formation of an additional region 2 (R2) current, predominantly in the dusk sector. Such events are associated with substorm onset, hence we propose that this new R2 FAC is formed by plasma injections into the inner magnetosphere during the substorm expansion phase. In this talk, we focus on the interhemispheric conjugacy, or otherwise, of the observed FACs, and on the seasonal dependence of the conjugacy, for the years 2010 to 2016.

Caoimhe Doherty (Mullard Space Science Laboratory, UCL)

C. Doherty (MSSL, UCL), A. Fazakerley (MSSL, UCL), C. Owen (MSSL, UCL), A. Kavanagh (BAS), R. Fear (University of Southampton), Y. Bogdanova (RAL)

Poster

Cluster and ground-based observations in the northern high-altitude cusp during the 2017/8 winter season

The northern and southern magnetospheric cusps contain recently opened magnetic flux, with footpoints typically confined to a region about 1 degree wide in magnetic latitude and 2-3 hours wide in magnetic local time (MLT), near noon and just poleward of the last closed field line on the Earth's dayside. Magnetic reconnection at the magnetopause allows solar wind entry and particle precipitation on cusp field lines. Statistical studies suggest that the

mid-altitude cusps vary in width, magnetic latitude and MLT in response to the Interplanetary Magnetic Field (IMF) and solar wind dynamic pressure. When IMF Bz is southward, the cusp moves lower in latitude. Under northward IMF the By component controls the cusp position in MLT, and its influence is less clear for southward IMF. Solar wind dynamic pressure increases cause widening in MLT.
In the early years after their launch, the Cluster spacecraft visited the northern high-altitude cusp, making crossings at roughly steady MLT and changing latitude, but over time this became impossible due to natural orbital evolution. Recently the Cluster orbit has evolved to allow the spacecraft to traverse across the northern exterior cusp at a roughly steady latitude and changing MLT. Using this new opportunity, we are examining a set of events during the Cluster cusp crossing of the 2017/8 winter season for high-altitude measurements in conjunction with ground-based radar coverage, including a subset with dedicated EISCAT radar observations. We will introduce these set of events and present an initial case study.

David Jackson (Met Office)

D. Jackson (Met Office), E. Down (Met Office), J. Manners (Met Office)

Poster

Development of Radiation Schemes for the Extended Unified Model

A goal of Met Office space weather research is to develop an operational coupled Sun to Earth model forecast system, including a model spanning the Earth's surface to the thermosphere. The first step is to extend the Met Office Unified Model (UM) from its current upper boundary near 85 km to an upper boundary near 150 km. This work is also an important part of the EU project SWAMI (Space Weather Atmosphere Model and Indices).
We focus on the changes to the representation of radiative transfer in the UM to make the model fit for purpose in the mesosphere and lower thermosphere (MLT). The existing UM radiation scheme does not represent non-local thermodynamic equilibrium (NLTE), which is needed for accurate heating rates at MLT altitudes. Here, we describe work to replace pre-existing heating rates with NLTE heating rates from the Fomichev scheme at such altitudes. The UM scheme does not address radiative transfer from wavelengths less than 200 nm. This approach is acceptable in the lower atmosphere where these wavelengths do not penetrate, but in the MLT shorter wavelengths in the Extreme Ultraviolet (EUV) and Far Ultraviolet (FUV) also need to be included. We describe work to extend absorption calculations to these wavelengths, using the correlated-k approach to ensure accuracy while maintaining computational speed. The FUV / EUV actinic fluxes derived from two-stream calculations are used to calculate photolysis rates in order to drive the exothermic chemical reactions responsible for the large increases of temperature with altitude in the MLT.

Joseph Eggington (Imperial College London)

J. W. B. Eggington (Imperial College London), J. P. Eastwood (Imperial College London), L. Mejnertsen (Imperial College London), R. T. Desai (Imperial College London), J. P. Chittenden (Imperial College London)

Poster

Dipole Tilt Effect on the Steady-State Magnetosphere-Ionosphere System: Global MHD Simulations

Magnetic reconnection is a key driver of magnetospheric dynamics at Earth. Its 3-dimensional nature is highly complex, occurring predominantly along the magnetic separator: a continuous line along which differing magnetic topologies meet. The global reconnection rate (i.e. reconnection voltage) is determined by the length of the separator and the parallel electric field along its extent, both of which are sensitive to changes in driving conditions. Under steady-state and in the absence of parallel electric fields within the magnetosphere, this voltage maps down as the ionospheric cross-polar cap potential (CPCP). Diurnal and seasonal variations in dipole field orientation can therefore directly affect ionospheric conditions, and the potential impact of a severe space weather event. Understanding the response of the separator to changes in dipole tilt is thus crucial in fully describing the factors which control the coupled magnetosphere-ionosphere system.
Using the Gorgon MHD code, we have implemented an algorithmic approach to tracing out the separator in global magnetospheric simulations. The location of the separator for various interplanetary magnetic field orientations and dipole tilts is identified, and thus the impact on energy transfer rates across the magnetopause. We investigate changes in the strength and morphology of ionospheric region-I field-aligned currents and convection patterns, revealing a non-linear response to dipole tilt which is explained in the context of varying separator geometry. This demonstrates a strong sensitivity of the magnetospheric response to the onset time of a given severe space weather event, due to changes in the location of reconnection on the magnetopause.

Ian McCrea (RALSpace)

I. W. McCrea (RAL), A.J. Kavanagh (BAS), M. P. Freeman (BAS), Y. Bogdanova (RAL), S. Crothers (RAL)

Poster

EISCAT 3D: the future is nearly here

EISCAT 3D will be the most advanced incoherent scatter radar (ISR) in the world. It is not a dish-based radar like the current EISCAT systems, instead it will use a field of antennas: a phased array which has the capability to produce a beam pointing in any direction and switch rapidly to another direction. Because of this versatility, the radar will effectively be able to produce multiple simultaneous beams looking in different directions within a given integration period.

E3D will image a volume of the ionospheric plasma allowing users to study features in unprecedented detail and across different scales. Not only this, but by using remote sites it produces multiple vectors so that the plasma motion can be imagined in 3D.

As well as rapid changes in beam direction, E3D will be able to quickly switch pulse-codes meaning that multiple experiments will run simultaneously. For example users could run a low elevation, multi beam experiment studying plasma flow and interleave it with a vertical, mid-altitude code for studying noctilucent clouds. E3D will be highly versatile with variable duty cycle giving the opportunity for continuous measurements for monitoring and synoptic studies.

Construction has begun and phase 1 is due for completion in 2021; the operational radar will initially consist of a powerful transmitter at the main site and two remote sites. Additional phases will introduce even higher power and a further two remote sites, providing higher resolution measurements. Come and learn about the capabilities of this revolutionary radar.

Michaela Mooney (Mullard Space Science Lab, UCL)

M.Mooney (Mullard Space Science Lab, UCL), M. Marsh (Met Office), C. Forsyth (Mullard Space Science Lab, UCL), T. Hughes (Met Office), M. Sharpe, S. Bingham (Met Office)

Poster

Evaluating Auroral Forecasts Against Satellite Observations

During periods of high geomagnetic activity, particles precipitating into the upper atmosphere can cause auroral emission and affect long-range radio communications, whilst the accompanying geomagnetic storm could potentially induce strong currents in oil pipelines and electricity transmission lines at ground level. These effects may impact industry sectors such as aviation, energy and defense. Forecasting the location and probability of aurora is therefore of interest to many end users. In addition, forecasting when the aurora may be visible can also be a key tool in promoting public awareness and engagement with space weather.

The OVATION Prime-2013 auroral precipitation model (Newell et al., 2014) is currently in operation at the UK Met Office and delivers a 30-minute forecast of the probability of observing the aurora in the polar regions of the northern and southern hemispheres. Using techniques developed for terrestrial weather forecast verification, we evaluate the performance of this operational implementation of OVATION against the boundaries of auroral emission regions determined by the far-ultraviolet (FUV) observations of the auroral oval captured by the IMAGE satellite over the period 2000-2002. We compare seasonal variations in the auroral forecasts to determine the factors which impact the model performance.

Daniel Griffin (The Met Office)

Daniel Griffin, Matthew Griffith, David Jackson

Poster

Extension of the Met Office Unified Model into the Thermosphere

The Met Office aims to extend its Unified Model (UM) for weather and climate into a whole atmosphere model that can simulate the atmosphere from the surface to the thermosphere above altitudes of 100km. In this talk, I will discuss the progress that has been made towards improving the UM's dynamical stability and realism.

With suitable radiation and chemistry schemes not yet available, we had to set up a realistic basic state for our tests of the UM dynamics, so we replaced the radiation scheme with a nudging to the climatology in the mesosphere and lower thermosphere region. This has led to stable, accurate simulations that have enabled us to test the model with the top boundaries set at different altitudes (100km, 120km, 135km), different vertical and horizontal resolutions, and different sponge layer strengths. We describe the results of these sensitivity experiments here.

We aim to further extend the UM up to 150km - 170km, and here show initial results with a 135km lid. At these higher altitudes, we need the real physical process of vertical molecular viscosity and diffusion to realistically damp vertically propagating model waves. Vertical molecular viscosity and diffusion becomes a significant damping mechanism above 130km, and may be a better alternative to the artificial "sponge layer" that has been applied near the UM upper boundary to date. Progress on this work is outlined here.

Shaun Dempsey (University of Bath)

S. Dempsey (University of Bath), N. Hindley (University of Bath), T. Moffat-Griffin (British Antarctic Survey), N. Mitchell (University of Bath)

Poster

First Observations of Mesospheric Winds, Waves and Tides Over South Georgia

The dynamics of the mesosphere/lower-thermosphere (MLT) region are dominated by gravity waves, tides and planetary waves of large amplitude. These waves and tides play a critical role in the transfer of energy and momentum between atmospheric layers. Gravity waves can be generated by winds blowing over mountains, jet stream instabilities, storms or in-situ secondary excitation. However, Global Circulation Models (GCMs) currently under-represent gravity-wave fluxes near 60S, leading to the so-called “cold-pole” problem in which the GCM Antarctic winter polar stratospheres are much colder than observed. Further, in order to extend GCMs into the mesosphere and above, there is a need to make observations to constrain mesospheric gravity-wave fluxes. Here we present observations in the MLT from a new meteor radar on the isolated, mountainous island of South Georgia in the Southern Atlantic (54S, 36W). We use these observations to determine the winds, tides, planetary waves and gravity-waves in the mesosphere over the island. Mesospheric meridional winds and temperatures are found to be closely connected, indicating the role of the planetary-scale general circulation in governing the temperature of the MLT. A rich field of winds, waves and tides is revealed, including exceptionally large semi-diurnal amplitudes up to 60 m/s. A strong semi-annual cycle in gravity-wave variances is observed, which we explain in terms of critical-level filtering by the underlying winds. Statistical measurements are used to investigate the modulation of gravity-wave fluxes by intense planetary waves and tides - a process that can allow wave signatures to be transferred to high altitudes.

Adrian Grocott (Lancaster University)

N. A. Case (Lancaster University), A. Grocott (Lancaster University), R. Fear (Southampton University), J. Lane (Lancaster University)

Poster

IMF By control of plasma flow in the magnetosphere-ionosphere system: a multi-region superposed epoch analysis

The By-component of the interplanetary magnetic field (IMF) has consistently been shown to exert significant influence on the variability of the coupled solar wind-magnetosphere-ionosphere system. Through multiple superposed epoch analyses, we have identified some of the timings involved in the SW-M-I system's response to reversals in the orientation of IMF By component. Data from the Cluster Electron Drift Instrument indicates that the lobes respond quickly, with initial changes starting in as a little as 5 min after a reversal and an end state being reached within 30-40 min. Data from the ground-based SuperDARN radar network show that ionospheric flows also respond on these prompt timescales. However, plasma flows recorded in the plasmasheet, including an analysis of fast flow events, shows that this region is much more complex with significant variation in its response to IMF By reversals - perhaps due to the effect of local small-scale processes.

Christopher Scott (University of Reading)

C J Scott (University of Reading), S. Jones (University of Reading), L A. Barnard (University of Reading)

Talk

Inferring thermospheric composition from ionograms

The visibility of the F1 peak in ionospheric soundings from ground-based instrumentation is a sensitive function of the thermospheric composition. The shape of the ionospheric profile in the transition region between F1 and F2 peaks can be expressed in terms of the 'G' factor, a function of ion production rate and loss rates via atomic and molecular processes. This in turn can be expressed as the square of the ratio of ions lost via molecular and atomic processes. We present a comparison of the G factor obtained from ionograms recorded at Kwajalein (9 N, 167.2 E) for 25 events during which the TIMED spacecraft was making co-located measurements of the neutral thermosphere. An estimate is made of the relationship between √G and the molecular: atomic composition ratio. A linear relationship is found. Scatter within this relationship will be due to the assumptions used and the fact that the two measurements

are not truly simultaneous (being made 15 minutes and 5 degrees in latitude and longitude from each other). Nevertheless, this relationship reveals the potential for using ground-based ionospheric measurements to infer variations in the composition of the neutral thermosphere. Such information can be used to investigate spatial and temporal variations in thermospheric composition which in turn has applications such as understanding the response of thermospheric composition to climate change and the efficacy of the upper atmosphere on satellite drag.

Maria-Theresia Walach (Lancaster University)

M.-T. Walach (Lancaster University), A. Grocott (Lancaster University), F. Staples (Mullard Space Science Laboratory, UCL), E. G. Thomas (Thayer School of Engineering, Dartmouth College)

Poster

Influences of the equatorward SuperDARN expansion on data coverage and measured parameters

The Super Dual Auroral Radar Network (SuperDARN) was built to study ionospheric convection at Earth and has in recent years been expanded equatorward to observe ionospheric flows over a larger latitude range. The SuperDARN expansion to midlatitudes started in 2005 with the building of the Wallops Island Radar at 37.93 degrees geographic latitude, and a geographic longitude of -75.47 degrees. Since then, nine more mid-latitude radars have been added to the network, allowing us to measure ionospheric convection on a larger scale than ever before. Using data from the years 2012 to 2018, we perform a statistical analysis on processed SuperDARN convection maps for the entire dataset. Â We process a number of versions of the maps, using different background models both with and without the inclusion of data fromÂ midlatitude radars. This enables us to explore the difference the addition these radars make to the dataset, as well as simulate how much information was missing from the previous decades of SuperDARN research. To show the importance of growing the radar network to include measurements at mid-latitudes we study a variety of parameters, such as changes in the equatorward boundary of the ionospheric electric field, changes in the cross polar cap potential, changes in the locations of the minimum and maximum potentials, and the width of the return flow region. We show that there is a clear difference between the datasets, especially when comparing the measured parameters to geomagnetic indices, such as AL.

Aisling Bergin (University of Warwick)

A. Bergin (University of Warwick), S. C. Chapman (University of Warwick), J. W. Gjerloev (Johns Hopkins University Applied Physics Laboratory, University of Bergen), N. W. Watkins (University of Warwick, London School of Economics and Political Science, O

Talk

Large Excursions in AE and Dst Geomagnetic Indices and their SuperMAG Counterparts: A Comparison Study

Communication, power grids, aviation and satellite systems may be impaired by severe space weather events. Geomagnetic indices are frequently used in the characterization of space weather events. The auroral electrojet (AE) index [1] and the disturbance storm time (Dst) index [2] are two such indices which have been recorded almost continuously for multiple solar cycles. SuperMAG [3], provide a collated full set of ground based magnetometer observations and have produced analogues to AE and Dst which span the last four solar cycles. SME is an electrojet index which shares methodology with AE. SMR is a ring current index which shares methodology with Dst. SME and SMR are both at higher spatial and temporal resolution than AE and Dst. We compare the statistical distribution of AE with SME and Dst with SMR for the last four solar maxima. We carry out a quantitative statistical characterization of how well the indices track large excursions in geomagnetic activity. The construction of the indices and differences in sampling rates lead to subtle differences in their performance. We find that SMR and DST track each other reasonably well over the range of observed Dst values, and SMR captures larger excursions than Dst. However, AE begins to depart from SME at values ~1000 nT and significantly underestimates the ground magnetic perturbation at higher values, that correspond to more severe space weather events. A simple model is used to illustrate how the differences between AE and SME or Dst and SMR arise, and we discuss their significance with respect to the construction of the indices.

[1] Davis, T. N., Sugiura, M. (1966) Auroral electrojet activity index AE and its universal time variations, Journal of Geophysical Research; Vol. 71 Issue 3, p785-801, 17p
[2] Sugiura, M. (1964), Hourly values of equatorial Dst for the IGY, Ann. Int. Geophys., 35, 9, Pergamon Press, Oxford.
[3] Gjerloev, J. W. (2012), The SuperMAG data processing technique, J. Geophys. Res., 117, A09213, doi:10.1029/2012JA017683.

Hannah Laurens (Lancaster University)

H. J. Laurens (Lancaster), A. Grocott (Lancaster)

Poster

Magnetospheric boundary proxies determined from SuperDARN ionospheric convection maps

Observations of magnetospheric boundaries can provide useful information on the time-dependent dynamics of the coupled solar wind-magnetosphere-ionosphere system. We use an archive of Super Dual Auroral Radar Network (SuperDARN) data to perform a statistical analysis of two different ionospheric boundaries and test their applicability as a proxy for the open-closed field line boundary (OCB). The first is the boundary between eastward and westward flow, the so-called convection reversal boundary (CRB). The second is a new boundary that we have derived that follows the location of maximum curvature across successive convection streamlines (the convection curvature boundary, or CCB). The CRB has previously been shown to be a useful proxy for the OCB under certain circumstances, but we find that unchecked, this technique can identify unphysical boundary locations at a variety of local times, especially close to noon and midnight. The CCB appears to be more robust, identifying a more physical boundary at most local times. We investigate the behaviour of the CCB under differing solar wind driving and geomagnetic conditions. We also compare our results to observations of the poleward auroral boundary latitude (PABL), a well-established proxy for the OCB, made by the Far Ultraviolet (FUV) instrument on the IMAGE satellite. We find that the CCB location is dependent on radar data coverage, but that with sufficient data (60 measurements within a 1 h MLT bin) the CCB provides an extremely good proxy for the PABL at dusk and dawn to within 1-degree latitude.

James Lane (Lancaster University)

J. H. Lane (Lancaster University), A. Grocott (Lancaster University), N. A. Case (Lancaster University)

Talk

Magnetotail fast flows and ionospheric flow bursts associated with IMF By driven magnetotail asymmetries

The Interplanetary Magnetic Field (IMF) By component can have a profound effect on the asymmetry of the solar wind-magnetosphere coupling by introducing a ‘twisted’ magnetotail configuration, giving closed magnetotail field lines an induced By component. In this paper,

we discuss and analyse the link between magnetotail fast flows, from data taken by Cluster, and concurrent ionospheric flow bursts measured by SuperDARN, in an attempt to understand better their azimuthal asymmetry. We identify 604 fast flow events in the tail plasma sheet, from Cluster data between 2001-2014. We filter our event list to only include events that explicitly imply a dawn-dusk flow asymmetry in the magnetotail, e.g. dawnward flow observed duskward of midnight. We then look at the statistical correlation between these localised flows in the tail and the larger-scale magnetospheric morphology as inferred from the upstream IMF orientation and concurrent ionospheric flow patterns. Our results indicate a complicated picture with the dawn-dusk sense of the flows in the magnetotail disagreeing with the direction of the large-scale convection pattern in many cases. Furthermore, for events where radar data reveal a large-scale asymmetry, the convection pattern only seems to agree with the sense of the IMF By ~70% of the time. We apply different filtering thresholds to see how agreement with the expected flow direction varies, finding the best improvement when specifying that the local sense of By measured by Cluster in the Tail indicates a consistent twist (by comparing to the IMF By=0 T96 modelled tail magnetic field at Cluster's location).

Sofija Durward (Lancaster University)

S. Durward, J. Wild

Poster

Martian mixtures: Using clustering techniques to study the solar wind at Mars

Constant improvements in computing power have made data science techniques more accessible than ever to scientific researchers. However, these ideas have rarely been applied in the space science field, particularly in regards to clustering and data mining. This study presents the results of applying data science ideas to solar wind magnetic field and plasma data from the near-Mars environment, with the aim of bringing better understanding to the Sun-Mars magnetic interaction. Bayesian Gaussian mixture modelling and clustering methods are applied to Mars Global Surveyor (MGS) magnetometer and electron reflectometer data in an attempt to classify typical magnetic field signatures within the data. Focusing on intervals when the MGS spacecraft was located within the solar wind, this study finds clustered groups of magnetic field measurements that could represent event types found within the interplanetary magnetic field, as well as distinguishing the fast and slow ambient wind streams. The properties of these groups and the events that they may represent are discussed.

Jade Reidy (University of Southampton, British Antarctic Survey)

J. Reidy, (University of Southampton, British Antarctic Survey), R. Fear, (University of Southampton), D. Whiter, (University of Southampton), B. Lanchester (University of Southampton), A. Kavanagh (British Antarctic Survey)

Talk

Multi-scale observation of two polar cap arcs occurring on different magnetic field topologies

This talk will present observations of polar cap arc sub-structure down to unprecedented spatial and temporal scales. Two events containing polar cap arcs occurring over Svalbard are investigated: the first occurred on 4th February 2016 and is consistent with formation on closed field lines; the second occurred on the 15th December 2015 and is consistent with open field lines. These events were identified using global scale images from the Special Sensor Ultra-violet Spectrographic Imager (SSUSI) instruments on board Defence Meteorological Spacecraft Programme (DMSP) spacecraft. Intervals when the arcs passed through the small field of view of the Auroral Structure and Kinetics (ASK) instrument, located on Svalbard, were found using images from a co-located all sky camera. The structure from the two events are compared to each other and to previous ASK observations when it was located in TromsÃ¸, under the auroral oval. The energy and flux of the precipitating particles above these arcs are estimated using the ASK observations in conjunction with the Southampton Ionospheric model. These estimates are compared to in-situ DMSP particle measurements to infer further information about their formation mechanisms. The structure of the polar cap arcs and the energy estimated for each event are found to be consistent with formation on different magnetic field topologies.

Daniel Verscharen (UCL/MSSL)

D. Verscharen (UCL/MSSL & U New Hampshire), B. A. Maruca (U Delaware), K. G. Klein (U Arizona)

Talk

Multi-scale plasma processes in the solar wind

All plasma processes are associated with characteristic length and time scales. The characteristic length scales in the solar wind in the inner heliosphere cover about twelve orders of magnitude between the Debye length in the corona and the size of the system (1 au). The characteristic time scales cover about ten orders of magnitude between the period

of plasma oscillations near the Sun and the expansion time in the inner heliosphere. This wide range of scales is a major challenge for the numerical treatment of the solar wind, although interactions between the different scales are the very important building blocks of space-plasma physics.
We will review the most relevant multi-scale effects in space plasmas like the solar wind. These effects are a consequence of couplings between kinetic small-scale effects and the global evolution of the plasma dynamics and thermodynamics. In order to understand the behaviour of the solar wind, data from missions such as Parker Solar Probe and Solar Orbiter will connect these multi-scale effects and thus revolutionise our understanding of the processes that govern the physics of space plasmas. Our review addresses the ingredients for this multi-scale understanding of the solar wind including, for example, the role of expansion, collisions, waves/turbulence, and kinetic instabilities.

Luke Jenner (Nottingham Trent University)

L. Jenner, I. Ching, E. Lawley, A. Wood, G. Dorrian (presenting), I. Whittaker, and E. Breeds

Poster

Polar Cap Patches and Polar Holes in the High-Latitude Ionosphere: The Presence and Absence of Scintillation

Steep plasma density gradients at the edge of polar cap patches are commonly associated with scintillation of trans-ionospheric radio signals, including those used by Global Navigation Satellite Systems (GNSS).
A series of multi-instrument case studies have been conducted using the EISCAT (European Incoherent Scatter) radars, a GNSS scintillation receiver, the SuperDARN radars and optical instruments. A polar cap patch was observed on the evening of the 14th December 2015 under moderately disturbed conditions (Kp=5). This showed an absence of both phase and amplitude scintillation. This suggests that small-scale irregularities had not grown within this large-scale plasma structure as it was transported across the polar cap, possibly as a result of the gentle plasma density gradient at the edge.
Polar holes was observed on the 17th December 2014 and 10th December 2015 under quiet (Kp=1) and moderate (Kp=3) geomagnetic conditions, respectively. There was an absence of both phase and amplitude scintillation of GNSS signals at the steep plasma density gradients at the edge of these holes, possibly as a result of the low plasma density inside the holes. A series of special program experiments were run on the EISCAT radars in December 2018 and January 2019. These experiments were designed to identify steep plasma density gradients and determine whether or not they were associated with scintillation. These results are discussed. Minimum values for both the value of the plasma density and the gradient in

this density required for scintillation of GNSS signals is determined.

Luke Nugent (University of Birmingham)

L.D. Nugent (University of Birmingham), S. Elvidge (University of Birmingham)

Poster

Probabilistic forecasting of low latitude ionospheric scintillation

Trans-ionospheric transmissions and those which are refracted by the ionosphere (e.g. GPS, HF communications) are critical for a number of systems in a variety of industries (communications, mining, etc.). Transmissions which pass through bubbles or plumes of depleted plasma generated after sunset in low latitude regions can be subjected to rapid fluctuations of the transmission amplitude and phase (ionospheric scintillation). In this work a new approach is described to produce global low latitude probabilistic forecasts of scintillation caused by these Equatorial Plasma Bubbles (EPBs).
The Advanced Ensemble electron density (Ne) Assimilation System (AENeAS) is a state-of-the-art physics-based ensemble data assimilation model of the coupled ionosphere-thermosphere system. The individual ensemble members are used to generate probability density functions of parameters associated with EPB generation. Applying this technique at regularly spaced longitudinal intervals can provide an early warning forecast of low latitude ionospheric scintillation occurring during the current/upcoming evening. A case study is discussed which compares the forecast skill of using the probability of vertical plasma drift with the probability of Rayleigh-Taylor growth rates. Furthermore the impact of using AENeAS rather than a physics-based model without data assimilation is also discussed.

John Hargreaves (Lancaster University)

M. J. Birch (University of Central Lancashire); J. K. Hargreaves (University of Lancaster)

Poster

Quasi-periodic ripples in high latitude electron content, the geomagnetic field, and the solar wind: timing and magnitude relationships.

In a previous study it was found that ripples of about 25 minutes periodicity are generally present in the solar wind at L1, the magnetosphere, and the F-region ionosphere above Svalbard. The ripples appear to be present at all times, though varying in magnitude, and seem to be a general feature of the solar wind and the geospace environment. This extension of the study compares the relative timing and magnitude of well-defined peaks in these ripples. For example, the ripples in the geomagnetic field are spatially and temporally persistent, and exhibit greater coherence on the dayside than on the nightside, supporting the conclusion that the solar wind is the driving mechanism. There is also good correlation between the magnitude of the peaks in the solar wind dynamic pressure and those in the geomagnetic field. Statistics and regression relationships are presented.

Mark Lester (University of Leicester)

Beatriz Sanchez-Cano (University of Leicester), Mark Lester (University of Leicester), Pierre-Louis Blelly (IRAP, Toulouse, France), Olivier Witasse (ESTEC, Noordwijk), Marco Cartacci (INAF, Rome), Roberto Orosei (INAF, Bologna), Hermann Opgenoorth (UmeÃ¥

Poster

Radar blackouts in Mars' atmosphere produced by space weather events

The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) onboard Mars Express (MEX) and the Shallow Radar (SHARAD) onboard Mars Reconnaissance Orbiter (MRO) suffer from severe degradation in the ground reflection signal almost every time a solar energetic particle (SEP) event strikes Mars. The most notable case occurred in September 2017, when the signals of both radars were completely absent for several days. Thanks to the MAVEN mission, we now know that the cause was likely the precipitation of SEP electrons of a few tens of keV, associated with a series of powerful space weather events that struck Mars during 10-22 September 2017. Such energetic electron precipitation is believed to produce a lower ionospheric layer within the collision-dominated atmosphere, which can absorb the radar signal at the radar operational frequencies, around 5 MHz for MARSIS and 20 MHz for SHARAD. In this study, we assess the properties of this low ionospheric layer around the planet based on these radar attenuation estimates. In addition, taking advantage of a larger dataset during over the lifetime of both the MEX and MRO missions, we evaluate when and under which conditions this absorption layer appears. As it is leading to the loss of radar signals at least between 5 and 20 MHz, the outcome of his work will allow better assessment of high frequency radar performance during future space weather events.

DURAID AL-SHAKARCHI (Department of Astronomy& Space, University of Baghdad)

A. DURAID AL-SHAKARCHI(1 University of Baghdad, 2 Aberystwyth University), B. HUW MORGAN(Aberystwyth University)

Poster

The compound stream event of March 20-25, 2011 as measured by the STEREO B spacecraft

The interaction of interplanetary coronal mass ejections (ICMEs) with each other and with co-rotating interaction regions (CIR) changes their configuration, dynamics, magnetic field and plasma characteristics and can make space weather forecasting difficult. During the period of March 20-25, 2011, the Solar Terrestrial Relation Observatory (STEREO B) encountered a compound stream containing several interacting structures. Our analysis suggests that the stream consists of two ICMEs followed by an embedded ICME/CIR. The sudden appearance of ICME3 within the fast wind side of the CIR causes the temperature to drop suddenly to its lowest level in about 1.2 hours, by about factor of 36. The fast wind which follows the CIR influences not only ICME3's temperature but also its plasma Î². In addition, third ICME impacts the CIR through expansion and deceleration. A Penetration of a forward pressure wave has appeared within ICME1. It is difficult to identify its resource, whether ICME2, the combined ICME3/CIR, or it is a remnant shock. Because of the compression, the temperature and plasma beta of second ICME and part of the first one have increased. Despite the presence of signatures from four large-scale interacting structures within the compound stream, it is difficult to reconcile the in-situ sequence with other remote sensing observations of CMEs and ejecta close to the Sun because of the large system of coronal expanding loops above the active region. Compound streams therefore remain difficult to interpret, and further understanding of the subject will depend on the future study of similar events.

Jennifer Carter (University of Leicester)

J. A. Carter (University of Leicester), S. E. Milan (University of Leicester), H. Sangha (University of Leicester), A. R. Fogg (University of Leicester), and M. Lester (University of Leicester)

Talk

The evolution of a cusp spot with associated field-aligned currents and ionospheric flows

We present a detailed case study of high-latitude aurora observed in the dayside northern hemisphere polar cap, under particularly strong and sustained northward interplanetary field conditions, perhaps associated with an interplanetary magnetic cloud. The entire magnetopause is likely to be compressed, even under these northward conditions. The aurora are accompanied by well-defined NBZ currents, that dominate the nominal R1-R2 field-aligned current system. We track the evolution of the cusp spot, observing aurora resulting from both electron and proton precipitation, over a 12 hour period, as these emissions respond quickly to changes in the By component of the interplanetary magnetic field. Fast sunward flows are observed that often align with the eastern side of the cusp spot emission. This cusp spot occurs immediately prior to an occurrence of region 2 currents that bifurcate on the dusk side, and that appear to be associated with substorms.

Bingkun Yu (Unibersity of Reading)

Bingkun Yu, Christopher J. Scott, Xianghui Xue, Mathew J. Owens, Austin Jones, Xin'an Yue, Xiankang Dou

Poster

The global climatology of ionospheric sporadic E layer from the COSMIC satellite measurement

On the basis of S4max data retrieved from COSMIC GPS radio occultation measurements, the long-term climatology of the intensity of the ionospheric sporadic E layer is investigated. Global maps of Es intensity show the high-spatial-resolution geographical distribution and strong seasonal dependence of Es layers. The simulation results show that the convergence of vertical ion velocity could partially explain the seasonal dependence of Es intensity. Furthermore, some disagreements between the distributions of the calculated divergence of vertical ion velocity and the observed Es layers are found. Other processes in the formation of Es layer may be neglected. We suggest that the large-scale horizontal transport of Es should be considered.

Graziella Branduardi-Raymont (Mullard Space Science Laboratory / UCL)

G. Branduardi-Raymont (MSSL/UCL, UK), C. Wang (NSSC/CAS, China), C. P. Escoubet (ESA/ESTEC, The Netherlands), S. Sembay (University of Leicester, UK), E. Donovan (University of Calgary, Canada), L. Dai (NSSC/CAS, China), L. Li (NSSC/CAS, China), J. Rae (M

Poster

The SMILE mission: A novel way to study solar-terrestrial interactions

The interaction between the solar wind and the Earth's magnetosphere, and the geospace dynamics that result, comprise some of the key questions in space plasma physics. In situ measurements by a fleet of solar wind and magnetospheric missions now provide the most detailed observations of the Sun-Earth connections. However, we are still unable to quantify the global effects of the drivers of such connections, including the conditions that prevail throughout geospace. This information is the key missing link for developing a complete understanding of how the Sun gives rise to and controls the Earth's plasma environment and space weather.
SMILE (Solar wind Magnetosphere Ionosphere Link Explorer) is a novel self-standing mission dedicated to observing the solar wind - magnetosphere coupling via simultaneous X-ray imaging of the magnetosheath and polar cusps, UV imaging of global auroral distributions and in situ solar wind/magnetosheath plasma and magnetic field measurements. Remote sensing of the magnetosheath and cusps with X-ray imaging is now possible thanks to the discovery of solar wind charge exchange X-ray emission, first observed at comets, and subsequently found to occur in the vicinity of the Earth's magnetosphere. SMILE is a collaborative mission between ESA and the Chinese Academy of Sciences (CAS) that was selected in November 2015, adopted into ESA's Cosmic Vision Programme in March 2019, and is due for launch at the end of 2023. The science that SMILE will deliver, as well as the technical developments currently ongoing, will be presented.

Sadie Robertson (Imperial College London)

Sadie Robertson, Jonathan Eastwood, Julia Stawarz, Imogen Gingell and the MMS team

Talk

Topology of flux ropes on the magnetopause

Magnetic reconnection is a fundamental plasma physics process which governs energy and mass transfer from the solar wind into the Earth's magnetosphere. During reconnection we observe flux ropes: twisted magnetic field structures important for energy transfer processes. Whilst previous missions have observed and characterised flux ropes, the temporal resolution of the data was typically not great enough to study structures in detail, particularly on electron scales. Here we investigate magnetopause flux ropes using data from NASA's four spacecraft Magnetospheric Multiscale mission (MMS). MMS measures the thermal electron and ion 3D distribution at 30 msec and 150 msec time resolution respectively at spacecraft separations down to a few kilometers. We focus on electron pitch angle distributions and demonstrate how they can be used to deduce the connectivity and topology of the magnetic field inside flux ropes. Transfer of flux into the magnetotail ultimately requires one end of the twisted field line to be connected to the magnetosphere and the other to the solar wind. Initial results surveying the MMS data suggest that this may not be true of all flux ropes, or throughout the complete duration of a single flux rope, and that the topology is much more variable and dynamic than was previously anticipated. We discuss some possible implications for the role of flux ropes in flux transfer events and flux transport in the magnetosphere.

Matthew Wild (Rutherford Appleton Laboratory)

M.Wild (STFC RAL), Y. Bogdanova, (STFC RAL), S. Crothers (STFC RAL), C.Scott (University of Reading)

Poster

UK Solar System Data Centre : Data Archiving and Citizen Science for Improving Access

The UK Solar System Data Centre (UKSSDC) maintains a large archive of current and historical Solar-Terrestrial Physics data. Much of the historical data is only available on paper or film which limits its usefulness for scientific research. We are looking at creating a multi-strand citizen science (zooniverse) project to both analyse early film ionograms from Slough (1930-1950s) and digitisation of tabulated ionospheric parameters from many ionosonde stations worldwide. This will involve large scale scanning of the original paper print ionograms (up to

2m) and printed/hand written tables stored in the UKSSDC. Extension to other areas of the UKSSDC archives are feasible depending on levels of interest from the community.

PLANETARY MAGNETOSPHERES (MAGNETOSPHERES)

Dave Constable (Lancaster University)

D.A. Constable, L.C. Ray, S.V. Badman, C.S. Arridge, H. Gunell

Poster

1-D Hybrid Kinetic/Fluid Modelling of the Jovian Magnetosphere

Based on early measurements from the Juno spacecraft, magnetosphere-ionosphere-thermosphere (MIT) coupling studies of the Jovian system are thought to have under-estimated the densities of plasma species in the high-latitude regions of the magnetosphere. As the main auroral oval of Jupiter is driven by particles precipitating into the planetary atmosphere in these regions, characterising the density and potential structure along high-latitude magnetic field lines is of particular interest.

To that end, a 1-D spatial, 2-D velocity hybrid kinetic/fluid model is under development. This model will allow the middle magnetosphere regions (~20-50 RJ) responsible for the main oval to be investigated numerically. Previous 1-D kinetic models of the Jovian system have been constrained to the Io flux tube. Through the use of code parallelisation, non-uniform spatial mesh and fluid treatment of species, the computational challenge of modelling of the Jovian middle magnetosphere can be reduced. The model allows density profiles, potential structures, current flow and precipitating particle fluxes to be found. Comparison of these outputs to data from Juno will help to validate the model, along with providing refinements to MIT theory.

Chris Lorch (Lancaster University)

C.T.S. Lorch (Lancaster University), L.C. Ray (Lancaster University), C.E.J. Watt (University of Reading)

Poster

Alfvénic Acceleration of Auroral Particles at Jupiter

Recent Juno spacecraft observations of Jupiter's auroral acceleration region have shed light on the mechanisms responsible for energising auroral electrons. One such observation shows peaks in precipitating energy flux associated with broadband bidirectional electron distributions. It has been suggested that these structures may be signatures of a stochastic acceleration process driven by wave-particle interactions. Using models of magnetospheric plasma parameters, we determine where in the jovian magnetosphere kinetic Alfvén waves can efficiently accelerate particles.

Richard Haythornthwaite (Mullard Space Science Laboratory, University College London)

R. P. Haythornthwaite (MSSL), A. J. Coates (MSSL), G. H. Jones (MSSL)

Poster

An examination of Cassini CAPS Ion Beam Spectrometer (IBS) data at Enceladus.

The Ion Beam Spectrometer (IBS) was part of the Cassini Plasma Spectrometer - CAPS investigation (Young et al. 2004) sent to Saturn aboard the Cassini spacecraft.
IBS was designed to measure ion velocity distributions with a high angular and energy resolution, with a mind to measure highly directional rammed ion fluxes encountered in Titan's ionosphere.
IBS made valuable observations during close encounters of Saturn's moon Enceladus, complementing the ion, charged dust and electron measurements made by the CAPS ELS & IMS sensors within the moon's plumes.
The design of IBS combined with the cold background of the plume has the potential to provide higher resolution ion mass data than previously studied.
We present our initial analysis of previously unpublished IBS data from the E7 encounter in combination with the ELS & IMS data, concentrating on the composition of the ion populations detected whilst also commenting on other features observed.

William Dunn (UCL/MSSL, Harvard-Smithsonian)

W. Dunn (UCL/MSSL, CfA); Z. Yao (University of Liege); A. Sulaiman (University of Iowa); J-U. Ness (European Space Astronomy Center); G. Branduardi-Raymont (UCL/MSSL); G. R. Gladstone (SWRI); D. Grodent (Universite de Liege); G. Clark (APL); C. Paranicas

Poster

Correlations Between Jupiter's X-ray Aurora and the Outer Magnetosphere Plasma Sheet

Jupiter produces dynamic X-ray auroral emissions at both of its poles [e.g Gladstone et al. 2002; Cravens et al. 2003; Elsner et al. 2005; Branduardi-Raymont et al. 2004; 2007; Dunn et al. 2017]. These consist of two main components: 1. a lower latitude bremsstrahlung

emission from precipitating electrons along the UV main emission [Branduardi-Raymont et al. 2004; 2008] and 2. a more dominant poleward emission from the precipitation of highly energetic ions [e.g. Elsner et al. 2005; Branduardi-Raymont et al. 2007]. These emissions are often observed to pulse, sometimes erratically and sometimes with a regular beat (e.g. Jackman et al. 2018). For much of the last two decades, these remote signatures of energetic ion precipitations have been interpreted as indicators of the processes at Jupiter's cusp and/or Jupiter's return current system [e.g. Bunce et al. 2004; Cravens et al. 2003]. Here, we report on an extensive campaign totalling hundreds of hours of Jupiter observations by XMM-Newton that were conducted coincident with in-situ measurements of Jupiter by NASA's Juno mission. By comparing data from XMM-Newton and Juno's JEDI, WAVES and MAG instruments, we identify strong correlations between events at 50-70 Jupiter radii in the outer magnetosphere and Jupiter's X-ray auroral emissions. Strangely, these correlations connect the dawn and night-side magnetosphere with the aurora and not the expected noon magnetosphere [Dunn et al. 2016; Kimura et al. 2016]. We finish by leveraging our understanding of the UV emissions to interpret the triggers of these processes.

Gregory Hunt (Imperial College London)

G. J. Hunt (Imperial College London), S. W. H. Cowley (University of Leicester), G. Provan (University of Leicester), H. Cao (Harvard University), E. J. Bunce (University of Leicester), M. K. Dougherty (Imperial College London), and D. J. Southwood (Imper

Invited

Currents Associated with Saturn's Intra-D Ring Azimuthal Field Perturbations

During the final 22 full revolutions of the Cassini mission in 2017, the spacecraft passed at periapsis near the noon meridian through the gap between the inner edge of Saturn's D ring and the upper layers of the planet's atmosphere, revealing the presence of an unanticipated low-latitude current system via the associated azimuthal perturbation field peaking typically at ~10-30 nT. Assuming approximate axisymmetry, here we use the field data to calculate the associated horizontal meridional currents flowing in the ionosphere at the feet of the field lines traversed, together with the exterior field-aligned currents required by current continuity. We show that the ionospheric currents are typically~0.5-1.5 MA per radian of azimuth, similar to auroral region currents, while the field-aligned current densities above the ionosphere are typically ~5-10 nA m-2, more than an order less than auroral values. The principal factor involved in this difference is the ionospheric areas into which the currents map. While around a third of passes exhibit unidirectional currents flowing northward in the ionosphere closing southward along exterior field lines, many passes also display layers of

reversed northward field-aligned current of comparable or larger magnitude in the region interior to the D ring, which may reverse sign again on the innermost field lines traversed. Overall, however, the currents generally show a high degree of north-south conjugacy indicative of an interhemispheric system, certainly on the larger overall spatial scales involved, if less so for the smaller-scale structures, possibly due to rapid temporal or During the final 22 full orbits of the Cassini mission the spacecraft passed at periapsis near the noon meridian through the gap between the inner edge of Saturn's D ring and the upper layers of the planet's atmosphere, revealing the presence of an unanticipated low-latitude current system via the associated azimuthal perturbation field peaking typically at ~10-30 nT. Assuming approximate axisymmetry, we use the field data to calculate the associated horizontal meridional currents flowing in the ionosphere at the feet of the field lines traversed, together with the exterior field-aligned currents required by current continuity. We show that the ionospheric currents are typically ~0.5-1.5 MA per radian of azimuth, similar to auroral region currents, while the field-aligned current densities above the ionosphere are typically ~5-10 nA m-2, more than an order of magnitude less than auroral values. This difference is principally due to the ionospheric areas into which the currents map. While around a third of passes exhibit unidirectional currents flowing northward in the ionosphere closing southward along exterior field lines, many passes also display layers of reversed northward field-aligned current of comparable or larger magnitude in the region interior to the D ring, which may reverse sign again on the innermost field lines traversed. Overall, the currents generally show a high degree of north-south conjugacy indicative of an interhemispheric system, certainly on the larger spatial scales involved, if less so for the smaller-scale structures, possibly due to rapid temporal or local time variations.

Wayne Gould (Lancaster University)

W.Gould (Lancaster University), L.C.Ray (Lancaster University)

Poster

Deciphering Solar Wind Influences at Saturn

The effects of the solar wind on Saturn's magnetosphere are poorly understood because there are no consistent means of direct detection of the solar wind at Saturn. This limits our knowledge of the solar winds impact to case studies of single or few events where Cassini was outside the magnetopause. By statistically comparing solar wind propagation models to Cassini data sets when the Saturn-Sun-Earth angle is 50 degrees, we can identify proxies for the solar wind behaviour at Saturn. Finding and confirming the relation of these indirect proxies to solar wind propagation models presents the opportunity to open up years of data to interpretation with respect to the solar winds behaviour at the outer planets, using data

sets from past missions such as Cassini. This will improve our understanding of how planetary magnetospheres respond to changes in the solar wind.

Ned Staniland (Imperial College London)

N.R. Staniland (Imperial College London), E.J. Bunce (University of Leicester), M.K. Dougherty (Imperial College London), A. Masters (Imperial College London)

Poster

Determining the 'Nominal' Thickness and Variability of the Saturnian Magnetodisc Current Sheet

In the magnetosphere of Saturn, the dominant magnetic field contributors are the internal field and the magnetodisc current sheet. The co-rotating plasma, sourced from the moon Enceladus, that carries the azimuthal current in this equatorial sheet stretches the magnetic field into the characteristic magnetodisc geometry. This current sheet is observed at all local times but has a highly dynamic configuration due to multiple factors, including planetary period oscillations, variable solar wind conditions and the obliquity of Saturn.

In this study, we use the complete magnetic field dataset collected by the Cassini spacecraft to determine the north-south thickness of the magnetodisc current sheet. We identify crossings of the current sheet where a clear signature in the radial field component allows us to constrain the boundaries of the current layer. We begin by investigating the factors that are controlling the variability of the thickness. We then determine how the thickness varies both spatially and temporally with respect to these dynamical processes that are continuously perturbing the current sheet. Finally, we calculate the average thickness as a function of these parameters. Our results are essential for understanding the global configuration of the Saturnian system and how it is modified by the magnetodisc current sheet. They also enable us to better model the most significant current system in the Saturnian magnetosphere.

Licia Ray (Lancaster University)

L.C. Ray (Lancaster University), C.T.S. Lorch (Lancaster University), J. O'Donoghue (NASA/GSFC), J.N. Yates (ESA/ESAC), S.V. Badman (Lancaster University), T.S. Stallard (Leicester University), C.G.A. Smith (Brooksbank School)

Poster

Electrodynamic heating of Jupiter's GRS Thermosphere

Recent observations of Jupiter's Great Red Spot indicate that the thermosphere above the storm is hotter than its surroundings by more than 700 K. Possible suggested sources for this heating have thus far included atmospheric gravity waves and lightning-driven acoustic waves. Joule heating, driven by Great Red Spot vorticity penetrating up into the lower stratosphere and coupling to the thermosphere, may contribute to the large observed temperatures. The strength of Joule heating will depend on the local inclination angle of the magnetic field and thus the observed emissions and inferred temperatures should vary with planetary longitude as the Great Red Spot tracks across the planet. We derive estimates for the Joule heating rate as a function of GRS longitude and discuss in the context of H3+ observations.

Tom Stallard (University of Leicester)

M. N. Chowdhury (University of Leicester), T. S. Stallard (University of Leicester), H. Melin (University of Leicester), R. E. Johnson (University of Leicester)

Poster

Exploring Key Characteristics in Saturn's Infrared Auroral Emissions

We present a study of Saturn's H3+ northern auroral emission using data taken on 19 May 2013 with the Very Large Telescope's long-slit spectrometer Cryogenic Infrared Echelle Spectrograph (VLT-CRIRES) situated at Paranal, Chile. Adaptive optics, combined with the high spectral resolution of VLT-CRIRES (~100,000), mean that this dataset offers an unprecedented spatially and spectrally resolved ground-based view of Saturn's infrared aurora. We have used discrete H3+ emission lines to derive dawn-to-dusk auroral intensity, ion line-of-sight velocity, and thermospheric temperature profiles.
Our data reveal a dawn-enhanced auroral intensity with an average auroral temperature of 361 K and evidence for a localised dark polar region in the aurora. This dark feature is at the same location as a strong noon-midnight flow in the ion velocity on the scale of ~1.2 km per second - far exceeding other ion flow velocities nearby inside the polar cap - and resembles an ionospheric polar vortex. The thermospheric temperature profile reveals a subtle and

previously undetected gradient which increases across the polar cap going from dawn to dusk. We also find that a temperature hotspot of 379 K drives a region of emission near the pole, corresponding to a location where, unlike at Jupiter and Uranus, H3+ is failing to cool the thermosphere.

The findings of this work will aid ongoing investigations into the processes driving the energy mechanisms in Saturn's upper atmosphere and also inform models of the coupling between Saturn's upper atmospheric layers and its magnetic field.

Omakshi Agiwal (Imperial College London)

O. Agiwal (Imperial College), H.Cao (Harvard, UCLA), G. J. Hunt (Imperial College), M.K. Dougherty (Imperial College), S. W. H. Cowley (University of Leicester)

Poster

Exploring the sources of variability in the low-latitude field-aligned currents at Saturn measured by the Cassini Magnetometer during the Grand Finale

The Cassini spacecraft traversed magnetic field lines which connect the planet Saturn to its main ring system during the 22 Grand Finale orbits. The magnetometer (MAG) measurements from these orbits revealed the presence of a highly variable low-latitude field-aligned current (FAC) system, which is predominantly confined to the magnetic field lines mapping to the D-ring of Saturn. There is also evidence of the low-latitude FACs on field lines which map to the B-ring in the southern hemisphere, however the FACs are suppressed along the other field lines mapping to the A-C rings. The orbit-to-orbit variability in the fine structure of the measurements can be understood by considering the spatial and temporal variability of the Pedersen conductivities and/or neutral wind speeds in the day-side ionosphere of Saturn. Implications of interaction between the planet and the 'ring ionosphere' from the MAG measurements will be discussed.

Nawapat Kaweeyanun (Department of Physics, Imperial College London)

N. Kaweeyanun (Department of Physics, Imperial College London), A. Masters (Department of Physics, Imperial College London), X. Jia (The Climate and Space Sciences and Engineering Department, University of Michigan)

Talk

Favourable Conditions for Magnetic Reconnection at Ganymede's Upstream Magnetopause

Ganymede is the largest moon in the Solar System, and the only satellite to maintain a permanent magnetic field. Jovian plasma can enter the moon's magnetosphere via magnetic reconnection at the upstream magnetopause, where Ganymede's magnetic field lines are nearly anti-parallel to the Jovian field. Despite relatively steady magnetopause conditions, MHD numerical simulations have shown evidence of unstable reconnection events such as flux ropes. Nevertheless, viable locations for magnetic reconnection have not been formally assessed under fundamental plasma theory. Here we present an analytical model parametrizing typical steady-state conditions at Ganymede's upstream magnetopause and evaluate magnetic reconnection onset conditions at the boundary. We find that the onset is satisfied where the adjacent magnetic fields are partially anti-parallel, which is the case across the entire magnetopause. This result is not impacted by variations of Ganymede's position relative to the Jovian current sheet. The loose constraint on magnetic reconnection indicates the possibility of multiple X-lines consistent with MHD simulations. The reconnection electric field has magnitude ~3-6 mV/m and increases when Ganymede lies outside the current sheet, indicating a previously unconfirmed Jovian diurnal variation in reconnection rate. Understanding magnetic reconnection structure will improve our knowledge of plasma convection within Ganymede's magnetosphere. Further model development may include dynamical effects, which will provide insights into Ganymede's internal liquid ocean - a potential life source in the Solar System.

Sarah Badman (Lancaster University)

S.V. Badman (Lancaster Uni.), L. Lamy (Obs. de Paris), W. Pryor (Central Arizona College), E. J. Bunce (Uni. of Leicester), R. Prange (Obs. de Paris), P. Zarka (Obs. de Paris), B. Cecconi (Obs. de Paris), J. D. Nichols (Uni. of Leicester), J. T. Clarke (B

Poster

Interhemispheric asymmetries in Saturn's UV aurora

Simultaneous observations of Saturn's northern and southern UV aurora were acquired on 19 August 2016 by the Hubble Space Telescope and Cassini mission, respectively. Some auroral features were present in both hemispheres, including a dawn arc and a patch of lower latitude emission near noon. However, while the dawnside and noon sectors were brighter in the north, the southern aurorae were dominated by a bright, high latitude arc moving from the dusk to midnight sectors. Large-scale asymmetries can be attributed to the higher magnetic field strength and enhanced solar-driven conductivity in the north, plus modulation of intensities in both hemispheres by rotating field-aligned currents. Measurements made in situ by Cassini in the southern hemisphere indicate that the bright, high latitude dusk arc occurred adjacent to the open field region. This arc persisted for >8 h and rotated at ~70% corotation to the nightside. No counterpart was observed in the north although transient (10 min) flashes were observed at other times in this sector. The higher latitude, apparently persistent, rotating arc seen in the south is likely driven by a different process than the lower latitude, transient, non-rotating flashes captured in the north.

Affelia Wibisono (Mullard Space Science Laboratory, UCL)

A. Wibisono (Mullard Space Science Laboratory), G. Branduardi-Raymont (Mullard Space Science Laboratory), A. Coates (Mullard Space Science Laboratory), W. Dunn (Mullard Space Science Laboratory, Harvard-Smithsonian Center for Astrophysics)

Talk

Jupiter's X-ray Aurorae as seen by XMM-Newton concurrently with Juno

X-ray emissions from Jupiter's poles were first witnessed by the Einstein Observatory and subsequently by ROSAT. The launches of Chandra and XMM-Newton twenty years ago have helped to greatly improve our understanding of Jupiter's X-ray aurorae. Unlike at the Earth, Jupiter's north and south aurorae behave independently and may hint that the polar regions are at times driven by highly energetic, non-conjugate magnetospheric processes. Juno's

arrival at Jupiter in 2016 has meant that in situ data can be used to complement the data obtained by Chandra and XMM-Newton. Furthermore, the polar orbit of Juno has given us views of Jupiter's aurorae that remote sensing telescopes never could.

XMM-Newton carries three large collecting area X-ray telescopes equipped with CCD cameras collectively known as the EPIC instrument. The pn camera collects the full beam focussed by the first telescope, while the two MOS cameras receive only half of the photons entering the second and third telescopes. The rest of the photons are directed to the secondary RGS foci. Our observation campaign with XMM-Newton occurred over 26 hours between 16th and 17th July 2017 and coincided with Juno being in Jupiter's plasma sheet. Spectra of the northern and southern X-ray aurorae were extracted for the three EPIC cameras, combined and spectral fitting was carried out using an ion charge exchange model. We present novel results of the composition and abundances of the ions responsible for producing the X-ray aurorae which appear to support in situ measurements by Juno.

Chris Arridge (Lancaster University)

J. A. Wiggs (Lancaster University), C. S. Arridge (Lancaster University)

Poster

Magnetospheric Modelling from Earth to Jupiter using the Rice Convection Model

The Rice Convection Model (RCM) is a numerical model that self-consistently computes electric fields and plasma flows and utilises a multi-fluid approach to calculate adiabatic particle drift motions in coupled planetary magnetospheres and ionospheres. For forty years the RCM has provided insights into the complex physical magnetospheric dynamics and interactions occurring both terrestrially and at the outer planets. The underlying assumptions made in order to obtain the equations solved to construct the RCM are examined, the individual physical contributions permitted identified and the impacts of contributions prohibited considered. The mathematical equations, numerical techniques and computational logic combined to construct the model can then be clearly presented and described. Consideration is then given to the set-up of the computational domain inside which these operations are carried out to form the RCM. Completing this in-depth review of the RCM allows for a deep analysis of the results computed by the model. This provides an understanding of the physical phenomenon that are captured and explained by the model and those that are beyond the limitations of it currently. Special emphasis will be placed on plasma flows which exhibit the Radial-Interchange instability.

Jane Greaves (Cardiff University)

J. S. Greaves (Cardiff University), E. Drabek-Maunder (Royal Museums Greenwich)

Talk

Methanol at Enceladus: interaction of vents with Saturn's magnetosphere

Icy moons of Jupiter and Saturn are of huge interest in the context of possible eco-systems below the ice shells. Here we supplemented Cassini's measurements of organics venting from Enceladus with ground-based searches for complex molecules. We discuss our detection of methanol with the IRAM 30 m telescope, where the gas velocity was significantly red-shifted (by 8 km/s) with respect to the moon's orbital velocity. A trailing gas cloud could be used to explain the detection, i.e. confined by Saturn's magnetospheric interaction with Enceladus. The data agree with Cassini flyby measurements of plasma near the south pole of Enceladus, where electrons form a denser cloud and are redshifted with respect to Enceladus (i.e. trailing the moon). This unexpected result opens up new questions about how best to observe pristine chemistry of the vents, before reactions occur in the charged environment of the host planet - how close does in-situ sampling need to go, to detect true biomarkers of sub-surface organisms?

Tom Stallard (University of Leicester)

T. Stallard (U. Leicester), H. Melin (U. Leicester), K. Baines (U. Wisconsin-Madison), S. Miller (UCL), J. O'Donoghue (JAXA), L. Moore (Boston U.), N. Chowdhury (U. Leicester)

Poster

Observations of ionosphere-atmosphere coupling at Saturn and Jupiter

Cassini's ‘Grand Finale’ provided a unique opportunity to observe the connection between Saturn’s atmosphere, ionosphere and magnetosphere. In order to support this once in a lifetime view of Saturn, we planned and executed an ambitious series of observations from Earth, using the 10m Keck telescope to map out the physical conditions in Saturn’s aurora for the first time.
These observations mapped out emission from both the fluorescence from neutral CH4 and ro-vibrational emission from H3+ molecular ions, providing the first ever maps of neutral winds at 600km and ion winds at 1000km. This talk will compare and contrast local-time emission and wind structures seen at Saturn, providing a new view of atmospheric coupling

between auroral currents and the underlying neutral atmosphere.
These observations will then be contrasted with the same emission and wind structures observed at Jupiter, in order to reveal differences in the way the neutral upper stratosphere of these two planets are affected by the differing particle precipitation energies driven by their magnetospheric interactions.

Dale Weigt (University of Southampton)

D. Weigt (Soton), C. M. Jackman (Soton), W. Dunn (MSSL, Centre for Planetary Science, CfA), F. Allegrini (SWRI, UTSA), R. W. Ebert (SWRI, UTSA), P. W. Valek (SWRI), M. F. Thomsen (PSI), G. Clark (JHUAPL), R. Gladstone (SWRI, UTSA) and R. Kraft (CfA)

Poster

Observations of Jupiter's Auroral Emission during Juno Apojove June 2017

We present a case study of Jovian X-ray observations from a joint Chandra and XMM-Newton campaign on June 18th - 19th 2017. The 10-hour Chandra observation and 28-hour XMM-Newton observation overlapped by ~ 9 hours, allowing both spatial and spectral X-ray analysis of Jupiter in tandem. We showcase dynamic new X-ray auroral videos demonstrating the time-varying spatial morphology of the highest energy auroral emission over a 10 hour continuous observation. Alongside the X-ray auroral videos, we present light curves from Chandra; timing analysis of significant quasi-periodic oscillations detected in the north polar region and further discuss the morphology of the emission with new polar plots of the Chandra observations. In addition, we show spectra taken from XMM-Newton and frame the X-ray observations in the context of Juno in situ observations. During this X-ray observation interval Juno was near its apojove on the dawn flank, close to the expected nominal position of the magnetopause. Juno data can be used to infer the state of compression or expansion of the magnetosphere and to place these observations in context of possible magnetospheric drivers linked to boundary dynamics.

Gabby Provan (University of Leicester)

G. Provan, S. W. H. Cowley, E. J. Bunce, T. J. Bradley, G. J. Hunt, H. Cao, and M. K. Dougherty

Poster

On Saturn's Rings - Planetary Period Oscillations and the Intra-D Ring Current

During Cassini's final 23 orbits the spacecraft passed north-south through the equatorial plane on field lines inside of Saturn's D ring. We focus on the planetary period oscillations (PPOs) and the intra-D ring currents. The intra-D ring currents begin and end near-symmetrically at some point on field lines threading the D ring, consistent with the effect of interhemispheric field-aligned currents, and the currents generally extend to larger values within the interior region. Total currents are ~1 MA/rad comparable with auroral values. The signatures are variable in form and amplitude, their varaibility is not connected with pass altitude, local time, PPO phase, or D68 ringlet phase, but may relate to variable structured thermospheric winds and ionospheric conductivities suggesting a dynamical D ring-atmosphere interaction. Although the variation of the intra-D ring currents is not connected with the PPO phase, these fields are superposed on PPO oscillations of smaller amplitude which are found to be present throughout the periapsis pass data, from the auroral regions through to the field lines inside of the D ring. PPOs are thus observed throughout Saturn's magnetosphere without exception. We also determine the mean residual fields on these passes, and show that the persistent "lagging" azimuthal fields found previously in the dayside subauroral region on F ring orbits remains essentially unchanged on field lines threading the main ring system, even inside of field lines passing through synchronous orbit. This finding calls into question the usual dynamical interpretation of such "lagging" field geometries in this case.

Carley Martin (Lancaster University)

C.J.Martin (Lancaster University), L.C.Ray (Lancaster University)

Invited

Polar Wind Outflow Model at Jupiter

Polar wind is an important source of plasma in the magnetosphere at Earth, and it has been shown to be a contributor to the magnetospheric population at Saturn and Jupiter. We are developing a semi-kinetic, non-classical polar wind model for rapidly rotating systems to characterise the material escaping the upper atmosphere and the physical processes that

dominate the escape, including evaluating with the auroral current systems. We present early results from the model and compare to in situ data at Jupiter and Saturn.

David Southwood (Imperial College London)

David Southwood

Talk

Saturn's planetary period oscillations; what are they for?

The accumulated observational information on Saturn planetary period oscillations (PPOs) from the Cassini orbital phase places limits on the stress, forces and torques exerted by the signals on the magnetospheric plasma. Hitherto unnoticed is that the field aligned current latitudinal distributions suggest that the PPOs can be the primary means for angular momentum transfer between ionosphere and magnetosphere on closed field lines, i.e. more important than the traditional steady current system associated with sub-corotation. This would imply PPO phenomena are thus a fundamental dynamic feature of the ionised ionosphere-magnetosphere coupling system in the Saturn system rather than a by-product of a process in the neutral atmosphere. In addition, the signal phase structure indicates magnetospheric currents have a strong resistive component which would mean that the heavy ion plasma diffusing outward from Enceladus and ring sources is absorbing the energy and angular momentum transmitted from the ionosphere in the PPO fields. This carries implications for the time scale of the transverse plasma diffusion process but also can one speculate also that the PPOs also play a part in the actual diffusion process of the heavy material?

Jon Nichols (University of Leicester)

J. D. Nichols (Uni. Leicester), F. Allegrini (SWRI), F. Bagenal (Uni. Colorado), E. J. Bunce (Uni. Leicester), J.P. Connerney (NASA Goddard), S. W. H. Cowley (Uni. Leicester), W.S. Kurth (Uni. Iowa), D. Grodent (Uni. Liege), R. Wilson (U. Colorado), Z. Ya

Poster

Simultaneous Hubble Space Telescope and Juno observations

We present concurrent observations of Jupiter's auroras obtained with the Hubble Space Telescope and the planet's magnetodisc and M-I coupling currents as observed by the Juno spacecraft, indicating an association of Jupiter's auroral intensity with current intensity. During PJ11 inbound, Juno measured in the middle magnetosphere a substantial increase in

B_ϕ from a 'nominal' background of ~2 nT to 7-9 nT between ~30 and 55 R_J, implying increased equatorial radial current flowing as part of the M-I coupling current system associated with the planet's auroral emission. During this interval, the B_ρ component was also enhanced from ~10 to ~20 nT, indicating increased azimuthal current and associated radial force balance in the magnetodisc. During this interval of increased radial current, the Hubble Space Telescope observed a simultaneous enhanced intensity of the main emission, peaking at ~2 MR. We compare these observations with the Leicester magnetodisc model, referenced to preliminary Juno JADE plasma data, and the associated theoretical M-I coupling currents.

Joe Kinrade (Lancaster University)

J. Kinrade (Lancaster University), S. V. Badman (Lancaster University), C. P. Paranicas (JHU APL), D. G. Mitchell (JHU APL), R. L. Gray (Lancaster University), C. S. Arridge (Lancaster University), A. Bader (Lancaster University), G. Provan (University of

Poster

Simultaneous imaging of recurrent plasma injection signatures in Saturn's auroras and energetic neutral atom flux

Recent studies have revealed that large-scale injections of plasma into Saturn's magnetosphere are significant in driving morning-sector auroral emissions in its ionosphere. Here we report on observations taken by Cassini's imagers on 9 April 2014, the UVIS and INCA, providing simultaneous global views of the southern ultraviolet auroras and magnetospheric ion dynamics respectively. Two injection events, separated by ~ 8 h, are detected as rotating enhancements in the magnetospheric energetic neutral atoms (ENAs) and the auroral intensity. The ENA and auroral patches track at similar local time positions throughout their observed lifetimes and display no reduction in azimuthal speed as they move through the dayside sector. This apparent 1:1 mapping, spread across a local time range of ~3-6 hours, indicates a region of possible current flow linking the two enhancements, which is not fully resolved by the instruments. However, a third subsequent auroral signature has no obvious ENA counterpart as it rotates to the dayside. We also identify possible planetary period modulation of the onset and intensity of injection signatures.

Robert Fear (University of Southampton)

R. C. Fear, J. C. Coxon and C. M. Jackman (University of Southampton)

Talk

The contribution of flux transfer events to Mercury’s Dungey cycle

Observations from MESSENGER have demonstrated that bursty dayside reconnection plays a proportionally larger role in the driving of Mercury's magnetosphere than it does at Earth. Studies using MESSENGER data indicate that individual bursts of dayside reconnection, called flux transfer events or FTEs, open magnetic flux equivalent to up to 5% of Mercury’s polar cap, whereas equivalent spacecraft studies at Earth find that individual FTEs typically open 0.1-1% of the terrestrial polar cap. Coupled with the much higher repetition rate of FTEs at Mercury, this has led to the suggestion that bursty reconnection is the dominant driver of Mercury's magnetosphere, whereas quasi-steady reconnection predominates at Earth. However, our recent work suggests that the contribution of FTEs at Earth may have been severely underestimated. If correct, similar arguments could apply at Mercury, and the significance of FTEs there could be underestimated too. Therefore, we extend our earlier work and consider upper limits for the contribution of individual FTEs at Mercury. We find that it could be reasonable for an individual FTE to open 20-30% of Mercury's polar cap - in other words, in cases of extreme driving, only a handful of FTEs (with corresponding magnetotail reconnection) might be needed to refresh Mercury's polar cap entirely.

Alexander Bader (Lancaster University)

A. Bader, S.V. Badman, S.W.H. Cowley, Z.H. Yao, L.C. Ray, J. Kinrade, E.J. Bunce, G. Provan, T.J. Bradley, C. Tao, G.J. Hunt, W.R. Pryor

Poster

The dynamics of Saturn’s main aurorae

Saturn's main aurorae are thought to be generated by flow shears associated with a strong gradient in angular plasma velocity between the outer magnetosphere and the open field region, causing a steady upward directed ring of field-aligned current near the open-closed field boundary. Under strong solar wind driving, Dungey cycle convection imposes an antisunward flow on the slowly subcorotating polar open field region, maximising this flow shear and hence the main aurorae at dawn where the subcorotating magnetospheric flow is sunward and minimizing it at dusk where it is antisunward. Snapshots of Saturn's aurorae showed such an asymmetry, leading previous studies to assume significant solar wind driving of Saturn's magnetosphere.

We investigate this asymmetry with large sets of Cassini-UVIS imagery, using image sequences with short exposure times and continuous coverage for sometimes more than two full Saturn rotations. Surprisingly, we find no persistent local time-fixed asymmetry between dawn and dusk UV powers, but instead demonstrate that the previously observed "dawn arc" is a signature of quasiperiodic auroral injections from midnight-dawn local times. While highly energetic, these injections seem to be transient signatures of magnetotail reconnection and not to be associated with the static main aurora.

We conclude that direct Dungey cycle driving must be rather negligible in Saturn's magnetosphere under usual conditions, and hence propose that the large-scale auroral dynamics observed here are predominantly controlled by internal plasma loading, with plasma release in the magnetotail being triggered both internally through planetary period oscillation effects and externally through solar wind compressions.

Fran Bagenal (University of Colorado)

F. Bagenal (University of Colorado)

Poster

The Io-Europa Space Environment

The components of the Io-Europa system are generally discussed in isolation. To understand physical processes and the interconnections of the components, we need to look at the whole system. Our goal is to summarize the current understanding of this multi-component system and to present the outstanding questions. We compare their atmospheres, and summarize what is known about the interaction with the plasma in which they are embedded. These interactions produce clouds of escaping neutrals that extend for a substantial fraction of Io’s and Europa’s orbits around Jupiter. Electron impact ionization of these neutral clouds produces the Io plasma torus and plasma sheet. The magnetospheric plasma primarily corotates with the planet’s 10-hour spin period, but also moves radially outwards over several weeks. Only about 10% of the torus material moves inwards from Io’s orbit. The inward flows are about a factor 50 slower than the outward flow. Charge exchange reactions between the corotating plasma and the neutral clouds produces energetic neutral atoms that escape Jupiter to form a neutral disk that extends 100s of RJ around Jupiter. When the energetic ions move inward through the neutral cloud around Europa’s orbit, they charge exchange, making very energetic neutral atoms which have high speeds in all directions and likely spread into a huge sphere around the Jupiter system. This system of ~ten coupled components comprises a wide range of physics and extends from 10s of kilometers to AU scales.

PRO-AM COLLABORATIONS IN ASTRONOMY (PROAM)

Jeremy Shears (British Astronomical Association)

Jeremy Shears (British Astronomical Association)

Talk

Amateur astronomers and cataclysmic variables

The study of cataclysmic variable stars has long been a fruitful area of co-operation between amateur and professional astronomers. I shall provide examples of recent projects on dwarf novae, VY Scl and AM CVn stars. I shall also consider the sky surveys that are already coming on stream, which will provide near continuous and exquisitely precise photometry of these systems. Whilst these surveys might be perceived as a threat to amateur observations, they will actually provide new opportunities, although the amateur community shall need to adapt and focus its efforts. I will identify areas where amateurs equipped for CCD photometry can make scientifically useful observations.

Grant Privett (Defence Science and Technology Laboratory (Dstl))

G Privett (Dstl), A Ash (Dstl), W Feline (Dstl), T Gainey (Basingstoke AS) and A Lorrain (Basingstoke AS)

Talk

Argus: A Citizen Science Project

We discuss Project Argus: a Citizen Science type collaborative research activity undertaken by Dstl (Defence Science and Technology Laboratory - An Agency of the Ministry of Defence) and members of the Basingstoke Astronomical Society (BAS).

The activity encouraged accomplished amateur astronomer to image low Earth orbit satellites using commercial-off-the-shelf amateur astronomy level equipment. The BAS team thereby acted as a surrogate for a potential future distributed system aimed at updating satellite orbit determinations and thereby reducing the risk of on-orbit collision events.

The project aims, techniques employed and overall results will be discussed, but most importantly the difficulties encountered and lessons learned in creating and executing such an activity will be highlighted as many are likely to be encountered with other collaborative endeavours.

The presentation will discuss the execution of the project from the perspective of both the data provider and the recipient. In addition, it will make recommendations to support the

successful execution of such activities more generally.

Robin Leadbeater (British Astronomical Association)

Robin Leadbeater (British Astronomical Association)

Talk

Confirming and Classifying Supernovae Spectroscopically Using Amateur Equipment.

Once a niche area for amateurs, spectroscopy is now a mainstream activity with around a hundred amateurs worldwide capable of producing research quality spectra across a wide range of targets and resolutions, tens of thousands of amateur spectra available in databases and dozens of publications a year referencing amateur spectra.

Historically amateurs have played a significant role in the discovery of supernovae and other transients. Today, although they still find over 100 supernova a year, most transient objects are now discovered by automated surveys and the amateur emphasis is shifting towards following up and characterising these events. The rapid confirmation and classification of transients is key to understanding the early history of these objects. For supernovae this needs a spectrum, which has traditionally been beyond the capabilities of amateurs due to their low apparent brightness.

Described here is a low resolution faint object spectrograph specifically optimised for supernova classification, which has been in use intermittently over the past three years at an amateur observatory in North West England. Although initially a proof of concept, to date the system has been used to confirm and classify 24 supernovae to 17th magnitude officially via the IAU Transient Name Server, 11 of which were also discovered by amateurs. These include the early classification of the much studied nearby type Ia supernova SN2018oh and the possible blue supergiant type II supernova SN2018hna.

Anthony Cook (British Astronomical Association)

A.C. Cook (BAA)

Talk

Lunar Impact Flash Observing

A lunar impact flash is the light produced from a meteoroid striking the lunar surface. Less than 1% of the kinetic energy involved in forming the crater is converted to light. Depending upon the velocity and mass, objects from tens of grams to hundreds of kilograms have been detected. Impact flashes have been observed and confirmed by different observing programmes around the world since 1999 and now total over 400. Amateur astronomers were involved in the first discoveries in 1999 and can still make valuable contributions; for example, by performing high frame rate video to resolve different phases in the impact fireball development and multiple waveband observations to establish the black body temperature of the impact - as has been pioneered by ESA’s NELIOTA project. Because amateur astronomers have plenty of free time, they can explore lower success rate, experimental observing approaches than professional observatories can. For example, attempting higher angular resolution imaging in order to see if ejecta clouds can be resolved, or even looking for impact flashes on the dayside of the Moon in shadowed/shaded areas near the terminator where ejecta clouds might become visible in sunlight. BAA members also hold archives of lunar videos of the day/night side of the Moon, and lunar eclipses, going back to the late 1980’s which can be studied to see if there any impact flashes here that would predate the 1999 discovery observations.

Matt Darnley (LJMU)

M. J. Darnley (LJMU), M. Henze (SDSU), on behalf of the '12a Collaboration'

Talk

M31N 2008-12a - A remarkable system and an equally remarkable Pro-Am collaboration

M31N 2008-12a is a remarkable recurrent nova which has unprecedented annual eruptions. Located in the Andromeda Galaxy this accreting white dwarf has grown to almost the Chandrasekhar mass and accumulates matter more rapidly than any other known white dwarf. The annual eruptions are both faint and exceptionally short-lived, but over time a vast nova 'super-remnant' has been grown around the central system.
The '12a Collaboration' is a group of around 100 astronomers, half of which are employed to do astronomy, the other half are not. The contributions from groups such as the BAA, AAVSO, VSOLJ, and individuals to this project are priceless.
In this talk I will talk about '12a' itself, how it has revolutionised nova-physics, and how this research is only made possible by the fabulous Pro-Am team that has come together. I will include stories of some of the heroic efforts many members of our team have gone to in order to obtain observations of this system!
Our future plans are to continue this fruitful collaboration for 12a as it evolves towards an eventual type Ia supernova explosion in (hopefully much) less than 20,000 years.

Callum Potter (British Astronomical Association)

T. Haymes (BAA Asteroids and Remote Planets Section), C. Potter

Poster

Pro/Am collaborations in the observation of Occultations

Pro/Am collaborations in the observation of Occultations.
The British Astronomical Association (BAA) and the International Occultation Timing Association (IOTA) have strong ties with research groups studying the positon and shape of distant solar system objects. The collaboration in the UK and Europe is between amateurs in the European Section of IOTA (IOTA-ES) and professional teams.
More directly, the RIO-TNO and PARIS teams (ERC/lucky-star project) request observations of stars predicted to be occulted by TNOs, Centaurs, Irregular satellites of Jupiter and Trojans. The success of these Campaigns has been improved by the ESA Gaia DR2 and there have been six successfully observed objects in the first quarter of 2019 to which amateurs have contributed.
A close Pro/Am collaboration is achieved by the use of software (OccultWatcher) which displays the predicted events through an internet feed. In this way amateur observers (world-wide) can plan their observations - or travel to specific locations. This is necessary for increasing the chance of detecting events. Observers in the US, Japan, Europe, N Africa, Middle East, Australia, New Zealand, Brazil, Israel use similar instrumentation and software. A poster will provide more information on the techniques used by amateurs and some preliminary results. IOTA publish The Journal for Occultation Astronomy (ISSN 0737-6766) and amateur observations are listed on EURASTER.NET

Tim V.Haymes, on behalf of the BAA Asteroids and Remote Planets section - Occultations.

Our Pro. colleagues: Josselin Desmars, Felipe Braga Ribas, Prof. Bruno Sicardy.
Our IOTA colleagues: Wolfgang Beisker, David Dunham, Dave Herald, Steve Preston.
http://lesia.obspm.fr/lucky-star/predictions.php

Callum Potter (British Astronomical Association)

R. Miles, C. Potter

Poster

Some reflections on amateur astronomers publishing papers in the professional literature

There are many underlying reasons why amateurs pursue their interest in Astronomy. Some love immersing themselves in the subject either through in-depth reading, or by engaging in serious observations. But the speaker suggests that more amateurs should consider publishing their work, more especially in those journals traditionally considered the territory of the professional. This talk summarises some of the speaker's experiences to date in writing papers aimed at such mainstream periodicals. Examples from work by other amateurs are also presented. It recommends that, when devising observing programmes, amateurs look to collaborate with astronomers already engaged in their proposed areas of investigation.

Jeremy Shears (BAA)

R. D. Pickard, J. Shears

Poster

THE BAA VARIABLE STAR SECTION

The VSS offers members a range of interests be it observing, analysing or data mining.

Observations are of course of prime concern and we offer several programmes to cater for all types of observing from naked eye, through to binocular, telescopic and of course, CCD and DSLR observing.

Having obtained the observations it is necessary to analyse them and this can either be done by the observer or as part of an undertaking by another person (amateur or professional) who will usually combine data from several sources (or individuals).

Professional astronomers also ask, either directly or through the AAVSO, for observations either generally or of specific stars and this is something many of amateurs enjoy participating in.

Details of a number of the above examples will be displayed.

Dirk Froebrich (University of Kent)

D.Froebrich (University of Kent), J.Evitts (University of Kent)

Talk

The HOYS-CAPS Citizen Science Project

The Hunting for Outbursting Young Stars with the Centre for Astrophysics and Planetary Science is aiming to study the long term variability of Young Stars in nearby clusters. The talk will briefly introduce the project and present some of our initial results. We will focus on the study of the statistics of dimming events from structures in the accretion disks of the sample of young stars. We will also discuss some of the more unusual objects in our sample.

Dirk Froebrich (University of Kent)

D.Froebrich (University of Kent), J.Evitts (University of Kent)

Poster

The HOYS-CAPS Citizen Science Project

The poster will present the details of the Hunting Outbursting Young Stars with the Centre of Astrophysics and Planetary Science citizen science project, i.e. its science aims but in particular explains how to participate and access the data.

RADIATION BELT DYNAMICS AT EARTH AND BEYOND (RADIATIONBELT)

Jonathan Eastwood (Imperial College London)

Ravindra T. Desai, Jonathan P. Eastwood, Lars Mejnertsen, Joseph W. B. Eggington, Richard H. Horne, Nigel P. Meredith, Jeremy C. Chittenden

Poster

An Integrated Van Allen Radiation belt model for Global-MHD simulations

The Van Allen radiation belts dynamically vary across timescales ranging from minutes to hours and thus pose significant challenges to modelling efforts. Here, we describe an Integrated Van Allen Radiation belt model which is implemented within the Global-MHD simulation code, Gorgon. Within the radiation belt model, energetic ions and electrons are represented as test-particles due to their negligible contribution to the overall magnetospheric current systems. Relativistic Lorentz and Guiding Centre integrators are implemented to trace particle's gyro, bounce, and drift-motion using fields from the MHD grid, and particle phase-space weightings are used to represent realistic radiation belt distributions. Two levels of parallelisation are presented. The first method utilises a Particle-in-Cell algorithm to push particles within the simulated magnetosphere whereas the second method is further optimised to balance the computational load across all processes. The model is tested for the scenario of a strong fast-forward interplanetary shock rapidly compressing the magnetosphere and driving the sub-solar magnetopause from >10 Re to 6 Re. The two different model implementations are shown to excel at capturing different aspects of the resultant radiation belt evolution. The load-balanced method efficiently reproduces shock-induced adiabatic acceleration across particle-drift timescales, whereas the PIC method is able to accurately resolve complex magnetopause particle dynamics such as drift-orbit-bifurcations. The Integrated Van Allen Radiation belt model is thus shown capable of simulating radiation belt behaviour whilst running in parallel with a global MHD simulation model of the type commonly used for space weather forecasting.

Nigel Meredith (British Antarctic Survey)

N. P. Meredith (British Antarctic Survey), R. B. Horne (British Antarctic Survey), M. A. Clilverd (British Antarctic Survey), J. P. J. Ross (British Antarctic Survey)

Poster

An investigation of VLF transmitter wave power in the inner radiation belt and slot region

Signals from manmade VLF transmitters, used for communications with submarines, can leak into space and contribute to the dynamics of energetic electrons in the inner radiation belt and slot region. In this study we use ~5 years of plasma wave data from the Van Allen Probe A satellite to construct new models of the observed wave power from VLF transmitters both as a function of L* and MLT and geographic location. Average power peaks primarily on the nightside of the Earth for the VLF transmitters at low geographic latitudes. At higher latitudes the peak average power extends further in MLT due to more extensive periods of night-time in the winter months. Night-time power is typically orders of magnitude more than that observed near noon, implying that loss rates from a given VLF transmitter will also maximise in this region. The observed power from any given VLF transmitter is tightly confined in longitude, with the nightside peak power typically falling by a factor of 10 within 10 degrees longitude of the location of the peak signal. We show that the total average wave power from all VLF transmitters lies in the range 3-9 pT^2 in the region 1.3 L* 3.0, with approximately 50% of this power emanating from three VLF transmitters, NWC, NAA and DHO38.

Johnathan Ross (British Antartic Survey)

J. Ross, N. Meredith, S. Glauert, R. Horne, M. Clilverd

Talk

Effects of VLF transmitter wave on the inner belt and slot region

Signals from VLF transmitters can leak from the Earth-ionosphere wave guide into the inner magnetosphere, where they propagate in the whistler mode and contribute to electron dynamics in the inner radiation belt and slot region. Observations show that the waves from each VLF transmitter are highly localised, peaking on the nightside in the vicinity of the transmitter. In this study we use 5 years of Van Allen probe observations to construct global statistical models of the bounce-averaged pitch angle diffusion coefficients for each individual VLF transmitter, as a function of L*, Magnetic Local Time (MLT) and geographic longitude. We construct a 1D pitch-angle diffusion model with implicit longitude and MLT dependence to show that using global averages of the wave power, determined by averaging the wave power over MLT and longitude, captures the long-term dynamics of the loss process, despite the highly localised nature of the waves in space. We use our new model to assess the role of VLF transmitters on electron loss in the inner radiation belt and slot region. At moderate relativistic energies, ~500 keV, waves from VLF transmitters reduce electron lifetimes by an order of magnitude or more, down to the order of 200 days near the outer edge of the inner radiation belt. However, these waves are ineffective at removing multi-MeV electrons from either the inner radiation belt of slot region.

Oliver Allanson (University of Reading)

Oliver Allanson (Reading), Clare Watt (Reading), Heather Ratcliffe (Warwick), Nigel Meredith (BAS), Teo Bloch (Reading), Hayley Allison (BAS) and Sarah Bentley (Reading)

Poster

Electron diffusion in self-consistent numerical experiments due to whistler-mode wave-particle interactions

The diffusion of electrons in energy and pitch angle space by whistler mode waves is a cornerstone of our current theoretical framework of acceleration and loss in Earth's Outer Radiation Belt. The quasilinear theory of waveparticle interactions provides us with a tractable method to estimate the amount of diffusion that occurs for a range of wave and ambient plasma conditions. However, the whistler mode manifests in different ways throughout the outer belt: naturally generated chorus and hiss waves, and large amplitude nonlinear wave packets; artificially generated transmitter waves; and lightning generated whistler waves. It is likely that, formally speaking, the quasilinear theory is not applicable in all of these cases. In order to test the theory, we model the interactions between driven whistler-mode waves and ambient background plasma. Specifically, we propagate incoherent, broadband whistler-mode waves through conditions characteristic of equatorial magnetic latitudes in the plasma trough. We explore whether quasilinear diffusion is a reasonable description for different wave amplitudes. Using particle data directly extracted from the particle-in-cell simulation, we find that diffusive response of the plasma due to whistler-mode wave particle interactions is a strong function of phase-space. The mathematical description implicit in the underlying quasilinear theory, i.e. Einstein/classical diffusion such that variance(X) ~ t^a (with a = 1, and for X either energy or pitch angle), is not borne out for all energies and pitch angles. We observe different regimes in phase space for which 'super-diffusion' (a > 1) and 'sub-diffusion' (a 1) occur.

Alexander Lozinski (British Antarctic Survey)

Alexander R. Lozinski (British Antarctic Survey), Richard B. Horne (British Antarctic Survey), Sarah A. Glauert (British Antarctic Survey), Giulio Del Zanna (DAMTP - University of Cambridge), Hugh D. R. Evans (ESA), Daniel Heynderickx (DH Consultancy)

Talk

Evaluation of Solar Cell Radiation Damage during Electric Orbit Raising

Electric propulsion technology now enables satellite operators to achieve geostationary orbit without the use of chemical propellant via electric orbit raising. This enables lower cost access to space by reducing mass, but necessitates a longer (~200 day) raising period, during which satellites pass through the hazardous radiation environment of the Van Allen belts.

Increased radiation exposure during electric orbit raising must be accounted for by mission planners through the use of environment models such as NASA's AP9/AE9. However, case studies such as the CRRES mission show that our predictive capability is limited by the drastic changes to the proton (inner) belt and slot region that can occur in a large solar energetic particle trapping event. Such changes raise the risk for shielding to be under-designed.

We show the accumulation of damage calculated by a range of models in terms of non-ionising dose for a variety of electric orbit raising scenarios that have been used to date, and discuss how varying key parameters affects the result. We use the reduction in solar cell performance as a measure of degradation, with the dominant contribution coming from 3 - 10MeV trapped protons.

In particular, we show that the trajectory, solar cell coverglass thickness and state of the proton belt can affect solar cell degradation accrued during electric orbit raising and before the beginning of service by up to ~10%. We conclude that more real-time information is required on the transient nature of the proton belt's outer region to help assess radiation damage.

Samuel Walton (Mullard Space Science Laboratory, UCL)

S. D, Walton (MSSL, UCL), C. Forsyth (MSSL, UCL), I. J. Rae (MSSL, UCL), C. E. J. Watt (University of Reading)

Poster

Examining the cohesive nature of radiation belt dynamics

The electron population inside Earth's outer radiation belt is highly variable and is typically linked to geomagnetic activity such as storms and substorms. These variations can differ with radial distance, such that the electron fluxes at the outer boundary are different from those

in the heart of the belt. Using data from the Proton Electron Telescope (PET) aboard NASA's Solar Anomalous Magnetospheric Particle Explorer (SAMPEX), we have examined the correlation between electron fluxes at all L-shells within the radiation belts for both quiet and active times. Our analysis shows that during storm times, L-shells are correlated more locally than during quiet times, e.g. during storms the flux at L=4 is well correlated with the fluxes at L's up to 5, whereas in quiet times it is well correlated with the fluxes at L's up to 8. Furthermore, when particles are injected into the slot region, it is well correlated with itself but not the rest of the belts, indicating that the variability of the electron fluxes in this region is dominated by different mechanisms to the rest of the radiation belts. We examine whether, and to what extent this correlation is related to the level of enhancement of the outer radiation belt during geomagnetic storms.

Colin Forsyth (UCL Mullard Space Science Laboratory)

C. Forsyth, C.E.J. Watt, I. J. Rae, M. K. Mooney, S. D. Walton, H. E. Spence, C-L. Huang, A. J. Boyd

Poster

Forecasts of Earth's outer radiation belt based on geomagnetic indices and upstream parameters.

Earth's radiation belts are a dynamic natural hazard to spacecraft in or passing through near-Earth space and, as such, forecasting the conditions in the radiation belts has been a topic of interest to the space weather community and space operators for a number of years. Current models forecast the >2 MeV fluxes at geosynchronous orbit. However, the fluxes in the heart of the outer radiation belt can be much higher and are not well correlated with the fluxes at GEO. Using quantitative measures of forecasting skill that are often used to assess terrestrial weather forecasts, we examine the extent to which the peak fluxes in the radiation belts, and changes to these fluxes, can be forecast by upstream solar wind conditions or geomagnetic indices. Our results show that AL, SYM-H, solar wind pressure and solar wind density give the best forecasts and nowcasts of the maximum >2 MeV electron flux in the outer radiation belts. AL gives good binary forecasts over a few days, while solar wind density and pressure give good forecasts over the 27-day solar rotation period, with accuracies above 90%. The amount of time SYM-H is below a set threshold can be used to construct probabilistic forecasts of the >2 MeV flux with Brier Skill Scores of up to 0.34. Our results show that, in general, geomagnetic indices, rather than solar wind conditions, provide better forecasts of the conditions of the radiation belts.

Jonathan Rae (MSSL/UCL)

I. Jonathan Rae (MSSL/UCL), Kyle R. Murphy (University of Maryland), Clare E. J. Watt (University of Reading), Jasmine K. Sandhu (MSSL/UCL), Marina Georgiou (MSSL/UCL), Alex W. Degeling (Shandong University), Colin Forsyth (MSSL/UCL), Sarah N. Bentley (Un

Talk

How do Ultra-Low Frequency waves access the inner magnetosphere during geomagnetic storms?

Wave-particle interactions play a key role in radiation belt dynamics. Traditionally, Ultra-Low Frequency wave-particle interaction is parameterised statistically by a small number of controlling factors for given solar wind driving conditions or geomagnetic activity levels. Here, we investigate solar wind driving of ultra-low frequency (ULF) wave power and the role of the magnetosphere in screening that power from penetrating deep into the inner magnetosphere. We demonstrate that, during enhanced ring current intensity, the Alfvén continuum plummets, allowing lower frequency waves to penetrate deeper into the magnetosphere than during quiet periods. With this penetration, ULF wave power is able to accumulate closer to the Earth than characterised by statistical models. During periods of enhanced solar wind driving such as coronal mass ejection driven storms, where ring current intensities maximise, the observed penetration provides a simple physics-based reason for why storm-time ULF wave power is different compared to non-storm time waves.

Sarah Glauert (British Antarctic Survey)

Sarah Glauert, Richard Horne, Nigel Meredith (British Antarctic Survey)

Poster

Long-term variations of the Earth’s radiation belts

Even with the recent success of the Van Allen Probes (VAP) and other long-term missions like SAMPEX and Cluster, satellite measurements of the high energy electron flux in the Earth’s radiation belts are still relatively sparse when considered on the timescale of the solar cycle. Here we present a simulation of the high-energy electron flux for nearly 3 solar-cycles, covering the region from the outer edge of the inner belt to geostationary orbit. The simulation uses the BAS-RBM, a physics-based model that includes the effects of wave-particle interactions, radial transport and losses to the atmosphere and magnetopause, and is validated by comparison with spacecraft measurements. It provides a ‘climatology’ of the radiation belts; consistent features are present during different parts of the solar cycle and the average and peak fluxes also vary with the phase of the solar cycle. We compare the VAP period to similar phases of previous cycles. A comparison between the simulation and the AE9 design model identifies the locations and times when the design model may significantly underestimate the flux.

Sarah Bentley (University of Reading)

S N Bentley, C E J Watt, I J Rae, M J Owens, K Murphy, M Lockwood, J K Sandhu

Talk

Probabilistic driving of radiation belt electrons by ultra-low frequency waves

Twenty-first century life is highly dependent on satellite services, which are at risk from the hazardous radiation belt environment. Ultra-low frequency waves (ULF, 1-20 mHz) driven by the solar wind are responsible for the radial transport and energisation of electrons in Earth's radiation belt, and are therefore essential components of radiation belt modelling. Current models of ULF waves and the resulting radial diffusion are deterministic, producing a single output for each set of input parameters. Meanwhile, weather and climate models increasingly use stochastic parameterisations to account for the effects of sub-scale processes and model uncertainty. To apply stochastic parameterisation to radial diffusion, we require probabilistic forecasts of the power in ULF waves in order to estimate diffusion coefficients. Our solar wind driven, probabilistic wave map can be used to address the inherent variability in ULF waves and their effects on radiation belt electrons. We compare radial diffusion coefficients from our model and existing parameterisations. By using these probability distributions, we can also investigate the physics underlying ULF wave generation in a novel manner.

Richard Horne (British Antarctic Survey)

Richard B Horne and Sarah A Glauert (BAS)

Poster

Relativistic electron flux variations at geostationary orbit and their effects on satellite charging

The relativistic electron flux in the outer radiation belt can vary by orders of magnitude during geomagnetic storms, fast solar wind streams and other space weather events. These variations are driven by acceleration, transport and loss processes associated with many different types of waves in the ULF to VLF frequency range. Periods of high flux can cause satellite charging leading to disruptions to satellite services and in rare cases satellite loss. Here we examine the time history of the electron flux at geostationary orbit using data from the GOES satellite. We consider the peak flux and 24 hour fluence and examine periods where satellites may be a risk. We develop a model for satellite charging that takes into account the properties of difference dielectric materials. We demonstrate that the charging risk is far more complicated than simply looking at the electron flux and depends critically on the time history of the electron flux. We discuss what this means in terms of protecting satellites and the difficulty of calculating the risk for orbits where there are little data, such as medium Earth orbit.

Elias Roussos (Max Planck Institute for Solar System Research)

E. Roussos (Max Planck Institute for Solar System Research)

Invited

The dynamics of Saturn's and Jupiter's radiation belts

The outer planet orbiters (Galileo, Juno and Cassini) have greatly advanced our understanding of how the radiation belts of Jupiter and Saturn are structured. For a long time, however, relevant investigations ignored the aspect of radiation dynamics, citing the lack of solar wind monitoring and the limitations associated with single point spacecraft measurements. The extended, 13-year stay of Cassini at Saturn, which involved more than 200 crossings through the planet's radiation belts, allowed us to develop ways to overcome such obstacles and to gain valuable insights into the proton and electron belt variability time scales. In several cases, these insights have been decisive for identifying the dominant processes that form and sustain these energetic systems. In this presentation I will introduce Saturn's radiation belts

and describe key aspects of their time variability, their interpretation and importance for understanding an even more complex system: Jupiter's radiation belts.

Emma Woodfield (British Antarctic Survey)

E. E. Woodfield (British Antarctic Survey), S. A. Glauert (British Antarctic Survey), R. B. Horne (British Antarctic Survey)

Poster

The effect of Ion Cyclotron Waves on energetic electrons in the radiation belts of Saturn

Electromagnetic Ion Cyclotron Waves (EMIC) at the Earth are thought to scatter very high energy electrons out of the Earth's radiation belts. In contrast to the Earth where EMIC generation is not continuous, EMIC waves at Saturn are always present at all local times from the orbit of the moon Enceladus out to near the orbit of Dione. Freshly ionized neutral particles from the Enceladus plume are accelerated by the corotating magnetospheric plasma and this gives rise to a ring distribution in velocity space which is the source of the ion cyclotron waves. This band of strong water group EMIC waves gives us a unique opportunity to study the role of EMIC waves in the scattering process both at Saturn and in comparison to the Earth. We use cold plasma dispersion calculations from the PADIE code combined with quasi-linear theory in the BAS Radiation Belt Model to show the effect this band of EMIC waves has on the energetic electron population of the radiation belt at Saturn.

Jasmine Sandhu (MSSL, UCL)

J. K. Sandhu (MSSL, UCL), I. J. Rae (MSSL, UCL), M. Gkioulidou (John Hopkins University), C. Forsyth (MSSL, UCL), G. D. Reeves (Los Alamos National Laboratory), M. P. Freeman (British Antarctic Survey), K. R. Murphy (University of Maryland), M.-T. Walach

Talk

The importance of substorm - ring current coupling for radiation belt dynamics

Substorms are a highly dynamic process that results in the global redistribution of energy within the magnetosphere, which has substantial consequences for both radiation belt and ring current dynamics.
Using ion observations (H+, O+, and He+) from the RBSPICE and HOPE instruments onboard

the Van Allen Probes, we evaluate changes in the total ring current energy and temperature anisotropies associated with substorms. We find that, on average, ~ 5% of the total energy released at substorm onset is transferred into the ring current ion population, which increases the ring current energy by 12%. Furthermore, the energy increase is found to depend on whether the substorm is isolated or not.

The spatial variation of the energy enhancement matches that expected from particle injections into the inner magnetosphere, and larger enhancements in the O+ contribution to the energy content compared to the H+ contribution suggest important compositional variations. Finally, ion temperature anisotropy is found, on average, to decrease during the substorm expansion phase, suggesting a transfer of energy driving EMIC wave growth in the inner magnetosphere. These ring current dynamics have important implications for wave-particle interactions and the transport and loss of radiation belt electrons. For example, ring current intensifications weaken the geomagnetic field, which allows significant ULF wave power to access the inner magnetosphere and drive rapid radiation belt electron transport via enhanced ULF radial diffusion. Furthermore, EMIC waves generated by ion anisotropies from substorm injections couple to ultra-relativistic MeV electrons and drives rapid radiation belt electron loss through particle precipitation.

Frances Staples (University College London, MSSL)

A. Franes Staples (UCL) B. Jonathan Rae (UCL) C. Colin Forsyth (UCL) D. Ashley Smith (University of Edinburgh) D. Katie Raymer (University of Leicester) E. Nathan Case (Lancaster University) F. Ferdinand Plaschke (Austrian Academy of Sciences) G. Steve Mi

Poster

The importance of understanding magnetopause location and it's role in electron losses from the outer radiation belt

Under steady-state conditions the magnetopause location is described as a pressure balance between internal magnetic pressures and the external dynamic pressure of the solar wind. Under more extreme solar wind driving, such as high solar wind pressures or strong southward-directed interplanetary magnetic fields, this boundary is significantly more compressed than in steady-state, playing a significant role in the depletion of magnetospheric plasma from the Van Allen Radiation Belts, via magnetopause shadowing.

We use a database of >42,000 spacecraft magnetopause crossings, to determine how the magnetopause position differs from a statistical model, and under which conditions. The role of magnetopause compressions in creating radial gradients of electron phase space densities are further investigated by comparing electron measurements from the Van Allen Probes to our database of magnetopause crossings.

We find that the observed magnetopause is on average 6 % closer to the radiation belts than the model during periods of sudden dynamic pressure enhancement, such as during storm sudden commencement, with a maximum of 42% closer. This demonstrates that large step-changes in solar wind conditions enable the magnetopause to have a significant time-dependence which empirical models cannot capture. Therefore empirical magnetopause models such as the Shue et al. [1998] model should be used cautiously to interpret energetic electron losses by magnetopause shadowing.

Clare Watt (University of Reading)

C. E. J. Watt (University of Reading), H. J. Allison (British Antarctic Survey), N. P. Meredith (British Antarctic Survey), R. L. Thompson (University of Reading), S. N. Bentley (University of Reading), I. J. Rae (Mullard Space Science Laboratory), S. A.

Poster

Variability of Quasilinear Diffusion Coefficients in Outer Radiation Belt

In the Outer Radiation Belt, the acceleration and loss of high-energy electrons is largely controlled by wave-particle interactions. Quasilinear diffusion coefficients are an efficient way to capture the small-scale physics of wave-particle interactions due to magnetospheric wave modes such as plasmaspheric hiss. Observations indicate that the waves, plasma and hence diffusion processes vary in space and time, over a wide range of scales. We perform an initial analysis into alternative ways to construct quasilinear diffusion coefficients from observations, and the resulting variability of those coefficients. We use co-located and simultaneous in-situ measurements from the Van Allen Probe mission as inputs for calculations of diffusion coefficients that vary in space and time. We show that the distribution of plasmaspheric hiss diffusion coefficients in three different locations in the inner magnetosphere is highly non-Gaussian with large variance, and that the distributions themselves vary strongly across the three selected location bins. In most locations studied, the plasmaspheric hiss diffusion coefficients tend to increase with geomagnetic activity, as seen in previous studies. However, the large variance of diffusion coefficients with time motivates the future use of methods such as stochastic parameterizations of wave-particle interactions in the Outer Radiation Belt. We discuss the implications of the large variability of the diffusion process over a range of timescales and propose methods that can include such variability in diffusion models.

Role of shocks in the solar atmosphere and solar-terrestrial environment (SolarSTPShocks)

Nicolina Chrysaphi (University of Glasgow)

N. Chrysaphi (University of Glasgow), E. P. Kontar (University of Glasgow), G. D. Holman (NASA GSFC), M. Temmer (University of Graz)

Talk

A new look at CME-driven shock radio emissions with LOFAR

Heliospheric shocks driven by Coronal Mass Ejections (CMEs) can excite electrons causing them to emit radio waves. The observed signatures are referred to as Type II radio bursts and can produce pairs of bands with a 1:2 frequency ratio relating to the local plasma frequency and its second harmonic. Each of these bands can split into two thinner lanes, a phenomenon known as band splitting. The physical processes resulting in band splitting have been debated since the discovery of Type II bursts around 70 years ago. The novel observing capabilities of the LOw-Frequecy ARray (LOFAR) allowed us to image the emission sources of the split-band Type II burst simultaneously, for the first time. A large separation between the higher- and lower-frequency sources was observed. The effects of scattering - the dominant radio-wave propagation effect - were taken into account. We found that scattering shifts the lower-frequency source farther from its true location compared to the higher-frequency source, so that two virtually co-spatial sources appear separated. We provide supporting evidence for band-splitting models that require the emission sources to originate in virtually co-spatial locations, like the interpretation suggesting that the sources generate upstream and downstream of an MHD shock front.

Paolo Pagano (University of St Andrews)

P, Pagano (University of St Andrews), P. Antolin (University of St Andrews), H. J. Van Damme (University of St Andrews), I. De Moortel (University of St Andrews), V. Nakariakov (University of Warwick)

Talk

In situ generation of transverse magnetohydrodynamic waves from colliding flows in the solar corona

Transverse MHD waves permeate the solar atmosphere and play a role in the dynamic and thermal evolution of the corona. However, the origin of these waves is still not completely understood. Antolin et al. (2018) analysed coordinated observations from Hinode/SOT and IRIS of a prominence/coronal rain complex at the limb of the Sun. Loop-aligned flows of cool and dense plasma were observed along a structure stemming from a prominence core high above the surface. A collision between a downward and an upward flow was observed to generate oscillatory transverse perturbations of the strands. These perturbations were interpreted as transverse sausage and kink waves based on 2D MHD simulations of colliding plasma flows. Observational signatures of the transverse perturbations were successfully reproduced. These results suggest that such in-situ collisions from counter-streaming flows could be a source of transverse MHD waves. The presence of asymmetry between the plasma flows is crucial to generate a kink mode. Using 2D and 3D MHD simulations, we present a parameter study investigating the effect of the nature of this asymmetry on the properties of the generated kink and sausage waves.

Ciara A. Maguire (Trinity College Dublin, Ireland)

Maguire C. A. (1,2) , Gallagher P. T. (1 ,2), Carley E. P. (1,2), Zucca P. (3) [1.Trinity College Dublin, Ireland. 2.Dublin Institute for Advanced Studies,Ireland. 3.ASTRON Netherlands Institute for Radio Astronomy, Dwingeloo,The Netherlands]

Talk

Insights into Coronal Mass EjectionShocks with the Irish Low FrequencyArray (I-LOFAR)

he Sun can produce large-scale energetic events such as solar flares and coronal mass ejections (CMEs) which can excite shock waves that propagate through the corona. To date, the shock kinematics responsible for particle acceleration and emission at radio wavelengths are not well understood. Here, we investigate these phenomena using radio observations of the 2017 September 2, C7.7 solar flare at 10-240 MHz from Irish Low Frequency Array (I-LOFAR, www.lofar.ie). We investigate the relationship between the features in I-LOFAR's dynamics spectra and the shock kinematics as derived from imaging observations using the GOES/SUVI and SOHO/LASCO C2. We calculated the shock Mach number from both shock geometry in SUVI and modelling of coronal Alfvén speed. The relationship between shock characteristics from SUVI and data driven modelling are compared to shock characteristics from radio in order to determine the plausibility of shock accelerated electron release into the solar corona.

Ben Snow (University of Exeter)

B. Snow (University of Exeter), V. Fedun (University of Sheffield), F. A. Gent (Aalto University), G. Verth (Univerity of Sheffield), R. Erdelyi (University of Sheffield)

Poster

Magnetic shocks and substructures excited by torsional Alfven wave interactions in merging expanding flux tubes

We perform numerical simulations to investigate the behaviour of vortex driven waves propagating in a pair of such flux tubes in a non-force-free equilibrium with a realistically modelled solar atmosphere. The two flux tubes are independently perturbed at their footpoints by counter-rotating vortex motions.

When the flux tubes merge, the vortex motions interact both linearly and nonlinearly. The linear interactions generate many small-scale transient magnetic substructures due to the magnetic stress imposed by the vortex motions. Thus, an initially monolithic tube is separated into a complex multi-threaded tube due to the photospheric vortex motions. The wave interactions also drive a superposition that increases in amplitude until it exceeds the local Mach number and produces shocks that propagate upwards with speeds of approximately 50 km/s. The shocks act as conduits transporting momentum and energy upwards, and heating the local plasma by more than an order of magnitude, with peak temperature approximately 60,000 K.

Therefore, we present a new mechanism for the generation of magnetic waveguides from the lower solar atmosphere to the solar corona. This wave guide appears as the result of interacting perturbations in neighbouring flux tubes. Thus, the interactions of photospheric vortex motions is a potentially significant mechanism for energy transfer from the lower to upper solar atmosphere.

Samuel Grant (Queen's University Belfast)

S. D. T. Grant

Invited

Modern Observations of Solar Chromospheric Shocks

The formation of shocks within the solar atmosphere remains one of the few observable signatures of energy dissipation arising from the plethora of MHD waves generated at the solar surface. The chromosphere is a dynamic region marked by significant gradients in many plasma properties, allowing for the potential formation of a variety of theorised shock

phenomena. Previously, inherent limitations in observing capabilities made intricate studies of the chromosphere prohibitive. However, in recent years, modern ground- and space-based observing suites have begun to reveal much of the underlying physics of this tenuous region. In this talk, the recent advances in chromospheric observations of shock phenomena manifesting in magnetically dominated regions will be presented. In particular, the first evidence of Alfvén-induced and intermediate shocks will be discussed through the combination of cutting edge observations, coupled with advanced inversion techniques and observationally led modelling. The future of such studies will also be considered, with upcoming facilities such as DKIST in mind, to characterise more elusive shock formations throughout the solar atmosphere.

Ben Snow (University of Exeter)

B. Snow, A. Hillier

Poster

Shock substructure in partially-ionised plasma.

The atmospheric conditions in the solar chromosphere allow both ionised and neutral particles to exist and interact. Under such conditions, fine substructures exist within slow-mode shocks due to the decoupling and recoupling of the plasma.
We study numerically the fine substructure within slow-mode shocks in a partially ionised plasma, in particular, analysing the formation of an intermediate transition within the slow-mode shock.
High-resolution 1D numerical simulations are performed using the (PIP) code using a two-fluid approach.
We discover that long-lived intermediate (Alfven) shocks can form within the slow-mode shock, where there is a shock transition from above to below the Alfven speed and a reversal of the magnetic field across the shock front. The collisional coupling provides frictional heating to the neutral fluid, resulting in a Sedov-Taylor-like expansion with overshoots in the neutral velocity and neutral density. The increase in density results in a decrease of the Alfven speed and the plasma inflow is accelerated to above the Alfven speed within the finite width of the shock leading to the intermediate transition. This process occurs for a wide range of physical parameters and an intermediate shock is present for all investigated values of plasma-beta, neutral fraction, and magnetic angle. As time advances the magnitude of the magnetic field reversal decreases since the neutral pressure cannot balance the Lorentz force. The intermediate shock is long-lived enough to be considered a physical structure, independent of the initial conditions.

Malcolm Druett (Stockholm University)

Malcolm Druett (Stockholm University) Jorrit Leenaarts (Stockholm University)

Talk

Using tracer particles to study the density variations of fibrils

As a part of project designed to address the question, “what are the physical mechanisms that supply the solar chromosphere with mass?” we present 3D radiation-MHD simulations of the Sun, from the corona to the convection zone, using the Bifrost code with the new “corks” module.

The corks module allows us to insert passive tracer particles into our simulations and then inspect the experiment from a Lagrangian viewpoint, as well as the Cartesian solution provided by the underlying method. Tracer particles are injected and pruned from the simulation in order to avoid voids and gluts of corks that results form compressive and expanding flows.

In this part of the project, we consider the tracer particles in fibrils at a given time of the simulation, then trace these particles both forward and backward in time, in order to analyse the origins and destinations of this plasma, and thereby address the posed question. We present our findings on the changes to mass density and temperature of the plasma elements over time, and link the journey of this plasma to the forces acting on the fibrils, with a focus on the effects and amount of impact that shocks impart upon the material contained in fibrils. We also evaluate the effect of varying the frequency of saved data snapshots upon our ability to identify and analyse the effects of shocks.

STUDYING GALAXY EVOLUTION FROM REIONIZATION TO COSMIC NOON WITH THE LATEST-GENERATION MULTIWAVELENGTH FACILITES (GALEVOLUTION)

Matthew Doherty (University of Hertfordshire)

M.Doherty(University of Hertfordshire), J.Geach(University of Hertfordshire)

Talk

A magnified view of the ISM and star formation in a strongly lensed AGN hosting SMG at z = 2.6

Sub-mm Galaxies (SMG's) are among the most prolific star forming galaxies in the universe, with star formation rates (SFRs) up to 1000 Msun/yr. Our understanding of the nature of the dense star-forming interstellar medium (ISM) in these galaxies is still in its infancy, because it is difficult to access the spatial scales relevant for assessing the astrophysics of star formation in galaxies at high-z. '9io9' is a strongly lensed SMG at z~2.6, with an intrinsic infrared luminosity exceeding 10^13Lsun. The fact that it is strongly lensed allows us to examine the ISM on spatial scales of a few 100pc in a galaxy forming stars at several 1000 solar masses per year. We present new ALMA Band 4, 8 and 9 data tracing the molecular and atomic gas and thermal dust continuum in this object. We reveal evidence for a large star bursting molecular gas disc and possible molecular outflow, and present a study of the resolved dust temperature across the source (which also contains a radio-loud AGN). Our detection of both the 122 and 205um [NII] lines in 9io9, in combination with CI and CO(4-3), allow us to map the physical conditions of the ionised and molecular ISM across the source, providing a unique resolved insight into the nature of star formation at its most extreme at the peak epoch of galaxy assembly.

Janet Bowey (Cardiff and UCL)

J. E. Bowey (Cardiff and UCL), A. M. Hofmeister (Washington University in St. Louis, USA), J. Greaves (Cardiff), H. L. Gomez (Cardiff) and M. J. Barlow (UCL)

Poster

A spectral probe of grain growth in galaxies: preparation of an observing proposal for MIRI on the JWST

The 5- to 8- micron overtone-combination bands of silicates could be used to test the theory that grain growth occurs in the ISM of galaxies (Rowlands et al. 2014 and Zhukovska 2014) because overtone bands occur when near optically thick conditions exist for the 10-micron silicate absorption feature (Bowey & Hofmeister 2005). As a rule of thumb grains responsible for an optically-thin 10 micron feature have diameters ~0.1 to 0.3 micron. However, room-temperature laboratory silicate overtones are measured in films of compressed powder that are 5 to 15 micron-thick which is analogous to larger or clumped grains in space.
We shall use the Spitzer spectrum of the z = 0.89 absorber toward PKS 1830-211 published by Aller et al. (2012) as a test case because this spectrum exhibits uninterpreted bands near 5.9 micron and 6.9 micron similar in shape to those matched by the overtones of silicates in young stellar objects (Bowey & Hofmeister 2005). A high abundance of clumped grains could explain the absence of the more commonly observed smooth 10 micron feature in this line of sight, which led Aller et al. to conclude the structured 10-micron feature could be due to a blend of 95% crystalline silicates.

Mirko Curti (Kavli Institute for Cosmology - University of Cambridge)

Talk

A “KLEVER” probe of the ISM in high redshift galaxies with multi-band KMOS observations

We will present KLEVER, an ESO Large Programme aimed at investigating dynamics, gas excitation properties and chemical abundances in high redshift galaxies, by means of near-IR spatially resolved spectroscopy. Exploiting KMOS multi-IFU observations in the J,H and K bands we aim to map multiple optical rest-frame emission lines (from [O II]3727 to [S III]9530) in a sample of ~100 galaxies between 1.2 z 2.5. The survey targets both gravitationally lensed galaxies in Frontier Fields clusters and non-lensed galaxies in the COMOS and GOODS fields. Our observing strategy allows us to obtain a detailed characterisation of the properties of the ISM in these sources on spatially resolved basis, thanks to the wealth of nebular diagnostics provided.

We investigate the physical drivers responsible for the evolution in the emission line ratios at these redshifts, as clearly seen e.g. in the BPT diagrams, by assessing whether the offsets from the relations observed in the local Universe correlate with different quantities like electron density, ionization parameter and nitrogen abundance.
We also derive full metallicity maps, exploiting different calibrators and evaluate presence and evolution of metallicity gradients.
Although the bulk of the analysed galaxies are characterised by flat gradients, suggesting that efficient feedback and gas mixing processes are in place at these epochs, the irregular and non-axisymmetric patterns often seen in the full 2D metallicity maps suggests to move beyond the classical "radial-averages" approach to get meaningful constraints on galaxy evolution models and allow for fair comparison with prescriptions of high resolution simulations.

Joseph Cairns (Imperial College London)

J. Cairns (Imperial College London), D. Clements (Imperial College London), D. Farrah (University of Hawaii)

Poster

Case Study of an Extremely Luminous Quasar and Starburst at z=3.65

We present multi-wavelength observations of the z = 3.65 quasar SDSS J160705.16+533558.5. Prior observations demonstrated that this source is bright in both the FIR and sub-mm, with SED analysis indicating that the source is comprised of an AGN component that is hyper-luminous in the MIR, and a starburst component with a SFR ~ 2000 solar masses per year. SDSS J160705.16+533558.5 also proved to have an interesting morphology, with the AGN located roughly in the centre of the structure while the sub-mm emission is offset and significantly extended. Recent observations using the WFC3/IR camera on the HST are used to estimate spatially resolved SFRs and extinctions. Observations with the SMA are also used to trace the spatial and velocity distribution of the molecular gas that fuels star formation, as well as the warmer material that may be associated with the AGN. These observations enable us to characterise the nature of this source, allowing insights into the population of dusty luminous starbursts at z > 3 and the role of AGN in galaxy formation and evolution.

Nimisha Kumari (University of Cambridge)

Nimisha Kumari, Bethan James, Mike Irwin, Alessandra Aloisi, Ricardo Amorin, Enrique Perez-Montero

Talk

Galaxy evolution via blue compact dwarfs: Local analogues of high redshift galaxies

Galaxy formation and evolution are regulated by the complex interplay between star-formation, chemical abundance and gas dynamics. Detailed spatially-resolved kinematical and chemical analysis of the ionised gas may help unravel several secrets of the key mechanisms involved in galaxy formation and evolution. Integral Field Spectroscopy (IFS) is the best available technique to carry out spatially-resolved studies of the ionised gas in galaxies, because it not only allows us to access information encoded in the emission lines from the ionised gas, but also enables us to map their distribution and varying properties throughout each system. I use IFS observations from the Gemini Multi-Object Spectrograph-North to study the distribution of physical and chemical properties of H II regions in a sample of BCDs, the local analogues of high redshift galaxies. While answering questions related to chemical homogeneity, ionisation mechanisms and stellar populations within BCDs, I address more profound issues, which go beyond the characterisation of studied BCDs and aim to explain global phenomena with broader implications. Such studies are imperative to enhance our understanding of the chemical abundance patterns and star-formation in galaxies in the high-redshift Universe, and hence be better prepared for a whole new era of high-redshift astronomy initialised by JWST, and complemented by facilities like MUSE and MOONS.

Poster presenters

Janet Bowey, Gareth Dorrian, David Whitworth, Kristan Boyett, David Maltby, Joseph Cairns, Stephen Wilkins

Talk

Lightning Talks by Poster Presenters

1. A spectral probe of grain growth in galaxies: preparation of an observing proposal for MIRI on the JWST; Janet Bowey (Cardiff & UCL), id284
2. The impact of ionospheric variability on deep space radio observations at ultra low frequencies; Gareth Dorian (Nottingham Trent), id420
3. Simulating cold molecular gas in low metallicity dwarf galaxies.; David Whitworth (Jodrell

Bank Centre for Astrophysics), id475
4. Star formation rates and metallicity of galaxies at cosmic noon from Slitless HST spectroscopy; Kristan Boyett (University of Oxford), id290
5. Post-starburst galaxies and the origin of galaxy bimodality; David Maltby (University of Nottingham), id170
6. Case Study of an Extremely Luminous Quasar and Starburst at z=3.65; Joseph Cairns (Imperial College London), id138
7. The Impact of the IMF on Galaxy Observables in the Early Universe; Stephen Wilkins (University of Sussex), id72

Emma Curtis Lake (KICC, University of Cambridge)

E. Curtis Lake, S. Charlot, J. Chevallard, M. Hirschmann

Talk

Modelling the mass-SFR relation at high redshifts - future constraints from JWST

The mass-SFR relation of galaxies encodes information of present and historical star formation in the galaxy population. We expect the intrinsic scatter in the relation to increase to low mass where SFR becomes more stochastic. Measurements at z>~4 from the Hubble Frontier fields have hinted at this (Santini et al. 2017), however, with the added uncertainty of lensing magnification we await JWST to provide robust measurements. Even with data-sets provided by JWST, uncertainties on mass and SFR estimates are often large, potentially covariant and dependent on assumptions used. I will present our method of Bayesian hierarchical modelling of the mass-SFR relation that self-consistently propagates uncertainties on mass and SFR estimates to uncertainties on the mass-SFR relation parameters. I will expose the biases imposed by standard SED-modelling practices, and address to what significance we can measure an increase in intrinsic scatter to low masses with JWST.

Joseph Cairns (Imperial College London)

J. Cairns (Imperial College London), A. Stroe (CfA, Harvard & Smithsonian)

Talk

Molecular Gas in the Antlia Galaxy Cluster

At 0.2 z 1.0 around 30% of galaxy clusters are in a disturbed state. Recent studies have shown that interactions between gas-rich cluster members and merger-induced shocks can enhance star formation activity in disturbed clusters, resulting in a reversal of the environmental trends typical of relaxed clusters. In order to understand how the enhanced star formation rates in these disturbed clusters are fuelled, it is vital to link observations tracing recent star formation to the reservoirs of cold, molecular gas. In this talk, I will present observations of the CO J=2-1 rotational transition for 92 galaxies in the nearby Antlia cluster from the Atacama Pathfinder Experiment (APEX). These measurements are used to trace the molecular gas content of our sample, which is then correlated with the galaxy properties, including stellar mass, star formation rate and HI mass. We also look for evidence of outflows or ram pressure stripping revealed either by velocity offsets between the optical position of the galaxy and the molecular gas, or by asymmetries in the CO line profile.

David Maltby (University of Nottingham)

David Maltby (Nottingham), Omar Almaini (Nottingham), Vivienne Wild (St Andrews)

Poster

Post-starburst galaxies and the origin of galaxy bimodality

Post-starbursts (PSBs) are a rare population of transitional galaxy in which a major burst of star formation was rapidly quenched sometime within the last few hundred Myr. Consequently, these systems provide a valuable 'snapshot' of galaxy evolution during (or shortly after) an event that quenched the galaxy's star formation. In this poster, I review the recent work on the structure of these galaxies at 0.5 z 1 are surprisingly compact and spheroidal, with structures that differ significantly from their star-forming progenitors but are similar to massive passive galaxies. This suggests that these galaxies formed during a major disruptive event (e.g. major merger, or protogalactic collapse) which formed a centrally-condensed and compact remnant. Using the deep optical spectroscopy available within the UDS field, I also present new results on the existence of gaseous outflows in these high-z PSBs, which may represent the residual signature of a feedback process that ultimately quenched the galaxy.

Nick Wrigley (Jodrell Bank Centre for Astrophysics)

Wrigley et al. (JBCA)

Talk

Probabilistic classification of starburst and AGN radio emissions in the eMERGE Survey

Radio emissions trace star-formation rates within galaxies using the well established Radio-FIR correlation and obviates the problem of dust extinction that plague some other wavebands. Hence radio imaging of star forming galaxies can provide a tracer of global star-formation rates if emissions can be disentangled from the contributions of Active Galactic Nuclei (AGN). We present a probabilistic categorisation of these two broad emission classes of sources, ubiquitously observed in deep fields. Whereas traditional classification methods have relied almost exclusively upon human judgement of individual objects, leading to a simple binary designation (or perhaps none at all), this method generates a classification probability based on metrics derived from high angular resolution measurements of sources. Using recent data from e-MERLIN's Galaxy Evolution (eMERGE) survey which probes ~800 star-forming galaxies and AGN to z~5, classification probabilities are derived revealing disentangled differential source counts. The method can be extended to include deeper multi-wavelength data to further decrease uncertainties at even earlier epochs, revealing global star formation rates as a function of cosmic time.

Nicholas Amos (Lancaster University)

Amos, N. (Lancaster University), Stott, J. (Lancaster University)

Talk

Resolved spectroscopy of cluster galaxies at z=1.4.

The star formation rate density of the universe peaks at z=1-3 and has subsequently declined to the present day. Much effort has gone into quantifying and assessing possible secular and environmental quenching mechanisms (e.g. AGN feedback, supernovae, ram pressure stripping and galaxy mergers). I will present results that spatially resolved the gas properties of star-forming galaxies in the clusters XMMXCS2215 (z~1.46) and XMMUJ2235 (z~1.39), taken from the KMOS Cluster Survey (KCS). I have used this state-of-the-art IFU data to obtain the star formation rate and dynamical properties of the galaxies, and have combined this with

morphology from HST imaging. This is crucial in quantifying the impact of environmental quenching mechanisms in z=1.4 clusters.

David Sobral (Lancaster University)

D. Sobral (Lancaster), J. Matthee (ETH), B. Darvish (Caltech)

Talk

Resolving the UV and [CII] structure of luminous galaxies within the epoch of re-ionisation with HST & ALMA

I will present new deep and high resolution ALMA and HST/WC3 observations of luminous Lyman-alpha emitters (LAEs) in the epoch of re-ionisation at z~7: MASOSA, VR7 and CR7. We do not detect dust continuum in any of the LAEs, indicating little amounts of obscured star formation and/or high dust temperatures reaching up to 70-90K, even though MASOSA, the faintest in the UV, shows a red UV Beta slope. While VR7 and CR7 are strongly detected and resolved in multiple components in [CII], indicating clump metallicities of about 0.01-0.2 Z_sun, MASOSA is not detected in [CII], implying an even lower metallicity, consistent with its very compact size and extremely high Lyman-alpha EW. For both VR7 and CR7, we explore the rest-frame UV and [CII] sub-kpc resolved emission to find that the dynamics seen are consistent with merging: neither of the systems is rotation dominated. We also find clear evidence for outflows from [CII], large internal variations in the [CII]/UV ratio, and overall small velocity offsets between Lya and [CII], indicating that these sources reside in early ionised bubbles. I will conclude with commenting on how these sources fit into the general population of galaxies in the epoch of re-ionisation.

David Whitworth (University of Manchester)

D. Whitworth (University of Manchester), R. Smith (University of Manchester)

Talk

Simulating cold molecular gas in low metallicity dwarf galaxies.

In this contribution we investigate the molecular gas content of a low metallicity dwarf galaxy using the moving mesh code Arepo. Our chemical treatment is based on the approach of Gong et al. 2016 and in our gas physics we include self-gravity, gas self-shielding, cosmic ray heating, sink particle formation, and supernova feedback. The dwarf galaxy has a 4kpc radius, 4.0 x 10^7 M_sol gas mass, and1.0x10^9 M_sol of dark matter. Using this we vary the metallicity

of the gas to investigate how the CO dark gas mass fraction, and XCO conversion function change for a given metallicity.

Stephen Wilkins (University of Sussex)

Talk

Simulating the First Light and Reionisation Epoch

The formation of the first stars and super-massive black holes some few hundred million years after recombination brought an end to the cosmological dark ages. These early galaxies were likely responsible for reionizing the Universe, enriched their surroundings with heavy elements, andÂ harboured the formation and growth of the first super-massive black holes. Providing insights into the physical processes shaping galaxy formation and evolution are fully hydrodynamical simulations which include both gravity and baryonic effects such as cooling, star formation, and feedback. I'll introduce two simulation projects (Bluetides and FLARES) aimed at exploiting existing and upcoming observational constraints to understand the physics of galaxy formation in the early Universe.

Kristan Boyett (University of Oxford)

K.Boyett (Univeristy of Oxford), A.Bunker (University of Oxford)

Poster

Star formation rates and metallicity of galaxies at cosmic noon from Slitless HST spectroscopy

The WFC3 infrared spectroscopic parallel survey (WISPS) identifies strong emission line galaxies over cosmic noon (tracking H-alpha at z~1). This enables us to select more directly on current star formation rate (SFR), unlike previous surveys which have typically selected on stellar mass through a broad-band magnitude limit. WISPS allows us to assess any bias in previous SFR studies, which can potentially miss high SFR systems which have low stellar mass, and which may contribute significantly to SFR density through bursty star formation histories. However many WISPS galaxies have only single line detections (usually assumed to be H-alpha), and we have been conducting follow up optical spectroscopic observations to eliminate any ambiguity in the redshift. Our multi-slit optical spectroscopy with VLT-FORS2 and Gemini-GMOS provides the rest-optical lines H-beta, [OIII]5007 and [OII]3727 measurements, in addition to the H-alpha from the slitless WISPS spectra. We can use emission line diagnostics to determine the metallicity and ionisation conditions, estimate the extinction, and assess AGN contamination. Hence we can determine the nature of the z~1 star-forming population of galaxies, selected on their star formation rates rather than broad-band magnitudes.

Tracy Garratt (University of Hertfordshire)

T. Garratt (Herts), K. Coppin (Herts), J, Geach (Herts)

Talk

The Cosmic Evolution of Molecular Gas Mass Density probed by Dust Emission.

Three key observational tracers fundamental to our understanding of the cosmic evolution of galaxies are the star formation rate, stellar mass and molecular gas mass. Our current understanding of the cosmic evolution of galaxies is dominated by observations of the former two. Ultimately it is the evolution of the molecular gas mass density which drives the evolution of galaxies because it fuels on-going star formation and is the reservoir from which stars are assembled. In recent years direct measurements have now been placed on the shape of the CO luminosity function, which constrain the evolution of cosmic molecular gas mass density. However, due to low number statistics the statistical uncertainties on these measurements are very large. We use a statistical approach to estimate the evolution of the cosmological molecular gas density, not by measuring the CO luminosity function directly, but by measuring the average observed 850um flux density of a sample ~200,000 galaxies as a function of redshift. We present new empirical constraints on the evolution of the cosmological mass density of molecular hydrogen to z=6, which suggest that the cold molecular gas content in galaxies follows the increase in cosmic star-formation rate towards its peak about 10 billion years ago and declines towards early epochs.

Rosemary Coogan (University of Sussex)

Talk

The environmental effect on galaxy evolution at z=2: merger-driven star formation, AGN, and the ISM of sub-M* galaxies.

Cl J1449+0856 is an excellent case to study the development of environmental trends seen at low-redshift - a galaxy cluster at redshift z=2 with an already virialised atmosphere. We have obtained a wide range of multiwavelength observations of cluster members, including multiple transitions of CO and dust continuum emission. With these data, we study how

obscured star-formation, ISM content and AGN activity are linked to environment during this crucial phase of cluster and mass assembly.
Probing beyond the massive population, we place our z=2, sub-M* galaxies on alphaCO and G/D ratio scaling relations at low-metallicity, and compare with those relations calibrated in the local Universe. We also quantify the effect of low enrichment on high-J CO transitions, investigating this so-far poorly probed ISM regime at z=2.
Looking towards the future, we have constructed mock images of entire survey fields as observed by the Square Kilometre Array - namely GOODS-N and GOODS-S. These images can be used to explore the power of the SKA to resolve star-formation in galaxies at 0.5z3.0, and inform future observational strategies.

Nial Tanvir (University of Leicester)

N. R. Tanvir

Talk

The evolution of the ionizing radiation escape fraction from observations of GRBs

Whether stars could have driven the reionization of the intergalactic medium depends critically on the proportion of ionizing radiation that escapes the galaxies in which it is produced. Spectroscopy of gamma-ray burst (GRB) afterglows can be used to estimate the opacity to extreme ultraviolet (EUV) radiation along the lines-of-sight to the bursts. Assuming that long-duration GRBs trace the locations of the massive stars dominating EUV production, the average escape fraction of ionizing radiation can be calculated independently of galaxy size or luminosity. Analysis of a compilation of HI column density measures for 140 GRBs in the range 1.6 z 6.7 establishes an escape fraction at the Lyman limit of <fesc> ~ 0.005, with a 98 per cent confidence upper limit of <fesc> ~0.015. This suggests that stars provide a small contribution to the ionizing radiation budget at z 5. At higher redshifts firm conclusions are limited by the small size of the GRB sample, but any decline in average HI column density seems to be modest. No significant correlation of N(HI) is found with galaxy UV luminosity or host stellar mass. Given that many GRB hosts are low-metallicity dwarf galaxies with high specific star-formation rates, these results present a particular problem for the hypothesis that such galaxies dominated the reionization of the Universe.

Tom Sedgwick (Astrophysics Research Institute (LJMU))

T. M. Sedgwick (ARI), I. K. Baldry (ARI), P. A. James (ARI) & L. S. Kelvin (ARI)

Talk

The Galaxy Stellar Mass Function & Low Surface Brightness Galaxies from Core-Collapse Supernovae

I will introduce a galaxy sample selection method using core-collapse supernovae (CCSNe). Using a complete sample of ~900 z0.2 CCSNe, identified from the SDSS-II Supernova Survey, as pointers towards their host galaxies, we find 140 'new' low surface brightness galaxies whilst identifying the hosts. Selecting star-forming galaxies using CCSNe leads to the removal of surface brightness and mass biases. I will demonstrate how CCSN-rates as a function of galaxy stellar mass can be used to trace both star-formation rates and the form of the galaxy stellar mass function. Resultant number densities are well-constrained deep into the dwarf regime and are found to increase following a power-law with decreasing mass down to the low mass limit of ~10^6.4 M⊙, well represented by a single Schechter function with a faint-end slope of α = -1.41. This lack of downturn to galaxy number densities down to the low mass limit implies that overcoming surface brightness and stellar mass biases is important for an assessment of the sub-structure problem.

Stephen Wilkins (University of Sussex)

S. Wilkins (Sussex)

Poster

The Impact of the IMF on Galaxy Observables in the Early Universe

The impact of the IMF on the observational properties of galaxies is perhaps most acute in the early Universe where galaxies are dominated by emission from massive stars. Using the very-large Bluetides cosmological hydrodynamical simulation we have investigated the impact of the assumed IMF on the observational properties of galaxies, including broadband photometry and nebular emission, in the early Universe. Of particular note is the sensitivity of the ionising photon production efficiency to the choice of IMF. This quantity is used to convert the observed UV emission from galaxies to an ionising photon luminosity and is thus essential when attempting to constrain the contribution of star formation to the process of reionisation.

Sergio Santos (Lancaster University)

Sergio Santos (Lancaster University), David Sobral (Lancaster University)

Talk

The nature and evolution of UV properties in z~2-6 young star-forming galaxies with SC4K

I will present new results on the evolution of UV properties in our sample of ~4000 Lyman-alpha emitters (LAEs) in the COSMOS field (SC4K, Sobral et al. 2018a). Our LAEs are uniformly selected in the wide redshift range z~2-6 using 16 narrow/medium-bands, allowing us to probe the evolution of LAEs from the end of reionisation until cosmic noon. We explore data from UV to FIR to constrain the spectral energy distribution (SED) of each galaxy (and the average of different populations) and derive stellar masses, star formation rates, UV luminosities (MUV) and UV beta slopes. We measure little to no redshift evolution of rest-frame equivalent width which suggests no evolution in Lyman-alpha escape fraction. We find that our LAEs typically have low stellar masses (average ~10^9 Msun) and are typically located above the "star formation main sequence" which indicates a more bursty star formation nature than "normal" galaxies. Our LAEs are typically bluer than UV-selected Lyman Break Galaxies at similar redshifts (~0.5 dex at z~2-3), suggesting they always constitute the youngest and most metal-poor component of the UV-selected sources.

Amy Whitney (University of Nottingham)

A. Whitney (University of Nottingham), C. Conselice (University of Nottingham), R. Bhatawdekar (University of Nottingham), K. Duncan (Leiden Observatory)

Talk

Unbiased Size Evolution and Inside-Out Growth of Galaxies at 1z7

We present a new analysis of a sample of galaxies from the GOODS North and South fields of CANDELS using distance independent relative surface brightness metrics to determine an unbiased measure of the size evolution over the redshift range 1z7. We introduce a new method of removing background objects from images of galaxies, used in order to reduce the effect extraneous objects have on measuring the size of a galaxy. Using the Petrosian radius, we are able to determine whether the size of a galaxy increases most in the inner or outer regions. We find a slower evolution of the inner regions of galaxies compared to the outer regions which implies mass is added to the outer edges of a galaxy as it evolves and therefore suggests inside-out formation. Our results place new limits on the history of galaxy structural evolution through the past 12 Gyr of cosmic evolution.

Adam Carnall (Royal Observatory Edinburgh)

A. C. Carnall, R. J. McLure, J. S. Dunlop, B. D. Johnson, V. Wild, F. Cullen, R. Dave, S. Appleby + The VANDELS Team

Talk

VANDELS with BAGPIPES: The star-formation histories of high redshift massive quiescent galaxies

VANDELS is a uniquely deep, recently completed spectroscopic survey, designed to obtain high-SNR continuum spectroscopy for ~2000 galaxies from 1 z 7. These spectra allow us to extend detailed studies of galaxy physical properties, such as star-formation histories, stellar and nebular metallicities and dust contents to large, representative samples at high redshift. In this talk I will introduce the survey and present the first science results from the VANDELS quiescent sample. The quality of this dataset allows us to break the age-metallicity-dust degeneracy which plagues photometric studies, and a novel Bayesian full-spectral fitting approach within the BAGPIPES code allows us to obtain strong yet realistic constraints on physical parameters. We consider the trend in mean stellar age with stellar mass, recovering a strong downsizing trend of ~1.5 Gyr per decade in stellar mass, in agreement with similar studies at lower redshifts. This is a strong observational constraint on feedback models in numerical simulations, and we demonstrate that the downsizing trend at z=1 is insufficiently strong in both Simba and IllustrisTNG. We also consider how galaxies which undergo quenching events move across the UVJ diagram towards the red sequence, and hence explore the relationship between the green-valley, post-starburst and quiescent populations. We find that there may be considerable overlap between these populations if dusty green-valley galaxies quench rapidly. Finally, I will discuss the new insights which will be available from upcoming instruments such as MOONS at the VLT and NIRSpec on JWST.

The ESA M5 Missions (ESA M5)

Peter Roelfsema (SRON, Netherlands)

P.R. Roelfsema (SRON) and the SPICA collaboration

Invited

SPICA - a joint infrared space observatory

SPICA is a mission concept aimed at taking the next step in mid- and far-infrared observational capability by combining a large, cold telescope with instruments employing state-of-the-art ultra-sensitive detectors. The mission concept foresees a 2.5-meter diameter telescope cooled to below 8 K. Rather than using liquid cryogen, a combination of passive cooling and mechanical coolers will be used to cool both the telescope and the instruments. With cooling not dependent on a limited cryogen supply, the mission lifetime can extend significantly beyond the nominal three years. The combination of low telescope background and instruments with state-of-the-art detectors means that SPICA can provide a huge advance on the capabilities of previous missions.
The SPICA instrument complement offers spectral resolving power ranging from R~50 through 11000 in the 17-230 Î¼m domain as well as R~28.000 spectroscopy between 12 and 18 Î¼m. Additionally SPICA will be capable of efficient 30-37 Î¼m broad band mapping, polarimetric imaging at 110, 220 and 350 Î¼m and small field spectroscopic mapping in the 35-230 Î¼m range. SPICA’s unique infrared spectrometers will provide an unprecedented sensitivity of ~5x10-20 W/m2 (5σ/1hr) - at least two orders of magnitude improvement over what has been attained to date. With this exceptional leap in performance, new domains in infrared astronomy will become accessible, allowing us, for example, to unravel definitively galaxy evolution and metal production over cosmic time, to study dust formation and evolution from very early epochs onwards, and to trace the formation history of planetary systems.

Colin Wilson (Oxford University)

R. Ghail, C. Wilson, T. Widemann, and the Envision team

Invited

The EnVision M5 Venus orbiter

Why are the terrestrial planets so different? Venus should be the most Earth-like of all our planetary neighbours: its size, bulk composition and distance from the Sun are very similar to those of Earth; its original atmosphere was probably similar to that of early Earth, with abundant water that would have been liquid under the young sun's fainter output. Even today, with its global cloud cover, the surface of Venus receives less solar energy than does Earth, so why did a moderate climate ensue here but a catastrophic runaway greenhouse on Venus? What lessons can be learned about the life story of terrestrial planets in general, in this era of discovery of Earth-like exoplanets?

The EnVision M5 orbiter mission will determine the current geological state of Venus, and examine its geological record in unprecedented detail, to decipher its past. EnVision carries a modern interferometric radar system capable of high resolution imaging, cm-scale change detection, radiometry and polarimetry; this is complemented by a subsurface radar, and a suite of spectrometers to map volatiles in the atmosphere, and will map Venus' gravity field and track variations if its spin, in order to constrain its interior structure.

EnVision will produce geophysical datasets comparable in resolution and quality to those available for Earth and Mars, finally enabling comparative planetology between these sibling planets, with implications for our understanding of the diversity of evolutionary pathwyays for Earthlike planets.

Nial Tanvir (University of Leicester)

N. Tanvir (Univeristy of Leicester)

Invited

THESEUS: Transient high energy sky and early universe surveyor

THESEUS is a space mission concept under study for the ESA M5 opportunity. It is aimed at exploiting Gamma-Ray Bursts for investigating the early Universe and providing a substantial advance in multi-messenger and time-domain astrophysics. These goals will be achieved through a unique combination of instruments allowing GRB and X-ray transient detection over a broad FOV (more than 1sr) with 0.5-1 arcmin localization, an energy band extending from several MeV down to 0.3 keV and unprecedented sensitivity in the soft X-ray domain, as well as on-board prompt (few minute) follow-up with a 0.7 m class IR telescope with both imaging and spectroscopic capabilities. THESEUS will be perfectly suited for addressing key open issues in cosmology such as, e.g., star formation rate and metallicity evolution of the inter-stellar and inter-galactic medium up to redshift ~10, signatures of Pop III stars, sources and physics of re-ionization, and the faint end of the galaxy luminosity function. In addition, it will perform an unprecedented monitoring of the X-ray variable sky, thus detecting, localizing, and identifying the electromagnetic counterparts to sources of gravitational radiation, which may be routinely detected in the early 2030s by next generation gravitational wave detectors. THESEUS will also provide powerful synergies with the new multi-wavelength observatories (e.g., LSST, ELT, SKA, CTA, ATHENA etc.).

Theory and Observations of the Cycling of Baryons around Galaxies (BaryonGal)

Jonathan Davies (Astrophysics Research Institute, Liverpool John Moores University)

Jonathan Davies (ARI, LJMU)

Talk

Black hole feedback and the circumgalactic medium

Galaxy formation models require energetic feedback from supernovae and active galactic nuclei (AGN) to regulate the growth of galaxies and, at present, observations do not strongly constrain the influence of these processes on the physical state of circumgalactic gas. We have examined the EAGLE simulations, which were calibrated to yield realistic galaxy masses, and find that mass and structure of the CGM is largely insensitive to the intensity of ongoing feedback. However, these properties are markedly influenced by the overall "history" of feedback over cosmic time, for which the present-day central black hole mass is a good proxy: dark matter halos whose central galaxies host relatively massive black holes exhibit systematically lower gas fractions at fixed mass, and vice versa. Whether a halo will host a relatively high or low mass central BH is intimately tied to its central binding energy - a property that is effectively written into the halo's initial conditions. For ~L* galaxies, the diversity of present day CGM gas fractions is thus governed by the diversity of their haloes' central binding energy, and we offer predictions of this picture that can be tested with forthcoming X-ray and CMB (via the SZ effect) observatories. Examination of the evolution of EAGLE galaxies and their CGM implicates gas ejection by AGN feedback and the reconfiguration of the CGM's entropy profile as crucial steps in the quenching and subsequent morphological evolution of galaxies.

Daniele Sorini (Institute for Astronomy, University of Edinburgh)

Daniele Sorini (Institute for Astronomy, University of Edinburgh), Jose Onorbe (Institute for Astronomy, University of Edinburgh), Joe Hennawi (University of California Santa Barbara), Romeel Dave' (Institute for Astronomy, University of Edinburgh), Zarij

Talk

Constraining Models of Galaxy Formation with Lyman-Alpha Absorption around Halos

Galaxy formation depends critically on the physical state of gas in the circumgalactic medium and its interface with the intergalactic medium (IGM), determined by the complex interplay between inflow from the IGM and outflows from supernovae and/or AGN feedback. The average Lyman-alpha absorption profile around galactic halos represents a powerful tool to probe their gaseous environments. We compare predictions from hydrodynamical simulations (Illustris, Nyx, Mufasa, Simba) with the observed absorption around foreground quasars and galaxies. We show how large-scale BOSS and small-scale quasar pair measurements can be combined to precisely constrain the absorption profile over three decades in transverse distance (20kpc-20 Mpc). Far from galaxies (>2Mpc), the simulations converge to the same profile and provide a reasonable match to the observations. However, significant differences between the simulations, and between simulations and observations, are present on scales 20 kpc - 2 Mpc, illustrating the challenges of accurately modeling and resolving galaxy formation physics. It is noteworthy that these differences are observed as far out as ~2 Mpc, indicating that the "sphere of influence" of galaxies could extend to approximately ~7 times the halo virial radius. Recent and ongoing observations (e.g.,BOSS, CLAMATO survey) are very precise on these scales and can thus strongly discriminate between different galaxy formation models. We demonstrate that the Ly-alpha absorption profile is primarily sensitive to the underlying temperature-density relationship of diffuse gas around galaxies, thus providing a fundamental test for galaxy formation models, which should be adopted by simulators to improve the accuracy of feedback prescriptions.

Egidijus Kukstas (Liverpool John Moores University)

E. Kukstas, I. G. McCarthy, A. Font

Talk

Environment from cross-correlations: characterising the role of hot gas in galaxy quenching

There is significant evidence suggesting that galaxies evolve differently depending on the environment they live in: for a fixed stellar mass, cluster galaxies are preferentially red ellipticals, whereas field galaxies are blue spirals. These properties are found to be governed by the star formation activity which is, thus, influenced by environment.
Despite decades of research, little progress has been made in determining which processes are driving this evolution. We hypothesise that the reason for this is that, until recently, it has not been possible to directly measure the local physical conditions around galaxies. Instead, existing studies have focussed on optical proxies for local environment, from galaxy observations alone, and compared these with observed galaxy properties.
However, there has been a revolution in recent years; with large area, precise, and accurate galaxy surveys such as SDSS, DES, and DESI, in addition to CMB and X-ray instruments, it is now possible to directly constrain the local hot gas and dark matter properties. The process can be carried out by employing map-based techniques, working entirely in the pixel domain. Cross-correlating these direct measures of hot gas and gravitational components with galaxy properties can effectively constrain the processes of environmental quenching.
In this talk I will introduce the method and present the first detection of a correlation between gas properties and passive fraction, together with a comparison to state-of-the-art hydrodynamic simulations.

Ruari Mackenzie (ETH Zurich)

R. Mackenzie (ETH Zurich), M. Fumagalli (Durham), S. Cantalupo (ETH Zurich)

Talk

Linking galaxies in emission and absorption systems at z~3

Understanding the connection between reservoirs of neutral hydrogen and star-forming galaxies at high redshift has long been the subject of observational and theoretical study. I will present the results of a survey of six z~3 Damped Lyman alpha systems with MUSE, to search for associated galaxies and to probe their environments. The detected systems include a very metal poor DLA which is revealed to be embedded in a filamentary structure spanning 400 kpc. We compare our results to the EAGLE hydrodynamical simulations and a semianalytic model, to interpret the observed galaxy distributions statistically. By studying the mean environment of the absorbers we can constrain the properties of host galaxies, even if they are not detected directly. We conclude that our results are both compatible with galaxy-formation simulations and the large-scale clustering of DLAs, supporting a picture where DLAs have a characteristic halo mass of 10^11-10^12 solar masses. I will additionally present new work which aims to study the link between neutral hydrogen and extended Lya halos around galaxies. Currently this connection is only understood through matching by incidence rate, however a more direct comparison could constrain competing explanations for the origin of the extended emission. We will study how the morphology of the CGM in emission relates to absorption probes. My talk will focus on linking galaxies in emission with circum-galactic gas over scales from 10-250 kpc, both to study the gas content of galaxies and the processes responsible for emission.

Chiaki Kobayashi (University of Hertfordshire)

Chiaki Kobayashi and Philip Taylor

Poster

Metal flows in cosmological simulations

Feedback from stars and active galactic nuclei (AGN) is the most important process in galaxy formation and evolution. In our cosmological hydrodynamical simulations, we introduced a new AGN model, where super-massive blackholes originate the first stars with only ~100-1000 Msun, contrary to the merger products in other models. We also have chemical and thermal feedback from core-collapse supernovae (Type II supernovae and hypernovae), Type Ia supernovae, and asymptotic giant branch stars.

Our AGN feedback cause large-scale metal outflows and enrich circum-galactic and inter-galactic medium.

As a result, we can reproduce many observations well, including cosmic star formation rates, blackhole mass-galaxy mass relation, size-mass relation, mass-metallicity relations of galaxies, and radial metallicity gradients within galaxies.

Emma Lofthouse (Durham University)

E. K. Lofthouse, M. Fossati, M. Fumagalli

Talk

MUSE Analysis of Gas around Galaxies (MAGG) and the environment of a candidate Pop III remnant

In recent years it has become well established that the evolution of galaxies across cosmic time is regulated by inflows and outflows of gas. At present, however, we have only a crude understanding of the mechanisms that regulate the cycle of gas around and within individual galaxies.

In this talk, I will present results from the MUSE Analysis of Gas around Galaxies (MAGG) survey, a 106-hour MUSE Large Programme focusing on 28 z>3.5 quasars to understand the mechanisms that regulate the cycle of gas. Combined together, these sightlines contain over 50 optically-thick absorbers at z~3-4, offering an unprecedented dataset for the study of the connection between gas and galaxies. I will present the motivation behind MAGG and describe the survey design and dataset. With the survey observations nearing completion, I will discuss the first key results on the link between dense gas and star-forming galaxies across a wide range of column densities and metallicities. This includes a detailed study of the environment around one of the most metal-poor Lyman Limit systems yet discovered, for which we have found 3 star-forming galaxies residing at the absorption redshift indicating that this potential Population III remnant is within a galaxy overdensity.

Alyssa Drake (MPIA)

A. B. Drake

Talk

Probing the CGM in Emission Around Quasars at z~6 with MUSE

I will present deep MUSE observations of five quasars within the first Gyr of the Universe, four of which display extended Lya halos. Until recently, the cool gas that fuels the growth of the first quasars and galaxies has evaded direct detection, however this picture is beginning to change. With large-area IFUs such as MUSE facilitating the detection of diffuse Lya emission, we can now directly probe the CGM in emission. After careful PSF-subtraction, we reveal halos surrounding two z~6 quasars for the first time, and confirm two more nebulae for which tentative halo detections exist in long-slit spectroscopy and narrow-band imaging. The four Lya nebulae presented here are diverse in morphology and size, they each display spatial asymmetry, and none are centred on the position of the quasar. Spectra of the diffuse emission regions demonstrate that none are dramatically offset in velocity from the systemic redshift of the quasars (Δv 200 kms-1), however each nebula shows a broad Lya line, with a velocity width 1000 kms-1, indicating that the quasar is effecting some fraction of the Lyα emission. Total Lyα luminosities range between ~2x10^43 erg s-1 and ~2x10^44 erg s-1, reaching maximum extents of 27 - 60 pkpc from the quasar positions. As we enter the regime where IFU data circumvent filter- and slit-losses, we find larger sizes and higher Lya luminosities than previous results, and reconsider our understanding of the evolution of halo properties over cosmic time.

Peter Mitchell (Leiden Observatory)

Peter Mitchell, Joop Schaye, Richard Bower & Rob Crain

Talk

The baryon cycle in the Eagle simulations

Galaxy evolution is to leading order set by the rates of gas inflow and outflow at the boundary of galaxies. I will present a full analysis of gas flows in the Eagle simulation suite, quantifying outflow rates, the rates of inflow split between pristine and recycled accretion, and the important role of feedback in reducing the rate of cosmological gas infall onto dark matter halos. I will explain how these gas flux measurements fit into the larger context of galaxy evolution, for example by setting galaxy star formation rates and metallicities. I will finish by discussing the ongoing task of identifying observable tracers of this baryon cycle to test simulation predictions.

Rich Bielby (Durham University)

R. Bielby (Durham University)

Talk

The Circum-Galactic Medium probed via OVI at z~1 with QSAGE

We present the first results from a study of OVI absorption around galaxies at z~1 using data from a near-infrared grism spectroscopic Hubble Space Telescope Large Program, the Quasar Sightline and Galaxy Evolution (QSAGE) survey. Based on the WFC3 grism, the galaxy sample is Ha flux limited (f(Ha)>2x10^-17 erg/s/cm^2) at 0.68z1M_odot/yr star-forming galaxies within 2Rvir show no associated OVI absorption to a limit of at least N(OVI)=10^13.9/cm^2. That we detect OVI at such large distances from galaxies and that a significant fraction of star-

forming galaxies show no detectable OVI absorption disfavours outflows from ongoing star-formation as the primary medium traced by these absorbers. Instead, by combining our own low and high redshift data with existing samples, we find tentative evidence for many strong (N(OVI)>10^{14}/cm^2) OVI absorption systems to be associated with M\star~10^9.5-10Modot mass galaxies (Mhalo~10^{11.5-12}Modot dark matter halos), and infer that they may be tracing predominantly collisionally ionised gas within the halos of such galaxies.

Teresita Suarez (University of Edinburgh)

Talk

The effects of quasar beaming on the large-scale Lyman alpha forest

The absorption spectra from background sources, such as galaxy and quasars (QSOs), allow us to measure the statistical spatial distribution of the intergalactic medium (IGM) and to probe its ionisation state. These properties can also be studied through the radiation field the IGM produces. The ultraviolet (UV) photoionizing radiation field is often considered to be uniform in models of the IGM after reionization. This assumption may not always be valid as the radiation field depends on contributions from sources distributed over cosmological distances and times. In this work I consider QSOs to have a large contribution to the shot-noise to the total power spectrum in the radiation field fluctuations. Their beamed geometry and their inhomogeneous distribution cause the intensity of radiation to vary from place to place, as well as, their discrete distribution produces local fluctuations that have an effect on the gas density. I will describe how the radiation fluctuations affect the 3D power spectrum of the Lyman-alpha forest using an analytic model of radiative transfer - for the first time including the effect of beaming of the QSO light emission. I include a correction of the number density of sources in terms of the probability of a QSO to be detected, and also the direct effects of anisotropic emission on the radiative transfer equations. I will show that these fluctuations in the UV background enhance the Lyman alpha forest flux power spectrum on large scales, while suppressing it on intermediate scales.

Nastasha Wijers (Leiden Observatory)

Nastasha Wijers, Joop Schaye

Talk

Tracing hot missing baryons: O VII and O VIII absorption in EAGLE

We used the EAGLE cosmological, hydrodynamical simulations to predict the column density and equivalent width distributions of O VII (E=574 eV) and O VIII (E=654 eV) at low redshift, and to investigate the physical conditions probed by these absorption systems. We find that the column density distributions evolve little at observable column densities from redshift 1 to 0, and that the distributions for these ions are sensitive to AGN feedback, which strongly reduces the number of strong (log column density N [cm^-2] > 16) absorbers. The distributions have a break at log N ~ 16, corresponding to overdensities of ~100, likely caused by the transition from sheet/filament to halo gas. Absorption systems with log N > 16 are dominated by collisionally ionized O VII and O VIII, while the ionization state of oxygen at lower column densities is (also) influenced by photoionization. At these high column densities, O VII and O VIII arising in the same structures probe systematically different gas temperatures. This complicates the use of column density ratios to estimate absorber temperatures without further information from e.g., simulations. We also find that various UV absorption lines (H I, O VI, and Ne VIII) can be used to predict where along a line of sight strong O VII and O VIII absorption is likely, which can be helpful in pre-selecting targets for expensive X-ray observations.

Alice Concas (Kavli Institute for Cosmology, Cambridge)

A.Concas

Talk

Two-Face(s): ionized and neutral galactic winds in the local Universe.

The physical mechanism(s) driving the "quenching" of the star formation activity in galaxies, remains one of the least understood puzzles in the galaxy formation theoretical framework. According to the most recent theoretical models, the energetic feedback from active galactic nuclei (AGN) is believed to provide an effective mechanism to eject the gas away from the galaxy by powerful winds in very massive galaxies. However, below halo masses of 10^12Mo the galactic winds driven by the energy and momentum imprinted by massive stars to the surrounding ISM, are believed to be sufficiently energetic to eject the gas away from the galaxy potential well and stop the star formation.

In order to unmask the nature of these two quenching processes (AGN and SF), we analyzed a complete spectroscopic galaxy sample (~600 000 spectra) drawn from the SDSS to look for evidence of galactic winds in the local Universe.

We focused on the shape of the [OIII]λ5007 emission line and interstellar Na I λ5890, 5895 (Na D) resonant line profiles as tracers of ionizing and neutral gas outflows, respectively. I will show how the average [OIII]λ5007 and NaD line profile changes as a function of star formation rate (SFR), stellar mass, disk inclination and nature of the dominant ionizing source in different BPT classes.

We find that, statistically, only “Light Breeze" can be observed in the local Universe only in AGN dominated sources. For purely SF galaxies we do not observe ionized gas outflows regardless of the SFR level. Only at very high SFR we detect a

Ashley Kelly (Durham University)

A. J. Kelly (Durham), A. Jenkins (Durham), C. S. Frenk (Durham)

Talk

Understanding the origin and properties of hot x-ray coronae

Galaxy formation theories in a dark matter cosmogony predict that spiral galaxies, at present day, are embedded in a reservoir of hot gas. This gas can cool and accrete onto the central galaxy providing fuel for on-going star formation. The hot halo is predicted to be at the virial temperature of the galaxies halo and therefore should emit in the soft x-ray band. Early (non-)detections found limited evidence for the hot corona and postulated that the x-ray emission was associated with feedback from supernovae. However, more recent observations, utilising CHANDRA and XMM-Newton, have found evidence for diffuse, more metal-poor x-ray coronae around Milky Way (MW) like galaxies which are consistent with gas accreted from the inter-galactic medium (IGM).

This work uses the smoothed particle hydrodynamics simulations APOSTLE (based on EAGLE) and the magneto-hydrodynamical simulations Auriga (based on IllustrisTNG). These are cosmological "zoom-in" simulations of MW-like galaxies.

The origin, and fate, of gas around these galaxies is traced. The origin is classified as accretion from the IGM, accretion from satellites and injection from the disk. The results of this work suggest that CGM is predominantly formed via an "outside-in" process due to accretion of gas from the IGM. The simulations further recover a coronal soft x-ray luminosity that is consistent with observations. The x-ray emitting gas within the corona is found to originate from two sources; heating from supernova feedback and shock-heating of gas from the IGM. These sources produce two distinct populations of x-ray emitting gas which are readily distinguishable.

TIME-DOMAIN ASTRONOMY WITH THE NEXT-GENERATION LIVERPOOL TELESCOPE (ASTROLIVT)

Conor Ransome (Astrophysics Research Institute, LJMU)

C. Ransome (ARI, LJMU), M. Darnley (ARI, LJMU), S. Habergham-Mawson (ARI, LJMU), P. James (ARI, LJMU)

Poster

An analysis of Classical Novae Environments in M31

We have compiled the most complete catalogue of spectroscopically confirmed classical novae in the Andromeda Galaxy (M31). This catalogue, containing over 980 novae, includes observational parameters such as spectral class, peak magnitude, expansion velocity, recurrence status, and decline times. By utilising archival ground-based Halpha imaging, and near- and far-UV data from the Galaxy Evolution Explorer (GALEX) observatory, we have used the Normalised Cumulative Rank (NCR) pixel statistic method to probe any correlation between the location of these novae and star forming regions in M31, which can also be employed to constrain the age of the underlying population. Archival spectra from the Liverpool Telescope (LT) will be used to give spectral classification to novae which currently have no spectral class. Here we present preliminary results from this work.

Michael Healy (Astrophysics Research Institute)

Talk

AT 2017fvz: a nova in the dwarf irregular galaxy NGC 6822

A transient in the Local Group dwarf irregular galaxy NGC 6822 (Barnard's Galaxy) was discovered on 2017 August 2nd and is only the second classical nova discovered in that galaxy. This nova contributes to the small sample of extragalactic novae originating in low metallicity environments which help us to pin down any effects this may have on the system's properties. We utilised a number of robotic telescopes for this observational campaign but collected a relatively sparse photometric data set due to the extragalactic origin. We conducted optical, near-ultraviolet, and X-ray follow-up observations of the eruption, the results of which I will talk about. I will also briefly explore how upcoming robotic telescopes such as the 4-meter New Robotic Telescope will help detect more objects such as AT 2017fvz as well as allowing more detailed follow up in the future.

Tricia Sullivan (Astrophysics Research Institute, Liverpool John Moores/LIV.DAT)

T.Sullivan (Astrophysics Research Institute), P.R. McWhirter (Astrophysics Research Institute), I.A. Steele (Astrophysics Research Institute)

Poster

Correcting the imprint of seasonal sampling cadence on structure function parameters of AGN optical light curves: a machine learning approach

The stochastic variability of active galactic nuclei (AGN) is typically modelled by a damped random walk (DRW) whose features are subsequently parametrised by a structure function (SF). The SF measures root-mean-square flux change as a function of time lag. It is a bent power law with red noise on short-time lags and white noise on long lags. The literature has used survey data extensively to seek correlations of SF powerlaw index and amplitude with physical features of the system. However, photometry is typically sampled in a seasonal pattern that may imprint on the SF, risking spurious results. Therefore, simulated light curves were generated to explore the impact of sampling patterns from Sloan Digital Sky Survey (SDSS) Stripe 82 and Large Synoptic Survey Telescope (LSST) upon the resulting SFs. After fitting a powerlaw index to the first ~100 days for both LSST and SDSS SFs, the powerlaw index is seen to decrease with the length of the sampling season. Powerlaw amplitude is also affected, and substructure associated with sampling is imposed on long lags. We propose training a denoising autoencoder (machine learning) to make flexible corrections to unevenly-sampled SFs to remove these effects. If successful, this method could inform on approaches to scheduling with Liverpool Telescope 2, including the viability of opportunistic monitoring; i.e., observing AGN during scheduling gaps to conserve telescope resources.

Eoin O'Connor (NUI Galway)

E. O'Connor (NUI Galway), N.Devaney (NUI Galway), A. Shearer (NUI Galway)

Talk

High time Resolution Astronomical Polarimetry with the GASP Instrument.

The Galway Astronomical Stokes Polarimeter (GASP) is a high-time resolution astronomical polarimeter working on the principle of division of amplitude polarimetry (DOAP) to measure the full Stokes parameters using differential photometry. The GASP instrument uses a retarding beam-splitting prism to split the incoming light from a telescope into two optical channels, these two optical channels are then split into their orthogonally polarised components resulting in four images, which are imaged simultaneously on two electron-multiplying charge-coupled devices (EMCCDs).

The GASP instrument uses a Polarisation State Generator (PSG) and the eigenvalue calibration method (ECM) to determine the Mueller matrix of the instrument. In this sense it is a complete Mueller Matrix Ellipsometer (MME) as the system is self-consistent and can unambiguously determine the optical characteristics of all of the elements contained in the system without any first-order approximations.

We will present an overview of the challenges facing high-time resolution polarimetry with respect to the calibration and characterisation methods used and the resultant accuracy of an independently calibrating imaging polarimeter with reference to measurements taken of polarimetric standards. As the GASP instrument is a full Stokes polarimeter, a concern for the future is the development of a catalogue of circularly polarised standard stars.

Éamonn Harvey (LJMU)

É. J. Harvey (LJMU), I.A Steele (LJMU), M. Shrestha (LJMU), H. E. Jermak (LJMU), D. A. Arnold (LJMU), C. M. Copperwheat (LJMU), D. Copley (LJMU), A. Ranjbar (LJMU)

Talk

Instrumentation for the New Robotic Telescope

We are entering a new era of synoptic surveys where alerts for young transients are increasing at a rate faster than they can be followed up. The bottleneck is related to spectroscopic follow-up, with the problem getting worse as surveys get wider and deeper, moving towards the LSST era. To remedy this dearth of spectral follow-up we are building a fast-slewing, fully robotic 4m class telescope on La Palma. The workhorse instrument is to be a medium resolution, high-throughput IFU spectrograph. The aim of being on target 30 seconds following an alert will allow us to explore a previously difficult to observe parameter space. Many areas of transient physics will be positively impacted by fast and frequent spectral follow-up at early times. For example, the relative frequency of the ever-increasing zoo of exotic supernova subtypes can be addressed and their unusual environments probed. The new facility will work in parallel with the synoptic surveys by not only providing object classification, thanks to the broad spectral range to be covered, but will also better observe the high velocity features in early time SN Ia spectra. Early spectral observations will help to pin down contested issues like deflagration and detonation models; the single/double progenitor question and spectral evolution of rare supernova subclasses. Other key science drivers include gravitational wave counterpart follow-up and gamma-ray bursts. The advantages of having a fully robotic observatory are that both downtime and time-to-target are significantly reduced. Here I will discuss the optical design and the prospective instrumentation We are entering a new era of synoptic surveys where alerts for young transients are increasing at a rate faster than they can be followed up. The bottleneck is related to spectroscopic follow-up, with the problem getting worse as surveys get wider and deeper, moving towards the LSST era. To remedy this dearth of spectral follow-up we are building a fast-slewing, fully robotic 4m class telescope on La Palma. The workhorse instrument is to be a medium resolution, high-throughput IFU spectrograph. The aim of being on target 30 seconds following an alert will allow us to explore a previously difficult to observe parameter space. Many areas of transient physics will be positively impacted by fast and frequent spectral follow-up at early times. For example, the relative frequency of the ever-increasing zoo of exotic supernova subtypes can be addressed and their unusual environments probed. The new facility will work in parallel with the synoptic surveys by not only providing object classification, thanks to the broad spectral range to be covered. Early spectral observations will help to pin down contested issues like deflagration and detonation models; the single/double progenitor question and spectral evolution of rare supernova subclasses. Other key science drivers include gravitational wave counterpart follow-up and gamma-ray bursts. The advantages of having a fully robotic observatory are that both downtime and time-to-target are significantly reduced. Here I will discuss the optical design and the prospective instrumentation suite that aim to cover the science drivers for the new telescope.

Heidi Thiemann (The Open University)

H. B. Thiemann (The Open University), A. J. Norton (The Open University)

Poster

Investigation of the Rotation-Activity Relation in the SuperWASP All-Sky Survey

The Wide Angle Search for Planets - SuperWASP - is the most successful ground-based survey for transiting exoplanets, having discovered ~160 hot Jupiters. The SuperWASP archive contains high cadence light curves of more than 30 million unique objects, up to 1 million of which have detectable photometric periodicities on timescales from hours to years, and is a valuable archive to exploit for time-domain astronomy.
It is well established that late-type main-sequence stars display a relationship between X-ray activity and the Rossby number, the ratio between rotation period and the convective turnover time. However this relationship breaks down for rapid rotators, and there is a possibility that super saturation of X-rays occurs for very rapid rotators, and anti-solar

differential rotation occurs for the oldest and slowest rotating stars.
We aim to characterise the rotation-activity relation in late-type stars from an all-sky perspective, using high-cadence, long baseline observations from SuperWASP.
We have cross-correlated SuperWASP photometric, XMM-Newton X-ray, and Gaia-DR2 parallax data to identify objects displaying a rotational modulation in their light curve and their corresponding X-ray observations, calculating bolometric corrections, and splitting into spectral type based on V - K colour. We have identified 909 stars with X-ray luminosities and photometrically defined rotation periods, and characterised the rotation-activity relation of 800 F- to M-type stars. We also find evidence of supersaturation in fast rotating stars, and a fourth regime of anti-solar differential rotation in the slowest rotators.

Poster presenters

Marcus Lohr, Conor Ransome, Tricia Sullivian, Heidi Thiemann

Talk

Lightning talks by Poster Presenters

"Massive binaries in the Arches cluster", Marcus Lohr (OU), id. 354.
"An analysis of Classical Novae Environments in M31", Conor Ransome (LJMU), id. 112.
"Correcting the imprint of seasonal sampling cadence on structure function parameters of AGN optical light curves: a machine learning approach", Tricia Sullivan (LJMU), id. 416.
"Investigation of the Rotation-Activity Relation in the SuperWASP All-Sky Survey", Heidi Thiemann (OU), id. 160.

Kirsty Taggart (LJMU)

K. Taggart (LJMU), D. Perley (LJMU), L. Yan (Caltech), C. Copperwheat (LJMU), A. Bagdasaryan (Caltech)

Talk

Liverpool Telescope follow-up for the Zwicky Transient Facility

The Zwicky Transient Facility (ZTF) is routinely discovering thousands of transient sources per night. Dedicated follow-up strategies have never been so important and coordinating this follow-up effort will become even more challenging in the era of LSST. Liverpool Telescope (LT) is a key resource for ZTF; its robotic nature makes it ideal for early follow-up of rapidly evolving transient sources. We will discuss how we have integrated LT with ZTF so that ZTF Marshal users can directly trigger LT; reduced and image-subtracted light curve data and spectra are uploaded in real-time. We will also describe two unusual fast-transient events with rise times of only a few days discovered by ZTF and classified by LT, and present preliminary results on 30 SLSNe discovered by ZTF during the first year of operations.

Marcus Lohr (The Open University)

M. E. Lohr (Open University), J. S. Clark (Open University)

Poster

Massive binaries in the Arches cluster

We have carried out a multi-epoch spectroscopic survey of stars in the Arches cluster near the centre of our Galaxy, made in the K band with SINFONI and KMOS on the VLT. The Arches is one of the densest and most massive young open clusters in the Milky Way, containing around 100 O-type stars and a dozen Wolf-Rayet stars. By searching for significant radial velocity variability with amplitude exceeding 20 km/s, we have found evidence for likely binarity in a third of the bright targets studied, including Wolf-Rayets, O hypergiants and supergiants. Notably, three out of four highly X-ray-luminous WNL targets show significant radial velocity variability and are also detectable as bright radio sources, suggesting colliding wind binaries. One target is also photometrically variable, and has been modelled as a near-contact eclipsing SB2 binary with a 10.5 day orbital period, consisting of components of 82 and 60 solar masses: one of the most massive binaries dynamically measured in the Galaxy. Another, with a period of 13.4 days, appears strongly eccentric. These results run counter to earlier arguments that the most luminous Arches members are rejuvenated products of binary interaction and merger, implying a greater age for the Arches; instead, we find evidence for current pre-strong interaction binaries in the cluster, which supports a younger age around 2.5 Myr. Our findings also contribute to the understanding of the evolutionary pathways followed by the most massive stars.

Mark Magee (Trinity College Dublin)

Talk

Modelling the early time behaviour of type Ia supernovae: Effects of the 56Ni distribution

Despite being generally regarded as a homogeneous group, it is becoming increasingly evident that normal SNe Ia can show significant diversity. Differences in the explosion mechanisms and conditions are imprinted on the light curve shapes and colours, allowing for

the interrogation of the physical conditions (density profile, composition, etc.) within the supernova. In this talk, I will show how differences in the nucleosynthesis of the explosion impacts the light curves and discuss how key physical parameters have been neglected in previous studies. I will present models calculated with our radiative transfer code and show that these may be used to provide constraints on the explosion mechanism for individual objects and to determine the exact explosion date. With these models in hand, I will also discuss what observations are necessary to constrain the properties of future objects. This will become increasingly important in future years, as upcoming surveys discover SNe at earlier times, and in greater numbers.

Joseph Fernandez (Astrophysics Research Institute - Liverpool John Moores University)

Joseph John Fernandez (ARI-LJMU) and Shiho Kobayashi (ARI-LJMU)

Talk

NRT Polarimetry and Neutron Star Mergers

A large number of neutron star mergers will be detected by LIGO/Virgo in the coming years. GW170817 confirmed that neutron star mergers would actually produce relativistic outflows (e.g. relativistic jets and cocoon). The polarimetry by LT and NRT would enable us to study the properties of the outflow in details (i.e. magnetic field structure/strength, and its angular dependence). We discuss polarization signals in the outflow emission, and we show the expected signal distributions for an upcoming neutron star merger sample.

Doug Arnold (Liverpool John Moores University)

D.M. Arnold (LJMU), R.J. Smith (LJMU), J.M. Marchant (LJMU)

Talk

Observation entry and Scheduling for transient astronomy in the LSST Era

The LSST era will herald a new era of new transient identification which will have a large impact on the operations of facilities which will perform more detaiuled follow-up. One of the prime science goals of the 4m class New Robotic Telescope NRT is to provide photometric, spectroscopic and polarimetric followup of transient alerts.

Whilst the Southern Hemisphere site of the LSST means that there is a limited overlap of observable sky from the Northern Hemisphere NRT site, the anticipated number of transient alerts (~10^7) per night means that the NRT could be highly focused on time critical follow-up observations.

The era has been called the `transient firehose', where numbers of transient alerts which are generated are many orders of magnitude more than could ever be followed up. Alert broker systems linked with smart filters and machine learning classifications will aid in reducing the dataset into a more manageable size for selecting targets for follow-up.

For the NRT, we must design an Observation Entry interface and Scheduling system which enables integration with the alert brokers and contains scheduling decisions and features based on the temporal sampling of specific transient scientific cases.

Gavin Lamb (University of Leicester)

Gavin Lamb, Simon Prentice

Talk

Searching for r-process element origins in core-collapse Supernovae and short GRB afterglows

The origin of the heavy r-process nucleosynthesis elements in the local Universe is commonly thought to be dominated by the merger of binary neutron stars (BNS) resulting in a thermal kilonova powered by the radioactive decay of heavy nuclei synthesized in the merger ejecta. However, due to the low mass of the ejecta in a BNS a large fraction of r-process material may come from another origin. Here we propose a method to systematically search for the existence of an r-process `bump' in the late-time lightcurve of collapsar supernovae (SNe). Depending on the degree of mixing within the stellar envelope, the r-process emission from a disc wind will result in a red (JHK-band) excess in the late-time, ~100 days, light-curve of a collapsar, or core-collapse SNe. By performing deep JHK-band observations of the very late light-curves of Type Ibc SNe, and similarly by performing rapid observations of the afterglow to short-duration GRBs, 10-15 days at z0.35, constraints on the mass fraction of r-process material from each of these sources can be made. We propose the development of a near-infrared imaging spectrograph for the New Robotic Telescope to help constrain the origin of r-process material in the local Universe.

Éamonn Harvey (Astrophysics Research Institute, Liverpool John Moores University)

Éamonn Harvey (ARI, LJMU) Doug Arnold (ARI, LJMU), David Copley (ARI, LJMU), Chris Copperwheat (ARI, LJMU), Carlos Guttierrez de la Cruz (Instituto de AstrofÃ-sica de Canarias), Helen Jermak (ARI, LJMU), Asier Oria (Instituto de AstrofÃ-sica de Canarias

Poster

The New Robotic Telescope - A new instrument for transient science

We are entering a new era of synoptic surveys where alerts for young transients are increasing at a rate faster than they can be followed up. The bottle-neck is related to spectroscopic follow-up, with the problem getting worse as surveys get wider and deeper, moving towards the LSST era. To remedy this dearth of spectral follow-up we are building a fast-slewing, fully robotic 4m class telescope on La Palma, to be known as the New Robotic Telescope. The workhorse instrument is to be a medium resolution, high-throughput IFU spectrograph. Other first-light instruments are to be a fast readout camera, a wide-field camera and a polarimeter. The aim of being on target 30 seconds following an alert will allow us to explore a previously difficult to observe parameter space. Many areas of transient physics will be positively impacted by fast and frequent spectral follow-up of transients at early times. For example, the relative frequency of the ever-increasing zoo of exotic supernova subtypes can be addressed and their unusual environments probed. The new facility will work in parallel with the synoptic surveys by not only providing object classification, thanks to the broad spectral range to be covered, but will also better observe the high velocity features in early time SN Ia spectra. Early spectral observations will help to pin down contested issues like deflagration and detonation models; the single/double progenitor question and spectral evolution of rare supernova subclasses. Other key science drivers include gravitational wave counterpart follow-up and gamma-ray bursts. The advantages of having a fully robotic observatory is that both down-time and time-to-target are significantly reduced.

Helen Jermak (Liverpool JM University)

Copperwheat, C., Harvey, E., Arnold, D., Steele, I., Smith, R., McGrath, A., Ranjbar,A.

Talk

The New Robotic Telescope: An update

The 2-metre Liverpool Telescope (LT) has seen great success in its 15 year lifetime, but its high time we built a faster, larger telescope to act alongside the LT in the follow-up of new and exciting transient alerts. The New Robotic Telescope (NRT) will be a 4-metre aperture rapid

response telescope, slewing to targets and taking data within 30 seconds of receipt of trigger, allowing us to see faint and rapidly fading transient sources that no other optical facility can catch. In this talk I will give an introduction to the project and an update on the current status, along with presenting possible science cases and subsequent engineering and instrumentation requirements.

Nuria Jordana (University of Bath)

N. Jordana (University of Bath) on behalf of a larger collaboration

Talk

Understanding the nature of magnetic fields in Gamma-Ray Burst's ejecta through rapid follow-up

Gamma-Ray Bursts (GRBs) are the brightest explosions in the Universe and are modelled theoretically using the standard fireball model and synchrotron emission. Under this framework, after the initial characteristic prompt Î³-ray emission, the collimated ejecta collides with the circumburst medium to produce an afterglow. A variety of afterglow light curve properties are expected depending on the relative contributions of the reverse and forward shock.

Using the newest leading technology facilities for GRB rapid follow-up, including the largest fully autonomous robotic optical telescope 2-m Liverpool Telescope, we can obtain early-time multi-wavelength photometry and polarimetry of the afterglow. Polarimetric observations are key to infer the magnetic field structure of the emission region and distinguish between baryonic and magnetic jet models. The reverse shock is predicted to be highly magnetized with globally ordered fields advected from the central engine (Gomboc et al. 2009, Steele et al, 2009 and Mundell et al,. 2013), whilst the forward shock emission should be unpolarized as the magnetization is thought to be produced locally in shocks.

In this talk, I will summarise the current state of the art, what insight our observations give into the structure, the evolution and the role of magnetic fields in the outflow and look to future prospects.

Fiona Murphy-Glaysher (Astrophysics Research Institute, Liverpool John Moores University)

F Murphy-Glaysher, ARI, LJMU

Talk

V392 Persei: A Gamma-Ray Bright Nova

V392 Per is a known Galactic Z-Camelopardis type dwarf nova (DN), characterised by luminosity standstills in its light curve. On 29th April 2018, V392 Per underwent a classical nova (CN) eruption, joining a handful of cataclysmic variables observed to experience both DN outbursts and CN eruptions. One day post-eruption a strong gamma-ray signal from V392 Per was detected by the Large Area Telescope on the Fermi Gamma-ray Space Telescope, adding to the small but growing population of gamma-ray bright novae. The emission mechanism of this gamma-ray emission is not understood, but is proposed to be related to shocks due to the interaction of the nova ejecta with either the accretion disk or circumbinary material. In this talk, I will present panchromatic photometric and spectroscopic observations of V392 Per and discuss their significance.

TRANSIENTS IN THE WIDE-FIELD SKY SURVEY ERA (TRANSIENTS)

Rhaana Starling (University of Leicester)

R. Starling et al.

Talk

The class of ultra-long gamma-ray bursts: the case for early optical observations

A new class of transient, the ultralong gamma-ray bursts (ULGRBs), was proposed following the Swift detection of three new transients active for thousands of seconds at gamma-ray energies and with afterglows as luminous as typical GRBs (e.g. Levan et al. 2014). Ideas to generate such long-lasting emission include the collapse of a larger progenitor star than those thought responsible for classical long GRBs, while other studies looked at mechanisms that could combine with a classical GRB scenario such as late-time energy injection from fall-back material.

The definition of a ULGRB must currently be restricted to its high energy characteristics, and the optical/UV light behaviour of the few candidates to date appears unrelated to the X-ray behaviour. Optical detection and monitoring, particularly during the extended prompt emission phase of ULGRBs is going to be a crucial element in revealing their energy generation mechanisms and constrain the progenitors. Only then will we be able to securely categorise the diverse range of GRB-like transients.

Mark Magee (Trinity College Dublin)

Talk

Detecting the signatures of helium in type Iax supernova

Type Iax supernovae (SNe Iax) are an extreme class of thermonuclear explosions related to type Ia supernovae (SNe Ia). Although the exact origin of SNe Ia remains unclear, significant progress has been made in our understanding of the explosion mechanisms and progenitor scenarios leading to SNe Iax - despite their rarity. Specifically, observations of the environments in which SNe Iax occur suggests that they are consistent with resulting from binary systems containing a white dwarf and helium star companion. The presence of helium in SNe Iax is therefore an important constraint on the progenitor system. Here, I will present an investigation of potential helium signatures in SNe Iax. I will show helium can be detected in at least one object, however the large helium mass required may be difficult to reconcile with current theories. I will also discuss the prospect of observing helium in future objects and what observations are necessary for robust detections.

Peter Clark (Queen's University Belfast)

P. Clark (QUB)

Talk

Expanding the zoo of 'Fast' Transients: LSQ13ddu & AT2018cow

The discovery of an increasing number of rapidly evolving objects is prompting new exploration into the extremes of the parameter space occupied by astrophysical transients, highlighting the need for prompt classification and detailed short-term follow up campaigns. Here I present new analysis of the unusual, rapidly rising and declining supernova LSQ13ddu, including modelling of its underlying power source and discussion of its possible progenitor system. Its spectral evolution transitioned from that of an SN Ibn to one more closely matching that of a SN Ic, with evidence of some residual helium within the ejecta. AT2018cow was first detected by ATLAS shortly after explosion showing a rise of more than 5 magnitudes in 3.5 days. Its rapid rise in brightness and interesting spectra triggered an intensive follow up campaign spanning from X-ray to radio wavelengths. Its light curve has been shown to be incompatible with nickel decay, with a range of other power sources suggested as potential explanations e.g. a magnetar or accretion onto a compact object. The next generation of transient surveys such as the LSST will reveal a range of objects with exotic properties and behaviours with LSQ13ddu and AT2018cow providing a small glimpse into the zoo of unusual objects awaiting discovery.

Poster Presenters

Miika Pursiainen (Southampton), Jonathan Carrick (Lancaster), TomÃ¡s MÃ¼ller (Southampton), Nora Eisner (Oxford)

Talk

Lightning Talks by Poster Presenters

1. Peculiar transients identified by the Dark Energy Survey; Miika Pursiainen (Southampton), id. 417
2. Optimising a spectroscopic training sample for photometric classification of supernovae with machine learning; Jonathan Carrick (Lancaster), id. 186
3. PISCoLA: Python for Interactive Supernova Cosmology Light-curve Analysis; TomÃ¡s

MÃ¼ller (Southampton), id. 167
4. The Hunt for Planets Using Citizen Science; Nora Eisner (Oxford), id. 411

Matt Darnley (LJMU)

M. J. Darnley (LJMU), M. Henze (SDSU), on behalf of the '12a Collaboration'

Talk

M31N 2008-12a - Truly one of a kind, or the tip of an iceberg?

At present, M31N 2008-12a appears to belong to a population of just one. It is a (near) Chandrasekhar mass white dwarf that is accreting at an "infeasibly" high rate - driving thermonuclear nova eruptions on an annual basis.
Conservative estimates indicate that the white dwarf will surpass the Chandrasekhar mass in less than 20,000 years. With the eruptions showing no evidence for the presence of any enhanced neon, this system is a leading, if not the best, pre-explosion type Ia supernova candidate yet discovered.
Systems such as "12a" conspire against detection. Their eruptions are under-luminous in the optical (emitting most of their energy in the far- or even extreme-ultraviolet) and have exceptionally rapid evolution. But if the hydrogen accretor single degenerate pathway to SNe Ia plays any important role, then there must be a large "hidden" population of such "12a-like" systems.
The advent of high cadence, deep, wide-field surveys will prove invaluable in assessing the true size of this population, and hence its contribution to the Ia population. However, we remain at the mercy of dedicated follow-up classification observations.

Evan Keane (SKA Organisation, Jodrell Bank Observatory)

E. F. Keane

Invited

Multi-messenger transient astronomy: the radio view

In this talk I will overview recent, ongoing and expected transient discoveries with wide-field radio telescopes. I will describe the diverse range of scientific questions that one can address with these discoveries, with a particular focus on the fastest timescale sub-second transients. In addition to the radio aspect, there are many instances when an enhanced view can be obtained by effecting a well-connected multi-wavelength multi-messenger approach. In this regard I will summarise the various efforts underway to integrate the communities across other wavelengths and observational windows as we approach the era where we have copious new transients detected every day.

Kate Maguire (Trinity College Dublin)

Invited

Optical transients in the wide-field sky survey era

Wide-area transient surveys that scan the sky at high cadence are revolutionising our understanding of extragalactic transients and the processes by which they explode. In this talk I will highlight the recent progress that has been made in optical transient surveys and discuss some of the exotic and unexplained transients that are testing our understanding of explosion models and the many ways that stars can die.

Jonathan Carrick (Lancaster University)

J. Carrick (Lancaster University), I. Hook (Lancaster University)

Poster

Optimising a spectroscopic training sample for photometric classification of supernovae with machine learning

In the era of new telescopes, new challenges are being presented, some of which can be overcome through machine learning. Spectroscopic follow-up of every supernova discovered in LSST's vast data stream is unrealistic. Reliable classification of Type Ia Supernovae is important if we want to use these discoveries for constraining cosmological parameters. My work involves developing methods to optimise a training sample of supernovae for photometric classification with machine learning. This training data will come from spectra obtained with 4MOST by a rapid follow-up of LSST's early discoveries. In TiDES (Time-Domain Extragalactic Survey), we are therefore working towards maximising survey overlap with LSST to acquire a large, good-quality training set. Performance of classification is dependent on multiple factors, including size of the training sample, machine learning algorithms used and class representativeness in terms of supernova magnitudes, redshifts, as well as the common machine learning challenge of balancing classes (i.e. the different types).

Tomás Müller (University of Southampton)

Tomás Müller (University of Southampton), Mark Sullivan (University of Southampton), Mat Smith (University of Southampton)

Poster

PISCoLA: Python for Interactive Supernova Cosmology Light-curve Analysis

Type Ia Supernovae (SNe Ia) have been studied for many years as standardisable candles for cosmological distance measurement. In addition, these objects have shown to be standard candles in the Infrared (IR), where they are less affected by extinction, probing to be exceptional for cosmology. With the large number of on-going (e.g., ZTF, ATLAS, VEILS) and future surveys (e.g., LSST), both in the Optical and IR, the samples of SNe Ia is rapidly increasing. However, we need not to focus only on the size of the samples, but also on how we analyse these data. Cosmology with SNe Ia usually relies on templates for the light curve fits, which introduces biases due to the underlying assumptions. For this reason we created "Python for Interactive Supernova Cosmology Light-curve Analysis" (PISCoLA), a new light curve fitting tool. PISCoLA relies on Gaussian Process, a non-parametric data-drive method, letting the data "speak" for itself. We analyse the multi-color light curves with machine learning techniques to search for new parameters for the standardisation of SNe Ia and further understanding of the physics behind these explosions.

Matt Nicholl (University of Edinburgh)

E. Berger, P. K. Blanchard, S. Gomez (Harvard University), R. Chornock (Ohio University)

Talk

Superluminous supernovae at late times: a statistical view of their nebular properties

The discovery of superluminous supernovae (SLSNe) is one of the major results of recent synoptic sky surveys. However, the rarity of nearby SLSNe has meant that most studies focus on the properties close to maximum light. Studying these events at later times, when possible, has significant advantages: as the ejecta eventually become transparent, we can see more directly the composition and structure, along with vital clues to the power source(s).
I will present a detailed analysis using a sample of 41 late-time spectra of 12 low-redshift SLSNe. Mean properties are compared to other SN sub-types and the key emission lines are

identified. The line velocities and luminosity ratios are used to map the structure of the ejecta. Principle component and clustering analyses are performed to characterise the diversity within the population, and to test prospects for classifying SLSNe discovered only well after maximum light.
For one event in the sample, spectroscopic coverage -- along with HST / VLA / XMM imaging -- extends to 1000 days after explosion. I will discuss these data in the context of competing explosion models.

Lisa Kelsey (The University of Southampton)

L. Kelsey (University of Southampton), M. Smith (University of Southampton), M. Sullivan (University of Southampton), P. Wiseman (University of Southampton), On behalf of the Dark Energy Survey

Talk

The Effect of Local Environment on Type Ia Supernovae in the Dark Energy Survey

Type Ia supernovae (SNe Ia) are vital cosmological probes as standardisable candles, due to their brightness and low intrinsic luminosity dispersion. They have been used to reveal the accelerating expansion of the universe, and place constraints on the cosmological parameters. However, there remains a puzzling ~0.15mag dispersion in their peak magnitudes that is not understood. This has prompted a search for further light curve corrections.
Recent studies have found that the corrected brightness correlates with the stellar mass of the supernova host galaxy. After standardisation, SN Ia in high-mass, passive hosts are brighter than those in lower-mass, star-forming regions. It has been suggested that the stellar mass acts as a proxy for the galactic characteristics and supernova progenitor and could be utilised as an additional light curve correction parameter.
Here, we compare local and global properties of the host galaxies of the Dark Energy Survey 3-year spectroscopically confirmed SNe Ia, with a redshift range of 0.05 z 0.85. We perform photometric measurements of the host and local aperture photometry within a fixed proper distance radius centred around the locations of the supernovae in griz filter bands. Spectral Energy Distribution (SED) fitting is then applied to both the global and local photometry, from which we calculate the host galaxy star formation rate, stellar mass, and rest-frame U-V colour. We compare these quantities against the SN Ia corrected luminosity to find the most effective host galaxy correction to use in cosmological analysis.

Elizabeth Swann (Institute of Cosmology and Gravitation)

Elizabeth Swann, The TiDES team

Talk

The Time-Domain Extragalactic Survey

The Large Synoptic Survey Telescope (LSST), will revolutionise our understanding of the extragalactic variable sky by discovering millions of transient detections per night. The key to fully exploiting this exciting science will be rapid spectroscopic classification of transients, combined with a systematic and unbiased follow-up strategy. The Time-Domain Extragalactic Survey (TiDES) has secured a quarter million fibre hours on 4MOST (4-metre Multi-Object Spectroscopic Telescope) to follow up LSST transients and their host galaxies (Swann et al. 2019). We will present an overview of the science aims and goals of TiDES as well as details of our simulations predicting the success of our rapid spectroscopic follow-up programme, which aims to generate the largest ever sample of spectroscopically confirmed Type Ia supernovae as well as their host galaxy spectra.

UV ASTRONOMY IN THE POST-HST ERA (POSTHST)

Patrick Cote (National Research Council of Canada)

P. Cote (NRC-Herzberg), on behalf of the CASTOR team

Invited

CASTOR: The Cosmological Advanced Survey Telescope for Optical and uv Research

CASTOR is a wide-field, nearly diffraction-limited space telescope concept that is being developed by the Canadian Space Agency (CSA). The 1m CASTOR telescope would produce panoramic imaging of the UV/optical (150-550 nm) sky, using a three mirror anastigmat design to provide HST-like image quality over a wide field of view (0.25 sq. deg.) in three filters, simultaneously. Operating from low-earth orbit, CASTOR would be optimized for wide-field surveys, although the telescope may also feature low- and medium-resolution spectroscopic capabilities over the 150 to 400 nm region. A recent science maturation study conducted by the CSA has demonstrated a wide range of research programs that would be enabled by this facility, including Dark Energy and Weak Lensing; Time Domain and Multi-messenger Astrophysics; Galaxy Evolution and AGNs; Star Formation, ISM, & IGM; Stellar & Galactic Astronomy; Compact Objects; Exoplanets; and Trans-Neptunian Objects. As a versatile 'smallSAT'-class mission, CASTOR would surpass any ground-based optical telescope in angular resolution, and would have powerful synergies with upcoming dark energy missions (Euclid, WFIRST) and the ground-based LSST. Combining one the largest focal planes ever flown in space with an innovative optical design that delivers HST-quality images over a field nearly two orders of magnitude larger than Hubble, CASTOR would survey about 1/5th of the sky to a (u-band) depth 1.3 magnitudes fainter than will be possible with LSST, even after a decade of operations.

Ruben Sanchez-Janssen (UK ATC)

Sanchez-Janssen

Talk

Extreme star formation modes in dwarf galaxies: the power of the UV

I will present a detailed study of the extreme star formation properties of a pair of closely interacting dwarf galaxies. The strong interaction has triggered nearly coeval galaxy-scale starbursts, with a delay time of only ~100 Myr from one galaxy to the other. It has also altered their stellar structure and content, as indicated by the presence of prominent tidal features, some of which host young massive star clusters (YMCs). I will show how HST UV-to-VIS photometry is instrumental to determine the ages, masses and sizes of the YMCs. This allows for an investigation of the cluster formation efficiency in a gas-rich, high-density, metal-poor environment--conditions very reminiscent of those at higher redshifts. I will emphasise the need in the coming decade for a high-spatial resolution, high-UV sensitivity facility, given HST's limited lifetime.

Brad Peterson (Ohio State University & STScI)

Bradley M. Peterson (Community co-chair, LUVOIR Science and Technology Definition Team)

Invited

LUVOIR: An Ambitious Future for UV Astronomy

The Large Ultraviolet Optical Infrared Surveyor (LUVOIR) is one of four major mission concept studies that has been commissioned by the NASA Astrophysics Division in preparation for the next Astronomy and Astrophysics Decadal Survey that is being undertaken by the US National Research Council. The goal is to have multiple mission concepts, each with downscope and upgrade options available, at a sufficient level of maturity that the Decadal Committee will be able to recommend at least one of these as a new start in the 2020s. LUVOIR is intended to be a true successor to the Hubble Space Telescope in terms of wavelength coverage (100 - 2500 nm) and instrumentation suite of imagers and spectrographs, and because it is intended to be both serviceable and upgradable, even though it will operate Sun-Earth L2. Like Hubble, LUVOIR is intended to carry out a broad range of astrophysical investigations from Solar System objects to the most distant galaxies. LUVOIR will for the first time enable direct spectroscopy of a statistically meaningful sample of exoplanets in the habitable zone around nearby stars to search for biosignatures. There are two potential architectures under study, both built around deployable segmented primary mirrors with James Webb Space Telescope heritage: LUVOIR-A is an on-axis 15-m telescope that will require an SLS Block 2 launch vehicle. LUVOIR-B is an off-axis 9-m telescope that can be launched by a number of launch vehicles that are currently under development.

Florence Concepcion (Imperial College London)

Florence Concepcion (Imperial College London), Maria Teresa Belmonte (Imperial College London), Christian P. Clear (Imperial College London), Florence S. Liggins (Imperial College London), Juliet C. Pickering (Imperial College London)

Talk

New Accurate Atomic Data of Fe III for Astrophysical Applications

Modern observations of astrophysical spectra are in many cases of higher quality than those observed within a laboratory setting. This can result in the possibility of inaccurate conclusions being drawn. There is a need in astrophysics for improved atomic data for light and heavy elements across the spectrum, from IR to vacuum-UV (VUV). Accurate measurements of spectral line wavelengths and oscillator strengths are required particularly for use in stellar models and chemical abundance calculations, and in surveys such as Gaia-ESO or APOGEE and future surveys. Laboratory astrophysicists aim to measure the atomic data most useful for astronomers.
Atomic data of iron-group elements are particularly important due to their high abundance and line-rich spectra. Our high-resolution Fourier Transform Spectrometry (FTS) group at Imperial College London has, supported by STFC, been providing accurate atomic data for use in astrophysics.
Recent results include new Fe I oscillator strengths for use in Galactic surveys (Belmonte et al. 2017). There has been an order of magnitude improvement in atomic data for Co III (Smillie et al. 2016) and in the accuracy of energy levels and transition wavelengths for Mn II (Liggins, PhD Physics, Imperial College, 2018) and Ni II (Clear, PhD Physics, Imperial College, 2018). The first high-resolution measurements of UV transition wavelengths of Cr III are being used as wavelength standards (Smillie et al. 2008). Continuing our programme for doubly excited species, with new spectra recorded in the VUV at IC, analysis is underway for accurate wavelengths and atomic energy levels in Fe III.

Chris Evans (UKATC)

C. Evans, C. Neiner, J.-C. Bouret, M. Barstow

Talk

POLLUX: European study of a UV spectropolarimeter for LUVOIR

I will introduce the POLLUX study for a high-resolution, UV spectropolarimeter for the LUVOIR mission concept. The key science cases motivating the design include exoplanet atmospheres, stellar magnetic fields across the H-R diagram, and studies of the intergalactic and circumgalactic medium. I will report on the recent Phase 0 study of the instrument, led by the French Space Agency (CNES), and will highlight the leading roles for UK scientists and technical groups in the consortium.

Martin Barstow (University of Leicester)

SIRIUS consortium co-investigators

Talk

SIRIUS: An EUV spectrograph to study stars and the local interstellar medium

We present the SIRIUS (Stellar & ISM Research via In orbit Ultraviolet Spectroscopy) mission, which has been proposed for flight as an ESA Fast Mission. The mission has been shortlisted as one of six, invited to submit a full proposal following a first stage scientific and technical assessment. One will be selected to fly in tandem with the ARIEL mission in 2028. The SIRIUS instrument comprises a high throughput, high resolution, EUV spectrograph, covering a 19-26nm wavelength range, tuned for the study of white dwarfs, stellar coronae and the local interstellar medium. We will describe the instrument design and examples of the science that can be achieved with it.

Boris Gaensicke (University of Warwick)

B. Gaensicke (University of Warwick)

Talk

Ultraviolet spectroscopy of white dwarfs: providing insight into the fate of planetary systems and the progenitors of SNIa.

White dwarfs are the remnants of stars born with less than ~10Msun, and hence represent the final destination of all known planetary systems. Many white dwarfs reside in binaries, some of which on evolutionary pathways towards thermonuclear supernovae. Using white dwarfs as probes across a wide range of astrophysical requires access to high-resolution space ultraviolet spectroscopy. I will provide a brief overview of the progress resulting from nearly a decade of HST/COS observations, and will then discuss the enormous opportunities that a next-generature large-aperture ultraviolet mission will have in combination with Gaia and massive ground-based spectroscopic surveys.