In this paper we report the detection of a new heliospheric 2-3 kHz radio emission event by the Voyager 1 spacecraft, the first to be observed during solar cycle 23. The new event started on Nov. 1, 2002, and is believed to be associated with a strong interplanetary shock that originated from a period of intense solar activity in early April 2001. Following previous interpretations of events of this type, we assume that the radio emission is produced when the interplanetary shock interacted with the heliopause, which is the boundary between the solar wind and the interplanetary medium. From the onset time of the radio emission and a simple model for the propagation speed of the interplanetary shock the heliocentric radial distance to the nose of the heliopause can be calculated, and is about 153 to 158 AU, depending on the parameters used. From computer simulations that give the ratio of the radial distance to the termination shock to the radial distance to the heliopause, the distance to the termination shock can also be calculated and is estimated to be about 101 to 108 AU.

SH12B-06 1455h INVITED

The Solar Wind Near 70 AU in the Declining Stage of the Solar Cycle.

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The declining portion of the solar cycle near 35 AU was characterized by a shock-ramp structure with a period of roughly a solar rotation. We discuss the structure observed near 70 AU by Voyager 2, where the shock ramp structure is again seen but with a period of 4-5 solar rotations. At Voyager 2, merging of solar wind driven by CMEs results in correlated changes in speed, density, and magentic field magnititude and thus in dynamic pressure. These order of magnitude changes in pressure should have significant effects on the movement of the termination shock and the propagation of ACRs.

SH12B-07 1510h

Observations of the Anisotropies of Enhanced MeV Ion Fluxes at Voyager 1 at ∼85 AU

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From ∼2002 day 195 through 2003 day 38, the Cosmic Ray Subsystem (CRS) experiment on Voyager 1 (V1) at 85 AU and 34 degrees N recorded a large increase (factor of ∼100) in the intensity of protons with 2-3 MeV. There was no similar increase at Voyager 2 (V2) (∼68 AU and 24 degrees S) during this period. Large and variable field-aligned anisotropies of 3.3-7.8 MeV protons were observed during this period. The variable field direction resulted in large outward and inward radial components of the flow that were much larger than the Compton-Getting convective component. Although the average radial streaming for the entire period was small, it was dominated by the large positive and negative radial components of the field-aligned flows and is not a definitive indicator that V1 crossed the solar wind termination shock. The spectra of anomalous cosmic rays suggests that V1 was not at or beyond the main portion of the termination shock. This work was supported by NASA under contract NAS7-1407 and by JPL under contract 959167.

SH12B-08 1525h

Is the Local Interstellar Medium Strongly Magnetized?

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The magnitude and direction of the magnetic field in the Local Interstellar Medium remain by far the poorest known parameters of the solar system space environment. The current prevailing opinion is that the magnitude of the field is relatively small (1.5 microGauss) and close to the galactic average. The above value is based on the heliospheric confinement data and remains too small to account for the general equilibrium between matter in the Local Bubble and the Local Interstellar Cloud. Here we analyze the consequences of the magnetic field being almost 3 times larger on the structure of the heliospheric interface in the axisymmetric case when the LIC magnetic field direction is parallel to the relative direction of motion between the LISM and the Sun. A field of such strength is expected to exist in the LIC, if the latter condensed from material inside a magnetic flux tube rebounding from the wall of the Local Bubble cavity. The analysis is performed using a newly developed multifluid-neutral MHD model. We show that a bow shock ahead of the heliopause still exists for supersonic and subalfvenic LISM parameters, and is of a slow, rather than a fast, type. Our results agree well with the observations of the Lyman-Alpha absorption spectra and exhibit positions of the termination shock and the heliopause similar to those obtained from the standard superalfvenic model.

SH12C MCC: 2008 Monday 1600h

The Termination Shock, Heliosheath, and Heliopause III

Presiding: **V Florinski,** Institute of Geophysics and Planetary Physics, University of California, Riverside; **W H Matthaeus,** Bartol Research Institute, University of Delaware

SH12C-01 1600h

Rapid Slow-Down of the Solar Wind Upstream of the Termination Shock from Strong Electron-Impact Ionization of Interstellar Neutrals: A Possible Explanation of the Voyager Observations

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Slow-down of the solar wind due to mass-loading from interstellar pickup ions upstream of the heliospheric termination shock may explain the recent Voyager 1 low-energy particle and magnetic field observations. This slowing down of the solar wind is expected to be accompanied by comparable increases in magnetic field strength, B, as is required by the "frozen-in" magnetic field condition. We suggest that the solar wind speed decrease during 2002, and consequently the B increase, is likely to have occurred in two steps: first, the speed decreased gradually due to mass loading by pickup H and He from ∼430 km/s at 1 AU to ∼350 km/s at 70 AU, and then more rapidly to lower values at ∼85 AU, due to, e.g., additional production of pickup ions from electron-impact ionization with enhanced fluxes of suprathermal electrons produced in, e.g., the fast-slow wind stream-stream interaction region associated with the heliospheric current sheet. These additional pickup ions would cause the additional decrease in speed to between ∼200 and ∼300 km/s at 85 AU, consistent with the solar wind speed inferred from Voyager 1 LECP measurements during 2002-2003 upstream of the termination shock. We will discuss the implications of this scenario on the termination shock location and present some ideas on how the suprathermal electrons may be produced.

SH12C-02 1615h

Hydromagnetic Wave Excitation at a Heliospheric Shock

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We present observational evidence for self-consistent wave-particle interaction upstream of the main interplanetary traveling shock driven by the Bastille Day coronal mass ejection. Spectra of protons in the energy range 300 keV to 2 MeV derived from SOHO/CELIAS/HSTOF data and the power spectral densities of the magnetic field fluctuations measured by the magnetometer onboard ACE are consistent with theoretical predictions on coupled hydromagnetic wave excitation by protons with asymmetric distribution near interplanetary traveling shocks. We discuss theoretical models and apply them to describe the generation of turbulent plasma waves in the outer heliosphere by Anomalous Cosmic Rays. These waves mediate the termination shock, which has impact on its structure and location. Lee, M.A., Coupled Hydromagnetic Wave Excitation and Ion Acceleration at Interplanetary Traveling Shocks, JGR 88, 1983, pp. 6109-6119

SH12C-03 1630h

Location of the termination shock: an attempt to reconcile recent Voyager observations with Ulysses/SWICS pickup ion data and other diagnostics

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Our Solar System moves through a warm (∼6,500 K), partly ionized local interstellar cloud (LIC) with a relative speed of ∼26 km/s. The solar wind interacts with the LIC to form a cavity around the Sun called the heliosphere. The solar wind meets the interstellar charged component at the heliopause, where solar wind pressure balances the pressure of the LIC. Before reaching the heliopause, the supersonic solar wind is decelerated at an extended shock wave, the heliospheric termination shock (TS). Here we apply our new multi-component time-dependent model of the interaction of the solar wind with the local interstellar medium to predict the location of the TS. We put constraints on the model parameters by using (1) IMP 8, ACE, Wind and Ulysses observations of the solar wind velocity and numbers density at one to several AU, (2) SWICS/ Ulysses pickup ion data, (3) Ulysses and Wind measurement of interstellar helium, and (4) recent results on ionization of helium and hydrogen in the LIC (Wolff et al., 1999). These four sets of observational data allow us to determine that the TS location should be between 93−100 AU in 2003. Our model predicts the heliopause location at ∼ 160 AU, which is in agreement with analyses of the heliospheric radio emission events of 1983−1984 and 1992−1994 at the plasma cutoff frequency 2.2−2.8 kHz detected by Voyagers 1 and 2. However, recent measurements of the enhanced fluxes of energetic particles observed by the LECP and CRS instruments on Voyager 1 suggest that Voyager 1 at ∼ 85 AU was close or beyond the TS

during 2002/07-2003/02. In this paper we will try to reconcile recent Voyager observations with other diagnostics of the heliospheric interface and discuss different scenarios. Wolff, B., D. Koester and R. Lallement, Evidence for an ionization gradient in the local interstellar medium: EUVE observations of white dwarfs, Astron. Astrophys. 346, 969-978, 1999.

SH12C-04 1645h

Evidence of Dynamical Variations in the Termination Shock

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In the vicinity of the termination shock, changes in the spectra of anomalous cosmic ray (ACR) He and O ions will reflect changes in the location of the shock and in the intensity of ACRs at the shock where they are accelerated. Comparing the evolution of the ACR spectra at Voyager 1 and 2 over the last two years indicates the shock has moved inward during that time while the ACR source intensity at the shock increased. This is consistent with the recovery of the shock from a collision with a Merged Interaction Region in early 2001 as modeled by Zank and Mueller and Jokipii et al. and suggests that the termination shock is likely very dynamic with transient motions of several AU driven by collisions with regions of high pressure solar wind. This work was supported by NASA under contract NAS7-1407.

SH12C-05 1700h

Anomalous-Cosmic-Ray and Plasma Signatures of the Termination Shock

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We consider the response of anomalous cosmic rays (ACR) and the solar-wind plasma to a transient radial incursion of the solar-wind termination shock, in the context of recent Voyager observations. Such an incursion is likely to *not* be global and have limited extent in the transverse directions (latitude and longitude). We find that the (ACR) spectrum and anisotropy have temporal variations which depend on the time and transverse spatial scale of the radial incursion, its speed, and the energetic-particle transport coefficients. For reasonable parameters, the energy spectrum of the very-low-energy particles shows the largest effect, and the spectrum of the higher-energy particles the least. The transverse component of the heliospheric magnetic field must increase by a factor equal to the ratio of preshock to post-shock solar wind speed. Finally, the shock-accelerated energetic-particle anisotropies near, but upstream of the shock will have a signficant *diffusive* anistropy comparable and opposite to the Compton-Getting anisotropy. We conclude that the ACR spectrum and anisotropies expected at or near a shock crossing may be consistent with the observed spectra if one considers the likely case of transient,localized incursions of the termination shock.

SH12C-06 1715h

Structure of the Heliospheric Termination Shock Revisited

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With the possibility that the Voyager spacecraft are flirting with a termination shock crossing, the question of just what might be observed is assuming greater importance. Although the shock is expected to be quasi-perpendicular, suprathermal pickup ions and superthermal anomalous cosmic rays are likely to play a fundamental role in determining the shock structure and associated scale-lengths. This has led to a model termination shock in which upstream pickup ions decelerate the incident solar wind flow, reflected pickup ions determine the scaling of the foot ahead of a subshock transition, and anomalous cosmic rays create a smooth precursor ahead of the shock which scales with the anomalous cosmic ray diffusive length scale. The general picture is therefore one of a smoothed shock with well-defined length scales. However, the structure of a cosmic ray mediated termination shock is unlikely to be as simple as suggested. We show that the gradient in shock accelerated anomalous cosmic rays can generate strong compressive instabilities in the foreshock and strong incompressible instabilities along the face of the quasi-perpendicular termination shock. The latter are particularly effective in promoting the growth of large magnetic fields at the shock. These cosmic ray gradient driven hydrodynamic and MHD instabilities are analogous to a generalized form of Rayleigh-Taylor instability. Secondly, we show that the pickup ions themselves can drive a buoyancy-like hydrodynamic instability which is further amplified in combination with the cosmic ray driven instabilities. The picture of the termination shock that emerges is instead one that is highly turbulent on hydrodynamic and MHD scales and bears little resemblance to the conventional smoothed cosmic ray mediated shock model. In view of the highly turbulent nature of the shock, we reconsider particle transport in the presence of a highly perturbed flow field and find that the usual cosmic ray transport equation is modified substantially. The new transport equation is solved for conditions appropriate to the termination shock and the resulting anomalous cosmic ray spectra described.

SH12C-07 1730h

Anisotropies of anomalous and galactic cosmic rays upstream and downstream of the termination shock

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Anisotropies of low-energy anomalous and galactic cosmic rays observed in the heliosphere can come from the Compton-Getting effect, particle diffusion and gyration effect associated with particle density gradient. When the spacecraft is connected to the particle source at the termination shock by magnetic field lines within a few particle mean free paths, particle streaming may also contribute to the anisotropy. A straightforward determination of solar wind speed based on the simple assumption that the anisotropy comes from the Compton-Getting effect may derive an incorrect value. This is particularly true near and upstream the termination shock where the particle gradient could be large enough to yield a diffusive anisotropy that cancels the Compton-Getting effect. In this paper, we present the results of a calculation of anomalous and galactic cosmic ray anisotropy using a heliospheric model that includes the termination shock and a heliosheath. Comparison with recent Voyager observations at 85-89 AU will be discussed. This work was supported in part by NASA Grant NAG5-11036.

SH12C-08 1745h

Interstellar Ne and Ar in the Heliosphere: Diagnostics of Interstellar Ionization and Outer Heliosphere Processes

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Interstellar material dominates the mass density in the heliosheath, and the physical properties of the heliosheath regions are shaped by the interaction of the interstellar medium (ISM) with the solar wind. The characteristics of pickup ions, anomalous cosmic rays, and He observed inside of the solar system depend on the chemical composition and ionization of the cloud surrounding the solar system. Currently, radiative transfer models of the surrounding cloud, constrained by observations of ISM inside and outside of the heliosphere, provide the best determination of cloud properties. We present recent models of the surrounding cloud based on in situ and astronomical observations of the ISM. These models imply n(HI) 0.21 /cc at the solar location and subsolar interstellar abundances for many common elements. The models also yield direct predictions of filtration in the heliosheath regions, yielding F(H) 0.4, F(O) 0.6, F(N) 0.7, and F(Ar) 0.6. The robustness of these models is tested against observations and models of pickup Ne and anomalous cosmic ray Ar in the heliosheath regions, which in turn constrains the ionization of the surrounding interstellar cloud.

SH21A MCC: 3006 Tuesday 0800h

Physics of Eruptions in the Low Solar Atmosphere I

Presiding: **G R Lawrence,** NASA Goddard Space Flight Center**; D Alexander,** Rice University

SH21A-01 0800h INVITED

The Acceleration of Coronal Mass Ejections

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To determine quantitative estimates of the net force acting on a CME requires knowledge of the CME acceleration as a function of distance from the solar surface. The CME acceleration is determined directly from the observed time-height trajectory of the event by two methods: (a) sucessive differentials and (b) the use of polynomial and exponential function curve fitting to the trajectory, followed by successive derivatives. We examine the acceleration of a set of Coronal Mass Ejections (CMEs) observed over a wide range of coronal scale heights by combining observations of the low corona from the Mauna Loa Solar Observatory and the Extreme ultraviolet Imaging Telescope (EIT) on the Solar and Heliospheric Observatory (SOHO) spacecraft with observations from the LASCO coronagraphs onboard SOHO. We apply both of the above techniques to the events and conclude that CME acceleration is greatest in the low corona despite the strong force of gravity in that region. (In addition, CME start times determined from outer coronal (LASCO) observations alone tend to be systematically later than the actual start times, most likely due to the fact that LASCO observations cannot observe CME acceleration in the low corona.)

SH21A-02 0820h INVITED

Acceleration of CMEs: A Diagnostic for Driving Mechanisms?

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Typical coronal mass ejections (CMEs) undergo the bulk of their acceleration low in the corona. Theoretical analysis based on a three-dimensional flux-rope geometry [1] shows that CME acceleration profiles exhibit a universal scaling law characterized by the critical scale height $Z_* \equiv S_f/2$, where S_f is the separation distance between the two stationary footpoints of the flux rope. Specifically, maximum acceleration is attained shortly after the apex of the flux rope reaches height Z_* from the solar surface, and the acceleration is subsequently reduced to about 1/4 of the peak value when the apex reaches height $Z_m \simeq 3Z_*$. This means that the observed acceleration profile in the low corona can directly yield information on the geometrical size of the flux rope, i.e., S_f. The S_f scaling is applicable regardless of the eruption speed so long as the pre-eruption structure is a flux rope or becomes one early enough in the eruption process. The scaling law has been tested against observed CMEs using TRACE, C1, C2, and C3 data, with good quantitative agreement, and is consistent with a recent simulation of a 3-D flux rope [2]. We discuss the observational implications of these results with respect to various proposed CME models and driving mechanisms. [1] Chen, J., and J. Krall, Acceleration of coronal mass ejections, *J. Geophys. Res.*, in press, 2003 [2] Roussev, I. I., et al., *Astrophys. J.*, *588*, L45, 2003. Work supported by ONR and NASA