SH21B MC: 302 Tuesday 0830h

Shocks and Shock Manifestations Over the Solar Cycle I *(joint with SM)*

Presiding: **D B Berdichevsky,** NASA/Goddard Space Flight Center**; A Lazarus,** Massachusetts Institute of Technology

SH21B-01 0830h INVITED

Solar Cycle Variation of Shocks in the Heliosphere

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IMP 8 has measured solar wind parameters since 1973 near Earth. Voyager 2 has observed the solar wind at increasing heliospheric distances since 1977. This paper presents a statistical study of shock parameters from these two spacecraft supplemented with WIND data after 1994. As expected, a solar cycle dependence of shock frequency is observed. We determine shock strength and angles and report their time variation near Earth. We also compare shock frequencies and characteristics at 1 AU with those observed by Voyager 2 out to 60 AU.

SH21B-02 0850h INVITED

Multi-Spacecraft Observations of Interplanetary Shocks in the ISTP Era

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Interplanetary shocks near Earth have been observed, even with multiple spacecraft, since the very beginning of the space age. The ISTP fleet of upstream solar wind monitors (WIND, IMP 8, ACE and on occasion Geotail and Interball and mosr recently Cluster) allowed the collection of a very large database of a wide range of interplanetary shocks observed by two or more spacecraft in a variety of configurations. This talk will review the observed characteristics of the shocks based on in-situ observations. Also the various shock fitting techniques available today will be compared and sources of uncertainties in the obtained shock surface normals and speeds will be discussed. Cases with demonstratible surface curvatures will be shown along with highly complex observations defying simple interpretations. Special emphasis will be placed on the largest and strongest shocks that may have the most pronounced geomagnetic effects.

SH21B-03 0905h

Formation and Development of Shock Waves in the Solar Corona and Near-Sun Interplanetary Space and Solar Energetic Particle Events

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At the Sun shock waves are produced either by flares or by coronal mass ejections and are regarded as the source of solar energetic particle events. In the corona shock waves appear as solar type II radio bursts often associated with coronal transient (or EIT) waves. The propagation of a disturbance through the corona away from an active region into the interplanetary space is considered by evaluating the radial behaviour of the Alfven speed. The magnetic field of an active region is modelled by a magnetic dipole and is superimposed on that of the quiet Sun as deduced from the EIT wave analysis. Such a behaviour of the magnetic field leads to a local minimum of the Alfven speed in the range 1.2-1.8 solar radii in the corona as well as a maximum of 740 km/2 at a distance of 3.8 solar radii. The occurrence of such a minimum and maximum of the Alfven speed has important consequences to the formation and development of shock waves in the corona and near-Sun interplanetary space and to their ability to accelerate particles leading to a special temporal behaviour of solar energetic particle events.

SH21B-04 0920h

Relation between Shock and CME Velocities During the Rise to Solar Maximum in the Intermediate Corona

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We considered type II radio bursts observations in conjunction with the SOHO-UVCS synoptic program of monitoring of the extended solar corona. We selected events observed during the period 1999-2000, in order to have a good continuity in the synoptic observations and frequency of radio bursts. Our main purpose is to obtain information about the velocity of the shock, and compare it with the observed CME speed to determine if the shock is piston-driven or blast-wave driven. A major improvement with respect to previous analogous studies, is that we do not use electron density models taken from literature, but we estimate the densities soon before and after the passage of the shock from UVCS observations of the O VI doublet line intensities. The background outflow speed of the coronal plasma is calculated with the Doppler dimming technique applied to the O VI doublet. The above density determinations allow us to constrain the magnetic field intensity above the active regions corresponding to CME's and radio bursts with proper assumptions about the magnetic field geometry and the propagation direction of the shock.

SH21B-05 0935h

Modelling of a CME-driven Shock Detected by UVCS/SoHO on March 3, 2000

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We report the observation of a 1100 km/s CME-driven shock with the UltraViolet Coronagraph Spectrometer (UVCS) telescope operating on board SoHO on March 3, 2000. The CME was observed by the Large Angle Spectroscopic Coronagraph (LASCO), and the radio signature of the shock was detected by the Hiraiso and Culgoora radio spectrographs as an intense type II radio burst. We derived the density profile just before the passage of the shock from UVCS observations and obtained a reliable estimate of the shock speed from the type II radio burst drift rate. The spectral profiles of both the O VI and Lyman alpha lines were Doppler dimmed at the passage of the shock and showed broad wings caused by the emission from shocked material along the line of sight. By estimating a compression ratio of 1.8 from the observed splitting of the radio emission bands in the spectrographs and assuming perpendicular propagation of the shock we derive a magnetic field strength of 1 Gauss at 1.8 solar radii and an Alfvenic Mach number of 1.7. The observed line broadening for both the protons and the Oxygen ions was modeled by adopting a mechanism in which the heating is due to the nondeflection of the ions at the shock ramp.

SH21B-06 1025h INVITED

Formation of the Bastille Day Merged Interaction Region

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We present a simulation study for the radial evolution of the large solar wind stream associated with the flare of July 14, 2000 (Bastille day). An interaction region bounded between a forward-reverse shock pair first formed near 1 AU at the leading edge of the large stream; the interaction region continued to interact with the solar wind structures and other shocks identified at the leading edges of nearby streams to form a merged interaction region (MIR). The model treats shocks as surfaces of zero thickness, and the Rankine-Hugoniot relations are used to calculate the jump conditions at all shocks. The simulation shows how merging of shocks, collision of shocks, and formation of new shocks contributed to the evolution process. The solar wind was restructured from a series of large and small streams at 1 AU to a huge MIR outside 5 AU. The magnetic field structure outside 5 AU bore no resemblance to the parent structure at 1 AU; the magnetic field had relatively small variation throughout the interior of the MIR, and the field intensity was a few times stronger than that outside the MIR. This MIR can act as a barrier to the propagation of galactic cosmic rays. Possible Voyager 2 observation of this MIR at 63 AU in January 2001 has been reported by Burlaga et al. [2001] and by Wang et al. [2001].

SH21B-07 1045h

A Survey of Corotating Shocks at Pioneer, Voyager, and Ulysses at Low Heliographic Latitudes

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Interplanetary shocks associated with corotating interaction regions (CIRs) are a dominant feature in the solar wind in the vicinity of the solar equator over most of the solar cycle between heliocentric distances of 1 and 15 AU. These events are associated with a broad range of phenomena in the inner and outer heliosphere. The region between heliocentric distances of 1 and 5 AU is of particular interest, for this is the region where most CIRs form and the strength of their associated shocks is at a maximum. Observations from the Pioneer, Voyager, and Ulysses spacecraft provide a unique opportunity to examine the behavior and evolution of corotating shocks in this region. The Pioneer 10 and 11 spacecraft provided observations between 1 and 5 AU during the descending phase of solar cycle 20, when solar activity was low. The Voyager 1 and 2 spacecraft provided observations between 1 and 5 AU during the ascending phase and maximum of solar cycle 21, when solar activity was significantly higher. The Ulysses spacecraft provided comparable observations during the ascending phase and maximum of solar cycle 22 during the low latitude phase of its mission. Measurements of solar wind and IMF parameters from the Pioneer 10 and 11, Voyager 1 and 2, and Ulysses spacecraft were used to conduct a large-scale survey of corotating shocks at heliocentric distances between 1 and 5 AU. Comparison of observations from these five spacecraft makes it possible to resolve many of the effects of radial evolution, solar cycle variation, and differences between successive solar cycles. The results of this survey are discussed.

SH21B-08 1100h

Observations of the Sudden Compression of the Earth's Magnetotail by the Passage of Interplanetary Shocks: Comparison with Equilibrium Theory

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In the ISEE-3/ISEE-2 data set, four instances have been found in which an interplanetary shock passes the magnetosphere while ISEE-2 is in the magnetotail plasma sheet. Each time, an increase of the plasma density and plasma temperature is seen during the shock passage, along with a plasma flow toward the center of the magnetotail. A few minutes after the shock passes, a strong earthward flow of plasma commences in the magnetotail. This earthward flow lasts for about 6-7

minutes. The magnetosphere, which was in MHD equilibrium with the solar wind before the shock, is suddenly put out of dynamical equilibrium by the increased pressure behind the shock; for a plasma-sheet adiabatic index that is less than 2, Birn and Schindler [J. Geophys. Res., 88, 6969, 1983] have predicted that this global magnetotail flow should be directed earthward as the magnetotail seeks its new equilibrium. These four ISEE-3/ISEE-2 interplanetary shock intervals are very useful for magnetospheric physics because (a) the adiabatic index of the magnetospheric plasma can be measured by ISEE-2 during the shock compression of the magnetosphere and (b) the spatial structure of turbulence in the magnetotail can be viewed as the global earthward flows sweep the plasma and magnetic fields past the ISEE-2 satellite.

SH21B-09 1115h

Post-shock ULF Wave Activity Driven by Dynamic Pressure Variations

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In this work we present analyses of events in which ULF wave activity was observed following the impact of an interplanetary shock. The transmission of compressional energy from the impact of such shocks on the magnetosphere has been postulated as a source for global cavity mode oscillations. We show that oscillations inside the magnetosphere following the shock passage are well correlated with oscillations of the solar wind dynamic pressure, a result unexpected from the cavity mode model. Rather than providing a broadband source of energy to the magnetospheric cavity, we suggest that the magnetospheric pulsations are directly driven by the dynamic pressure variations.

SH21B-10 1130h

AN ASSESSMENT OF THE US ELECTRIC POWER INDUSTRY HAZARD RISK DUE TO SSC, SC, SI AND RELATED MAGNETOSPHERIC SHOCK DISTRUBANCES

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A discussion will be provided on the impacts of large SSC shock events on the geomagnetic field and resulting impacts to electric power infrastructures caused by these events. Recent work by Metatech has shown that SSC events have been a large-scale threat to reliable operation of the power grid and that the impact of these disturbances can occur over very large geographic extent and can impact power systems even at very low-latitudes. Evidence of previous SSC events and impacts will be provided along with an assessment of potential threat impacts to the US and world electric power industry. Discussion regarding forecast needs for these events will also be provided.

SH22A MC: Hall D Tuesday 1330h

Cosmic Rays

Presiding: **J Kota,** University of Arizona

SH22A-0743 1330h POSTER

Long-Term Fluences of Energetic Particles in the Heliosphere

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We report energy spectra of He, O, and Fe nuclei, extending from ∼0.3 keV/nucleon to ∼300 MeV/nucleon, integrated over the period from the Fall of 1997 to mid-2000. These fluence measurements were made at 1 AU using data from the SWICS,. ULEIS, SIS, and CRIS instruments on ACE, and include contributions from fast and slow solar wind, coronal mass ejections, pickup ions, impulsive and gradual solar particle events, acceleration in corotating interaction regions and other interplanetary shocks, and anomalous and galactic cosmic rays. Measurements of six additional species are presented in the energy region from ∼0.04 to ∼100 MeV/nucleon. We discuss the relative contributions of the various particle components, and comment on the shape and time dependence of the measured energy spectra. In the energy range from ∼10 keV/nucleon to ∼10 MeV/nucleon as many as 100 or more separate particle events somehow combine to produce E^{-2} power-law spectra that are common to all of the species measured, including ^{3}He. These are the first spectral measurements to extend continuously from solar-wind to cosmic-ray energies. Given the highly variable composition and intensity of the contributing events, the overall similarity of these fluence spectra is surprising.

SH22A-0744 1330h POSTER

The Ulysses fast latitude scan at solar maximum: COSPIN/KET observations

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Ulysses, launched in October 1990, began in December 1997 its second out of ecliptic orbit, and in September 2000 its second fast latitude scan. In contrast to the first fast latitude scan in 1994/1995 solar activity is close to maximum. It is important to note, that in addition to the different solar activity levels the solar magnetic field had reversed in 2000. While the first latitude scan gave a snapshot of the spatial distribution of galactic cosmic rays the second one is determined by temporal variations. Solar particle increases are observed at all heliographic latitudes, including events producing >250 MeV protons and ∼50 MeV electrons. Sources of MeV electrons in the inner heliosphere are 1) solar energetic particle events, 2) galactic cosmic rays, and 3) Jupiter. Since the first population is generally accompanied by energetic nucleons they can be distinguished from the other components by investigating e.g. 34-69 MeV protons. We found "quiet time" increases at all heliospheric latitudes, which indicate either very large perpendicular diffusion or the possibility of direct magnetic connection from low latitudes to polar regions. Concerning galactic cosmic ray modulation, we will compare the latitudinal gradient as well as the charge sign dependent variation for both Ulysses fast latitude scans.

SH22A-0745 1330h POSTER

Ulysses/KET Cosmic Ray Variability in Polar Coronal Hole Flow

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Large-scale solar wind structures such as corotating interaction regions (CIRs) are responsible for recurrent modulation of galactic cosmic rays. High latitude observations of >125 MeV protons by Ulysses/COSPIN/KET give indications that modulation on the basis of the solar rotation period is present at high heliographic latitudes. The fact that the observations were recorded at latitudes beyond the reach of CIRs points towards the field model with large-scale motion of magnetic field lines introduced by Fisk [1996]. The model predicts direct magnetic connections of field lines at high and low latitudes. We investigate the nature of cosmic ray modulation for the 1993/1994 Ulysses south polar pass by applying a 3-D field line mapping technique based on this field model. The results will be discussed.

SH22A-0746 1330h POSTER

The Mean Free Pathlength of Anomalous Cosmic Rays in the Outer Heliosphere at Solar Maximum

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By December 2001, the Voyager 1 (V1) spacecraft will be at 83.1 AU and 33.8° North heliographic latitude and Voyager 2 (V2) will be at 65.7 AU and 23.1° South. At that time, the reversal of the Sun's magnetic field, which was complete at the Sun by the beginning of 2001, should be complete in the vicinity of the Voyager spacecraft. The current sheet should still be highly inclined in the outer heliosphere and the anomalous cosmic ray (ACR) intensities should be near their minimum values. By comparing the intensities of ACRs at V1 and V2 we will infer the magnitude and rigidity dependence of the particle mean free path in the outer heliosphere at solar maximum and compare the results with those obtained during the previous solar maximum period in 1990-91.

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SH22A-0747 1330h POSTER

Small Residual Modulation of >2.5 GV Anomalous Cosmic Rays at 81 AU

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The flux of >13 MeV/nuc anomalous cosmic ray oxygen observed by ACE at 1 AU has been reduced by a factor of more than sixty during the current solar maximum. However, the recent arrival of solar maximum conditions in the outer heliosphere has resulted in a reduction of less than factor of two at Voyager 1 at 81 AU. This indicates there is little residual modulation between Voyager 1 and the ACR source at the termination shock for ions with rigidities greater than 2.5 GV. The modulation between Voyager 1 and Voyager 2 at 64 AU is somewhat larger, suggesting that Voyager 1 is closer to the shock than to Voyager 2. The most recent observations will be compared with model calculations to estimate the remaining distance between Voyager 1 and the termination shock.

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