SH24A-04 1615h

Transverse Anisotropies of 40-90 MeV Solar Energetic Protons: A Re-interpretation

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Zhang *et al.*, [*Astrophys. J.*, **595**, 493-499, 2003; *J. Geophys. Res.*, **108**, A4, 1154, SSH 4-1, 4-13, 2003] report strong anisotropies of 40-90 MeV protons transverse to the local magnetic field in two solar energetic particle events (2000:196 and 2000:256) observed by Ulysses/COSPIN/HET. They interpret their results in the context of diffusive transport and consequently conclude these events constitute strong evidence for the existence of transverse diffusion in the helisosphere. We see three difficulties with this interpretation. 1) The magnetic field was unusually well ordered during the periods of transverse anisotropies. Theories of transverse diffusion require the presence of irregularities in the magnetic field. 2) Fourier analysis of the angular distribution reveals a second harmonic whose amplitude is comparable to that of the first harmonic. This is inconsistent with diffusive transport (Fick's law) that predicts a dominant first harmonic. 3) Only two such intervals have been identified in a search of the mission-long Ulysses COSPIN data set. The paucity of such intervals is inconsistent with this being a pervasive mode of transport. We have independently analyzed the COSPIN/HET channel H45 data and we confirm the data analysis of Zhang *et al.* for both events. However, we find that the data are much more consistent with a quantitative interpretation in terms of weak scattering with an evolving field-aligned streaming and a bi-directional anisotropy component in the presence of a gradient anisotropy. The scale of the gradient extracted from the pitch-angle distributions is comparable to that of the flux-rope-like magnetic structures in which it occurs. The above-mentioned three points are thus explained as follows. 1) Weak-scattering is expected in regions of quiet fields. 2) The pitch-angle distribution in both events eventually becomes predominantly bi-directional, indicating a mirroring within the structure. Consequently the significant second harmonic is immediately explained. 3) The conditions for observing a strong gradient anisotropy at these energies is restricted to a special class of structures, and hence should be a relatively rare occurrence.

SH24A-05 1630h

Trapping of Solar Energetic Particles by Small-Scale Topology of Solar Wind Turbulence

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The transport of energetic particles perpendicular to the mean magnetic field in space plasmas long has been viewed as a diffusive process. However, there is an apparent conflict between recent observations of solar energetic particles (SEP): 1) impulsive solar flares can exhibit "dropouts" in which SEP intensity near Earth repeatedly disappears and reappears, indicating a filamentary distribution of SEPs and little diffusion across these boundaries. 2) Observations by the *IMP-8* and *Ulysses* spacecraft, while they were on opposite sides of the Sun, showed similar time-intensity profiles for many SEP events, indicating rapid lateral diffusion of particles throughout the inner solar system within a few days. We explain these seemingly contradictory observations using a theoretical model, supported by computer simulations, in which many particles are temporarily trapped within topological structures in statistically homogeneous magnetic turbulence, and ultimately escape to diffuse at a much faster rate. This work was supported by the Thailand Research Fund, the Rachadapisek Sompoj Fund of Chulalongkorn University, and the NASA Sun-Earth Connections Theory Program (grant NAG5-8134).

SH24A-06 1645h

Nonlinear theories of parallel and perpendicular scattering of energetic particles

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Recently the nonlinear guiding center (NLGC) theory [1,2] of perpendicular diffusion of charged test particles has shown promise in providing a needed improvement in the correpondence of scattering theory to numerical results from computation of charged particle orbits in model magnetic turbulence. This has motivated a search for extensions of particle diffusion theory in which the parallel and perpendicular diffusion are simultaneously computed, and each is an implicit function of the other. Here we report on two such approaches. In the first, self-consistency is obtained as a nonlinear extension of quasilinear theory, in the context of a Fokker Planck approach. The second approach seeks to develop a theory that is approriate to strong turbulence, in which decorrelation from unperturbed orbits occurs rapidly. Here we derive the coupled integral equations that are solved for the diffusion coefficients in each case, and the results are compared with numerical simulations.This research supported in part by NSF grant ATM-0000315 and NASA grant NAG5-11603. [1] W H. Matthaeus, G. Qin, J. W. Bieber and G. P. Zank, Astrophys. J., 590, L53 (2003) [2] A. Shalchi, J. W. Bieber and W. H. Matthaeus, Astrophys. J., in press (April 2004)

SH31A CC: 220 C-E Wednesday 0830h

Acceleration, Release, and Propagation of Solar Energetic Ions and Electrons: When, Where, and How? IV Posters

Presiding: **E C Roelof,** Applied Physics Laboratory, Johns Hopkins University**; G C Ho,** Applied Physics Laboratory, Johns Hopkins University

SH31A-01 0830h POSTER

A study of the injection of electrons in solar impulsive events observed from $\leq$0.4 to $\geq$200 keV

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We present a detailed analysis of several solar impulsive electron events detected from a few hundred eV to >200 keV by the WIND 3D Plasma and Energetic Particle experiment. For the event beginning at ~17:20UT on August 7, 1999, the electron flux profiles show sharp peaks (~5 to 10s of minutes FWHM at energies > 20 keV) and a path length derived from the peak times of ~1.16±0.09 AU, indicating that the electron propagation is essentially scatter free. Under the scatter-free assumption and correcting for the contamination by higher energy electrons on onsets observed in lower energy channels, we find that for the higher energy $\geq$40 keV, electrons appear to be released 10±3 minutes after the start of type III radio burst at the Sun. The event durations at energies below ~5-10 keV are substantially larger,suggesting a different behavior at those energies.

SH31A-02 0830h POSTER

Low Energy SEP Events of October/November 2003 at 1 and 5 AU

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The late October-early November solar energetic particle (SEP) events during the declining stage of solar cycle 23 provide an outstanding opportunity to investigate the propagation of solar-produced ions and electrons in the inner (< 5 AU) heliosphere. The EPAM instrument on the ACE spacecraft (1 AU) and the HISCALE instrument on the Ulysses spacecraft (essentially in the ecliptic plane at 5.2 AU and about 117° east of the Earth-Sun line) were ideally situated to measure the in-ecliptic interplanetary particles produced by the series of large solar eents. Of particular interest is the particle event on 28 October 2003 (day 301) following the exceptionally large X17 flare in Active Region 486. Particles were observed at both ACE and Ulysses; quite rapid onsets of the intensities of ions were measured at both spacecraft. Indeed, this event may have the most rapid onset of any SEP event ever measured at 5 AU. This presentation will concentrate on an examination of the intensities, time dependence, and radial gradients of protons and heavy ions (Z$\geq$2) that were measured during the series of SEPs in this time interval.

SH31A-03 0830h POSTER

The effect of adiabatic energy loss during interplanetary propagation of solar energetic particles

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Because of the divergence of the solar wind flows, energetic particles should experience adiabatic energy loss almost everywhere in the interplanetary space. The energy loss of particles gyrating in magnetic fields is a pitch-angle dependent process and it is present with or without particle scattering by magnetic turbulences. The energy loss is much faster close to sun than at large radial distances. Our particle simulations show that adiabatic energy loss is significant even in a short period of less than one day. The result indicates that adiabatic energy loss cannot be completely neglected in the modeling of solar particle events. This is particularly true for gradual events that can last as long as one solar rotation. Even the initial phase, adiabatic energy loss may be important, because it takes a few hours to a day for a solar particle event to reach its maximum intensity at 1 AU. In this paper, we will show how the inclusion of the adiabatic energy loss into the focus transport equation will affect the spatial distribution, time profile and dissipation of solar energy particles in large gradual events.

SH31A-04 0830h POSTER

Relativistic Solar Particles on 1989 October 22: Injection along Both Legs of a Closed Interplanetary Magnetic Field Loop

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Worldwide neutron monitor observations of relativistic solar particles on 1989 October 22 have proven puzzling, with an initial spike sometimes followed by a

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second peak, which is difficult to understand in terms of transport along a standard Archimedean spiral magnetic field or a second injection near the Sun. Here we present an analysis of selected polar monitors, a subset of the present-day Spaceship Earth network, which provide a clean measurement of the directional distribution of solar energetic particles at $\sim$ 1-3 GV. The omnidirectional intensity dips after the initial spike, followed by a nearly isotropic hump and a slow decay. The intensity and anisotropy data are fit by simulating the particle transport for various magnetic field configurations and determining the best-fit injection function near the Sun. The data are not well fit for a magnetic bottleneck beyond Earth or for particle injection along one leg of a closed magnetic loop. A model with simultaneous injection along both legs of a closed loop provides the best explanation: particles moving along the near leg make up the spike, those coming from the far leg make up the hump, and trapping in the loop accounts for the slow decay of the intensity. This work was supported by the Thailand Research Fund, the Rachadapisek Sompoj Fund of Chulalongkorn University, and NSF grant ATM-0000315.

SH31A-05 0830h POSTER

Finite Time Shock Acceleration at Interplanetary Shocks

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Observations of energetic ion acceleration at interplanetary shocks sometimes indicate a spectral rollover at $\sim$ 0.1 to 1 MeV nucl^{-1}. This rollover is not well explained by finite shock width or thickness effects. At the same time, a typical timescale of diffusive shock acceleration is several days, implying that the process of shock acceleration at an interplanetary shock near Earth usually gives only a mild increase in energy to an existing seed particle population. This is consistent with a recent analysis of *ACE* observations that argues for a seed population at substantially higher energies than the solar wind. Therefore an explanation of typical spectra of interplanetary shock-accelerated ions requires a theory of finite-time shock acceleration, which for long times (or an unusually fast acceleration timescale) tends to the steady-state result of a power-law spectrum. We present analytic and numerical models of finite-time shock acceleration. For a given injection momentum p_0, after a very short time there is only a small boost in momentum, at intermediate times the spectrum is a power law with a hump and steep cutoff at a critical momentum, and at longer times the critical momentum increases and the spectrum approaches the steady-state power law. The composition dependence of the critical momentum is different from that obtained for other cutoff mechanisms. The results are compared with observed spectra. Work in Thailand was supported by the Commission for Higher Education, the Rachadapisek Sompoj Fund of Chulalongkorn University, and the Thailand Research Fund. Work at the University of Maryland was supported by NASA contract NAS5-30927 and NASA grant PC 251428.

SH31A-06 0830h POSTER

Sharp Trapping Boundaries in the Random Walk of Interplanetary Magnetic Field Lines

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Although magnetic field lines in space are believed to undergo a diffusive random walk in the long-distance limit, observed dropouts of solar energetic particles, as well as computer simulations, indicate sharply defined filaments in which interplanetary magnetic field lines have been temporarily trapped. We identify mechanisms that can explain such sharp boundaries in the framework of 2D+slab turbulence, a model that provides a good explanation of solar wind turbulence spectra and the parallel transport of solar energetic particles. Local trapping boundaries (LTBs) are empirically defined as trajectories of 2D turbulence where the mean 2D field is a local maximum. In computer simulations, the filaments (or "islands" in the two dimensions perpendicular to the mean field) that are most resistant to slab diffusion correspond closely to the mathematically defined LTBs, that is, there is a mathematical prescription for defining the trapping regions. Furthermore, we provide computational evidence and a theoretical explanation that strong 2D turbulence can inhibit diffusion due to the slab component. Therefore, while these filaments are basically defined by the small-scale topology of 2D turbulence, there can be sharp trapping boundaries where the 2D field is strongest. This work was supported by the Thailand Research Fund, the Rachadapisek Sompoj Fund of Chulalongkorn University, and NASA Grant NAG5-11603. G.R. thanks Mahidol University for its hospitality and the Thailand Commission for Higher Education for travel support.

SH31A-07 0830h POSTER

Analytic Forms of the Perpendicular Diffusion Coefficient in Magnetostatic Turbulence

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Recently a nonlinear theory for perpendicular diffusion of charged particles was presented [1]. This theory is called the Nonlinear Guiding Center (NLGC) theory and provides an integral equation for the perpendicular mean free path. Here we report on analytical solutions of this equation in the case of magnetostatic turbulence. The resulting formulas for the perpendicular mean free path are discussed. We also compare these new results with results of the quasilinear theory (QLT) for parallel diffusion and with observational results [2]. This research supported in part by NSF grant ATM-0000315 and NASA grant NAG5-11603. [1] W H. Matthaeus, G. Qin, J. W. Bieber and G. P. Zank, Astrophys. J., 590, L53 (2003) [2] I. D. Palmer, Rev. Geophys. Space Phys., 20, 2, 335 (1982)

SH31A-08 0830h POSTER

Transport of Turbulence Throughout the Heliosphere and Determining its Impact on Solar Modulation of Cosmic Rays

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A global solar wind turbulence model is considered in a simulation domain which spans from close to the Sun to 100 AU and excludes the effect of termination shock at present. The four governing equations that model the turbulence describe fluctuation energy, correlation scale, temperature, and cross-helicity everywhere in the heliosphere. The transport equation for cross-helicity is new in this simulation [1]. These four equations are solved numerically along every radial direction in our simulation domain. The parameters present in these equations are plasma shear, wind speed, and strength of pick-up ions among others. Magnetic variance, correlation length, cross helicity and plasma temperature have latitudinal dependence along the inner boundary at 0.2 AU. The solar wind speed and velocity shear are varied across the simulation domain. A simple model of pick-up ions is employed at present. The early indication shows that the simulation results thus obtained have a good agreement with observations. Heating is suppressed in the inner heliosphere and at high latitudes by the cross helicity effect, and the Alfvenicity of the turbulence almost completely vanishes by 10 AU. This turbulence model will be combined with a modulation code that integrates Parker's transport equation numerically. This approach gives a better physical basis for the heliospheric distribution of turbulence, and thus it is expected that the physics of the scattering and modulation is improved. The whole exercise is part of our ongoing effort to develop ab initio turbulence and modulation models and integrate them together. The combined effort will enhance our understanding of solar modulation of cosmic rays. Supported by NSF grant ATM-0000315 and NASA NAG5-8134. W H Matthaeus, J. Minnie, B. Breech, S. Parhi, J. W. Bieber and S. Oughton, submitted to Geophys. Res. Lett. (2004)

SH31B CC: 518 A Wednesday 0830h

Violent Sun-Earth Connection Events of October-November 2003: Genesis

(joint with SA, SM)

Presiding: **N Gopalswamy,** NASA Goddard Space Flight Center**; S W Kahler,** Air Force Research Laboratory

SH31B-01 0830h INVITED

Flare Activity during the October-November 2003 Storms

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The high solar activity during the last weeks of October and beginning of November 2003 with 11 X-class flares provides a great opportunity to study particle acceleration in flares. First results of multi-spacecraft and ground-based observations are summarized with a focus on X-ray observations from the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI).

URL: http://plasma2.ssl.berkeley.edu/~krucker/hessi/oct2003.html

SH31B-02 0850h INVITED

Irradiance Observations of the October 28, 2003 X-17 Flare

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The Solar Radiation and Climate Experiment, SORCE, carries four instruments that measure solar irradiance – both total solar irradiance, TSI, and spectral irradiance from soft X-rays, ultraviolet, visible and near infrared. During the X-17 flare at 11:00 UT on October 28, 2003 the SORCE instruments were in ideal configurations to record increases in TSI and at most observed wavelengths. The X-ray and UV irradiance originating in the transition region and corona increased by factors as large as fifty. This large flare also provided the first measurement of an increase in TSI, a unique measurement that places an important new constraint on the energy release during the flare. This report is a survey and interpretation of the irradiance variations observed during this X-17 flare.

SH31B-03 0910h INVITED

Coronal Mass Ejections observed by SOHO during the October-November 2003 Storms

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