SPA-Solar and Heliospheric Physics

SH13A CC: 518 C Monday 1330h

Fresh Perspectives in Solar-Heliospheric Science I

Presiding: **I G Richardson,** NASA Goddard Space Flight Center**; E J Smith,** Jet Propulsion Laboratory, California Institute of Technology

SH13A-01 1330h INVITED

Ubiquitous Energy Dependence of Ionic Charge States - Challenge and Opportunity

Eberhard Moebius (1 603 862 3097; eberhard.moebius@unh.edu)

Dept. of Physics and Inst. for the Study of Earth, Oceans and Space, University of New Hampshire, 39 College Road, Durham, NH 03824, United States

Early observations of ionic charge states in energetic particles had drawn a relatively simple picture: strong CME-related energetic particle events resembled the charge states of coronal material, while impulsive flare events were characterized by rather high charge states with full ionization for elements up to Mg. In other words, the charge state of energetic particles appeared to reflect nothing but the charge distribution at the source, with no modification in energy. However, the advent of high collection power and resolution instrumentation on ACE, SAMPEX, and SOHO that covers a wide range of energies from the potential sources to several MeV/nuc has revealed an almost ubiquitous presence of energy dependence in the charge states under a wide variety of circumstances. In particle populations that clearly originate from interplanetary acceleration a modest increase in the charge state of Fe with energy is observed that can be explained in terms of rigidity dependent acceleration and loss mechanisms. In several strong solar energetic particle events with unusual composition signatures and in impulsive flare events a very steep increase of the charge state with energy has been observed, which has been shown to be consistent with the effects of stripping for higher energy ions when escaping through a large column density of material. For impulsive events this lends independent support for the idea that the combination of selective acceleration and almost fully stripped ions up to Mg requires a similar scenario. Finally, contributions from sources with different composition and acceleration efficiencies can explain the observation that the He+/He2+ ratio increases with energy for many of the observed episodes. The observed variety of observations poses the challenge to sort out confusing combinations of phenomena, but on the other hand it also provides the opportunity to probe source combinations, acceleration, and escape mechanisms.

SH13A-02 1350h

The Interstellar Boundary Explorer (IBEX)

David J. McComas[1] (210-522-5983; dmccomas@swri.edu); Frederic Allegrini[1]; Peter Bochsler[2]; Maciej Bzowski[3]; Michael R. Collier[4]; Hans Fahr[5]; Horst Fichtner[6]; Priscilla Frisch[7]; Herb Funsten[8]; Steve Fuselier[9]; Mike Gruntman[10]; Vladislav Izmodenov[11]; Paul Knappenberger[12]; Marty Lee[13]; Stefano Livi[14]; Don Mitchell[14]; Eberhard Moebius[13]; Tom Moore[4]; Dan Reisenfeld[8]; Ed Roelof[14]; Nathan Schwadron[1]; Martin Wieser[2]; Manfred Witte[15]; Peter Wurz[2]; Gary Zank[16]

[1] Southwest Research Institute, P.O. Drawer 28510, San Antonio, TX 78228, United States

[2] University of Bern, Sidlerstrasse 5, Bern, Switzerland

[3] Space Research Ctr, Polish Academy of Sciences, Bartycka 18 A, Warsaw, Poland

[4] NASA Goddard Space Flight Center, Code 692, Greenbelt, MD 20771, United States

[5] Universitaet Bonn, Auf dem Hugel 71, Bonn, Germany

[6] Ruhr-Universitaet Bochum, Lehrstuhl IV, Bochum, Germany

[7] University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637, United States

[8] Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545, United States

[9] Lockheed Martin, 3251 Hanover Street, Palo Alto, CA 94304, United States

[10] University of Southern California, MC 1191, Los Angeles, CA 90089, United States

[11] Lomonosov Moscow State University, Vorob-evy Gory, Glavnoe Zdanie MGU, Moscow, Russian Federation

[12] Adler Planetarium and Astronomy Museum, 1300 South Lake Shore Drive, Chicago, IL 60605, United States

[13] University of New Hampshire, Space Science Center, Morse Hall, Durham, NH 03824, United States

[14] Applied Physics Laboratory, JHU, 11100 Johns Hopkins Road, Laurel, MD 20723, United States

[15] Max Planck Institute Aeronomie, Max Planck Strasse 2, Lindau, Germany

[16] University of California, Riverside, Inst. Geophy. and Planetary Physics Dept., Riverside, CA 92521, United States

The Interstellar Boundary Explorer (IBEX) is one of five Small Explorer (SMEX) missions undergoing Phase A study for NASA's Office of Space Science. Around November 2004, NASA expects to select two of these five missions for development and flight. If selected, IBEX will provide the first global views of the Sun's interstellar boundaries by taking a set of global energetic neutral atom (ENA) images at a variety of energies. Recent advances in ENA imaging have made it possible to remotely image space plasmas and ENA imaging is now poised to image the interstellar interactions and interstellar boundaries at the edge of our heliosphere. On IBEX, these groundbreaking ENA observations are achieved with high sensitivity measurements provided by two very large aperture ENA cameras, using heritage technologies, on a simple spinning spacecraft. IBEX's highly elliptical Earth orbit provides viewing of the outer heliosphere from beyond the relatively bright emissions of the Earth's magnetosphere. IBEX's sole, focused science objective is to discover the global interaction between the solar wind and the interstellar medium. IBEX achieves this objective by answering four fundamental science questions: (1) What is the global strength and structure of the termination shock, (2) How are energetic protons accelerated at the termination shock, (3) What are the global properties of the solar wind flow beyond the termination shock and in the heliotail, and (4) How does the interstellar flow interact with the heliosphere beyond the heliopause? The IBEX objective is central to the Sun-Earth Connection (SEC) theme as demonstrated by both the 2003 SEC Roadmap and 2002 NRC's Decadal Survey and is specifically identified in the 2003 NASA-wide Strategic Plan. In short, the IBEX mission provides the first global views of the Sun's interstellar boundaries, unveiling the physics of the heliosphere's interstellar interaction, providing a deeper understanding of the heliosphere and thereby astrospheres throughout the galaxy, and creating the opportunity to make even greater unanticipated discoveries.

SH13A-03 1405h

Travelling interplanetary shocks: their local orientations and inference of their global characteristics

Daniel B Berdichevsky[1,2] (301 286 4608; xrdbb@lepvax.gsfc.nasa.gov); Donald V Reames[2] (reames@lheavx.gsfc.nasa.gov); Ronald P Lepping[2] (rpl@leprpl1.gsfc.nasa.gov); Rainer Schwenn[3] (schwenn@linmpi.mpg.de); Charles J Farrugia[4] (charlie.farrugia@unh.edu); Chin-Chun Wu[2,5] (ccwu@lepvax.gsfc.nasa.gov); Robert J MacDowall[2] (robert.macdowall@gsfc.nasa.gov); Michael L Kaiser[2] (mkaiser@pop600.gsfc.nasa.gov); Alan J Lazarus[6] (ajl@space.mit.edu); Justin C Kaspers[6] (jck@space.mit.edu)

[1] L3 Goverment Services Inc, 1801McCormickDrive, Suite 170, Largo, MD 20774, United States

[2] NASA/GSFC, Mail Code 600, Greenbelt, MD 20771, United States

[3] Max-Planck-Institut für Aeronomie, Max-Planck Strasse 2, Max-Planck-Institut für Aeronomie, Katlenburg-Lindau D 37191, Germany

[4] University New Hampshire, Space Science Center, Durham, NH 03824, United States

[5] University of Alabama, CSPAR, Huntsville, AL 35899, United States

[6] MIT, 77 Massachusetts Ave Space Science, Cambridge, MA 02139, United States

The orientation of the evaluated normal direction to the interplanetary shock tells us of its local propagation in the interplanetary medium. It has recently been established for case studies like the Oct 19, 1995 and the July 15, 2000 (1) interplanetary magnetic clouds that the orientation of the respective shock normals appear consistent with their overall evolution, e.g., orientation and propagation of the driver. We test this result for a series of shocks observed simultaneously at widely extended locations. Preliminary single case studies (Jan 1978, Sept 1978, and Apr 1979) are used to infer the global geometry of the shock. We examine the relationship between the existence of a strong shock and the level of energization and intensity of the gradual solar energetic particle events. We will test hypotheses on the possible correlation between the extension of the strong shock and the level of energization and flux intensity observed for gradual solar energetic particle events. For selected cases, we also apply type II radio burst remote sensing using ISEE-3 radio data. Also we compare with some unusual shocks of the current solar cycle. For this purpose we will mainly use Wind magnetic field and plasma data from the MFI and SWE instruments, as well as radio emissions from its radio receiver WAVES. The shock normal will be tested against shock passage at other spacecraft (ACE, IMP-8). [(1) see e.g. Lepping et al, Sol Phys, 204, 287, 2001.]

SH13A-04 1420h

Opening a New Window on the Inner Heliosphere: Remote Characterization of Particles and Fields With Emerging Low-Frequency Radio Telescopes

Justin C Kasper[1] (617-253-7611; jck@mit.edu); Divya Oberoi[2] (doberoi@haystack.mit.edu); Miguel Morales[1] (mmorales@mit.edu); Alan J Lazarus[1] (ajl@mit.edu); Joseph Salah[2] (jsalah@haystack.mit.edu); Colin Lonsdale[2] (clonsdale@haystack.mit.edu)

[1] MIT Center for Space Research, 77 Massachusetts Avenue, Cambridge, MA 02139, United States

[2] MIT Haystack Observatory, Route 40, Westford, MA 01886, United States

We present the results of an ongoing study of the potential for conducting solar and heliospheric science with next generation low-frequency digital aperture synthesis radio interferometers. These new designs for ground-based radio observations build on the rapid advancement in computing power and network bandwidth to enhance observational capabilities. The signals from each antenna may be digitized and sent to a central processing facility for simultaneous aperature synthesis in multiple directions limited solely by the available computing power. Tracking of sources from many locations coupled with sophisticated real-time models of the ionosphere permit the extension of measurements to previously unexplored low-frequencies. It is possible that these telescopes could be used to remotely measure magnetic field and density structures from the corona out to 1 AU. Our study has focused on the baseline design for the Low Frequency Array (LOFAR), a potential future radio array which would operate in the frequency range of about 40 to 240 Mhz. In the current design LOFAR is a centrally-condensed array with 25% of the collectors within a 2 km diameter, 50% within 12 km, 75% within 75 km, and the remainder extending to 400 km. We have identified promising capabilities in the Wide-Field Correlator (WFC) design for LOFAR that would permit new observations of the state of the inner heliosphere. An All-Sky Monitor (ASM) making use of the WFC could produce images of the heliosphere at a cadence of half a second with sub arc-minute resolution. These images could then be used to reconstruct the Faraday Rotation (FR) due to the magnetic field of the inner heliosphere. The output from the WFC could also be used to simultaneously monitor several hundred sources for interplanetary scintillations (IPS). The new observations possible are outlined in a series of case studies. It is shown that there are a sufficient number of linearly polarized extra-galactic sources for the telescope to monitor the FR of about 1,000 sources within 30° of the Sun. Simulations of transient Coronal Mass Ejections suggests that flux ropes could be detected in up to 10,000 sources in the case of Earthward directed events, and that these observations could be used to determine the magnetic topology of the CME ejecta. IPS at lower frequencies could detect the formation of interaction regions and the evolution of interplanetary shocks.

SH13A-05 1435h

Multispacecraft Views of Global Heliospheric Structure

D. Aaron Roberts[1] (301 286-5606; aaron.roberts@gsfc.nasa.gov)

Melvyn L. Goldstein[1] (301 286-7828; melvyn.l.goldstein@nasa.gov)

Jonathan Eastwood[2] (jeastwood@lepvax.gsfc.nasa.gov)

S H

[1]NASA Goddard Space Flight Center, Code 692, Greenbelt, MD 20771, United States

[2]NASA Goddard Space Flight Center, Code 696, Greenbelt, MD 20771, United States

Following the lead of K. Shatten in work done for Solar Wind 2, we use the assumption of a stationary heliospheric structure to find the magnetic field pattern over significant regions of the ecliptic plane under quiet solar conditions. A measured dataset is time lagged to form sets for different heliolongitudes, and each of these sets is then kinematically projected to yield radial coverage. This can be done with one spacecraft (or OMNI data), but at times data from two Helios spacecraft can be combined with the 1 AU data to yield a richer set that also checks the consistency of the assumption of stationarity. The resulting pictures will be qualitatively compared to simulations. We will also examine to what extent these methods can be applied to Ulysses data to get a better view of fields over the solar poles, as well as combining that data with measurements from constellations near the Earth (including Cluster, Wind, ACE, and Geotail) for a more global view. This work will help us to sort out spatial and temporal effects in the heliosphere, and will be relevant to predicting the geoeffectiveness of solar events.

SH13A-06 1450h

Solar Wind Heating by Pickup Protons

Charles W. Smith[1] (603-862-0890; Charles.Smith@unh.edu)

Philip A. Isenberg[1] (603-862-3870; Phil.Isenberg@unh.edu)

William H. Matthaeus[2] (302-831-2780; yswhm@bartol.udel.edu)

John D. Richardson[3] (617-253-6112; jdr@space.mit.edu)

[1]University of New Hampshire, Space Science Center, Morse Hall, University of New Hampshire, Durham, NH 03824, United States

[2]University of Delaware, Bartol Research Institute, University of Delaware, Newark, DE 19716, United States

[3]Massachusetts Institute of Technology, Building 37, Room 655, Massachusetts Institute of Technology, Cambridge, MA 02139, United States

We review observations of solar wind heating in the outer heliosphere as measured by the Voyager and Pioneer spacecraft and described previously by a theory of pickup ion wave excitation and turbulent transport. That theory was most recently applied to observations by Smith et al. [2001] and with significant revision of the pickup proton component by Isenberg et al. [2003]. We extend the application of the theory to include time variation of solar wind parameters as recorded by the Omnitape dataset of 1 AU measurements. By averaging Omnitape observations over several solar rotations and using the resulting values as input to the theory, we are able to reproduce the variability of the thermal proton temperatures observed in the outer heliosphere. This is seen to be a direct result of the dependence of energy injection by pickup protons upon bulk solar wind parameters such as Alfven speed and wind speed and the fact that these parameters persist in a predictable manner from 1 AU to the outer heliosphere.

Smith et al., JGR, A106, 8253-8272 [2001]
Isenberg et al., ApJ, 592, 564-573 [2003]

SH14A CC: 518 C Monday 1530h

Fresh Perspectives in Solar-Heliospheric Science II

Presiding: **A Posner,** Southwest Research Institute**; I G Richardson,** NASA Goddard Space Flight Center

SH14A-01 1530h INVITED

Coronal Heating and Solar Wind Acceleration: From MHD Turbulence to Kinetic Effects

Marco Velli (velli@arcetri.astro.it)

Dipartimento di Astronomia, Universitàdi Firenze, Largo E Fermi 2, Firenze, FI 50125, Italy

The heating and acceleration of the solar wind remains a basic unsolved problem in solar and heliospheric physics. The dynamics of the solar corona and the interplanetary medium is dominated by the presence of the magnetic field and its capability of storing and transporting energy originating in solar convection. This energy is then released in the form of heating, accelerated particles and kinetic energy of the solar wind forming the interplanetary medium. Because of the low densities and high temperatures of the medium, collisional dissipation coefficients are very small and dissipative processes occur at scales which are microscopic when compared to the observed structures, and of the same order or less than the ion gyration radius (or skin depth) in the underlying magnetic field. In the open regions of the solar corona, outward propagating Alfvén waves are one way in which mechanical energy may be transported. In this scenario, the cascade to higher frequencies and then dissipation by wave-particle interactions of the initial outward spectrum would heat the corona and accelerate the solar wind. Alternatively, very high frequency waves and/or electron beams might be generated directly in the lower corona by reconnection events. Here we introduce and critically discuss the many puzzles/questions these scenarios leave open.

SH14A-02 1550h INVITED

Constant Energy Source for Solar Wind: Observations and Theory

Nathan A. Schwadron[1] (nschwadron@swri.edu)

David J. McComas[1] (dmccomas@swri.edu)

[1]Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78238-5166, United States

A simple, robust scaling law, was recently derived which explains naturally how the well known anti-correlation between final solar wind speed and freezing-in temperature results from loss of radiated energy in the corona. Further, if the Sun injects roughly fixed electromagnetic energy per particle, this law provides a constant energy model for the source of solar wind: fast tenuous solar wind from dark coronal holes; slow dense wind from hotter, brighter regions; and bound but unstable plasma in extremely hot regions, which may be related to solar transients. We discuss here the scaling law, and explore observational implications of solar wind composition and plasma properties for the constant energy model of the solar wind.

SH14A-03 1610h

3D MHD simulations of the May 2, 1998 halo CME: Comparison of CME initiation models and their characteristics at L1

Ward B. Manchester[1] (734-647-3475; chipm@umich.edu)

Ilia I. Roussev[1] (iroussev@umich.edu)

Tamas Gombosi[1] (tamas@umich.edu)

Igor V. Sokolov[1] (igorsok@umich.edu)

Terry Forbes[2] (terry.forbes@unh.edu)

[1]Center for Space Environment Modeling, The University of Michigan, 2455 Hayward St, Ann Arbor, MI 48109-2143, United States

[2]Department of Physics and EOS Institute, The University of New Hampshire, 39 College Rd., Durham, NH 03824, United States

We present the results of two numerical models of the partial-halo CME event associated with NOAA AR8210 on May 2, 1998. Our simulations are fully three-dimensional and involve compressible magnetohydrodynamics with turbulent energy transport. We begin by first producing a steady-state solar wind for Carrington Rotation 1935/6, following the methodology described in Roussev et al. (2003). For the first model, we superpose the Gibbson-Low magnetic flux rope into the helmet streamer of AR8210. In the second newer model, instead, we impose shearing motions along the polarity inversion line of AR8210, followed by converging motions, both via the modification of the boundary conditions at the Sun's surface. In the first model, a magnetic flux rope exists in the corona prior to the eruption, whereas in the second model, a flux rope forms from reconnection within the sheared arcade during the CME. In either case, flux ropes are expelled from the Sun, manifesting a partial-halo CME through a highly structured, ambient solar wind. We follow the ejected plasma flows from the corona to the Earth's orbit and compare the time evolution of the solar wind parameters predicted by the two models with satellite observations at the L1 point. With such a comparison, we hope to address much debated issue of whether magnetic flux ropes are a component of the pre-event corona.

SH14A-04 1625h

A THREE-DIMENSIONAL MHD SIMULATION OF THE SOLAR ERUPTION ON 1998 MAY 2

Ilia I. Roussev[1] (734-647-9689; iroussev@umich.edu)

Igor V. Sokolov[1] (igorsok@umich.edu)

Terry G. Forbes[2] (terry.forbes@unh.edu)

Tamas I. Gombosi[1] (tamas@umich.edu)

Marty A. Lee[2] (marty.lee@unh.edu)

[1]University of Michigan, Space Research Building , 2455 Hayward St, Ann Arbor, MI 48109, United States

[2]University of New Hampshire, Department of Physics and Institute for the Study of Earth Ocean and Space, Durham, NH 03824, United States

We present modeling results on the initiation and evolution of the coronal mass ejection which occurred on 1998 May 2 in NOAA AR8210. Our calculations are fully three-dimensional and involve compressible magnetohydrodynamics. We begin by first producing a steady-state solar wind for Carrington Rotation 1935/6, following the methodology described in an earlier publication. Shearing motions are then applied along the polarity inversion line of AR8210, complemented by converging motions, resembling an episode of flux emergence, once enough stress is built in the field for an eruption to occur. The flux rope formed in this process gradually accelerates, leaving behind the ashes of a flare loop system that results from an ongoing magnetic reconnection in the naturally formed current sheet. The rope marches away from the Sun, manifesting a partial-halo CME through a highly structured, ambient solar wind. For this event, diffusive-shock-acceleration theory predicts a distribution of solar energetic protons with a cut-off energy of about 10 GeV. Thus, there appears to be no need to introduce an additional acceleration mechanism to account for solar energetic protons with energies below 10 GeV. We conclude that a CME-driven shock can develop close to the Sun sufficiently strong to account for energetic particles at such high energies.

SH14A-05 1640h

MHD Modeling of the Solar Wind with a North-South Asymmetry

Arcadi V. Usmanov[1] (301 286-1033; arcadi.usmanov@gsfc.nasa.gov)

Melvyn L. Goldstein[1] (301 286-7828; melvyn.l.goldstein@nasa.gov)

[1]NASA Goddard Space Flight Center, Code 692, Greenbelt, MD 20771, United States

We present simulation results from a fully three-dimensional steady-state solar wind model with a magnetic field on the Sun composed of a tilted-dipole and a quadrupole. The quadrupole contribution is a source of north-south asymmetry and we study how the asymmetry translates into solar wind properties. The single-fluid MHD equations, which incorporate momentum and energy addition from Alfvén waves, are solved by a time-relaxation method in the region from $1-20$ solar radii and by integration of steady-state equations along radius from 20 solar radii to 1 AU. We show that while a north-south asymmetry in plasma parameters persists up to 1 AU, the asymmetry in magnetic field intensity decreases with heliocentric distance and virtually disappears by about 10 solar radii.

SH14A-06 1655h

Neutral hydrogen distributions in the heliosphere

Hans R Mueller[1,2] (603 646 0428; hans.mueller@dartmouth.edu)

[1]Dartmouth College, Dept. of Physics and Astronomy, Hanover, NH 03755, United States

[2]IGPP at UCR, Univ. of California at Riverside 1432 Geology, Riverside, CA 92521, United States

The numerical modeling of the interaction of the partially ionized local interstellar medium with the solar wind is complex and rich in details. This nonlinear interaction gives rise to an essentially non-Maxwellian neutral distribution function in the heliosphere, which requires a complex treatment of the neutrals in the numerical models. We report on recent developments in the numerical treatment of neutral hydrogen.