# SH11C MCC: Level 2 Monday 0830h

## The Termination Shock, Heliosheath, and Heliopause I Posters

***Presiding:*** **M Zhang,** Florida Institute of Technology**; M Opher,** Jet Propulsion Laboratory, California Institute of Technology

### SH11C-1108 0830h POSTER

#### Ion acceleration in quasi-perpendicular PIC simulations of a reforming heliospheric termination shock

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Recent Particle-in-cell (PIC) simulations have revealed time-dependent shock solutions for parameters relevant to astrophysical and heliospheric shocks [1,2,3]. These solutions are characterised by a shock which cyclically reforms on the spatio-temporal scales of the incoming protons. Whether a shock solution is stationary or reforming depends not only upon the correct treatment of the electrons, but also on the plasma parameters, the upstream $\beta$ in particular. In the case of the heliospheric termination shock these parameters are not well determined, however, some estimates suggest that the termination shock may be in a parameter regime such that it is time-dependent. It has been pointed out [3] that this will switch off some acceleration mechanisms, for example shock surfing, which has been proposed previously for time-stationary shock solutions. The introduction of time-dependent electromagnetic fields intrinsic to the shock does however introduce the possibility of new mechanisms for the acceleration of protons. Here we present for the first time one such process as revealed by high phase space resolution 1.5D PIC simulations in which all vector quantities are three dimensional, the solution then varying with the spatial coordinate and time. We find that a subset of the protons that reflect off the reforming shock front are accelerated by subsequent interaction with the shock to form a suprathermal population which then propagates into the downstream region with energies of order six times the upstream inflow energy. These may provide an injection population for further acceleration to cosmic ray energies. [1] Shimada, N., and M. Hoshino, *Astrophys. J, 543*, L67, 2000.

Schmitz, H., S.C. Chapman and R.O. Dendy, *Astrophys. J, 570*, 637, 2002

Scholer, M., I. Shinohara and S. Matsukiyo, *J. Geophys. Res., 108*, 1014, 2003

### SH11C-1109 0830h POSTER

#### Modulation Near the Termination Shock: Stochastic Particle Studies using an MHD Heliosphere

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Voyager observations near the termination shock have shown strong modulation of cosmic ray flux. In a recent study using stochastic particle simulations we showed that particles may cross the shock multiple times, and as a result we can obtain modulation even in regions where there is no divergence in the velocity field. Here we apply this idea to an MHD model of the heliosphere, which includes a non spherical termination shock boundary and a heliosheath region where the velocity field divergence is not identically zero. We will show the relative contributions to modulation from several regions, including the pre-shock solar wind, the shock itself, and the heliosheath. Comparisons will also be made with Voyager data.

### SH11C-1110 0830h POSTER

#### Ab Initio Modulation Modeling: The Effect of a Non-Linear Description of Perpendicular Diffusion

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In an ongoing effort to find an ab initio theory for the heliospheric modulation of cosmic rays, we combine modulation theory with the most recently available theoretical treatments of solar wind turbulence and the transport of charged particles in a magnetized medium. We present results from a 2D steady-state numerical modulation model that utilizes a parallel diffusion coefficient from quasi-linear theory (Teufel & Schlickeiser, *Astron. Astrophys.*, **390**, pp. 15-25, 2003) and perpendicular diffusion coefficients from non-linear guiding center theory (Matthaeus et al., *Astrophys. J. Lett.*, **590**, L53, 2003). This work is compared with previous work that utilized substantially different descriptions for the perpendicular diffusion coefficients.

### SH11C-1111 0830h POSTER

#### The Perpendicular Diffusion Coefficient for Charged Particles of Arbitrary Energy

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The problem of perpendicular diffusion by a particle in a turbulent plasma is a problem of enduring interest, and one that has yet to be fully solved. Analytic models do not agree with either observations or numerical simulations. Recently, a nonlinear theory was developed by Matthaeus et al. [2003] which, for the first time, appears to be consistent with numerical simulations in both the high- and low-energy particle regimes. Their approach is to assume that perpendicular transport is governed by the velocity of gyrocenters that follow magnetic field lines. Qin et al. [2002a,b] showed using numerical simulations that perpendicular diffusion could occur only in the presence of a transverse complex magnetic field. Flux surfaces with high transverse complexity are characterized by the rapid separation of nearby magnetic field lines and are therefore important to perpendicular diffusion. In particular, it appears that the combination of slab and 2D turbulence (a "two-component" model) is necessary to produce transverse complexity, and that slab turbulence alone, for example, is insufficient. The nonlinear theory is expressed through the solution of an integral equation. While the numerical solution of the integral equation in the appropriate parameter regime shows excellent agreement with numerical simulations for both high- and low-energy particles, the physical content is difficult to evaluate, nor is it evident how $\kappa_{xx}$ scales with parameters such as the energy density in magnetic fluctuations, mean field strength, particle gyroradius, MHD turbulence correlation length scales, parallel diffusion coefficient, etc. Furthermore, the integral equation formulation is not readily amenable to inclusion in models and numerical codes that require the perpendicular diffusion coefficient explicitly, such as heliospheric cosmic ray modulation models. We therefore introduce an explicit model for turbulence in the solar wind and solve the integral equation approximately for $\kappa_{xx}$. We show that our approximate solution agrees very well with the numerical solution of the fully nonlinear integral equation. The approximate solution reveals the dependence of $\kappa_{xx}$ on the characteristics of the turbulent magnetofluid and particle energy (through the particle gyroradius). We conclude by using the perpendicular diffusion coefficient to evaluate 1) the particle acceleration timescale for diffusive shock acceleration at perpendicular shocks, and 2) the diffusion coefficient for cosmic ray modulation throughout the heliosphere.

### SH11C-1112 0830h POSTER

#### Theoretical and Observational Aspects of Perpendicular Diffusion of Charged Particles in the Nonlinear Guiding Center Model

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The recently developed theory [1] of perpendicular diffusion of charged particles in the nonlinear guiding center approximation (NLGC) has shown promise in comparison with transport computed from ensembles of test particles. Here we demonstrate that the parallel scattering mean free path is the only particle property that influences the NLGC perpendicular mean free path. This leads to a relationship between perpendicular and parallel mean free paths, obtained from numerical solutions of the NLGC integral equation, that is consistent with results of a number of observational studies in which $\lambda_\perp/\lambda_\parallel \sim 1/20$ to 1/10. Finally we compare the NLGC prediction with the results of analysis [2] of Jovian electron data and find that NLGC accounts better for the observations than earlier theories of perpendicular particle diffusion. [1] W Matthaeus et al, Astrophys. J. (Lett.) 590, L53 (2003) [2] D. L. Chenette et al, Astrophys. J. (Lett) 215, L95 (1977)

### SH11C-1113 0830h POSTER

#### Self Consistent Modeling of Turbulence Transport with Implications for Cosmic Ray Transport and Modulation

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A global solar wind turbulence model is discussed in a simulation domain spanning from 0.2 AU to 100 AU excluding the effect of termination shock at present. The three governing equations which model the turbulence describe fluctuation energy, correlation scale and temperature at every point in the heliosphere. These equations are solved numerically along every radial direction in our simulation domain. The parameters present in these equations are varied along the inner boundary and across the simulation domain. These parameters are magnetic variance, correlation length, plasma temperature, plasma shear, wind speed, strength of pick-up ions, and cross helicity, among others. The simulation results thus obtained are compared with observations. The turbulence model is then combined with a modulation code that integrates Parker's transport equation numerically. This is part of our ongoing effort to integrate turbulence and scattering self consistently and develop an ab initio model of the solar modulation of cosmic rays. Implications for cosmic ray scattering and transport in the outer heliosphere will be discussed in light of recent Voyager observations at 85 AU.



### SH11C-1114 0830h POSTER

#### Magnetic Effects at the Edge of the Solar System: MHD Instabilities, the *de Laval nozzle* effect and an Extended Jet

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To model the interaction between the solar system and the interstellar wind magnetic fields, ionized and neutral components besides cosmic rays must be included. Recently (Opher et al. ApJL 2003) found, that by including the solar magnetic field in an high resolution run with the University of Michigan BATS-R-US code, a jet-sheet structure forms beyond the Termination Shock. Here we discuss the formation of the jet and its subsequent large period oscillation due to magnetohydrodynamic instabilities. We perform in a simplified two dimensional geometry resistive magnetohydrodynamic calculation of a plane fluid jet embedded in a neutral sheet with the profiles taken from our simulation. We find remarkable agreement with the full three dimensional evolution. We present an even higher resolution three dimensional case where the jet extends for 150$AU$ beyond the Termination Shock. We compare the temporal evolution of the jet showing that the sinuous mode is the dominant mode that develops into a velocity-shear-instability with a growth rate of $5 \times 10^{-9} sec^{-1} = 0.027 years^{-1}$. As a result the outer edge of the heliosphere presents remarkable dynamics, such as turbulence and flows caused by the motion of the jet. Further study, e.g., including neutrals and the tilt of the solar rotation from the magnetic axis, is required before we can definitively address how this outer boundary behaves. Already, however, we can say that the magnetic field effects are a major player in this region changing our previous notion of how the solar system ends.

## SH11C-1115 0830h POSTER

### The termination shock near 35 degrees latitude

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The paper calculates the solar cycle variation of the termination shock near 35 degrees latitude. The solution assumes that Voyager 1 crossed the termination shock at 85.5 AU on 2002.6. At mid latitudes, the termination shock is an oblique shock; the shock location is unambiguously solar cycle dependent with amplitude greater than 50 AU. The maximum (minimum) distance occurs during the rising (declining) phase of the solar cycle. During the period of high-speed (low-speed) solar wind, the termination shock moves outward (inward) and the shock is weaker (stronger). The calculation provides the shock speed, the shock strength, the preshock and postshock solar wind speed, and the flow speed in the shock frame of reference. The shock parameters are distinctly different depending on whether the shock moves outward or inward. If Voyager 1 did cross the termination shock in 2002.6, it would likely cross the shock coming back to the solar wind near 98 AU in 2006 during the next outward motion of the termination shock, while in 2010 the spacecraft would cross the termination shock back into the heliosheath near 113 AU during the inward motion of the termination shock near the maximum of Cycle 24. If Voyager 1 did not cross the termination shock in mid-2002, it might still do so before 2005.

## SH11C-1116 0830h POSTER

### Estimation of the Solar Wind Velocity at 85 AU from Voyager-1/LECP Energetic Ion Angular Distributions

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Voyager-1 (V1) encountered a remarkable region of the heliosphere at 85 AU during the last half of 2002 (Krimigis, *et al.*, this Conference). Because the plasma instrument on Voyager-1 is inoperative, we extract the solar wind velocity (V) by using its effect upon the intensity anisotropy measured by the Low Energy Charged Particle (LECP) instrument. The V1 LECP measurements indicated significant field-aligned anisotropies strong enough to invalidate the use of the linearized Compton-Getting transformation. Consequently, based on gyrotropic weak-scattering theory we assume an exponential distribution $\sim \exp(\alpha\mu)$ in pitch-cosine ($\mu$) that is convected with the solar wind. We transform it (non-linearly) into the spacecraft frame with a Galilean velocity transformation. We measure a power-law index for the energy spectrum k=1.5. We allow for weak coupling (backscatter) between hemispheres by setting the anisotropy parameter $\alpha = \alpha_+$ for the forward and $\alpha = \alpha_-$ for the backward hemisphere. The time-averaged LECP distributions consistently peak in spin sector 7 (the Sun splits sectors 1 and 8, the latter being blocked by a shield), so we assign the mean direction of the magnetic field to its center and normalize the intensities there. The normalized intensities in the remaining 6 sectors for each LECP channel are then fitted by a least-squares minimization that varies the remaining parameters ($\alpha_+$, $\alpha_-$, and V). Thus we extract the solar wind velocity from the LECP angular distributions. The best fits give V=0 over proton energies from 30 keV to 1 MeV, with energy-dependent uncertainties averaging $\sim$50 km/s. We cannot explain our observations using conventional diffusion-convection (strong-scattering) theory under the assumption that V1 did not leave the normal solar wind and magnetic field. The condition for diffusion-convection equilibrium with no radial streaming in the inertial frame implies a positive radial gradient with a source of particles beyond V1 in order to nullify the solar wind convection. Over the same time period, LECP observes a strong azimuthal anisotropy, which (if the average magnetic field is wound in a Parker sense), corresponds to gradient of increasing intensity as one moves inward along the field. This parallel streaming then implies a source of particles inside the radius of Voyager, but this is inconsistent with the positive radial gradient demanded by the radial transport equation. A quantitative analysis of the latter leads to a mean radial gradient $\sim$100%/AU with a comparable standard deviation. These are orders of magnitude bigger than gradients usually deduced for the outer heliosphere. We consider it unreasonable that such a configuration could endure there for half a year.

## SH11C-1117 0830h POSTER

### Comparison of 40-4000 keV Ion Angular Distributions with Magnetic Field Data Measured by Voyager-1 at 85 AU

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During the time period $\sim$2002.6 to $\sim$2003.1, Voyager-1 (V1) observed a number of unusual features in the Low Energy Charged Particle (LECP) data in the outer heliosphere not similar to what had been seen previously in the inner heliosphere (Krimigis, *et al.*, this Conference). Among the features measured by the V1 LECP instrument during this $\sim$0.5-yr. long 'event' were (1) sustained periods of large, near-azimuthal, anti-sunward streaming of ions 40-4000 keV, and (2) near-zero convective flow, as deduced by non-linear Compton-Getting analyses of these ion data averaged over the entire event. Feature (2) is analyzed in detail in a companion paper (Roelof *et al.*, this Conference). In the present paper we examine relatively high time-resolution ion angular distributions measured by the V1 LECP during 2002 to $\sim$2003.8 (83-90 AU, N34°) to determine the time- and energy-dependence of the ion anisotropies observed before, during, and after the event proper. Relevant LECP data include one- and three-day averaged intensities of ions 40-4000 keV that arrive in seven of eight 45° sectors. V1 observed short-lived ($\sim$days) intensity increases in early 2002 and mid-2003 with anisotropies that varied rapidly ($\sim$hrs) in magnitude and direction, e.g., from field-aligned sunward to field-aligned anti-sunward. It is likely that some of these pre- and post-event structures are precursor ions that propagate to V1 when the interplanetary magnetic field connects the spacecraft to the high-intensity source. During the event itself, ion anisotropies display energy-dependent variations. We express the ion anisotropies in terms of pitch angle by combining the ion angular data during selected periods of the event with magnetic field vector (**B**) measurements from the V1 Magnetic Field (MAG) instrument. Knowing the field direction, the non-linear Compton-Getting analysis will yield limits on the convection velocity for each given angular distribution. In addition, we can also calculate in the convective frame the parallel and perpendicular pressure components carried by ions 40-4000 keV, and compare these with the measured magnetic field pressure to assess, for instance, whether the streaming energetic particles can be driving a fire-hose instability.

## SH11C-1118 0830h POSTER

### Anomalous Cosmic Rays around the Termination Shock: Effects of a Dynamically Moving Shock

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The location and strength of the termination shock (TS) change in response to time variations in the ram pressure of the solar wind. The flux and energy spectrum of anomalous cosmic rays (ACRs) in the outer heliosphere reflect these variations of the TS. We present simple 1- and 2-D numerical simulations assuming different temporal variations in the solar wind, and in the position of the TS. The predicted variations of energetic ions accelerated at the TS will be discussed in the context of the recent intensity enhancements observed by Voyager-1 in late 2002. We also consider cases when magnetic field lines intersect the termination shock multiple times. This may occur either due to the non-spherical shape of the TS or due to spatial variations in the speed of the solar wind carrying the magnetic field. Some aspects of the mass loading of the supersonic solar wind will also be addressed.

## SH11C-1119 0830h POSTER

### Transport Parameters in the Heliosphere Inferred from Observed Cosmic Ray Spectra

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This contribution analyzes the cosmic ray (CR) modulation through the heliosphere during the solar minimum conditions for 1977/1997 positive and 1987 negative drift periods. We use a time-dependent two-dimensional model of the transport particle equation, that takes into account all physical processes of the modulation, including the effects of the solar wind termination shock and the heliosheath. The best set of diffusion coefficients that fits the observed CR spectra in the inner as well in the outer heliosphere for both anomalous and galactic CR (H and He), is presented. These parameters are compared with those predicted by scattering and turbulence theories. The implications of our results are discussed.

## SH11C-1120 0830h POSTER

### Particle Diffusion on Vortex Structures in the Heliosphere

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Standard theory of energetic particle transport in magnetic irregularities focus on weak random fluctuations described as linear MHD wave modes and does not include non-linear coherent structures such as vortices. To address this shortcoming, a study of energetic particle diffusion in heliosphere with taking into account scattering on vortices is made. We consider vortices as nonlinear coherent planar structures orthogonal to the background magnetic field. They can be derived in the framework of nearly incompressible 2D MHD for a subsonic plasma in the fluid frame with finite plasma beta. Partial solutions which correspond to "zero-frequency" modes in the linear regime are obtained. These solutions take the form of vortices or convective cells in the nonlinear regime. Transport coefficients for energetic

particles moving in a vortex field are evaluated using the Hamiltonian formalism and variational principles. Further applications for study of cosmic ray transport in the heliosphere are discussed.

## SH11C-1121 0830h POSTER

### Composition and Spectral Evolution of Energetic Ions at Voyager 1 in the Vicinity of the Solar Wind Termination Boundary

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For a six-month period beginning in mid-2002, measurements from the Low Energy Charged Particle (LECP) instrument aboard Voyager 1 (V1) indicate that the spacecraft was in a region having a low, subsonic solar wind speed. Before and after this period of interest (POI), the observations indicate higher, supersonic solar wind speeds. During the POI there was a low-energy particle enhancement showing intensity increases up to two orders of magnitude over the preceding period, with a composition that is poor in C, and for which the relative intensities of He and O are consistent with anomalous cosmic ray (ACR) composition. Consistency with ACR composition is determined based on "species scaling" arguments associated with transport effects. However, since the ACR peak for H is obscured by galactic cosmic rays, the relative H composition is uncertain and may diverge from ACR levels at higher energies per nucleon or may indeed differ from ACR-like composition. We have argued that these and other observations offer evidence that V1 crossed the termination shock (TS), resided downstream of the TS in the heliosheath for about six months, and then re-crossed the TS (which has a variable position), thus reentering the region of supersonic solar wind plasma early in 2003. To investigate this event further, we are undertaking analysis on time scales shorter than the entire six-month period, including the investigation of energy spectra using higher temporal resolution. The noted difference between the expected idealized TS spectrum and that which we observe is reduced when shorter time intervals are examined. There are also possible spectral features indicative of the transport of a very local ACR-like population from the TS to V1 in the upstream region just before and after the POI. Using the LECP instrument, which affords the lowest energy particle measurements from V1, we will pursue the ion composition by considering, e.g., the species scaling in light of the possible temporal or piece-wise rigidity dependence of the mean free path length. We will also analyze the spectral evolution before, during, and after the POI on as fine a temporal scale as statistical limitations will allow.

URL: http://space.umd.edu/VOYAGER/

## SH11C-1122 0830h POSTER

### A kinetic theory of energetic particle transport in intermediate-scale compressive velocity fluctuations associated with ion-acoustic waves

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Linear Vlasov kinetic theory indicates that ion-acoustic waves might be weakly damped at low latitudes in the solar wind in a propagation direction along the background magnetic field. The existence of a field-aligned ion-acoustic mode is also supported by nearly incompressible MHD theory of the solar wind. A kinetic pitch-angle dependent transport theory was developed to explore how energetic charged particles respond to the small-amplitude compressive intermediate-scale velocity fluctuations associated with undamped ion-acoustic waves propagating along the large-scale magnetic field. Note that the theory is extended beyond standard quasi-linear theory in the sense that it is assumed in the theory that the particles are already scattering on small-scale MHD fluctuations when interacting with intermediate-scale velocity fluctuations. This coupling between small and intermediate scales in the limit of nearly isotropic particle distributions results in compound parallel spatial diffusion with particle scattering taking place on both small and intermediate scales. Of interest is that the theory implies that diffusive compression particle acceleration can occur whereby suprathermal particles such as pickup ions might acquire a distribution function with a power law spectrum in the quiet low-latitude solar wind.

## SH11C-1123 0830h POSTER

### ROSAT X-ray Observations of the Primary and Secondary Streams of Interstellar Neutral Atoms

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Heavy neutral atoms entering the heliosphere from the interstellar wind are focused downstream of the Sun into a focusing cone, creating a region of enhanced neutral density. Solar wind high charge state ions charge exchange with these neutrals and, in the process, emit soft X-rays ($\sim$0.25 keV). In this presentation, we discuss ROSAT X-ray observations of both the primary and secondary streams of interstellar neutral atoms [Collier et al., Adv. Space Res., in press, 2003]. Results of the analysis indicate a value of $\alpha$ consistent with about $6\mathrm{x}10^{-16}$ eV cm$^2$ (e.g. Cravens, T.E., Ap. J., 532:L153, 2000, eq. 2), a heliospheric contribution to the total X-ray flux ranging from about 18% at about five-ten degrees off the downstream axis to about 40% directly above the downstream axis viewing southward, and a secondary stream entering the heliosphere from above the ecliptic plane which may contain 3-4 times more neutral density at 1 AU than the primary stream, at least during the time of the ROSAT All-Sky Survey. The origin, properties and implications of this secondary stream need to be examined before we can have any confidence that our understanding of the heliosphere is not flawed.

## SH11C-1124 0830h POSTER

### Penetration of interstellar hydrogen, oxygen and nitrogen atoms into the heliosphere through the solar wind-LIC interaction region

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We report on our study of the filtration of interstellar atoms of hydrogen, oxygen and nitrogen in the interaction region between the solar wind and the local interstellar medium. Filtration has great importance for the determination of local interstellar abundances of these elements, which becomes now possible due to measurements of interstellar pickup ions by Ulysses, ACE and Cassini, and anomalous cosmic rays by Voyagers, Ulysses, ACE, SAMPEX and Wind. The filtration of the different elements depends on the level of their coupling with the plasma in the interaction region. We study the dependence of filtration on local interstellar proton and H atom number densities and evaluate the role of charge exchange and electron impact ionization on filtration. We explore the effects of electron temperature in the inner heliosheath on the filtration process. Using our filtration coefficients and recent SWICS/Ulysses pickup ion measurements we determine local abundances of oxygen and nitrogen in the local interstellar medium.

## SH11C-1125 0830h POSTER

### Heliospheric Response to Different Interstellar Hydrogen Parameters

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A range of interstellar cloud types are found within $\sim$ 400 pc of the Sun, including the hot low density plasma interior to the Local Bubble (which the Sun exited some 10-100 kyr ago), diffuse warm quiescent gas, neutral clouds, and shocked and cooled interstellar gas. At present, the heliosphere is embedded in the local interstellar cloud (LIC) which is warm ($\sim$ 7000 K) and moderately dense ($\sim$ 0.2/cc), and travels through it at a Sun-LIC relative velocity of 26 km/s. This suggests that during its lifetime, the heliosphere has been exposed to a large variety of different interstellar environments. By means of numerical modeling, the interaction of the solar wind with a variety of partially ionized interstellar media is investigated. The basic solar wind parameters are assumed as they are today but a range of ISM densities, relative velocities, and temperatures is considered. In response to different interstellar boundary conditions, the heliospheric structure changes, as does the filtration of neutrals in the inner heliosphere, with consequences for pickup ion spectra and cosmic rays in the inner heliosphere. The neutral hydrogen filtration results are given for all models, and filtration results for three models that include the heavy elements He, C, N, O, Ne, and Ar, are added as an application.

## SH11C-1126 0830h POSTER

### Heliospheric X-Rays and the 1/4 keV Soft X-Ray Background Map

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X-rays are generated throughout the heliosphere as a consequence of charge transfer collisions between heavy solar wind ions and interstellar neutrals. The high charge state solar wind ions resulting from these collisions are left in highly excited states and emit extreme ultraviolet or soft x-ray photons. X-rays are also generated because of charge transfer collisions with neutral hydrogen in the Earth's geocorona. Our model simulates this charge transfer mechanism. It uses the Fahr hot model to determine spatial variations of interstellar helium and hydrogen densities. It also uses published terrestrial exospheric hydrogen distributions and solar wind speed, density and temperature distributions to determine x-ray intensities due to charge transfer with geocoronal hydrogen. We used the same viewing conditions as Snowden [1995] for the 1/4 keV channel soft x-ray background map in galactic coordinates, and produce an analogous heliospheric/geocoronal x-ray intensity map. Our preliminary conclusion is that roughly 50% of the total background soft x-ray intensity in the galactic plane and 25

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## SH11C-1127 0830h POSTER

### Ulysses Observations of Short-Period (<30 days) Modulation in Galactic Cosmic Rays

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Earlier a frequency analysis was carried out of the short–period GCR modulation as seen by Ulysses (EPAC, KET) for the time period from December 1993 to May 1994 (Blake et al. GRL 24, 671, 1997). During the five month period, the modulation of GCR protons with E>230 MeV was not the usual 26 days but more than 29 days, and the CIR–associated ∼MeV ions did not exhibit this period shift. Using data from the Energetic Particle Composition (EPAC) instrument on Ulysses, we have searched for other intervals in which the short period modulation of the GCRs deviates from its average value of ∼26 days. The data examined in this study were acquired between January 1992 and December 2001. Using more than one algorithm, we have derived frequency spectra from the data and have compared the results. We have also examined the behavior of the CIR–associated ∼MeV He flux from EPAC during the same time periods. Finally, we have looked for periodicity in the ratios of GCR proton fluxes from the 4 telescopes in the EPAC detector. We discuss the implications of the combined results from each of these analyses. This work was supported at The Aerospace Corporation by JPL under contract 958748 and at MPAe by the Max–Planck–Gesellschaft zur Förderung der Wissenschaften e.V.

### SH11C-1128 0830h POSTER

## Fisk-type Heliospheric Magnetic Fields and Short-Term Variations in Cosmic-Ray Intensities

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The Fisk model of the heliospheric magnetic field (HMF) has proven to be quite difficult to implement in three-dimensional numerical modulation codes. To overcome certain difficulties, we have developed a divergence-free hybrid HMF, which is a Fisk HMF at mid-latitudes, but changes to a Parker HMF in the solar equatorial plane and above the solar poles. Although this field will under-estimate the effects of the Fisk field, its use should give some insight into the effect of an HMF with a periodic meridional and azimuthal components on cosmic-ray modulation. To study the properties of this hybrid field, we solve the three-dimensional steady-state TPE in a system corotating with the Sun, using spherical coordinates in an ADI numerical scheme which covers the entire heliopshere. In this paper we investigate 27-day recurrent variations of both protons and electrons with our model. We find that the amplitude of these variations is directly proportional to the latitudinal gradient in the intensity, in agreement with observational studies. Moreover, we find that this relation becomes less clear if drift effects are reduced in the model. We also consider variations in the magnitude of the components of the HMF observed by the Ulysses spacecraft during its 1994/5 Fast Latitude Scan. Based on a theoretical analysis which predicts a long-term variation in the azimuthal component of the Fisk field, we searched for such variations in Ulysses magnetic field data. Our preliminary analysis shows quasi-periodic variations with periods of the order of several times the solar equatorial rotation period.

# SH11D MCC: Level 2 Monday 0830h

## Abundance Variations in the Solar Corona, Solar Wind, and Solar Energetic Particles II Posters *(joint with SA)*

***Presiding:*** **G Li,** Institute of Geophysics and Planetary Physics, University of California, Los Angeles

### SH11D-1129 0830h POSTER

## Alfvén Waves in Multi-ion Coronal Plasma: Observational Implications

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We investigate low-frequency Alfvén waves in a multi-ion coronal plasma by deriving the dispersion relation of the linearized three-fluid equations in magnetized plasma with coronal parameters. We study the effect of collisions on the velocity amplitude of minor ions due to the Alfvén waves compared to the proton wave amplitude. We find that in the collisionless plasma the minor ion velocity is reduced by the factor $Z/A$ compared to protons, where $Z$ is the ion charge, and $A$ is mass in units of proton mass. When the collision frequency is much larger then the Alfvén wave frequency the velocity amplitude of the minor ions is equal to the proton velocity amplitude. We show the effects of minor ions and collisions on the dispersion relation of Alfvén waves in the three fluid plasma. In view of our results we show how the observed nonthermal line broadening of minor ions relates to the wave motions of protons as a function of heliocentric distance, and the plasma physical parameters.

### SH11D-1130 0830h POSTER

## The X-ray source region of $^3$He-rich solar energetic particle events

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The Reuven Ramaty High Energy Spectroscopic Imager RHESSI allows for the first time to study simultaneously the spatial and spectral characteristics of solar hard X-ray emission in detail. In this paper, RHESSI X-ray imaging spectroscopy is used to investigate the source regions of $^3$He-rich solar energetic particles observed at 1 AU. A series of very large $^3$He-rich events that occurred between August 19-21, 2002 are investigated. The timing of the simultaneously observed electron events suggests that these particle events are related to a series of GOES M class flares. All events originated from the same active region AR0069 and show a similar behavior: Next to the main flaring loops, TRACE observations additionally show an EUV jet that appears to escape from the Sun with a speed of up to 500 km s$^{-1}$. X-ray emission is seen from the main flaring loops as well; however, the most prominent source in >30 keV hard X-rays appears to be displaced from the flaring loops, at the footpoint of the field lines along which the jet is moving outward. We investigate the possibility that the HXR footpoint is produced by the downward moving part of the same electron population that escapes to 1 AU, by comparing the derived electron spectrum from the HXR footpoint source with the in situ observed electron spectrum.

URL: http://sprg.ssl.berkeley.edu/∼krucker/hessi/ace/movie/

### SH11D-1131 0830h POSTER

## First Detection of Hard X-ray Emission From Solar Type III Radio Bursts

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We present the first detection of non-flare related hard X-ray emission from type III radio bursts as observed by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). During a period of 15 minutes on 19 July 2002 14:23-14:35 UT, the WAVES instrument on the Wind spacecraft observed interplanetary type III radio bursts approximately every 2 minutes and each was accompanied by a 12-15 keV X-ray brightening observed by RHESSI. The radio and X-rays fluxes were found to be strongly correlated. No flares were reported in the SEC solar event reports during this time and only the strongest brightening is associated with a detectable enhancement in the GOES levels (A3 above a B8 background). Phoenix-2, a ground-based radio spectrometer, observed each interplanetary type III to extend down to 300 MHz (0.1 $R_\odot$) The strongest type III was also accompagnied by a cluster of decimetric radio emission in the frequency range 1 to 2 GHz. A close correlation is found between X-ray fluxes and the decimetric fluxes. X-ray spectra show non-thermal emission (9-30 keV) with an electron spectral power-law index of ∼4, from the footpoint of a TRACE loop observed in FeXII (195 Å). Subsequently, jets are seen to originate from the RHESSI footpoint emission travelling with apparent speeds of ∼ 100 km s$^{-1}$. The observed RHESSI hard X-ray fluxes require $\sim 10^{33}$ electrons above 10 keV. This work was supported by NASA contract NAS5-98033.

URL: http://sprg.ssl.berkeley.edu/˜schriste/july19/

### SH11D-1132 0830h POSTER

## Temporal Variability of Gamma-Ray Lines from the X-Class Solar Flare of 2002 July 23

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On 2002 July 23, the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) detected a GOES X4.8 solar flare, and analysis of the data has produced the first spectrally resolved measurement of nuclear de-excitation gamma-ray lines in a solar flare. These narrow lines result from accelerated ions colliding with the ambient medium (which includes Fe, Mg, Ne, Si, C, and O nuclei), and thus their relative fluxes probe the composition of the solar atmosphere. We investigate the temporal variability of the flux of these lines by analyzing the observed spectrum for two separate time intervals of the flare (00:27:20-00:32:56 UT and 00:32:56-00:43:20 UT). The relative fluxes in the gamma-ray lines change dramatically between these two intervals, suggesting that the circumstances of ion acceleration change as the flare progresses. We consider the possibility of variations in the nuclear abundances, as well as other possible causes such as a varying alpha/proton ratio or a varying energy spectrum for the accelerated ions. Finally, we compare these variations with the source locations as determined by RHESSI's gamma-ray imaging. The work at the University of California, Berkeley, was supported by NASA contract NAS 5-98033.

### SH11D-1133 0830h POSTER

## Multiple Ions Resonant Heating and Acceleration by Alfven/cyclotron Fluctuations in the Solar Wind

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