RAS Lecture Theatre, Burlington House, Piccadilly, London, Friday 12 March 2010

WAVES AND TURBULENCE IN SOLAR-TERRESTRIAL PLASMAS

Organizers: Erwin Verwichte, Claire Foullon & Bogdan Hnat (University of Warwick)

Wave and turbulent phenomena are fundamental physical processes that have been shown through remote and in-situ observations to occur ubiquitously in all types of solar-terrestrial plasmas, ranging from the Sun, solar wind, magnetosphere to the ionosphere. They are intricately connected with coronal dynamics and heating, solar wind acceleration and interaction with the Earth's magnetosphere and upper atmosphere. The aim of this meeting is to bring together researchers from the different disciplines to compare theoretical and observational results on waves and turbulence, including shocks. The meeting will provide a forum to share seismological or spectral analysis techniques, and to address interdisciplinary questions such as the solar origin of turbulence in the solar wind and the solar wind drivers of magnetospheric pulsations and ionospheric turbulence. Presentations on applications from planetary and astrophysical research areas are also welcome.

09:15 Registration

Morning Session 1, Chair: E. Verwichte (Warwick)

09:30 **S. Cranmer (CfA Harvard)**
Turbulent origins of the Sun's hot corona and the solar wind
10:00 J. McAteer (Trinity Dublin)
Turbulence, complexity, and solar flares
10:15 S. Shelyag (Queens Belfast)
Simulations and radiative diagnostics of turbulence and wave phenomena in the magnetised solar photosphere
10:30 M. Marsh (UCLAN)
Exploiting the coronal slow mode
10:45 T. Van Doorsselaere (Warwick)
Anatomy of a slow wave in a coronal loop

11:00 Tea/coffee & Poster Session

Morning Session 2, Chair: B. Hnat (Warwick)

11:30 **R. Bruno (IFSI-INAF, Rome)**
Turbulence in the Solar Wind: an Overview
12:00 R. Wicks (Imperial College)
Turbulence as the source of magnetic field anisotropy in the fast solar wind

12:15 E. Camporeale (Queen Mary)
    PIC simulations: How do kinetic instabilities control the temperature anisotropy in an expanding plasma?
12:30 K. Kiyani (Warwick)
    Scale-invariance and Anisotropy of small-scale magnetic fluctuations in solar wind turbulence
12:45 J. Podesta (Los Alamos)
    A kinetic Alfvén wave cascade cannot reach the electron gyro-scale in the solar wind at 1 AU

13:00 Lunch & Poster Session

Afternoon Session, Chair: C. Foullon (Warwick)

14:00 **T. Yeoman (Leicester)**
    The Earth's ionosphere as a laboratory for the study of plasma waves
14:30 N. Bian (Glasgow)
    Parallel electric field generation by Alfvén wave turbulence
14:45 A. Balogh (Imperial College)
    Assessment of the stationarity of magnetic field fluctuations in the solar wind
15:00 H. Reid (Glasgow)
    The influence of solar wind density turbulence on solar flare accelerated electron beams
15:15 A. Diaz (Universitat de les Illes Balears)
    Instability of twisted magnetic tubes with axial mass flows

Posters

C. Burge (University of Glasgow)
    Particle acceleration in the presence of weak turbulence at an X-type neutral point
E. Camporeale (Queen Mary University of London)
    The dissipation of turbulent fluctuations at electron scales: Particle-in-Cell simulations
C. H. K. Chen (Imperial College London)
    Anisotropy of Solar Wind Turbulence in the Dissipation Range
C. Foullon (University of Warwick)
    On the Multi-spacecraft Determination of Periodic Surface Wave Phase Speeds and Wavelengths
M. Gruszecki (University of Warwick)
    Phenomenon of vortex shedding in solar corona
P. Guio (University College London)
    Weakly nonlinear ion-sound waves in magnetised plasmas with electron temperature gradients
I. Hannah (University of Glasgow)
    The effect of wave-particle interactions and turbulence on solar flare electron transport and X-ray spectrum
E. Leonardis (University of Warwick)
    Investigation of universal aspects of evolving MHD turbulence in astrophysical plasmas

S. Sultana (Queen's University Belfast)
Electrostatic wavepackets in the presence of superthermal (accelerated) electrons: modulational instability and envelope soliton modes

A. Turner (University of Warwick)
Variance anisotropy of small-scale magnetic field fluctuations in solar wind turbulence

Abstracts

Invited talk:

Steven R. Cranmer (Harvard-Smithsonian Center for Astrophysics)

Turbulent Origins of the Sun's Hot Corona and the Solar Wind

Beneath the solar surface is a layer of gas undergoing vigorous convective boiling. This chaotic activity gives rise to a wide spectrum of acoustic and magnetic fluctuations that propagate out into the solar system. In this talk I will review our knowledge about the waves, shocks, and turbulent eddies in the extended solar atmosphere, and also discuss how they are key to understanding why there is a hot (million degree) solar corona and a fast (million km per hour) outflow of gas from the Sun called the solar wind. Complete theoretical models are difficult to construct, however, because many of the proposed physical processes act on a wide range of spatial scales (from centimeters to solar radii) with feedback effects not yet well understood. Despite these difficulties, much progress has been made toward the goal of producing models that predict the plasma properties everywhere above the solar surface using only lower boundary conditions at the photosphere.

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R.T.James McAteer, P.A. Conlon, P.T. Gallagher (Trinity College Dublin)

Turbulence, complexity, and solar flares

The issue of predicting solar flares is one of the most fundamental in physics, addressing issues of plasma physics, high-energy physics and modelling of complex systems. With our ever-increasing need for accurate space weather forecasts it also poses societal consequences. Solar flares arise naturally as a competition between an input (flux emergence and rearrangement) in the photosphere and an output (electrical current build up and resistive dissipation) in the corona. As flares are powered from the stressed field rooted in the photosphere, a study of the photospheric magnetic complexity can be used to both predict activity and understand the physics of the magnetic field and solar dynamo. The magnetic energy spectrum and multifractal spectrum are highlighted as two breakthroughs in this research. We use advanced multiscale image processing to extract the turbulence scaling index and multifractal spectrum from MDI data. We show that active regions with a large

scaling index (great than 5/3), a large fractal dimension ($>$1.2), and a strongly non-Dirac Holder exponent ($>$0.5) are much more likely to produce large solar storms.

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S. Shelyag, M. Mathioudakis, F.P. Keenan, D.B. Jess (Astrophysics Research Centre, Queen's University, Belfast)

Simulations and radiative diagnostics of turbulence and wave phenomena in the magnetised solar photosphere

Despite the overall success of radiative magneto-convective models to reproduce the observational properties of solar photosphere, we still do not fully understand the physical processes involved in the solar magnetised photospheric plasma. In particular, it is difficult to use the results of these simulations for studies of acoustic wave propagation through the solar atmosphere and interior. Strong turbulent motions of the convectively unstable photospheric plasma hide the signatures of acoustic waves, making them a difficult subject in both numerical and observational investigations. The development of new methods for inferring the properties of solar plasma using sound waves have been followed by the successful modelling of the magneto-acoustic properties in the solar atmosphere and interior. However, due to non-locality of radiative processes in the solar atmosphere, a comparison of the plasma parameters at a certain geometrical depth in the computational box with the solar radiation parameters may not be entirely correct. The non-locality of radiative transport must be taken into account. Numerical simulations of solar wave phenomena require a static magnetic configuration model which incorporates as many physical properties of the real Sun as possible. We provide such a model, based on dynamic model of magneto-convection in the photosphere. The magnetic field is extracted from dynamic simulations of solar radiative magneto-convection and reconstructed using the self-similarity assumption. We demonstrate that the radiative properties of the magnetic configuration we created successfully reproduce those of magnetic bright points. We have used the model to examine the observational consequences of sound wave propagation though the magnetic field concentration. We show that the variation of continuum intensity is more pronounced in the magnetic bright point compared to the average granule. Using the radiative diagnostics, we demonstrate the detectability of the magnetic field variation in the bright point.

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Michael Marsh (UCLan)

Exploiting the Coronal Slow Mode

Observations of the three-dimensional propagation of waves within active region coronal loops and a measurement of the true coronal slow mode speed are obtained using STEREO. Intensity oscillations are observed to propagate outward from the base of a loop system, consistent with the slow magnetoacoustic mode. The wave phase velocity is measured in the observations from the A and B spacecraft. These stereoscopic observations are used to infer the three-dimensional velocity vector of the wave propagation and magnitude of 132 $\pm$ 9 km/s, giving the first measurement of the true coronal longitudinal slow mode speed, and an inferred temperature of 0.84 $\pm$ 0.12 MK. These results are confirmed using HINODE spectroscopic observations. It is found that the loop has a uniform temperature profile with a mean temperature of 0.89 $\pm$ 0.09 MK, in agreement with the temperature determined seismologically using the STEREO observations. The results further strengthen the slow mode interpretation, and imply that it is not possible to discriminate between the slow mode phase speed and the sound speed within the precision of the present observations.

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Tom Van Doorsselaere (University of Warwick)

Anatomy of a slow wave in a coronal loop

We analyse an observation of a 5 minute quasi-periodic oscillation detected in the coronal line FeXII at 195 Å, near the footpoint of a coronal loop in Hinode/EIS data on 08 Feb 2007. The same oscillation is detected simultaneously in two other coronal lines, FeXIII at 204 Å and FeXI at 192 Å. The oscillation is observed for a full 2 periods in both Doppler shift and intensity. We use Fourier and wavelet analysis to determine the period of the oscillation to be $P_V = 314 \pm 83$ s in the Doppler shift and $P_I = 344 \pm 61$ s in the intensity. We observe negligible phase shift between Doppler and intensity time series. This is strong evidence for the existence of a propagating slow magneto-acoustic MHD mode. For the first time, we use spectroscopy to detect oscillations in the electron density, using the CHIANTI atomic database. Comparing the density variations and the Doppler shifts allows us to derive the line-of-sight component of the phase speed.

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Invited Talk:
Roberto Bruno (IFSI-INAF, Rome, Italy)

Turbulence in the Solar Wind: an Overview

Pioneer 5 and Mariner 2 provided the first power spectrum of interplanetary magnetic field fluctuations more than four decades ago. This spectrum showed remarkable similarities with hydrodynamic turbulence spectra obtained in laboratory and represented the first evidence of the turbulent character of solar wind fluctuations. Since then, several other spacecraft performed in-situ observations at different solar distances and latitudes and allowed us to reach a rather good, although not complete understanding on many aspects of the complex phenomenon of solar wind turbulence. As a matter of fact, we now are able to give a reliable statistical description of the phenomenological behavior of high-amplitude low-frequency fluctuations of the fields that describe the state of the wind during its expansion. In-situ observations have been a sort of benchmark to test results obtained from numerical MHD simulations dedicated to unravel what kind of physical mechanisms are at the basis of turbulence generation and energy transfer across the spectral domain of the fluctuations. This presentation aims to provide an overview of the main aspects of the phenomenology associated to MHD turbulence in the solar wind.

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Robert T. Wicks (Imperial Collegel London)

Turbulence as the source of magnetic field anisotropy in the fast solar wind

We present the first study of the anisotropy of magnetic field (*B*) fluctuations over the whole inertial range of MHD turbulence. We use Ulysses fast polar solar wind data and a wavelet method (Horbury et al., Phys. Rev. Lett., 2008) to show that beyond the outer scale of turbulence, where the power spectral index of *B* is -1, both the power and spectral index are close to isotropic. As the turbulent cascade develops the power and spectral index become anisotropic in a way that is dependent on frequency. We show this is consistent with a "critical balance" approximation by comparing the power and estimated wave vector anisotropy to those predicted by critical balance.

We also show that as distance from the Sun increases the isotropic outer scale moves to lower frequency and both the power and spectral index anisotropies move with it. Thus lower frequencies become more anisotropic with distance from the Sun. This shows that the anisotropy is an inherent local property of the turbulence and not a structure imposed by the Sun.

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E. Camporeale and D. Burgess (Queen Mary University of London)

PIC simulations: How do kinetic instabilities control the temperature anisotropy in an expanding plasma?

In the solar wind, the expansion of the plasma in a decreasing magnetic field produces a parallel temperature anisotropy $(T_{\|} > T_{\perp})$, due to the conservation of adiabatic invariants. It is known that such anisotropy is bounded in value from the development of kinetic instabilities, like the fire-hose. The expansion of the wind and the electromagnetic fluctuations generated by the instabilities are two competing mechanisms for the increase and the reduction of the temperature anisotropy, respectively. We present full-kinetic Particle-in-Cell simulations, whose aim is to study the competition between expansion and instabilities. Our newest results include simulations in a large computational box, that allow us to study a proton-electron plasma, with realistic mass ratio, that expands radially in a decreasing magnetic field. We compare the simulation results with the linear theory prediction.

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Scale-invariance and Anisotropy of small-scale magnetic fluctuations in solar wind turbulence

In-situ observations of fluctuations in the solar wind typically show an 'inertial range' of MHD turbulence, and at higher frequencies, a cross-over to spatial temporal scales where kinetic effects become important. In-situ monitors such as WIND and ACE have provided observations over a decade of this dissipation/dispersion range that have motivated theoretical studies that in turn predict the nature of the scaling in this region. We will present some results from very high-frequency magnetic field data from the four Cluster II spacecraft in intervals where the spacecraft were in quasi-stationary ambient solar wind and where the instruments were operating in burst mode. The magnetic field data are from the fluxgate and search-coil magnetometers from the Cluster FGM experiment (∼67Hz), and the STAFF experiment (∼450 Hz). These data sets provide observations of this dissipation/dispersion range over approximately two decades in frequency. This high cadence allows a more precise determination of the statistics at these small scales; especially the estimation of scaling exponents. Theories centred around the dispersion of MHD waves and their associated damping and particle heating have been proposed to account for this scaling range. Since the spacecraft data shows a clean break from the scaling in the inertial range, followed by a different power-law spanning over approximately two decades, these theories centre around predictions of the spectral slope and the associated scaling exponents. Motivated by the need to distinguish these theoretical predictions, we perform a robust multiscale statistical analysis focusing on power

spectra, PDFs of field fluctuations, higher-order statistics to quantify the scaling of fluctuations; as well as describing the degree of anisotropy in the fluctuations parallel and perpendicular to the average magnetic field. We use these results to infer the nature of the physical processes as we pass through the crossover from inertial range to near-dissipation range phenomenology; with special attention being made on quantification of sources of error from both instrument noise and finite sample sizes.
Reference article: K. H. Kiyani, S. C. Chapman, Yu. V. Khotyaintsev, M. W. Dunlop, and F. Sahraoui, Phys. Rev. Lett. 103, 075006 (2009).

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John Podesta (Los Alamos National Laboratory)

A kinetic Alfvén wave cascade cannot reach the electron gyro-scale in the solar wind at 1 AU

Recent measurements of high frequency magnetic field fluctuations in the dissipation range of solar wind turbulence have been interpreted as evidence of a kinetic Alfvén wave cascade extending from lengthscales near the proton gyro-radius, $k_\perp \rho_i = 1$, to the electron gyro-radius, $k_\perp \rho_e = 1$, where the energy is believed to be dissipated by collisionless Landau damping (Sahraoui et al. 2009). It is important to realize, however, that kinetic Alfvén waves (KAWs) are subject to collisionless Landau and transit-time damping throughout this entire range of scales and the cumulative effect of this damping causes the energy cascade to terminate at smaller wavenumbers than one might expect based on an examination of the ratio of the linear damping rate to the real frequency of the waves, γ/ω. For an energy cascade supported solely by KAWs (KAW turbulence), a theory based on the conservation of energy in wavenumber space is used to compute the change of the energy cascade rate ε as a function of wavenumber caused by collisionless damping. For conditions typical of high-speed streams in the solar wind at 1 AU, the results show that the KAW cascade is practically dissipated before reaching the wavenumber $k_\perp \rho_i \sim 25$ and, therefore, the KAW cascade cannot reach the electron gyro-scale.

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Invited Talk:
Tim Yeoman (Leicester)

The Earth's ionosphere as a laboratory for the study of plasma waves

Magnetohydrodynamic (MHD) waves are a ubiquitous feature of the ionised atmospheres of stars and magnetised planets and indeed the whole astrophysical plasma environment. They, together with magnetic reconnection, are of central importance in the transfer of mass, energy, momentum and information around such systems. The magnetosphere and upper atmosphere of the Earth offer unique opportunities for the study of such phenomena, with the possibility of multipoint and in situ data from a wide variety of measurement techniques. The waves also play an important role in determining the state of the near-Earth space environment. This talk will review some recent observational progress in the investigation of such phenomena, including direct observation MHD wave mode coupling and the observation of MHD waves driven by wave-particle interactions with the energetic particle populations surrounding the Earth.

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N. Bian, E. Kontar and J. Brown (Department of Physics & Astronomy, University of Glasgow)

Parallel electric field generation by Alfvén wave turbulence

We investigate the spectral structure of the parallel electric field generated by strong anisotropic Alfvénic turbulence in relation with the problem of particle acceleration and heating in astrophysical plasmas, including flare electrons. Alfvénic fluctuations become anisotropic in the presence of a strong background magnetic field. A low-beta two-fluid reduced-MHD model is used to follow the turbulent cascade of the energy resulting from the non-linear interaction between kinetic Alfvén waves from the large MHD scales down to the small "kinetic" scales. Scaling relations are obtained for the magnitude of the turbulent electromagnetic fluctuations, as a function of parallel and perpendicular wave-vector, showing that the electric field develops a component parallel to the magnetic field at the large MHD scales. The spectrum of the parallel electric field fluctuations can be effectively used to model stochastic resonant acceleration and heating of electrons in solar flares.

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André Balogh[1,2] **and Silvia Perri**[1] ([1] International Space Science Institute, Bern, Switzerland, [2] The Blackett Laboratory, Imperial College)

Assessment of the stationarity of magnetic field fluctuations in the solar wind

Single point measurements of the solar wind and the embedded heliospheric magnetic field are routinely used for evaluating and interpreting fluctuations in the measured parameters in terms of spatial structures convected in the solar wind. Given that the transit time across the stationary observer in solar wind flow is generally much less than the evolution time of turbulent eddies, use is made implicitly or explicitly of the Taylor hypothesis for converting the observed time series into the spatial domain. This assumes that the fluctuations are stationary and therefore homogeneous. Previous studies, using the weak stationarity criteria, confirmed that magnetic fluctuations in the solar wind are almost everywhere stationary on large scales. In this paper we use Ulysses observations of the magnetic field and the same criteria for weak stationarity as previous authors to assess the limits of validity of this hypothesis as a function of scales and of solar wind regimes. We find that stationarity holds generally well in the fast solar wind but that in interacting mixed fast- and slow solar wind streams there are intervals when the conditions for stationarity at time scales of a day down to tens of seconds break down or are at best marginally satisfied.

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Hamish Reid (University of Glasgow)

The influence of solar wind density turbulence on solar flare accelerated electron beams

Solar flare accelerated electron beams propagating away from the Sun can interact with the turbulent interplanetary media, producing plasma waves and type III radio emission. These electron beams are detected near the Earth with a double power-law energy spectra. We simulate electron beam propagation from the Sun to the Earth in the weak turbulent regime taking into account the self-consistent generation of plasma waves and subsequent wave interaction with density fluctuations from low frequency MHD turbulence. The rate at which plasma waves are induced by an unstable electron beam is reduced by background density fluctuations, most acutely when fluctuations have large amplitudes or small wavelengths. This suppression of plasma waves alters the response of the electron beam which changes the beam transport effects. Assuming a 5/3 Kolmogorov-type power spectra of density fluctuations often observed near the Earth, we investigate the corresponding energy spectra of the electron beam after it has propagated 1AU. We find a direct correlation between the spectra of the double power-law below the break energy and the turbulent intensity of the background plasma. For an initial spectra index of 3.5, we find a range of spectra below the break energy between 1.7-2.1, with higher levels of turbulence corresponding to higher spectral indices.

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Antonio J. Diaz (Universitat de les Illes Balears (Spain))

Instability of twisted magnetic tubes with axial mass flows

Recent observations of various kinds of jets in the solar atmosphere motivate to study the influence of mass flow on the stability of solar magnetic structures. We use the incompressible magnetohydrodynamic equations to get the dispersion relation governing the behaviour of normal modes in uniformly twisted magnetic tubes with sub-Alfvénic flows. We found that the axial mass flow reduces the threshold of kink instability in twisted magnetic tubes and that the twist of magnetic tubes leads to the Kelvin-Helmholtz instability of sub-Alfvénic flows for the harmonics with sufficiently large azimuthal wave number- m.

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Posters

C. Burge (University of Glasgow)

Particle acceleration in the presence of weak turbulence at an X-type neutral point

It is well known that particles in space plasmas can be energised by interaction with reconnection regions, which form at magnetic topological features such as nulls and separatrices. Such energisation has been studied in simple, large-scale fields. Here we extend these studies to include noisy, turbulent electric and magnetic fields.The magnetic field is perturbed by a superposition of cold plasma eigenmodes,including self-consistent electric field oscillations,constructed as in the work of Craig and McClymont. Weak turbulence is modelled by adopting random phases for these eigenmodes. Using an adaptive stepsize method we numerically integrate particle orbits in realisations of this field and describe the resulting particle distributions.

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E. Camporeale and D. Burgess (Queen Mary University of London)

The dissipation of turbulent fluctuations at electron scales: Particle-in-Cell simulations.

In order to properly address the questions related to the dissipation of turbulent fluctuations in the solar wind, one must include the kinetic description of the plasma at small scales. The exact mechanism that controls the dissipation of the turbulent cascade of energy at small scales is still unknown. Different schools of thought indicate different waves, such as kinetic Alfven waves, or whistler waves, as responsible for the dissipation, and the consequent heating of the particles. Nevertheless, it is doubtless that kinetic effects must play a crucial role, since it has been shown from observations that the energy cascade in wavevector space becomes steeper at scales where the particle gyroradius becomes non-negligible. We present Particle-in-Cell simulations of the damping of turbulent fluctuations at electron scales. In particular, we show the power spectral density of the energy cascade, and possible interpretations of the cascading mechanism in terms of kinetic linear theory. We also discuss preliminary results about the cascade at larger scales, reaching few ion gyroradii.

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<u>C. H. K. Chen</u>, T. S. Horbury, A. A. Schekochihin, R. T. Wicks, O. Alexandrova, J. Mitchell (Imperial College London)

Anisotropy of Solar Wind Turbulence in the Dissipation Range

Although turbulence is readily observed in the solar wind, some aspects are poorly understood with unexplained observations and conflicting theoretical descriptions. In particular the dissipation range (fluctuations smaller than the ion gyroscale) is only just beginning to be thoroughly investigated. Here we present methods and results from a multi-spacecraft analysis of the solar wind dissipation range between the ion and electron gyroscales using the four Cluster satellites. We find that the fluctuations are anisotropic, having a higher power in the direction perpendicular to the local mean magnetic field than parallel to it. We also compare the observed anisotropic scaling to predictions for a kinetic Alfven wave cascade. The implications of anisotropic fluctuations for the interpretation of dissipation range measurements in general are also discussed.

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On the Multi-spacecraft Determination of Periodic Surface Wave Phase Speeds and Wavelengths

Observations of surface waves on the magnetopause indicate a wide range of phase velocities and wavelengths. Their multi-spacecraft analysis allows a more precise determination of wave characteristics than ever before and reveal that approximations, which take a predetermined fraction of the magnetosheath speed or the average flow velocity in the boundary layer, can overestimate phase speeds. We show that time-lags between two or more spacecraft can give a qualitative upper estimate, and we confirm the unreliability of flow approximations often used by analysis of a few cases. Using two-point distant magnetic field observations and spectral analysis of the tailward magnetic field component, we propose an alternative method to estimate the wavelength and phase speed at a single spacecraft from a statistical fit at the other site.

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M. Gruszecki (University of Warwick)

Phenomenon of vortex shedding in solar corona

It is well known that the interaction of a flow with a non-moving bluff body results in a so called von Karman vortex street, where vortices with opposite vorticity are periodically generated (shedded) alternating from either side of the bluff body in the downstream region. An important issue is how the phenomenon of vortex shedding is modified when a magnetic field is present. So far, there has not been shown that phenomenon of vortex shedding can exist under coronal conditions. Using full MHD simulations, we study the phenomenon of Alfvenic vortex shedding in low-beta high-Reynolds number plasmas, typical for the solar corona. The attention was restricted to the case of a cylindrical bluff body with the axis perpendicular to the steady flow.
The results show that the phenomenon of vortex shedding is possible in the highly magnetised solar coronal plasma, provided the magnetic field is parallel to the axis of the bluff body. The Strouhal number that is a dimensionless parameter linking the period of vortex shedding with the flow speed and the diameter of the bluff body, is found to be independent of the diameter and the plasma beta, and its average value is about 0.2. These results support the recently proposed scenario for the excitation of kink oscillations of coronal loops by CMEs.

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Weakly nonlinear ion-sound waves in magnetised plasmas with electron temperature gradients

Low frequency electrostatic waves are studied in magnetised plasmas for the case where the electron temperature varies with position in a direction perpendicular to the magnetic field. We analyse guided waves with characteristic frequencies below the ion cyclotron and ion plasma frequencies for the case where the ion cyclotron frequency is below the ion plasma frequency. A particular feature of low frequency electrostatic waves under these conditions is the existence of trapped waveguide modes when the frequency is below the ion cyclotron frequency, while the modes are radiative for higher frequencies. These conditions allow the formation of a new type of electrostatic shocks. The results are illustrated by results from a 2.5D PIC code.

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I. Hannah (University of Glasgow)

The effect of wave-particle interactions and turbulence on solar flare electron transport and X-ray spectrum

RHESSI solar flare hard X-ray observations sometimes cannot be adequately interpreted in terms of purely collisional electron transport. We instead present numerical simulations where we consider Langmuir waves generated by the energetic electron-beam. We demonstrate how the wave-particle interactions in the presence of turbulent density perturbations affect the high frequency Langmuir waves and in turn, the flare accelerated electron distribution. The consequences of this self-consistent treatment are discussed for the observable X-ray spectrum.

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E. Leonardis (University of Warwick)

Investigation of universal aspects of evolving MHD turbulence in astrophysical plasmas

ULYSSES spacecraft solar polar passes at solar minimum provide in situ observations of evolving MHD turbulence in the solar wind under ideal conditions of fast quiet flow. We focused on the south polar pass of 1994 and the north polar pass of 1995 which provide extended intervals of quiet, fast solar wind at a range of radial distances and latitudes. Fully developed inertial range turbulence has a characteristic statistical similarity property of quantities that characterize the flow, such as the magnetic field components $Bk(t)$, so that the p^{th} moment of fluctuations have power law dependence on scale τ such that $< |Bk(t+\tau) - Bk(t)|^p > \sim \tau^{\zeta(p)}$. We instead found a generalized similarity $< |Bk(t+\tau)Bk(t)|^p \gtrsim g(\tau/\tau_0)^{\zeta(p)}$ consistent with Extended Self Similarity; and in particular all of these ULYSSES observations, from both polar passes, share the same single function $g(\tau/\tau_0)$. If these observations are indeed characteristic of MHD turbulence evolving in situ, then this quantifies for the first time a key aspect of the universal nature of evolving MHD turbulence in a system of finite size. Further possibilities of testing universal aspects of evolving turbulence are also in progress using data from the Hinode mission. Many 2D images of the solar corona are provided by the Solar Optical Telescope on Hinode; showing several turbulent upflows in space and time. Current work on this analysis will be discussed briefly.

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S. Sultana and I. Kourakis (Centre for Plasma Physics, Department of Physics and Astronomy, Queen's University Belfast)

Electrostatic wavepackets in the presence of superthermal (accelerated) electrons: modulational instability and envelope soliton modes

Nonthermal particles are omnipresent in the solar wind [1, 2, 3] and in the solar corona [4]. Such plasmas usually exhibit a high energy tail in their particle distribution, which can be efficiently modeled by a parametrized kappa distribution function [5]. The parameter kappa determines the high-energy power law index and approaches Maxwellian distribution when $\kappa \rightarrow \infty$. We have investigated from first principles the dynamics of modulated electron-acoustic (EA) wavepackets in a collisionless unmagnetized plasma, bearing a kappa-distributed background electron population [6]. Bright- (pulses) and dark- (holes) type envelope excitations are shown to occur. A study of the modulational stability profile suggests instability occurrence at finite wavelengths. The growth rate is affected by superthermality, which thus inhibits the formation of bright envelope solitons. Explicit conditions are determined, in terms of the superthermal plasma component characteristics. These results complement earlier ones on EA [7] or ion-acoustic [8] excitations, and should be useful in understanding the basic features of modulated structures observed in the solar environment.

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Variance anisotropy of small-scale magnetic field fluctuations in solar wind turbulence

Cluster II allows for high cadence in-situ observations of the magnetic field in the Solar wind. These observations typically show an 'inertial range' followed by a clear break where a different power-law scaling exponent is seen. This break is historically known as the 'dissipation range' and has predictions centered on

the power-law behavior of this second range.
We will present results using a combination of the high cadence measurements from the STAFF experiment, which in burst mode samples at approximately 450Hz, and the low cadence DC field experiment FGM, which samples (in burst mode) at approximately 67 Hz. By combining these data sets we investigate the scaling behaviour of the structure functions and the power spectral density of the magnetic field fluctuations projected on the local scale-dependent mean magnetic field to consider variance anisotropy.

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