SH71A-08 1045h INVITED

Advances in Charged Particle Scattering Theory

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We review advances in charged particle scattering theory made in the last decade and attempt to apply these advances to solar and galactic cosmic ray propagation, pickup ion scattering, and interplanetary shock acceleration. In the process of doing this, we will draw on recent discoveries and trends in the interpretation of interplanetary magnetic fluctuations. These advances include, but are not limited to, magnetodynamic scattering theories, the geometry of interplanetary fluctuations, fully-consistent scattering through 90 degrees, electrodynamic scattering theory, and the role of transients.

This work was supported by CIT subcontract PC251439 under NASA grant NAG5-6912 for support of the ACE magnetic field experiment and by NASA grant NAG5-10911.

SH71A-09 1105h

Predicting Transport Coefficients of Heliospheric Particles from Solar Wind Observations

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We present a model for the parallel transport of energetic particles which addresses the effects of propagation and thermal damping of waves, and time dependent decorrelation of magnetic fluctuations.The model is able to explain the observations of particle mean free paths ranging from keV electrons to GeV protons. In particular, it is found that the dynamical effects, leading to a strongly non-resonant pitch angle scattering through 90° at low rigidities, can be described by a single parameter which is estimated from the observed density, temperature and magnetic field strength in the solar wind. The predictive power of the model is then basically limited by the current lack of knowledge of the exact decomposition of the fluctuations. Possibilties to, conversely, use the energetic particles to probe properties of the fluctuations are discussed. Supported by NASA grant NAG5-11603.

SH71A-10 1120h INVITED

Turbulence, magnetic field complexity, and perpendicular transport of energetic particles in the heliosphere

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In a dynamically active magnetoplasma such as the solar wind or lower corona, it is difficult to avoid generation of structure in the direction transverse to a large scale mean magnetic field. Magnetic fluctuations of this type having "high k-perp," and described in various formalisms as "structures," or "quasi-2D turbulence" or "reduced MHD," can be generated by resonant incompressive couplings as well as phase mixing-type couplings. These couplings are all present in the full description of MHD turbulence, and in each case the couplings that produce these fluctuations involve amplification of fine scale gradients that are transverse to the large scale magnetic field. Here we review the nature of the anisotropies that are expected in MHD turbulence, and describe the nature of the transverse complexity that is produced in the magnetic field. This gives rise to random walk or diffusion of magnetic field lines that differs greatly from what is expected in the quasi-linear or "slab" limits. In particular, strongly 2D field lines can admit islands of slowly transporting field lines separated by regions of rapid transport. Finally, implications are discussed for collisionless charged particle transport across the magnetic field. When transverse complexity is absent or weak, parallel diffusion suppresses perpendicular transport to a subdiffusive level. Recent work also shows that perpendicular diffusion is restored when transverse complexity is strong, but at a level lower than what is expected in the Field Line Random Walk limit in which particle simply stream along field lines. This research supported in part by NSF grant ATM-0105254, and by NASA SECTP theory program grant NAG5-8134.

SH71A-11 1140h

Energetic Charged Particle Transport in Two-dimensional MHD Solar Wind Turbulence

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In recent years, accumulative evidence from nearly incompressible MHD theory, simulations, and solar wind observations pointed to the possibility of the strong presence of two-dimensional (2D) MHD turbulence in the solar wind. However, not much has been done to investigate theoretically the consequences of 2D turbulence for energetic particle transport. Within the framework of quasi-linear kinetic theory we will discuss the theoretical implications of 2D MHD turbulence for large-scale energetic charged particle transport in the heliosphere during quiet solar wind conditions. We will deal with two cases: (i) Anisotropic particle distributions where we will focus on pickup ion pitch angle scattering and stochastic acceleration in the quiet slow low-latitude solar wind, and (ii) near-isotropic particle distributions where we will discuss cosmic-ray transport in terms of spatial diffusion parallel and perpendicular to the large-scale magnetic field. The discussion will include topics such as the importance of turbulent motional electric field fluctuations for particle transport in the solar wind, and how a new kind of cosmic-ray transport equation arises when 2D turbulence is important for parallel diffusion.

SH72A MCC: Hall D Sunday 1330h

Particle Populations Upstream of the Earth's Bow Shock: Observations, Theory, and Simulations III Posters

(joint with SM)

Presiding: **H Kucharek,** University of New Hampshire

SH72A-0545 1330h POSTER

Cluster Observations of ULF waves in the Terrestrial Foreshock

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The terrestrial foreshock exhibits a wide variety of wave activity, in particular Ultra Low Frequency (ULF) waves observed at frequencies well below the ion cyclotron frequency. Of particular interest is the way in which these waves are generated and subsequently interact with the ion populations in the foreshock, since the interaction of reflected ion beams with the inflowing solar wind is mediated by wave-particle processes. We present observations of ULF foreshock waves based on data from the multi-spacecraft Cluster mission, the first space mission to characterise the spatial variation of plasma properties in 3 dimensions simultaneously. Observations of wave power, frequency and polarisation are presented, in combination with an analysis of propagation directions and velocities in the plasma rest frame using multi-spacecraft techniques. Details of the associated plasma properties are also discussed.

SH72A-0546 1330h POSTER

The Possible Source of the Short Quasi-Harmonical Structures in the Earth's Foreshock

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Presence of accelerated ("reflected") particles propagating upstream from the shock front and wave modes generated in wide range of frequencies and amplitudes is the major characteristic feature of the foreshock. High time resolution plasma and magnetic field measurements made onboard INTERBALL-1 satellite during Earth's foreshock crossings allowed us to obtain information about interrelation between these accelerated particles and the waves in a very small time scale (few tens of seconds). Namely, the quasi-harmonical structures with a period of a few seconds and duration up to half of minute observed in the foreshock simultaneously in the magnetic field and solar wind ion flux data were compared with the features of accelerated particles. Dozens of such events were studied. In order to determine possible trigger or cause of these quasi-harmonical structures 3D distribution functions of accelerated ions in the foreshock were reconstructed on 10 sec. intervals. Almost all cases clearly demonstrate a presence of narrow additional beam of particles just before the occurrence of quasi-harmonical structure. This beam commonly propagates at some significant angle to the background magnetic field direction. Basic parameters of these beams were also calculated in each case and then statistically processed to determine their average values for several types of quasi-harmonical foreshock structures.

SH72A-0547 1330h POSTER

Chaotic transverse modes wave activity far upstream of the ion foreshock during intervals of an interplanetary magnetic field near parallel to the solar wind velocity.

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Several events have been identified of an ion foreshock extending up to 250 RE upstream of the Earth. These events occur mostly during periods of slowly drifting radial interplanetary magnetic field (IMF) when the 1-min average values of the strengths of the IMF and the solar wind (SW) speeds are mostly steady (Berdichevsky et al., 1999). Here we present an overview of our current investigation on the nature of the observed transverse modes of oscillation and a preliminary interpretation of their association to the observed diffuse ion population. These observations use high resolution Wind WAVES, MFI, 3DP, and SWE data.

Berdichevsky, D., G. Thejappa, R. Fitzenreiter, R. Lepping, T. Yamamoto, S. Kokubun, R. McEntire, D. Williams, and R.P. Lin, Widely spaced wave-particle observations during GEOTAIL and WIND magnetic conjunctions in the Earth's ion foreshock, J. Geophys. Res., 104, 463-482, 1999

SH72A-0548 1330h POSTER

An Analytic Gasdynamic Approach to the Modeling of Earth's Bow Shock

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A new analytical model of the bow shock surface is suggested for reasonably accurate and fast prediction of this boundary's position near obstacles of different shape. The model can be conveniently applied for studies of a wealth of physical processes that strongly influence the charged particle population upstream of the Earth's bow shock. For an axially symmetric magnetopause obstacle the bow shock model was verified by comparison with experiments and results of gasdynamic simulations for a wide range of upstream polytropic indexes, $1.15 < \gamma < 2$, Mach numbers, $1 < Ms < \infty$, and obstacle shapes. The model can be also used for the prediction of the bow shock position around non-axially symmetric magnetopauses.

SH72A-0549 1330h POSTER

Electron Heating Process at Quasi-Perpendicular Shocks: Shock Parameter Dependence

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The role of micro-instabilities in dissipation process in collosionless quasi-perpendicular shocks is investigated by the full-particles numerical simulation method. It is well-known that an anomalous dissipation is necessary in the super-critical Mach number. The reflected ions are mainly considered to produce the dissipation. Recently, the contribution of electrons are also well discussed and many waves are listed-up for the candidate of the dissipation process: ion acoustic waves, upper hybrid waves, whistler waves, and so on. In the present study, we discuss the variation of the wave types depends on both the shock parameters (shock Mach number, upstream plasma beta) and time. Here, the reflected ions again act as an important role. The distribution shape in velocity space of the reflected ions varies in time with the time period of over several times of ion gyro-period. Resultantly, different types of waves are excited because waves are excited by the interaction between the incoming electrons and the reflected ions. In the case that the temperature of the reflected ions is relative colder, ion acoustic waves are excited. On the other cases, the other type of waves are excited. In this sense, the ratio of the upstream plasma beta to Mach number is also the key parameter.

SH72A-0550 1330h POSTER

Bow Shock Specular Reflected Ions in Presence of Low Frequency Electromagnetic Waves: a Case Study

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An energetic ion event observed by CLUSTER CIS experiment upstream of the Earth's bow shock is studied in detail. The ion event is observed in association with quasi-monochromatic ULF MHD-like waves which modulate the ion fluxes. According to three statistical bow shock position models, the Cluster spacecraft are located at about .5 R_E from the shock and the averaged bow shock θ_{BN} is about 30°. The analysis of the three-dimensional angular distribution indicates that ions propagating roughly along the magnetic field direction are observed at the onset of the event. Later on the angular distribution is gyrophase-bunched and the pitch-angle distribution is peaked at $\alpha_0 \sim \theta_{BN}$ consistent with the specular reflection production mechanism. The analysis of the waves shows that they are left-handed in the spacecraft frame and propagate roughly along the ambient magnetic field; we have found that they are in cyclotron resonance with the field-aligned beam observed just upstream. Using the waves and particles properties we explain the observed particle flux-modulation in term of θ_{BN} changes at the shock due to the low frequency waves and therefore consistent with the specular reflection hypothesis as the source of ions.

SH72A-0551 1330h POSTER

3-20 MeV Electrons in the Inner Three-dimensional Heliosphere at Solar Maximum: Ulysses COSPIN/KET Observations.

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The Ulysses trajectory provides a unique opportunity to study the propagation of MeV electrons in a wide range of heliographic latitudes and during varying conditions in the inner heliosphere. From the Ulysses launch up to the beginning of 1998, the 3-10 MeV electron count rate of the COSPIN/KET instrument has been consistently described by modulation models taking into account galactic cosmic rays as well as Jovian electrons. In this paper we focus on the MeV electron observations from 1998 onwards, covering Ulysses' second out-of-ecliptic path, which was performed under solar maximum conditions. In contrast to our expectations, the electron intensity stayed at approximately the same level as the one observed in 1991 when Ulysses was magnetically well connected to Jupiter. In this paper we report on the discovery of short-term 3-10 MeV and 7-20 MeV electron intensity increases at highest southern heliographic latitudes, which are not correlated with solar particle events.

SH72A-0552 1330h POSTER

Jovian Electrons at SOHO From 1995 - 2002: Indications for Long-term Variations of the Jovian Source Strength

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SOHO was launched in December 1995 into the solar minimum between the cycles 22 and 23. Right after launch the COSTEP instrument detected 25 day recurrent periods of enhanced 0.25-15 MeV electron intensity that were not correlated with solar activity. This pattern reoccurred 13 months later, indicating a Jovian origin with the typical Jovian synodic period. However, the systematic 25 day periods present during solar minimum were not seen during solar maximum. Instead, the level of intensity of the 13 month periods increased from minimum to maximum, an observation that is in agreement with Ulysses observations at high latitudes. Possible mechanisms for this behavior will be discussed.

SH72A-0553 1330h POSTER

Analysis of Field Components Through SLAMS During Self-Reformation of Quasi-Parallel Shocks

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Full particle simulations are used in order to analyze the formation and the dynamics of embedded SLAMS during the cyclic self-reformation of quasi-parallel shocks. Features of SLAMS (time and space scales, leading-trailing edges dissymetry, polarisation reversal) already identified in experimental data (Schwartz and al., 1992; Mann and al., 1994) are fully recovered. Complementary diagnosis are proposed in order to identify more precisely the features of field components through SLAMS structures during their formation, which could be used for analysing data issued from multi-satellites Cluster mission. Results will be extensively discussed and applied to "embedded" and "isolated" SLAMS.

SH72A-0554 1330h POSTER

Signatures of Local Distributions Functions Through SLAMS

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Local distribution functions are analyzed in details through SLAMS structures formed in quasi-parallel shocks with the help of full particle distributions. These allow (i) to identify particular time periods at which ion reflection is reinforced or weakened corresponding respectively to a local strong and weak wave steepening of the SLAMS, (ii) to characterize some associated dissymetry in leading-trailing edges of the fields components. These distributions are shown to be used as signatures to characterize some particular features of SLAMS at different times of their formations. Such features are proposed to be compared with experimental data.

SH72A-0555 1330h POSTER

Super-Adiabatic and Sub-Adiabatic Electron Heating Through a Quasiperpendicular Supercritical Shock

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Recent statistical analysis of results issued from test particles simulations has been performed in order to analyze quantitatively the adiabaticity violation for electrons traversing a planar quasi-perpendicular shock wave The shock wave is moving in a supercritical regime and its profile is defined by all electric and magnetic field components issued from a full particle simulation. Test particles are initially distributed over a small sphere in 3D velocity space. The main results are: (i) both adiabatic and nonadiabatic electrons are identified and their respective contributions to the total heating are also estimated versus their initial distributions in velocity phases (for a given thermal velocity)

and versus the initial thermal velocity. This allows us to determine which part of the distribution function is responsible for nonadiabaticity. (ii) Two distinct nonadiabatic electron populations have been clearly identified: one is super-adiabatic (overheating), the other is sub-adiabatic (overcooling). Results are compared with recent theoretical calculations suggested to explain the existence of these two populations and to identify the underlying mechanisms responsible for their formation. Present results may be of importance for analysing new experimental data issued from CLUSTER-II mission.

NB: This work is supported by ISSI (Bern, Switzerland)

SH72A-0556 1330h POSTER

An Investigation of the Spatial Scales of the Change in Electric Field Observed at the Front of a Quasi-perpendicular Shock.

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Using data from the Cluster EFW instrument it is shown that there is a general increase in the level of the electric field observed as the shock is crossed and the extent of this region appears to be larger than that of the magnetic ramp. However, within this region, short scale spike-like features in the electric field are commonly observed. The scale size of these features is determined and their relationship to various upstream parameters investigated.

SH72A-0557 1330h POSTER

Predicting the Bow Shock Position for Average and Unusual Upstream Conditions

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The positions, shape and motion of the Earth's bow shock have been extensively studied for the last four decades. Although many bow shock models have been developed, they still do not sufficiently describe the observed bow shock. The models fail because they are intrinsically steady-state and (semi)empirical. On the other hand, physics-based 3-dimensional global MHD models of the Earth's magnetosphere are resident at the Community Coordinated Modeling Center (CCMC). These MHD models compute the configuration and evolution of the magnetosphere in response to the actual solar wind parameters. We will compare and discuss differences between the bow shock observations for average and unusual upstream conditions and predictions provided by the MHD numerical simulations or by the (semi)empirical models.

SH72A-0558 1330h POSTER

Analytic and Numerical Modelling of Langmuir Waves and Radio Emission from Earth's Foreshock

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We present theoretical predictions of the spatial distribution and flux levels of radio emission in Earth's foreshock due to Langmuir waves driven by backstreaming electron beams. We combine electron reflection and acceleration at Earth's bow shock with stochastic growth theory for the steady-state production of Langmuir waves and nonlinear wave processes for the emission of electromagnetic radiation at harmonics of the electron plasma frequency. We demonstrate that the model predictions agree remarkably well, both qualitatively and quantitatively, with observations.

SH72A-0559 1330h POSTER

Observations of Foreshock Langmuir Waves by the Cluster Wideband Data Plasma Wave Receiver

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The Wideband Data (WBD) Plasma Wave Receiver, which is part of the Cluster Wave Experiment Consortium (WEC), provides high-resolution measurements of waveform electric and magnetic fields in selected frequency bands up to 577 kHz. Continuous waveforms are transmitted to a DSN ground station in a 220 kbit/s real-time mode, making the Cluster Wideband Data Plasma Wave Receiver an excellent instrument for studying Langmuir waves in Earth's foreshock region. We will discuss the statistics of the frequencies and amplitudes of foreshock Langmuir waves observed by Cluster. We will also describe the characteristics of the observed electric field waveforms, and how the properties of the Langmuir waves depend on the spacecraft location within the foreshock region and on upstream solar wind conditions. We will examine the relevance of our Langmuir wave observations to various growth mechanisms and instabilities, such as the modulational instability and stochastic growth theory.

SH72A-0560 1330h POSTER

Ion Reflection, Acceleration and Transmission at the Quasi-Perpendicular Bow Shock: Cluster CIS Observations

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Two distinct populations of reflected and accelerated ions are known to come from quasi-perpendicular shocks, gyrating ions and reflected ion beams. Recent observations under such bow shock conditions with Cluster have shown that both particle distri-butions appear to emerge from the same reflection process. The beam results from effective scattering in pitch angle during the re-flection, with, for example, very strong scattering at high Mach number shocks. The Cluster spacecraft have crossed the Earth's bow shock many times and thus have accumulated an extended database of shock crossings. We have analyzed a number of quasi-perpendicular shocks with the Cluster Ion Spectrometry experi-ment (CIS). The spatial and temporal evolution of the reflected and transmitted ion populations is studied for a variety of shock angles, Mach numbers and plasma beta. The observed event-to-event differences and temporal variations of the ion populations are related to changes of these parameters and compared with models and simulations.

SH72B MCC: 124 Sunday 1330h

Energetic Charged Particle Transport in the Heliosphere II

Presiding: **J A le Roux,** University of California, Riverside**; W H Matthaeus,** Bartol Research Institute

SH72B-01 1330h INVITED

Quasi-linear Theory of Energetic Particle Spatial Diffusion in Static MHD Turbulence

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Quasi-linear theory of particle scattering parallel and perpendicular to the mean magnetic field B, is applied to static fully three-dimensional MHD turbulence described by its three-dimensional wave vector spectrum Pij(k). The method follows that of Forman et al. (Ap.J.,1974), but uses a more complete evaluation of the scattering tensor and does not assume that the particle pitch angle distribution is linear in the pitch angle. The form of Pij(k) derived by Oughton, et al. (1996) is essential to this new evaluation of the scattering tensor. The particle gyrophase distribution is assumed to be a simple cosine whose amplitude and phase are parameters to be determined, giving the perpendicular elements of the scattering tensor. In this picture, scattering parallel and perpendicular to the mean field is due to power, polarization, anisotropy and helicity in the power spectral tensor at (different sets of) resonant wavevectors perpendicular to the local mean field as well as in parallel and in intermediate directions.

To make the theory tractable, the Pij(k) are assumed to be cylindrically symmetric about the local mean magnetic field. Results are presented for the slab + 2D model; that is, Pij(k) is non-zero only at wavevectors parallel or perpendicular to the mean magnetic field.

I find that the 2D component wavevectors perpendicular to the mean field have no effect at all on pitch angle scattering. There could be parallel scattering by wavevectors at oblique angles, not included in the present theory. For perpendicular scattering, the slab component contributes a "power at zero frequency" term as known before, but the 2D component contributes a similar term for particles with gyroradius large compared with the correlation length of the field. If the slab power is a fraction F of fluctuations, this theory predicts a parallel diffusion coefficient 1/F times larger than if all the power in fluctuations were slab modes. The perpendicular diffusion coefficient is not changed at large rigidities, but is reduced by a factor F at rigidities where the gyroradius is small compared to the correlation length.

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SH72B-02 1350h INVITED

The global transport of energetic particles in the heliospheric magnetic field

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We present new results from modeling the global propagation of energetic particles (greater than $\sim$ 50 keV) in the heliosphere. Our models are applied to the interpretation of some observed events which provide information about the large-scale heliospheric magnetic field itself. Examples include the recurrent particle events at high heliographic latitudes associated with corotating interaction regions at lower latitudes, impulsive solar-flare events showing fine-scale intensity variations at 1 AU, and large global events, such as the one which occured on Bastille day, 2001. We show that the the diffusion of charged particles across the average magnetic field naturally explains many of the observed features of particle events. The physics of cross-field