# Schedule of Talks

NOTES

Monday, March 15, 2010: 8:00 - 8:25
Presenter: Cowee, Misa

**1D Hybrid simulations of ion cyclotron waves generated by pick-up ions at Titan**

Cowee, M.M., S.P. Gary, R.L. Tokar, Los Alamos National Laboratory
H. Wei, C.T. Russell, UCLA

We have yet to determine why ion cyclotron waves (ICW) generated by pickup ions have not been observed at Titan despite evidence of strong mass-loading. When Titan is in the magnetically noisy Saturnian plasma sheet, the ICW amplitudes would ideally need to be above dB/B ~ 0.2 to be clearly observed, while in the magnetically quiet lobe region the ICW amplitudes would need to be above dB/B ~ 0.01. We use a 1D hybrid simulation code (kinetic ions, inertialess fluid electrons) which allows for injection of newborn ions to mimic ion pickup in order to test conditions of the pickup process that would yield wave amplitudes too low to be seen. We consider the newborn heavy ions with m = 16 (i.e. $CH_4^+$) in a perpendicular pickup geometry ($B_0$ is exactly perpendicular to the bulk corotating plasma flow). The pickup rate and the pickup velocity are varied to see the effect on the instability growth and the saturation wave amplitudes. We find that for the nominal pickup velocity of 100 km/s, CH4+ mass loading rates of 1.2x10^-5 /cc/s and 1x10^-8 /cc/s will generate wave amplitudes at the ambient magnetic noise level in the noisy plasma sheet and quiet lobe environments, respectively.

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Monday, March 15, 2010: 8:25 - 8:50
Presenter: Giacalone, Joe

**The acceleration of inner-source pickup ions by interplanetary shocks**

Joe Giacalone, University of Arizona

Inner-source pickup ions are singly charged nuclei that presumably come from a source close to the Sun and are carried outward by the solar wind. The source is assumed to be close to the Sun because spacecraft observations of their distributions indicate a very cool population, which would result if the ions were created close to the Sun and suffered significant adiabatic cooling as they were carried outward to the observer. Ions created by the interaction of the solar wind with interplanetary dust have been suggested as a possible source. It has also been recognized that, in general, pickup ions of interstellar origin, are efficiently accelerated by shocks. This is because they are a suprathermal population in the solar wind, having a significantly higher temperature than solar-wind ions in the local plasma frame. However, to date, there has been no reported observation of accelerated inner-source pickup ions (C+, for example). The purpose of the present investigation is to study the acceleration of inner-source C+ ions by propagating interplanetary shocks moving through pre-specified magnetic turbulence. We apply test-particle numerical simulations to model the acceleration from low energies, and combine this with a global shock-acceleration model to determine expected energy spectra for C+ ions seen by an observer at 1AU. Results are compared with observational estimates of the upper bound on the energetic C+ intensity. We show that the lack of observations of accelerated inner-source C+ ions in the 50keV-10MeV energy range may provide constraints on the nature of the turbulent magnetic fluctuations close to the Sun, and possibly the properties of propagating shocks as well.

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Monday, March 15, 2010: 8:50 - 9:15
Presenter: Tokar, Robert

**Pick-up ions observed by Cassini near Enceladus and Rhea**

R.L.Tokar(1), M.F. Thomsen(1), R.E. Johnson(2), G.H. Jones(3), D.T. Young(4), F.J. Crary(4), T.W.Hill(5), R.J. Wilson(6), D.B.Reisenfeld(7), E.C.Sittler(8)

(1) Space Science and Applications, Los Alamos National Laboratory, Los Alamos, NM 87545 (rlt@lanl.gov)
(2) University of Virginia, Charlottesville, VA
(3) Mullard Space Science Laboratory, University College London, UK
(4) Southwest Research Institute, San Antonio, TX
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(7) University of Montana, Missoula, MT
(8) NASA Goddard Space Flight Center, Greenbelt, MD

Among the most fascinating observations obtained by the Cassini Plasma Spectrometer (CAPS) from Saturn orbit insertion in 2004 to the present are those of pick-up water-group ($O^+$, $OH^+$, $H_2O^+$, $H_3O^+$) ions. Here we review these observations for three distinct spatial regions: the inner magnetosphere away from the moons, the Enceladus ($R \sim 3.95\ R_S$) south polar plume (out gassing water vapor and dust from warm fractured terrain), and the region downstream of the moon Rhea ($R \sim 8.74\ R_S$). For orbits of Cassini in Saturn's equatorial plane during 2005, CAPS detected evolved water-group ion ring velocity space distributions that were most pronounced near the orbit of Enceladus ($3.5\ R_S < R < 4.5\ R_S$). These ions have sources both within the south polar plume and throughout the Enceladus torus and comprise about 8% of the total ion density. During close flybys of the moon Enceladus in 2008, CAPS detected both water-group pick-up ions and heavier water cluster pick-up ions. These pick-up ions were detected directly within their source region, the Enceladus plume, and are produced by charge exchange collisions between the ambient ion plasma (streaming through the plume) and plume water vapor. One of the most striking observations by CAPS is the acceleration of the freshly-produced ions out of their source region (at rest with respect to Enceladus) and into the ambient plasma flow around Enceladus. Finally, during close flybys of Saturn's moon Rhea in 2005 and 2007, non-gyrotropic pick-up ions are detected from localized sources near Rhea. Using the CAPS observations to constrain pick-up ion trajectories, the ion masses and source locations are calculated. These results will be compared with new CAPS data for the upcoming close (100 km) Rhea flyby on March 2, 2010.

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Monday, March 15, 2010: 9:15 - 9:40
Presenter: Isenberg, Phillip

**Solar wind turbulent heating by interstellar pickup protons - 2 component model**

P. A. Isenberg (University of New Hampshire, Durham NH 03824, USA)
S. Oughton (University of Waikato, Hamilton 3240, New Zealand)
C. W. Smith (University of New Hampshire, Durham NH 03824, USA) and
W. H. Matthaeus (University of Delaware, Newark DE 19716, USA)

In the outer heliosphere, the solar wind magnetic field is highly azimuthal and the ionization rate of inflowing interstellar neutrals is small. Under these conditions, the quasilinear isotropization of interstellar pickup protons yields a well-defined quantity of fluctuation energy as a function of observable parameters. This energy is believed to be the dominant driver of the turbulent cascade beyond about 20 AU in the upwind direction. Previous work has found good agreement between solar wind core proton temperatures measured at Voyager 2 and the dissipative heating predicted by a phenomenological turbulence model which assumes efficient redistribution of the unstable wave energy into the cascade.

In principle, however, this simple model was inconsistent since it assumed quasi-2D (Kolmogorov) phenomenology and ignored the fact that the pickup proton driving essentially consists of parallel-propagating waves. Additionally, more detailed comparison with the Voyager data (Smith et al., 2006) found that this model produced too much heating in the region of 60 - 70 AU.

Here, we investigate the predictions of a recent "2 component" model (Oughton et al., 2006, 2010), which establishes two distinct but interacting fluctuation fields: quasi-2D turbulence and waves, each with the appropriate phenomenology. We incorporate the detailed pickup proton driving into the wave component and compare the results to an extended Voyager data set. We will discuss the resulting proton temperatures and indicate where these interstellar pickup proton studies can provide important information on the turbulent processes in the solar wind.

Oughton, S. et al., *Phys. Plasmas*, *13*, 042306, 2006.
Oughton, S. et al., in *Solar Wind 12*, in press, 2010.
Smith, C.W. et al., *ApJ*, *638*, 508, 2006.

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Monday, March 15, 2010: 9:40 - 10:05
Presenter: McKenna-Lawlor, Susan

**Pickup ions measured near Mars: general implications for the planet of its interaction with the solar wind**

Susan M. P. McKenna-Lawlor, Space Technology Ireland, National University of Ireland, Maynooth, Co. Kildare

The solar wind interaction with Mars and its atmosphere involves a mixture of the physics underlying three classical interaction archetypes: [Venus-like (where ionospheric thermal pressure acts as the main obstacle to the solar wind); comet-like (where coma ionization creates pickup ions leading to mass loading) and Earth-like (where the magnetic field presents an obstacle to the solar wind)]. The present paper provides a general overview of successive spacecraft observations that have helped to develop our present perception as to how the Martian solar atmosphere interacts with the solar wind, thereby causing the escape from the planet of ionized material Also, modelling of feedback processes that effect sputter induced losses from the Martian atmosphere is considered. The current state of knowledge concerning solar wind interaction related atmospheric erosion at Mars on an historical time scale is outlined.

NOTES

Monday, March 15, 2010: 10:30 - 10:55
Presenter: Livadiotis, George

**Non-equilibrium stationary states in the Heliosphere: The influence of pick-up ions**

G. Livadiotis(1), D. J. McComas(1,2)

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(2) University of Texas at San Antonio, San Antonio, TX 78249, USA

Space plasmas from the solar wind to planetary magnetospheres and the outer heliosphere are systems in stationary states out of equilibrium. Empirical kappa distributions, which naturally emerge from Tsallis Statistics, successfully describe these space plasmas. The Tsallis formalism offers a solid statistical foundation and provides a set of proven tools for understanding these distributions. Here, by expressing the entropy in terms of the $k$-index, we show the detailed paths by which the transition of stationary states evolves toward equilibrium. This naturally exhibits four $k$-indices that are frequently observed in space plasmas: The extreme values of infinity and $k$~1.5, corresponding to the specific stationary states at equilibrium and the furthest state from equilibrium, respectively; the value of $k$~1.63, that is the fundamental state exhibiting the minimum entropy; and the value of $k$~2.45, that is the escape state which separates the near-equilibrium states, included in the monotonic region $k>2.45$, from the far-equilibrium states, included in the non-monotonic cavity $2.45>k>1.5$. The fundamental state separates the entropy in two monotonic branches, $k>1.63$ (A) and $1.63>k$ (D). As the entropy increases, the value of $k$-index increases along the A-branch, while it decreases along the D-branch, and the probability distribution is shifted toward larger or smaller velocities, exhibiting a phenomenological Acceleration or Deceleration of particles, respectively. Starting from stationary states near the fundamental state, spontaneous procedures that increase entropy, move the system toward equilibrium either directly, along the A-branch, or indirectly, along the D-branch first, and along the A-branch, after an isentropic switching between the branches. Finally, external factors that can decrease the entropy of the system, move it back into stationary states closer to the fundamental state. In the case of solar wind, newly formed pick-up ions may play just such a role because their motion is highly ordered. This motion is dictated by the relative orientation of the solar wind velocity and the interplanetary magnetic field, which become increasingly perpendicular on average as one moves out through the heliosphere

Monday, March 15, 2010: 10:55 - 11:20
Presenter: Goldstein, Melvyn

**A global model of the heliosphere that includes turbulent heating of the solar wind**

M. L. Goldstein, Code 673, NASA Goddard Space Flight Center
A. V. Usmanov, University of Delaware and Code 673, NASA Goddard Space Flight Center

We have developed a magnetohydrodynamic model to simulate the global steady-state structure of the solar wind in the region from 0.3 to 100 AU. The model is based on a numerical solution of the combined set of solar wind equations and small-scale turbulence transport equations and accounts for apparent heating of the solar wind by a turbulence cascade. Interstellar pickup protons are included as a source term. We use the model to study the distribution of plasma and magnetic field parameters and the effects of turbulence dissipation and pickup-proton-associated-heating on the variation of plasma temperature in the outer heliosphere. To illuminate the roles of the turbulent cascade and the pickup protons in heating the solar wind with heliocentric distance, we compare the model results with and without turbulence. The variations of plasma temperature in the outer heliosphere are compared with Voyager 2 observations.

# Schedule of Talks

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Monday, March 15, 2010: 11:20 - 12:00
Presenter: Coates, Andrew

**Ion pickup at comets: comparison with other unmagnetized objects**

Andrew J. Coates, Mullard Space Science Laboratory, University College London, Holmbury St Mary, Dorking RH5 6NT, UK

Comets provide a wonderful laboratory for studying the ion pickup process. As a comet nears the Sun, neutral atoms and molecules sublime away from the nucleus, providing an extended water-rich region. Photoionisation and charge exchange provide a source of new pickup ions, which immediately interact with the electric and magnetic field in the surrounding plasma. The missions to comets Halley, Giacobini-Zinner, Grigg-Skjellerup and Borrelly provided a wealth of data on pickup ions and their interaction with plasma waves, including observations of ring and bispherical shell distributions and mass loading over significant regions of space. At comet Grigg-Skjellerup, non-gyrotropic pickup ions were also seen. In this talk we will review the observations and interpretation of pickup ions at comets, illustrating what was learned from the cometary missions and following the evolution of the ion distribution. We also discuss the international Rosetta mission which will orbit rendezvous with and then orbit comet Churyumov-Gerasimenko as it nears the Sun and as activity develops. The interaction will change significantly as this occurs in 2014-15. We also compare the pickup process at comets with that observed at other unmagnetized objects, including Titan, Enceladus, Venus and Mars, using data from Cassini, Venus Express and Mars Express.

Monday, March 15, 2010: 14:00 - 14:25
Presenter: Usmanov, Arcadi

**Global solar wind structure: Effects of pickup protons**

A. V. Usmanov, University of Delaware and Code 673, NASA Goddard Space Flight Center
M. L. Goldstein, Code 673, NASA Goddard Space Flight Center

The structure of the heliosphere is strongly affected by the pickup protons produced by the photoionization of the interstellar neutral hydrogen and by the charge exchange of the hydrogen atoms with solar wind protons. In the distant heliosphere ($r > 5$–$10$ AU), the thermal pressure of pickup protons is higher than the solar proton and electron pressure and the energy and momentum redistribution between solar-wind and pickup protons leads to a deceleration of the solar wind flow and to an increase of the average plasma temperature with heliocentric distance. The deceleration effect, combined with the additional plasma pressure from the pickup protons, acts to weaken the corotating interaction regions (CIRs). It causes, however, an overall compression of the (mostly azimuthal) interplanetary magnetic field. Using a three-dimensional magnetohydrodynamic solar wind model that describes the pickup protons as a separate fluid, we have simulated the magnetic field and plasma distribution throughout the heliosphere from the coronal base to 100 AU. The source magnetic field on the Sun is assumed to be a tilted dipole. Comparing the simulation runs with and without pickup protons, we quantitatively evaluate the effect of the solar wind deceleration on the weakening of the CIRs and on the increase of interplanetary magnetic field intensity. Unlike our earlier studies, the present simulations incorporate Hollweg's "collisionless" heat flux approximation that obviates the need to use a non-adiabatic polytropic index.

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Monday, March 15, 2010: 14:25 - 14:50
Presenter: Zank, Gary P.

**Turbulence in the outer heliosheath**

G.P. Zank, D. Shaikh, V. Florinski, J. Heerikhuisen, and N.V. Pogorelov
Center for Space Plasma and Aeronomic Research (CSPAR), University of Alabama in Huntsville

With an explanation of the ribbon observed by IBEX that relies on the weak scattering of pickup ions in the outer heliosheath, it has become critical that we understand better the nature of turbulence in this region. Of course, turning the argument around implies that the IBEX observations of the ribbon may reveal a surprising amount about turbulence in the local interstellar medium. Here we discuss several aspects about outer heliosheath turbulence. We will present a detailed model of turbulence transport in the heliosheath, extending earlier ideas by Zank et al., 1996, including turbulence driving by pickup ions, anomalous cosmic rays, weak shocks, and possibly heliopause instabilities. We will also discuss the role of interstellar neutral H in modifying characteristics of turbulence and quantify this. Brief discussion will also be made of the nature of the pickup ion instability in the outer heliosheath, based on both recent simulations and work by Cairns and Zank, 2003.

Monday, March 15, 2010: 14:50 - 15:15
Presenter: Chapman, Sandra C.

**The fluctuating solar wind from smallest to largest scales- turbulence and signatures of coronal origin**

Sandra C. Chapman, University of Warwick, Centre for Fusion, Space and Astrophysics, Physics Dept., Coventry CV4 7AL, United Kingdom

We will discuss from a statistical point of view in- situ observations of the fluctuating solar wind. We can view the solar wind from two perspectives- as a unique astrophysical scale laboratory for both magnetohydrodynamic and ion kinetic scale turbulence, and as a flow carrying the signature of the dynamic corona. Both of these perspectives suggest the possibility of statistical scaling, that is, power law power spectra and fluctuations that show statistical similarity and non- Gaussian statistics. Quantifying these features of the solar wind provides direct input to models of the field and flow which in turn controls the dynamics and transport of pick up ions.

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Monday, March 15, 2010: 15:15 - 15:40
Presenter: Lundin, Rickard

**On the role of wave acceleration and ion pickup for the ion escape from Mars and Venus**

Rickard Lundin, Swedish Institute of Space Physics

Plasma measurements from Mars Express (MEX) and Venus Express (VEX) demonstrate that ionospheric plasma escapes the planets in a comet-like fashion. Low-energy (cold) ionospheric plasma is swept from the dayside, expanding into the nightside/tail, eventually picking up speed further down in the tail. Ion data suggests that there is a primary energization and outflow, at low (pericenter) altitudes <300 km, which bring ionospheric plasma to just above escape velocity (5 - 20 km/s). The ion outflow, apparently originating from the entire dayside and flank ionosphere, is sweept tailward alongside with the external/sheath flow, suggesting a "visous-like" coupling between the sheath plasma and ionospheric plasma. The flow is also characterized by strong low-frequency density modulations in the ULF frequency range. Intense ULF waves are observed in the sheath, implying a direct coupling to the density modulations in the outflow. This talk will address ionospheric ion energization at Mars and Venus on basis of MEX and VEX data. Two energization processes is discussed in more detail: Acceleration by waves, and mass-loaded ion pickup by the solar wind motional electric field. Both mechanisms are capable of explaining the very pronounced "viscous-like" tailward flow of planetary ions at Mars and Venus.

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Monday, March 15, 2010: 16:05 - 16:30
Presenter: Slavin, Jonathan

**The nature of the circumheliospheric interstellar medium and implications for pickup ions**

Jonathan Slavin, Harvard-Smithsonian Center for Astrophysics

Nearly all the pickup ions begin their lives as interstellar neutrals flowing into the heliosphere. Their flux and their interactions with the outer heliosphere depend on the nature of the interstellar medium that surrounds heliosphere, the circumheliospheric interstellar medium (CHISM). The CHISM is part of the Local Interstellar Cloud, which is believed to surround the Solar System. While we have more information about this cloud than any other region of the ISM, many uncertainties remain about its properties. I will summarize our current knowledge about the CHISM including the uncertainties and their possible impact on models for the heliosphere and pickup ions.

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Monday, March 15, 2010: 16:30 - 16:55
Presenter: Ng, Chung-Sang

**The effect of magnetic turbulence energy spectra and pickup ions on the heating of the solar wind**

C. S. Ng, Geophysical Institute, University of Alaska Fairbanks
A. Bhattacharjee, P. A. Isenberg, D. Munsi, and C. W. Smith, Space Science Center, University of New Hampshire

In recent years, a phenomenological solar wind heating model based on a turbulent energy cascade prescribed by the Kolmogorov theory has produced reasonably good agreement with observations on proton temperatures out to distances around 70 AU, provided the effect of turbulence generation due to pickup ions is included in the model. In a recent study [Ng et al., J. Geophys. Res., 115, A02101 (2010)], we have incorporated in the heating model the energy cascade rate based on Iroshnikov-Kraichnan (IK) scaling, derivable from incompressible magnetohydrodynamics. We showed that the IK cascade rate can also produce good agreement with observations, with or without the inclusion of pickup ions. This effect was confirmed both by integrating the model using average boundary conditions at 1 AU, and by applying a method [Smith et al., Astrophys. J., 638, 508 (2006)] that uses directly observed values as boundary conditions. The reduction of effects due to pickup ions is because less turbulence is generated by pickup ions for the IK spectrum, which has a shallower spectral index than the Kolmogorov spectrum. In this talk, we will discuss more on this part of the theory. This work is supported by NASA, DOE and NSF.

Monday, March 15, 2010: 16:55 - 17:20
Presenter: Bochsler, Peter

**On the origin of inner source pickup ions**

Peter Bochsler(1), Eberhard Möbius(1), and Robert F. Wimmer-Schweingruber(2)

(1)Space Science Center, University of New Hampshire, Durham NH 03824, USA
(2)Institut für Experimentelle und Angewandte Physik, University of Kiel, D-24118 Kiel, Germany

Inner Source Pickup Ions are thought to originate from the interaction of solar wind ions with interplanetary dust grains in the inner heliosphere. Processes which produce inner source pickup ions, and which have been considered so far are implantation of solar wind on grains and subsequent desorption, charge exchange of solar wind ions during transit through submicron dust grains, sputtering and backscattering of ions. A large fraction if not all of the dust crossing the sphere of the Earth’s orbit must end up as pickup ions as is evidenced from the comparable order of magnitude of dust flux inward and pickup ion flux outward at 1 AU. This suggests that the ultimate fate for a large fraction of small interplanetary dust particles after evaporation or sputtering is conversion into pickup ions. Sputtering becomes particularly efficient when dust particles - after erosion by collisions with each other – have reached sizes of the order of ranges of solar wind ions in dust materials. The sputter products, charged or neutral molecules, atoms or ions, ultimately will undergo photodissociation, photoionization, ionization by charge exchange with solar wind ions, or ionization by electron collisions. We will investigate the relative importance of the various processes on pickup ions on their way out of the inner heliosphere and the relevance of inner source pickup ions for diagnostics of dust particles near the Sun.

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Monday, March 15, 2010: 17:20 - 17:45
Presenter: Jackson, Bernard V.

**3-D reconstruction of the inner heliosphere: A global solar wind boundary from remote-sensing data**

B.V. Jackson, P.P. Hick, A. Buffington, J.M. Clover, Center for Astrophysics and Space Sciences, University of California at San Diego, La Jolla, CA, USA
D.B. Reisenfeld, and T.R. Abell, Department of Physics and Astronomy, University of Montana, Missoula, MT, USA

Preliminary IBEX observations suggest variations in the polar ENA flux on timescales $^{3}$50 days, which may be driven by variability in the solar wind flux. The ability to accurately propagate the solar wind to the interstellar boundary would be very helpful in trying to identify the source of the observed ENA variation, and also to certify the three-dimensional (3-D) shape of the interstellar boundary. At UCSD, observations of the inner heliosphere have been carried out on a routine basis using interplanetary scintillation (IPS) for more than two decades, and from the Solar Mass Ejection Imager (SMEI) since its launch in early 2003. These remote-sensing data have been used to measure and reconstruct 3-D solar wind structure throughout this time period. These global analyses, especially from Solar-Terrestrial Environment Laboratory (STELab) IPS observations, provide an inner boundary in density and velocity that is nearly complete over the whole heliosphere for the major part of the year with a time cadence of about one day. By using the IPS velocity analyses we are able to convect-outward solar surface magnetic fields measured during these periods in order to provide measurements of the field throughout the global volume. In the inner heliosphere these 3-D analyses of density, velocity, and vector magnetic field have been compared successfully with in-situ measurements obtained near Earth, STEREO, Mars, and at the Ulysses spacecraft. These provide a precise inner time-dependent boundary for these parameters that can be extrapolated outward to the edge of the heliosphere using current 3-D MHD modelling techniques. We present this boundary for recent IPS data, and we show its potential for extending these parameters globally to the edge of the heliosphere.

Tuesday, March 16, 2010: 8:00 - 8:25
Presenter: Smith, Todd

**Neutral clouds and their influence on pick-up ions in Saturn's Magnetosphere**

H.T. Smith, JHU Applied Physics Laboratory

The Saturnian system is interesting in that its magnetosphere is dominated by neutral particles. It was originally thought that the dense, relatively exposed nitrogen dominated atmosphere of Saturn's large moon, Titan, was the largest source of heavy particles. However, research based on recent Cassini observations confirm that the tiny icy moon Enceladus serves as the dominate source of heavy particles (water group) in Saturn's magnetosphere. Saturn's atmosphere and Titan as well as Enceladus also provide a significant source of hydrogen particles. These dynamic sources have interesting implications for ion source generation mechanisms which then modify the neutral particle distribution. Thus, pick-up ion sources and distribution is highly influenced by these neutral particles and vice versa. Here we present an overview of Saturn's magnetospheric neutral particle distribution and how this distribution affects pick-up ion production. We also show how detection of these ions has been used to identify neutral populations that elude direct detection.

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Tuesday, March 16, 2010: 8:25 - 8:50
Presenter: Krimigis, Stamatios (Tom)

**ENA suprathermal (>5 keV) images and Voyager "ground truth": Pressure balance in the heliosheath**

S. M. Krimigis(1,2), D. G. Mitchell(1), E. C. Roelof(1), and R. B. Decker(1)

(1) Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723, USA
(2) Office for Space Research and Technology, Academy of Athens, Athens, Greece

(MIMI) sensor suite on the Cassini orbiter at Saturn, is an ENA imager designed to obtain measurements of magnetospheric phenomena, and has done so for more than five years. When not pointing at the planet, INCA can sense ENA from other sources, notably those traversing the interplanetary medium from all directions. Maps of such emissions (Krimigis et al, 2009) have now been constructed spanning the energy range ~ 5 ≤ E ≤ 55 keV. Similarly, maps < 6 keV have been obtained by the IBEX mission (McComas et al, 2009). These maps, on the main, do not conform to standard models of the shape of the heliosphere. Measurements of energetic ions by Voyagers 1, 2 in the heliosheath (Decker et al, 2009) show pressures 28 <E< 4000 keV ~ 0.2 pdynes/cm$^2$ vs ~ 0.04 pdynes/cm$^2$ for the local B ~ 0.1nT (Burlaga et al, 2009), i.e. $\beta > 5$. The overlap in energy between Voyager ions and Cassini ENA intensities (averaged over the ENA line of sight) enables us to deduce ion fluxes in the heliosheath, thus providing a continuous spectrum 5 ≤ E ≤ 4000 keV. These measurements are then used to estimate the thickness of the heliosheath (~ 50 AU) and the local pressure (~ 1.3 pdynes/cm$^2$), suggesting $\beta$ >33. Thus, pick up ions (PUI) dominate the heliosheath, at least at the location of the two Voyagers. Based on the symmetrical distribution of ENA intensities in galactic coordinates, it is hypothesized that the local interstellar magnetic field plays an important role in determining the shape of the heliospheric cavity and it must have a central role in pressure balance of heliosheath plasma with local interstellar flow. The results will be discussed in the context of previous and evolving models.
References:
Burlaga et al, *J. Geophys. Res., 114*, A06106, 2009
Decker et al, *Solar Wind 12*, 25 June, 2009
Krimigis et al, *Science, 326*, 971, 2009
McComas et al, *Science, 326*, 959, 2009

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Tuesday, March 16, 2010: 8:50 - 9:15
Presenter: Gloeckler, George

**Pickup ions in the solar system**

G. Gloeckler and L. A. Fisk, University of Michigan, Department of Atmospheric, Oceanic and Space Sciences

Pickup ions, created by charge exchange and photo-ionization from neutral particles or dust, are most common throughout the solar system. Interstellar pickup ions are distributed over vast regions of the outer heliosphere and heliosheath, where they are dynamically the dominant component of the plasma. Inner source pickup ions, produced from material close to the Sun dominate the inner heliosphere. Local sources of pickup ions include planets and comets. Spatial distributions, composition, velocity distributions functions and ENA images and spectra provide vital information about physical characteristics and processes in the source regions as well as transport and heating mechanisms affecting pickup ions. We will present recent ACE and Ulysses measurements of pickup ions from various sources, and will use observations from Voyager, Cassini and IBEX to infer velocity distributions of the solar wind, pickup ions and suprathermal tails in the heliosheath.

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Tuesday, March 16, 2010: 9:15 - 9:40
Presenter: Roelof, Ed

**Implications of generalized Rankine-Hugoniot jump conditions for the PUI population at the Voyager 2 termination shock and the structure of the heliosheath**

E. C. Roelof(1), S. M. Krimigis(1,2), D. G. Mitchell(1), R. B. Decker(1), J. D. Richardson(3), M. Gruntman(4), H. Funsten(5), and D. McComas(6)

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(2)Office for Space Research and Technology, Academy of Athens, Athens, Greece
(3)Kavli Institute for Astrophysics and Space Research, MIT, Cambridge, MA 02139, USA
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(5)Los Alamos National Laboratory, Los Alamos, NM 87545, USA
(6)Southwest Research Institute, San Antonio, TX 78238, USA

ENA images of the heliosheath from Cassini/INCA (~5-50 keV), combined with *in situ* ion intensity measurements (~0.04-4.0 MeV) from VGR1/2 LECP imply significantly non-thermal ion distributions throughout the heliosheath [Krimigis *et al.*, 2009 and this Conference]. Under the assumption that the ion intensity measured at VGR1/2 extends from the termination shock (TS) a distance L into the heliosheath, the ion spectra derived from the INCA ENAs has been "normalized" to the *in situ* VGR ion spectra, yielding a heliosheath thickness L~50AU. ENA images are obtained by IBEX covering the PUI energy range (0.4-6 keV) [McComas *et al.*, 2009 and this Conference], but it has been argued by Heerikhausen *et al.* [2009] that the bulk of the ion population producing the "ribbon" in the IBEX ENA images is located beyond the heliospause (and therefore the PUI intensities are correspondingly less near the TS). Unfortunately, there are no *in situ* measurements of PUIs by Voyager. To observationally address this lack of information, we invoke the Rankine-Hugoniot jump conditions at the Voyager 2 termination shock, where we have estimates of the *in situ* particle distribution functions at all energies from thermal [Richardson *et al.*, 2009] to extreme suprathermal [Decker *et al.*, 2005; Stone *et al.*, 2009] *except* those of the PUIs. We have generalized the jump conditions to the conservation of mass, momentum, and energy for the observed mixture of thermal and non-thermal populations. The conclusion, consistent with theoretical extrapolation of Ulysses PUI measurements in the inner heliosphere [Gloeckler *et al.*, 2006], is that a significant fraction of the PUI population that produces the IBEX ENAs must be located in the innermost heliosheath downstream of the VGR2 termination shock.
References:
Krimigis et al, *Science, 326*, 971, 2009
McComas et al, *Science, 326*, 959, 2009
Decker et al, *Solar Wind 12*, 25 June, 2009

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Tuesday, March 16, 2010: 9:40 - 10:05
Presenter: Hill, Matthew

**An excess of accelerated pickup ions observed in the outer solar system**

Matthew E. Hill, Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA

Interstellar pickup ions (PUIs) are widely considered to become "more important" at increasing distances from the sun. Theoretically this comes from the fact that, beyond 1 AU, the pickup ion number density $n$ falls off as the inverse of distance from the sun while the solar wind (SW) density $n_{sw}$ falls off faster, as the inverse square of distance (thus the density ratio $K = n/n_{sw}$ grows linearly with distance). So PUIs are more important in the sense that $K$ gets larger in the outer solar system (i.e., $K_{outer} > K_{inner}$), but the theory does not require that PUIs should outnumber SW ions at any given point, and it is inconsistent with an actual larger number density in the outer solar system, so the condition $n_{outer} < n_{inner}$ should always hold. Using the clean mass, energy, and charge state measurement capability of the Cassini/MIMI/CHEMS instrument during the 1999-2004 1-9 AU cruise to Saturn, we compare the observed phase space density of PUI species $f$ with SW species $f_{sw}$ (at a given speed) using singly and doubly charged helium observations, respectively. We find (1) not only are there relatively more PUIs than SW ions as distance increases from 1 to 9 AU (i.e., $H_{outer} > H_{inner}$, where $H = f/ f_{sw}$), as expected, but (2) there are more in an absolute sense (i.e., $H > 1$). Most notably (3) the PUI phase space density $f$ itself is actually *larger* in the outer solar system (i.e., $f_{outer} > f_{inner}$). For example between 2 AU and 9 AU the measured value of *f increases* sixfold, compared to the fourfold *decrease* of $n$ in the theoretical case. Importantly, the speed range of the measured abundances is greater than the thermal populations for which the theoretical relationships strictly apply ($3V_{sw}$ - $7V_{sw}$ vs. $<2V_{sw}$, respectively, where $V_{sw}$ is a typical solar wind speed of 450 km/s). This indicates that the large, unexpected excess of PUI species need not be a source effect and is therefore more likely related to the acceleration mechanism. We highlight the observational constraints that theories of pickup ion acceleration in the heliosphere must meet.

Tuesday, March 16, 2010: 10:30 - 10:55
Presenter: Jones, Geraint

**The stucture of comets' induced magnetotails: Remote and in situ observations**

Geraint H. Jones (1,2), Robert J. Forsyth (3), Andrew J. Coates (1,2)

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(2) The Centre for Planetary Sciences at UCL/Birkbeck, London, UK
(3) Imperial College London, London, UK

Comets' plasma tails are the most obvious remotely-observable manifestation of ion pickup in the solar system. The ionization of cometary neutral gases by several processes allows the pickup of these ions by the solar wind. Resonance fluorescence makes visible the ion tail. The conservation of momentum during the tail formation process leads to the deceleration of the solar wind in the vicinity of the comet and hence the draping of the heliospheric magnetic field frozen into the flow. The International Cometary Explorer (ICE, formerly ISEE-3) was the first spacecraft to traverse a cometary ion tail, when it crossed the tail of 21P/Giacobini-Zinner in 1985. This was followed by serendipitous tail crossings by the Ulysses spacecraft of C/1996 B2 (Hyakutake), C/1999 T1 (McNaught-Hartley), and C/2006 P1 (McNaught), each at scales of astronomical units down-tail of the respective nucleus. We present an overview of the observations made during these crossings, concentrating on the tails' magnetic field structure, and suggest how recognizable structures can persist so far from their sources. The in situ observations are compared to remote imaging observations of cometary ion tails.

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Tuesday, March 16, 2010: 10:55 - 11:20
Presenter: Kucharek, Harald A.

**Hybrid simulations for pickup ion distributions at the termination shock**

Harald Kucharek(1), Nikolai Pogorelov(2) , Eberhard Moebius(1), Marty Lee(1)

(1) University of New Hampshire, Durham, United States
(2) University of Alabama in Huntsville, Huntsville, Alabama, United States

The Interstellar Boundary EXplorer IBEX finished its first sky maps in the light of Energetic Neutral Atoms ENAs and revealed features in the sky which where unexpected and which are not yet understood. ENAs are of interstellar origin, which charge exchange with energetic ions at the termination shock or in the heliosheath. During that process the interstellar neutral exchange its charge with a fast moving ion and this ion becomes a fast moving energetic neutral atom. The energy of the ENA is therefore the original energy of the charged component. In order to understand the observed features in the sky maps one needs to understand the properties of a perpendicular stationary shock under the influence of a high percentage of pickup ions and the velocity distributions of the various species at different locations. Only those ions that have a velocity component directed sunwards could create ENA's, which can be detected with IBEX. The phase space is therefore limited and thus the number of produced ENA's. Hybrid simulations appear to be a useful tool following ion distributions at the perpendicular shocks and to study their behavior. We performed a number of hybrid simulations and investigated the spatial evolution of solar wind protons and pickup ion distributions through the shock and we identified which fraction of these ion distributions could produce ENA's moving towards the Sun and being detected as ENA's on IBEX.

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Tuesday, March 16, 2010: 11:20 - 12:00
Presenter: Nagy, Andrew

**A 3D Multi-fluid MHD Study of the Interaction of the Solar Wind with the Ionosphere/Atmosphere System of Mars**

A. F. Nagy(1), D. Najib(1), G. Toth(1), and Y. J. Ma(2)

(1) Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI, 48109
(2) Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA, 90025

We use our new four species multi-fluid model to study the interaction of the solar wind with Mars. The lower boundary of our model is at 100 km, below the main ionospheric peak, and the radial resolution is about 10 km in the ionosphere, thus the model does a very good job in reproducing the ionosphere and the associated processes. We carry out calculations for high and low solar activity conditions and establish the importance of mass loading by the extended exosphere of Mars. We also calculate the atmospheric escape of the ionospheric species, including pick up ions. Finally, we compare our model results with the Viking, MGS and Mars observations.

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Tuesday, March 16, 2010: 14:00 - 14:25
Presenter: Lembege, Bertrand

**Impact of the shock front rippling and nonstationarity on ion acceleration processes for a supercritical perpendicular shock**

B. Lembège (1), Z. Yang (1, 2) and Q. LU (2)

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2) School of Earth and Space Sciences, USTC, Hefei, Anhui 230026 (P. R. of China)

Shock Surfing Acceleration (SSA) mechanism has been proposed by many authors as an interesting pre-acceleration process for slow pick-up ions (PI) interacting with shocks. Moreover, both simulations and experimental measurements (recently from CLUSTER mission) have clearly evidenced that the front of a supercritical quasiperpendicular shock is nonstationary. Different processes are recently proposed to be responsible for this nonstationarity. One well accepted process of non-stationarity is the shock front "self-reformation' due to the accumulation of reflected ions in front of the ramp. This self-reformation leads to a strong change both in amplitude and spatial width of the overshoot, the ramp and the foot. Presently, 1D test particle simulations have been performed based on shell/Maxwellian ion upstream distributions interacting with fields components issued from PIC simulation, and show that this self reformation has a strong impact on the SSA and SDA (Shock Drift Acceleration) mechanisms which contribute to the formation of energetic ions. More precisely: (i) SDA alone is dominant as the ramp width is broad (overshoot amplitude low); (ii) both SSA and SDA contribute as ramp width is narrow (overshoot amplitude high); (iii) SDA process is more efficient (higher energy gain) than SSA; (iv) according to the time of the encounter with the shock front, two types of SSA (mono and multiple bounces) ions can be identified, and their occurrence depends on the radius V-shell of the upstream distribution; (v) the density of reflected ions (including both SSA and SDA) varies with a period equal to that of the self reformation; and (vi) energetic ions (both SDA and SSA) are not only issued from the wings (as for a stationary shock) but also from the core of the upstream distribution. The present work will summarize these recent results which will be completed by corresponding energy spectra for each population. In extenso, recent results obtained from 2-D test particles simulations will be presented illustrating the impact of the shock front rippling on each population in terms of both (a) individual ion trajectory analysis and (b) statistical approach.

NOTES

Tuesday, March 16, 2010: 14:25 - 14:50
Presenter: Buchman, S.

**The Space-Time Asymmetry Research (STAR) program**

Sasha Buchman, Stanford University

Stanford University, NASA Ames, and international partners propose the Space-Time Asymmetry Research (STAR) program, a series of three Science and Technology Development Missions, which will probe the fundamental relationships between space, time and gravity. What is the nature of space-time? Is space truly isotropic? Is the speed of light truly isotropic? If not, what is its direction and location dependency? What are the answers beyond Einstein? How will gravity and the standard model ultimately be combined? The first mission, STAR-1, will measure the absolute anisotropy of the velocity of light to one part in $10^{17}$, derive the Kennedy-Thorndike (KT) coefficient to $7x10^{-10}$ (150-fold improvement over modern ground measurements), derive the Michelson-Morley (MM) coefficient to $10^{-11}$ (confirming the ground measurements), and derive the coefficients of Lorentz violation in the Standard Model Extension (SME), in the range $7x10^{-17}$ to $10^{-13}$ (an order of magnitude improvement over ground measurements). The follow-on missions will achieve a factor of 100 higher sensitivities. The core instruments are high stability optical cavities and high accuracy gas spectroscopy frequency standards using the "NICE-OHMS technique. STAR-1 is accomplished with a fully redundant instrument flown on a standard bus, spin-stabilized spacecraft with a mission lifetime of two years. Spacecraft and instrument have a total mass of less than 180 kg and consume less than 200 W of power. STAR-1 would launch in 2015 as a secondary payload in a 650 km, sun-synchronous orbit. We describe the STAR-1 mission in detail and the STAR series in general, with a focus on how each mission will build on the development and success of the previous missions, methodically enhancing both the capabilities of the STAR instrument suite and our understanding of this important field. By coupling state-of-the-art scientific instrumentation with proven and cost-effective small satellite technology in an environment designed for research and leadership participation by university students the STAR program will bring new answers to some of the most important physics questions of our time - questions that have faced physicists for over 100 years.

Tuesday, March 16, 2010: 14:50 - 15:15
Presenter: Travnicek, Pavel

**Proton heating by pick-up proton-generated waves in the expanding solar wind: Hybrid simulations**

Pavel Travnicek (1,2), Petr Hellinger (2)

(1) Institute of Geophysics and Planetary Physics/UCLA, Los Angeles, CA 90095, USA
(2) Astronomical Institute, Academy of Sciences of the Czech Republic, CZ 14131, Czech Republic

Proton heating observed in the outer heliosphere by Voyager 2 can be attributed to the dissipation of a wave energy generated by pick-up protons. First self-consistent hybrid simulation results of this kinetic phenomenon is presented in the approximation of expanding box. For the hybrid expanding model the magnetic field is assumed to be strictly transverse and the plasma does not contain any pick-up protons initially but they are injected continuously during the expansion assuming a simple model for the charge-exchange process. The injected pick-up protons form a ring velocity distribution function which becomes eventually unstable and generates cyclotrons waves which isotropize the pick-up ions (forming a shell distribution functions) and which scatter/heat the solar wind protons. This cyclotron heating of solar wind ions is very efficient and may overcome the adiabatic cooling as observed by Voyager 2 spacecraft.

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Tuesday, March 16, 2010: 15:15 - 15:40
Presenter: Moebius, Eberhard

**He pickup ion distributions in the inner heliosphere - diagnostics of the local interstellar gas and of interplanetary conditions**

E. Möbius(1), B. Klecker(2), P. Bochsler(1), G. Gloeckler(4), H. Kucharek(1), K.D.C. Simunac(1), A.B. Galvin(1), L. Ellis(1), C. Farrugia(1), L.M. Kistler(1), J.G. Luhmann(5), M.A. Popecki(1), C.T. Russell(6), R. Wimmer-Schweingruber(7), P. Wurz(3)

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The relative motion of the Sun through the Local Interstellar Cloud (LIC) leads to a neutral wind through the heliosphere. Because of its high ionization potential, He remains neutral to well within 1 AU, where it is deflected by the Sun’s gravity and forms a focusing cone on the downwind side. This flow pattern has been studied with UV backscattering, through pickup ions, and atom imaging. A consolidated set of the physical parameters of He in the LIC has been derived combining all three methods. However, it is still poorly understood why pickup ion fluxes and velocity distributions vary substantially on temporal scales from hours to many days, which leads among other phenomena to apparent changes in the appearance of the focus-ing cone, even after averaging over several days. With the combination of PLASTIC on STEREO A and B as well as SWICS on ACE, simultaneous pickup ion observations over an increasing range of heliospheric longitudes have become possible, for which we have initiated a cross-calibration effort between the distributed sensors. With these data that feature improved temporal resolution, spatial and temporal variations in the pickup ion fluxes and spectra can be separated. Therefore, we can probe the effects on pickup ion distributions and the observed structure of the focusing cone that arise from solar wind structures, such as compressions and rarefactions, from variations in magnetic field strength and direction, and from changes in the ionization rates. Making use of starkly different ionization rates during different phases of solar activity, these observations can also be employed to directly test the cooling behavior of pickup ions in the expanding solar wind plasma, which is typically modeled as purely adiabatic in spite of slow pitch angle scattering.

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Tuesday, March 16, 2010: 16:05 - 16:30
Presenter: Rymer, Abigail

**Electron signatures of ion pick-up**

Abigail M. Rymer, The Johns Hopkins University Applied Physics Laboratory

Bi-modal (bi-Maxwellian or bi-kappa) electron populations are commonly observed at Saturn. In the inner magnetosphere a 'cold' (< 100 eV) electron component is associated with local ionization of water group particles redistributed from Enceladus, a 'hot' electron component is associated with rapid (approximately adiabatic) inward transport from the middle magnetosphere. Additionally, bi-modal electron distributions associated with local ion pick-up have been recently identified in the outer magnetosphere near Titan. Inspection of Cassini ion data surprisingly revealed that the associated ions are water group and hence not of Titanian origin. Timescales for the relaxation of bi-modal electron distributions to a single distribution and for electrons to equilibrate to the local ion temperature are functions of density, kinetic temperature, relative mass and charge state. We will review these timescales in the context of the Saturn system and discuss how they inform the history and evolution of the observed plasma. Electrons are well measured irrespective of spacecraft orientation and so these observations are particularly powerful in the case of non-spinning spacecraft (such as Cassini at Saturn).

Tuesday, March 16, 2010: 16:30 - 16:55
Presenter: Omidi, Nick

**Hybrid simulations of plasma-neutral-dust interactions at Enceladus**

N. Omidi, C.T. Russell, R.L. Tokar, W.M. Farrell, W.S. Kurth, D.A. Gurnett, Y.D. Jia, J.S. Leisner

The plasma environment around Enceladus is governed by the interaction between the co-rotating plasma with the body of the moon, the neutral gas associated with Saturn's extended cloud, plumes ejected from its southern polar region and negatively charged dust particles. To understand the nature of this interaction, we use 3-D electromagnetic hybrid simulations that treat ions kinetically through particle-in-cell methods and treat the electrons as a charge neutralizing fluid. In these simulations, plasma interaction with the neutrals takes place through charge exchange and dust particles are charged through electron absorption. The results show that plasma absorption by Enceladus forms a density cavity tail and a depletion wake which is confined in the direction perpendicular to the magnetic field but extends many Enceladus radii along the magnetic field. Interaction of the co-rotating plasma with the extended neutrals results in the generation of ion cyclotron waves and plasma deceleration to velocities below the co-rotation speed. The results also show that plumes with base densities of ~ $10^6$ $cm^{-3}$ ($6.5 \times 10^{29}$ molecules in the plume) or lower have no significant impacts, while stronger plumes greatly modify the interaction region including generation of a strong Alfven wing. Similarly, absorption of 20% or more of electrons by dust particles is found to have a significant impact on the nature of the interaction region including generation of an Alfven wing. Comparisons of the simulation results with the Cassini data are used to deduce the shape and density of the plume and level of charged dust present in the vicinity of Enceladus.

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Tuesday, March 16, 2010: 16:55 - 17:20
Presenter: Munakata, Kazuoki

## Heliospheric signatures seen in the sidereal anisotropy of high-energy galactic cosmic ray intensity

M. Amenomori[1], X. J. Bi[2], D. Chen[3], S. W. Cui[4], Danzengluobu[5], L. K. Ding[2], X. H. Ding[5], C. Fan[6], C. F. Feng[6], Zhaoyang Feng[2], Z. Y. Feng[7], X. Y. Gao[8], Q. X. Geng[8], Q. B. Gou[2], H. W. Guo[5], H. H. He[2], M. He[6], K. Hibino[9], N. Hotta([10], Haibing Hu[5], H. B. Hu[2], J. Huang[2], Q. Huang[7], H. Y. Jia[7], L. Jiang[8],[2], F. Kajino[11], K. Kasahara[12], Y. Katayose[13], C. Kato[14], K. Kawata[3], Labaciren[5], G. M. Le[15], A. F. Li[6], H. C. Li[4],[2], J. Y. Li[6], C. Liu[2], Y.-Q. Lou[16], H. Lu[2], X. R. Meng[5], K. Mizutani[12],[17], J. Mu[8], K. Munakata[14], A. Nagai[18], H. Nanjo[1], M. Nishizawa[19], M. Ohnishi[3], I. Ohta[20], S. Ozawa[12], T. Saito[21], T. Y. Saito[22], M. Sakata[11], T. K. Sako[3], M. Shibata[13], A. Shiomi([23], T. Shirai[9], H. Sugimoto[24], M. Takita[3], Y. H. Tan[2], N. Tateyama[9], S. Torii[12], H. Tsuchiya([25], S. Udo[9], B. Wang[2], H. Wang[2], Y. Wang[2], Y. G. Wang[6], H. R. Wu[2], L. Xue[6], Y. Yamamoto[11], C. T. Yan([26], X. C. Yang[8], S. Yasue([27], Z. H. Ye([28], G. C. Yu[7], A. F. Yuan[5], T. Yuda[9], H. M. Zhang[2], J. L. Zhang[2], N. J. Zhang[6], X. Y. Zhang[6], Y. Zhang[2], Yi Zhang[2], Ying Zhang[7],[2], Zhaxisangzhu[5] and X. X. Zhou[7] (The Tibet ASγ Collaboration) and J. Kóta([29]

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Mapping the global heliosphere by detecting energetic neutral atoms (ENAs), the IBEX derived the semi-direct information on the structure of the large-scale magnetic field surrounding the heliosphere (McComas et al. 2009, Heerikhuisen et al. 2010). Multi-TeV galactic cosmic rays (GCRs) also sense on the global structure of the magnetic field within the whole heliosphere as well as the field surrounding the heliosphere, and can provide an additional tool to explore the global structure of these fields. We discuss, in this context, the multi-TeV GCR intensity observed with the Tibet Air Shower (AS) experiment, which clearly shows a large-scale sidereal anisotropy (i.e. the directional distribution of the intensity), and which contains a midscale component structure observed as the excess intensity along Gurnett's HDP (Hydrogen Deflection Plane), as well as the global component structure well modeled in terms of a superposition of the uni-directional and bi-directional flows of GCRs in the local interstellar space. The amplitude of the midscale component appears like decreasing with increasing GCR energy, while the global component is almost independent of the energy in 1-100 TeV. There is no clear signature of the Compton-Getting anisotropy expected from the ~26 km/s motion of the heliosphere relative to the interstellar medium surrounding the heliosphere.

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Tuesday, March 16, 2010: 17:20 - 17:45
Presenter: Volwerk, Martin

**Ion pickup signatures near Europa (and other icy Galilean satellites)**

Martin Volwerk, Space Research Institute, Austrian Academy of Sciences, Graz, Austria

The Galileo spacecraft explored the Jovian system and during its mission time (December 1995 – November 2003) encountered the four Galilean satellites numerous times. Pickup ions are very important near Io, the main plasma source in the Jovian system, and associated cyclotron waves and mirror mode waves have been observed there. In the case of the icy satellites, specifically Europa, the expected pick up ions through sputtering of the surface were shown through ion cyclotron waves at frequencies of various elements that could be present at the surface of the moon. Interestingly, for chlorine there are not just the expected left-hand polarized waves of $Cl^+$, but there is an interval of right-hand polarized waves. This can either happen when the waves cross the cross-over frequency in a multi-component plasma or when negatively charged ions are picked up. The Europa results will be presented and a preliminary look at the cyclotron wave activity near Ganymede and Callisto will be given.

Wednesday, March 17, 2010: 8:00 - 8:25
Presenter: Grygorczuk, Jolanta

**The heliospheric interface: MHD modeling vs data**

Jolanta Grygorczuk, Marek Strumik and Romana Ratkiewicz, Polish Academy of Sciences

The data from the deep space Voyagers' missions have been recently completed by the global observations of the interstellar interaction from the Interstellar Boundary Explorer (IBEX). On the basis of these data we formulate the following verification criteria of the heliospheric models: 1) The heliospheric model should place Voyager 1 and Voyager 2 at the termination shock according to the measured distances. 2) The solar wind in the inner heliosheath coming from the numerical simulation should follow the plasma physical parameters measured by Voyager 2. 3) The obtained model results should reproduce the ribbon shape observed by IBEX. In this paper we apply all these criteria looking for the relationship between the ribbon and the configuration of the heliospheric interface. We focus on the influence of the interstellar magnetic field to be able to predict its orientation and strength.

Wednesday, March 17, 2010: 8:25 - 8:50
Presenter: Burrows, Ross

**The case for shock surfing**

R.H. Burrows, G.P. Zank, G.M. Webb, B. Dasgupta, X. Ao
CSPAR-University of Alabama in Huntsville

Although it is becoming widely accepted that pickup ions (PUIs) play a crucial role in energy dissipation at the termination shock (TS) the precise physical processes occurring in the shock layer remain poorly understood. We examine the shock surfing or multiply reflected ion (MRI) acceleration mechanism and discuss evidence, pro and con, for this being the primary dissipation mechanism at the TS. Plasma fluid conservation laws are considered in terms of possible feedback between MRI acceleration in the shock layer and source terms introduced into the fluid equations. Using the fluid approach we make a quantitative estimate for the heating of PUIs at the TS and then discuss the possibility for MRI acceleration to provide this heating.

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Wednesday, March 17, 2010: 8:50 - 9:15
Presenter: Gary, Peter

**Hybrid simulations of the termination shock: Suprathermal ion velocity distributions in the heliosheath**

S. Peter Gary(1), Pin Wu(1,2,3), Kaijun Liu(1), Dan Winske(1), Nathan A. Schwadron(1), and Herbert O. Funsten(1)

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(2) Department of Astronomy, Boston University, Boston, Massachusetts, USA
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The Los Alamos hybrid simulation code has been used to examine kinetic properties of pickup ions at the heliospheric termination shock and in the downstream heliosheath. The simulations described here are one-dimensional in spatial variation, represent the electrons as a zero-mass fluid, and address only perpendicular shocks. Three topics are studied concerning the properties of suprathermal ions downstream of the termination shock. First, a careful examination of pickup ion scattering at the shock leads to a new interpretation of how most of these ions gain energy during a single transition of the shock. The primary factor in this energy gain is a gyro-phase-dependent interaction with the electric fields at the shock. Second, four shock simulations are carried out in which the upstream pickup ions are assumed to have four different types of velocity distributions. The downstream ion perpendicular velocity distributions $f(v_\perp)$ are similar in each of the four runs, and may be approximately characterized as a thermal Maxwellian and a suprathermal distribution. The suprathermal $f(v_\perp)$ may be fit with power-law distributions in $v_\perp$ for limited ranges of the perpendicular velocity. Third, simulations are carried out for three different upstream Mach numbers; the results show that faster solar wind flows lead to an increased flux of ions in the tails of the suprathermal component, consistent with energetic neutral atom observations by the IBEX spacecraft.

NOTES

Wednesday, March 17, 2010: 9:15 - 9:40
Presenter: Jian, LK

**Ion cyclotron waves in the inner heliosphere**

L.K. Jian (1), C.T. Russell (1), J.G. Luhmann (2), B.J. Anderson (3), S. Boardsen (4), T.L. Zhang (5), A. Wennmacher (6)

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(2) Space Sciences Laboratory, University of California, Berkeley, CA, USA
(3) Applied Physics Laboratory, John Hopkins University, MD, USA
(4) Goddard Earth Sciences and Technology Center, MD, USA
(5) Space Research Institute, Austrian Academy of Sciences, Graz, Austria
(6) Institute of Geophysics and Meteorology, University of Cologne, Germany

We report the in situ observations of the ion cyclotron waves in the solar wind from 0.3 to 1 AU, using the high-resolution magnetometer data from STEREO, MESSENGER, Helios, and Venus Express missions. These waves are almost circularly-polarized transverse waves, propagating nearly parallel to the magnetic field, and below the local proton gyro-frequency in the solar wind frame. Since we avoid planetary flybys and interplanetary shocks in our investigation, these waves are unlikely to be generated by planets or shocks. The ICWs are ubiquitous in the solar wind, but are preferentially detected when the field is close to the radial direction. The small angle between the magnetic field and the solar wind velocity suggests that these ICWs are unlikely to be generated by local pickup ions. The ICWs are narrow banded, indicating they probably were from a resonant instability. Although the waves appear both left-handed and right-handed in the spacecraft frame, their properties suggest they are all intrinsically left-handed waves in the solar wind frame. These waves are consistent with generation closer to the Sun followed by outward transport by the super-Alfvénic solar wind. The different handedness is due to inward or outward propagation in the solar wind frame. We analyze the wave properties of individual events to obtain the statistics of the wave power and wave frequency from 0.3 to 1 AU. By comparing these wave properties at different distances, we try to infer their generation mechanism and constrain their evolution.

Wednesday, March 17, 2010: 9:40 - 10:05
Presenter: Florinski, Vladimir

**Stability of pickup ion rings in the outer heliosheath**

V. Florinski, G. P. Zank, J. Heerikhuisen, CSPAR-University of Alabama in Huntsville

The IBEX satellite has discovered a band of enhanced neutral atom (ENAs) flux coming from a band-like circular structure in the sky. It has been suggested that the feature is due to secondary pickup ions (PUIs) produced by a sequence of charge exchanges between neutral solar wind and heliosheath atoms with the plasma and interstellar neutral hydrogen in the outer heliosheath, respectively. The theory relies on the assumption that the ring of newly born PUIs is slow to scatter to an isotropic shell allowing it to charge exchange again to produce the observed ENAs that will be concentrated in regions where the magnetic field is perpendicular to the line of sight. We test this assumption using a linear Vlasov theory and hybrid kinetic simulations of a low-density pickup ion ring interacting with instability-generated waves in a warm plasma of the outer heliosheath. We show that for any plausible initial PUI ring distribution a broadband spectrum of waves is excited as a result of a cyclotron instability. The waves lead to particle scattering onto an isotropic shell on a characteristic timescale of 1 day, which is much less than the timescale for charge exchange in the outer heliosheath. We also show that the ambient fluctuations contribute very little to the scattering process compared with the waves excited by the instability.

Schedule of Talks

NOTES

Wednesday, March 17, 2010: 10:30 - 10:55
Presenter: Young, David

**Ion pickup in Saturn's magnetosphere**

David T. Young, Southwest Research Institute, San Antonio, TX

One of the major objectives of the Cassini mission is to uncover the sources and sinks of plasma in Saturn's magnetosphere. After nearly six years orbiting the planet, Cassini has identified several important sources that contribute plasma through ion pickup driven by co-rotation of the giant planet's magnetosphere. Sources include the main rings, icy satellites (primarily but not exclusively Enceladus), the E-ring, and Titan. Because of the unique properties of these sources, Saturn's pickup populations are unlike those of any other planet. For example Titan, the only moon in the solar system with a thick atmosphere, sheds hydrocarbon ions at a high rate through the pickup process. Enceladus emits ~100 kg/s of water molecules that are ionized and picked up at a rate of ~1 kg/s, giving rise to a water-dominated magnetosphere. In addition, because of charging of nanograin dust particles, E-ring pickup acceleration extends to ions with masses >10,000 amu/e. Following pickup, these ion populations co-rotate with Saturn, leading to interesting feedback conditions and dynamics. This paper will provide an overview of pickup populations and processes at Saturn and examine the critical role ion pickup plays in global magnetosphere dynamics.

Wednesday, March 17, 2010: 10:55 - 11:20
Presenter: Yoon, Peter H.

**Kinetic theory of turbulence in magnetized plasmas**

Peter H. Yoon(1,2,3)

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The study of turbulence in magnetized plasmas is important for a number of applications, including solar coronal heating and wind acceleration, laboratory anomalous transport, and the charged particle acceleration and precipitation in the radiation belt, to name a few. In the literature, the turbulence in magnetized plasmas is customarily investigated by means of macroscopic fluid theory, such as ideal MHD and two-fluid (i.e., Hall-MHD) models, or quasi-linear kinetic theory where nonlinear wave-wave coupling is ignored. A heuristic semi-classical kinetic theory of turbulence in magnetized plasmas was formulated in the 1960s, but the statistical mechanical formulation of the same problem, which is necessary for a quantitative analysis, has not been accomplished. Recently, the author formulated the statistical mechanical kinetic turbulence theory, albeit, with the limited assumption of the turbulence assumed to be propagating along the ambient magnetic field. In the present presentation, the problem of Alfven waves interacting via three-wave decay process will be discussed. It will be shown that the cascade and inverse cascade of low-frequency Alfven waves to ion-cyclotron and ion-sound turbulence takes place mediated by the magnetosonic waves, accompanied by the proton and electron heating. I will also discuss the problem of nonlinear evolution of electromagnetic ion-cyclotron (EMIC) instability. EMIC instability is operative in a wide range of natural and laboratory plasmas. Linear theory of the instability is a textbook problem, but as far as nonlinear theory is concerned, no fundamentally new progress has been made since the mid 1970s when quasi-linear theory was employed to analyze the nonlinear behavior of the instability. I will report the first nonlinear theory of EMIC instability that goes beyond quasi-linear to include turbulent wave-wave interaction processes. It is found that nonlinear property of EMIC instability is markedly different from that based upon the standard quasi-linear analysis.

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Wednesday, March 17, 2010: 11:20 - 12:00
Presenter: Gurnett, Donald

**Plasma waves associated with pick up ions**

Donald A. Gurnett, Department of Physics and Astronomy, The University of Iowa

Pick up ions produced by charge exchange between a rapidly moving plasma and a neutral gas typically result in a highly unstable beam or ring-type velocity distribution, with the attendant generation of intense plasma waves. In this paper an overview is given of plasma waves produced by pick up ions in a wide variety of situations throughout the heliosphere. Examples are given of plasma waves produced by pick up ions (1) from the interaction of Earth's ionosphere with the water vapor cloud around the Space Shuttle; (2) from the interaction of the solar wind with neutral gas clouds around comets; and (3) the interaction of the rapidly co-rotating magnetospheric plasma of Jupiter and Saturn with neutral gas clouds associated with various moons of these planets. Three types of plasma waves are often observed: short wavelength electrostatic waves, especially near the lower-hybrid resonance frequency; electromagnetic ion cyclotron waves near the ion cyclotron frequency; and mirror-mode waves. We show that all three of these waves play an important role in heating and redistributing the pitch angle of the newly formed ions. The likely role of plasma waves produced by pick up ions in the outer regions of the heliosphere will be discussed.

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Wednesday, March 17, 2010: 12:00 - 12:25
Presenter: Mewaldt, Richard A.

**Solar flare neutrons and ENAs as a source of energetic pickup ions for acceleration by CME-driven shocks**

R. A. Mewaldt(1), E. Chollet(1), C. M. S. Cohen(1), and G. M. Mason(2)

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(2) Applied Physics Laboratory/Johns Hopkins University, Laurel MD, 20723

During large solar eruptions there is typically both an X-class flare and a fast coronal mass ejection (CME). The X-ray flare is often accompanied by gamma-radiation, including the 2.2 MeV neutron-capture line indicating that flare-accelerated H and He with >30 MeV/nuc have produced a large number of neutrons via nuclear interactions in the chromosphere. Recently, Feldman et al. (2010) suggested that protons and electrons produced by the beta-decay of escaping neutrons could serve as a source of energetic seed particles for acceleration by the CME-driven shock just as it is lifting off. In addition, STEREO observations during the December 6, 2006 solar event have identified energetic neutral hydrogen atoms (ENAs) with a time profile very similar to the X-ray flare (Mewaldt et al. 2009). Many of the escaping ENAs will be stripped in the corona, producing a second possible source of seed particles. In this talk we evaluate these suggested seed-particle sources using a) estimates of the yield of neutron-decay and stripped-ENA protons, based on observations and models; b) estimates of the density of ambient suprathermal seed particles; and 3) measurements of accelerated particle populations in large SEP events.

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Wednesday, March 17, 2010: 12:25 - 12:50
Presenter: Lazarian, Alex

**Reconnection of weakly magnetic fields and energetic particle acceleration**

Alex Lazarian, University of Wisconsin

As higher resolution studies confirm the model of the reconnection of weakly turbulent magnetic field proposed in Lazarian & Vishniac 1999, it is appropriate to start testing numerous implications of the model. One of the implication is the First order Fermi acceleration which was proposed in de Gouveia dal Pino & Lazarian 2003. In this model energetic particles entrained on a shrinking magnetic field line of the reconnected flux get accelerated. To test the model we use the snapshots obtained in the process of reconnection and send the test particles. We observe acceleration which is much faster than the turbulent one. The results support a reconnection-induced mechanism of the acceleration of the anomalous cosmic rays proposed in Lazarian & Opher 2009.

Thursday, March 18, 2010: 8:00 - 8:25
Presenter: Wellbrock, Anne

**Electron heating regions at and near Titan's ionospheric pile-up boundary**

A. Wellbrock, A. J. Coates, G.H. Jones, C. S. Arridge, F.C. Crary, D. T. Young

Titan is a large moon with a dense atmosphere but no significant intrinsic magnetic field (Neubauer et al, 1982). At its orbit (20 Saturn radii from Saturn) it is exposed to Saturn’s outer, sub-corotating magnetospheric plasma under typical solar wind dynamic pressure. The Cassini CAPS electron spectrometer (CAPS-ELS) is a hemispherical top-hat electrostatic analyzer and measures the flux of electrons as a function of energy per charge and aperture entry direction (Young et al, 2004). During flybys of Titan by Cassini, the CAPS-ELS data often shows evidence of electron heating regions where electrons are heated from a few eV up to several 10s of eV. These events have been observed on both the inbound and outbound parts of the encounters. In this paper we report on the characteristics of these events, such as latitude and altitude dependence, location with respect to the upstream magnetospheric flow, relation to the magnetospheric environment, and the amount of heating. We also investigate possible connections to ion pickup. In addition, we study two other regions in Titan’s ionosphere in order to consider possible relations with these electron heating events: (i) partial and significant magnetospheric bite-out regions and (ii) photoelectron peak regions in Titan’s sunlit ionosphere. Magnetospheric bite-outs (i) are regions that can be seen in electron spectrograms when higher energy electrons disappear or decrease in intensity as a result of being scattered down by particles in Titan’s ionosphere as they collide (Hartle et al, 2006). Photoelectron peaks (ii) at 24.1 eV can be observed when neutral nitrogen is ionized by the strong solar He(II) line at 30.4 nm. These peaks can be seen continuously during close encounters in Titan’s sunlit ionosphere (e.g. Galand et al, 2006).

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Thursday, March 18, 2010: 8:25 - 8:50
Presenter: Ratkiewicz, Romana

**The SW-LISM Interaction: Modeling and observations**

Romana Ratkiewicz, Jolanta Grygorczuk and Marek Strumik, Space Research Center, Polish Academy of Sciences

A short survey of work done on the interaction of the interstellar medium with the solar wind in view of the Voyagers data and observations of the Interstellar Boundary Explorer (IBEX) is made. The paper reviews several heliospheric numerical models presented in the last decades. Some philosophical questions concerning current possibilities of modeling are rised, in particular, to what extent it is necessary to complicate models to reproduce the nature.

Thursday, March 18, 2010: 8:50 - 9:15
Presenter: McComas, David J.

**Temporal evolution of the IBEX ribbon and implications for possible sources**

D.J. McComas(1,2) on behalf of the IBEX Team

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(2) University of Texas at San Antonio, San Antonio, TX 78249, USA

Global images of the heliosphere's interaction with the local interstellar medium have recently been published using observations from the Interstellar Boundary Explorer (IBEX) mission [McComas et al., *Science*, 326, 5955, 2009 and related articles in the same issue]. IBEX observes energetic neutral atoms (ENAs) emanating in from the interaction region at the edge of the heliosphere. IBEX observations cover the energy range from <100 eV – 6 keV, which includes the important populations produced by heliospheric pickup ion (PUIs) charge exchanging and producing ENAs in potentially both the inner and outer heliosheath (inside and out side the heliopause). In IBEX's first sky maps, we discovered a narrow, bright ribbon of ENA emissions unpredicted by any prior models or theories that appears to be ordered by the interaction of the heliosphere with the local interstellar magnetic field. This ribbon is superposed on more gradually spatially varying globally distributed ENA flux, which is ordered by both the solar wind structure and the direction of motion through the interstellar medium. Thus, IBEX observations indicate that the external galactic environment somehow strongly imprints the heliosphere. This talk 1) summarizes the published IBEX observations and explanations that were put forward for generating the ribbon, 2) shows newer IBEX observations to demonstrate that while the ribbon structure is largely stable, the detailed ENA emissions are in fact evolving over the six months between IBEX's first and second sky maps, and 3) discusses the implications for such temporal evolution for the various ideas and models for ribbon generation.

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Thursday, March 18, 2010: 9:15 - 9:40
Presenter: Krauss-Varban, Dietmar

**Simulations of pick-up ions in the lunar environment**

Dietmar Krauss-Varban and Jasper Halekas, Space Sciences Laboratory, UC Berkeley

The Moon presents us with a unique environment for studying the generation of pickup ions and their consequences. Solar wind ions generate a host of secondary ions during interaction with the Moon's surface. Most importantly, solar wind protons themselves are reflected at a significant ratio, retaining a major fraction of their original streaming speed. Since the solar wind ion beta typically is of order of unity or less, and the solar wind is super-Alfvénic (typically of the order of $M_A$ ~ 6 to 12, at 1 AU), such reflected ions behave like pick-up ions with a thermal speed that is several times that of the background - depending on solar wind ion beta and Mach number. Using a realistic dependence of reflectance and angle distribution, we study the phase space density of such ions, in particular pick-up protons, in the Lunar environment, using self-consistent hybrid (kinetic ion, fluid electron) simulations. Presence of these energetic ions is of interest all around the Moon. Most importantly, in the wake region behind the moon, only energetic ions have immediate access due to their speed and relatively large gyro radii. We provide statistics that help distinguish thermal protons, suprathermal solar wind tail background protons, and reflected pick-up protons in the wake region. One particularly enticing feature of the wake is that in principle it allows us to experimentally sample solar wind tail ion distributions in an energy regime that is otherwise instrumentally overwhelmed by the streaming solar wind. However, pick-up protons may add a substantial third contribution in this energy range. Kinetic simulations as presented here therefore are a useful tool for quantifying the respective preponderance of these three proton sources in various sub-regions of the wake, and thus, in the end, may help define characteristics of solar wind proton distributions in this otherwise difficult to evaluate suprathermal energy range. We discuss the impact of the reflectance properties of the moon and compare our results to recent observations.

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Thursday, March 18, 2010: 9:40 - 10:05
Presenter: Hsieh, Ke Chiang

**The return of the pick-up ions & the thickness of the heliosheath**

K. C. Hsieh(1), J. Giacalone(2), A. Czechowski(3), M. Hilchenbach(4), S. Grzedzielski(3), J. Kota(2), and R. Decker(5)

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Soon after Voyager 1 (V1) crossed the termination shock (TS), Czechowski *et al*. (*Astrophys. J*., **647**, L69, 2006) estimated $L$, the characteristic thickness of the heliosheath in the portion of the heliosphere facing the interstellar wind, by using the ENA data from HSTOF/SOHO (58-88 keV for H and 28-58 keV/A for He atoms) and the ion data from LECP on V1 in the same energy interval, assuming a uniform local interstellar H concentration of 0.1 $cm^{-3}$. After V2 crossed the TS, a firmer value of $L$ = 42 ± 12 AU was reported (Czechowski *et al*., *Astron. & Astrophys*., **487**, 329, 2008). Until V1 and V2 cross the heliopause (HP), these estimates and the simple model of the interaction between the ions and local interstellar gas in the heliosheath (HS) remain unchecked by in-situ observation. The recently reported ENA fluxes in the inner heliosphere at lower energies by IBEX and INCA/Cassini (in *Science*, **326**, 2009), and the advance in the numerical simulation of the processing of ions crossing TS into HS (Giacalone & Decker, *Astrophys. J*., **710**, 91, 2010), however, provided an independent means to cross check the approach of Czechowski *et al*. (2006 & 2008). The agreement between the proton spectrum in the HS deduced from ENA data for a given value of $L$ and the proton spectrum predicted by simulation of TS-processing of ions strongly suggest that 1) the ion population responsible for ENA is described by a common spectrum, extending from the pick-up ions to the energies approaching 100 keV, 2) the value of $L$ estimated by the approach of Czechowski (at this meeting) is of right order of magnitude and 3) the simulation of the TS-processing of ions by Giacalone and Decker (2010) is credible.

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Thursday, March 18, 2010: 10:30 - 10:55
Presenter: Jokipii, Jack R.

**Effects of interstellar magnetic-field turbulence on the IBEX ribbon**

J. R. Jokipii, J. Giacalone, K.C. Hsieh and J. Kóta, University of Arizona

We explore the effects of Interstellar turbulence on the ribbon observed by IBEX in the energetic-neutral-atom (ENA) intensity. The ribbon appears to be the result of the re-combination of 2nd-generation interstellar ions producing neutrals directed normal to the very local interstellar magnetic field (VLISMF). Hence, the ribbon traces approximately the direction in which the VLISMF is normal to the vector from point of observation in the inner heliosphere. We suggest that the structure of the ribbon, especialy its width, is at least in part, the result of turbulent fluctuations in the VLISMF. A variety of observations over the last few decades have revealed that the interstellar medium and its magnetic field are turbulent, exhibiting a broadband, Kolmogorov-like turbulence spectrum, with an outer (correlation) scale of a few parsecs and an inner scale less than about 1000 km. Hence the VLISMF direction is not expected to be (and indeed is not) the direction of the large-scale (tens of parsecs) average interstellar magnetic field. Moreover, the VLISMF has fluctuations down to 1000 km scales. Because of the very small gyro-radii of the pickup ions in the LISMF, the observed 2nd-generation neutrals travel nearly normal to the very local ISMF (VLISMF), and because the source of the observed ENA is distributed over the ionization mean free path of several hundred AU, the direction normal to the VLISMF indicated by the arrival directions of the ENA will fluctuate depending on the level of fluctuations in the VLISMF on scales of several hundred AU. We should therefore see spatial structure in the magnetic field, and hence, the ribbon, down to smaller scales, with corresponding time variations. These effects will give a lower bound to the width of the ribbon. Further, the structure of the ribbon may provide a valuable observational constraint on the interstellar turbulence spectrum. We find that the observed ribbon width is consistent with present estimates of the structure of the turbulent interstellar magnetic field.

Thursday, March 18, 2010: 10:55 - 11:20
Presenter: Hilchenbach, Martin

**Energetic neutral atoms from the heliotail and their potential source regions**

M. Hilchenbach (1) , and K.C. Hsieh (2) and A. Czechowski (3)

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(2) University of Arizona, Physics Department, AZ 85721 Tucson, USA
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The particle instrument CELIAS/HSTOF onboard SOHO is observing the energetic neutral atom (ENA) flux in the ecliptic plane since 1996. During quiet time periods, the ENA flux is well separated from the energetic ion flux, originating in the solar corona and/ or heliosphere. The instrument is capable to measure the energetic neutral hydrogen (ENH) and helium (ENHe) fluxes along the line-of-sight of the instrument field-of-view. We will discuss the neutral energetic flux measurements of hydrogen and helium in the 28 to 88 keV/n energy/mass range of CELIAS/HSTOF, focusing on the frequently increased fluxes from the tail direction of the heliosphere. Potential source regions might be corotating interaction regions (CIRs) and the helium cone in the inner heliosphere, solar energetic particle events, accelerated pick-up ions in the outer heliosphere and energetic neutral particles originating from the heliosheath region and beyond.

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Thursday, March 18, 2010: 11:20 - 12:00
Presenter: Pogorelov, Nikolai

**Relating IBEX and Voyager data through global modeling of the heliospheric interface**

N. V. Pogorelov(1,2), S. N. Borovikov(2), J. Heerikhuisen(1,2), G. P. Zank(1,2), L. F. Burlaga(3), R. W. Ebert(4,5), P. C. Frisch(6), D. J. McComas(5,4), J. D. Richardson(7), E. C. Stone(8), S. T. Suess(9)

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(2) CSPAR, University of Alabama in Huntsville
(3) Goddard Space Flight Center, Greenbelt, MD
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(5) Southwest Research Institute, San Antonio, TX
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(9) NSSTC, 320 Sparkman Dr., Huntsville, AL

While the Voyager 1 and 2 spacecraft are exploring the boundaries of the heliosphere, our newest spacecraft, the Interstellar Boundary Explorer (IBEX) has started exploring the outermost reaches of the heliosphere, but from an orbit at 1 AU using a sort of tomography based on the measurement of energetic neutral atoms (ENAs) created in the boundary regions separating the heliosphere from the LISM. The first IBEX results revealed a sky-spanning "ribbon" of unexpectedly intense emissions of ENAs that had not been predicted previously by any physical model. For the next 5-10 years, heliophysics research is faced with an extraordinary opportunity that cannot be soon repeated. This is to make *in situ* measurements of the SW from the Sun to the heliospheric boundaries and, at the same time, extract information about the global behavior of the evolving heliosphere through ENA observations by the IBEX. In this review, we describe the effects of unsteady solar wind (SW) and interstellar magnetic field (ISMF) pressure of the shape of the heliopause and the terminations shock. We investigate the ISMF effects on the deflection of the neutral hydrogen flow in the inner heliosphere from its original direction in the unperturbed local interstellar medium (LISM) and on the position of the ENA ribbon. Looking for the SW flow behavior, we investigate the distribution of the total pressure on the surface of the heliopause. It is shown that the ISMF direction strongly correlates with the ribbon location. The distributions of the SW parameters and magnetic field strength in the inner heliosheath are analyzed and compared with the Voyager observations.

# Schedule of Talks

NOTES

Thursday, March 18, 2010: 14:00 - 14:25
Presenter: Drake, Jim

## Magnetic reconnection and particle acceleration in the outer heliosphere

J. F. Drake(1), M. Swisdak(1), M. Opher(2), F. A. Bibi(2)

(1) University of Maryland
(2) George Mason University

The role of magnetic reconnection in the heliosheath as a mechanism for the acceleration of anomalous cosmic rays (ACRs) and at the heliopause (HP) as a source of radio emissions is discussed. The recent observations of the anomalous cosmic ray (ACR) energy spectrum as Voyagers 1 and 2 crossed the heliospheric termination shock have called into question the conventional shock source of these energetic particles. We suggest that the sectored heliospheric magnetic field, which results from the flapping of the heliospheric current sheet, piles up as it approaches the heliopause, narrowing the current sheets that separate the sectors and triggering the onset of collisionless magnetic reconnection. Particle-in-cell simulations reveal that most of the magnetic energy goes into energetic ions with significant but smaller amounts of energy going into electrons. The most energetic ions gain energy as they reflect from contracting magnetic islands, a first order Fermi process. The simulations also reveal that the mirror and firehose conditions play an essential role in the reconnection dynamics and particle acceleration. An analytic model is constructed in which the Fermi drive, modulated by the approach to firehose marginality, is balanced by convective loss. The ACR differential energy spectrum takes the form of a power law with a spectral index slightly above $1.5$. The model can explain several key ACR observations, including the similarities in the spectra of different ion species.Reconnection at the HP is suppressed in most locations due to the large pressure of pickup particles and associated diamagnetic drifts. Reconnection is predicted to occur only where the draped local interstellar magnetic field is anti-parallel to the heliospheric magnetic field. Reconnection is an efficient source of energetic electrons, which often take the form of spatially localized beams capable of producing ratio emission (e.g., type-III radio emission in the solar corona). We demonstrate that if $B_{ismy} > 0$ the region of anti-parallel magnetic field matches the location of radio emissions at the HP documented by Kurth and Gurnett (2003), while if $B_{ismy} < 0$ reconnection sites are far from the sites of radio emission. Combined with other observational constraints, we are able to predict the vector direction of the local interstellar magnetic field.

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Thursday, March 18, 2010: 14:25 - 14:50
Presenter: Karimabadi, Homa

**Why is reconnection in the solar wind so different than in other environments?**

H. Karimabadi(1), J. Scudder(2), V. Roytershteyn(3), W. Daughton(3), J. Gosling(4)

(1) SciberQuest, Inc. / UCSD
(2) University of Iowa
(3) Los Alamos National Lab
(4) University of Colorado

Studies of reconnection in the solar wind led by Gosling and collaborators have revealed surprising results that are posing serious challenges to current theoretical understanding of the reconnection process. The particular significance of the solar wind measurements is that they open up a new, and in many ways unparalleled, laboratory for studying the large-scale properties of reconnection in space plasmas. In contrast to conditions in the magnetosphere, the solar wind contains numerous large-scale current sheets with relatively stable boundary conditions; many of these current sheets are sufficiently extensive to be sampled by two or more spacecraft in the solar wind upstream from Earth. In addition, since the solar wind rapidly convects the exhausts past an observing spacecraft, almost instantaneous snapshots of the basic physical structure of the exhausts can be obtained. Further investigation of reconnection will not only yield understanding about its properties in the solar wind, but will have broad implications regarding reconnection as it occurs in the magnetosphere, in the solar atmosphere and in other plasma environments. In this talk, we will provide a brief overview of the observations of reconnection events in the solar wind and compare them with current theories of reconnection. We then discuss preliminary results of our large-scale full particle and hybrid simulations of reconnection in the solar wind which are providing some potential resolution to this mystery.

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Thursday, March 18, 2010: 14:50 - 15:15
Presenter: Czechowski, Andrzej

**Energetic ions and the observations of the heliosheath by means of ENA**

A. Czechowski(1), M. Hilchenbach(2), K.C. Hsieh(3), S. Grzedzielski(1)

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Voyager observations show that the inner heliosheath is characterized by high density of the energetic (E>28 keV) ions. Due to neutralization of these ions, the heliosheath is an important source of the energetic neutral atoms (ENA), which in turn can be observed in the inner solar system. The fluxes of the energetic hydrogen (58-88 keV) and helium (28-58 keV/n) atoms from the heliosheath have been measured by the instrument HSTOF on board SOHO. By combining these observations with the Voyager post-shock ion data it is possible to estimate the parameters of the inner heliosheath. We discuss recent developments related to this approach. Since Voyager ion data are restricted to the forward part of the heliosheath, they cannot be used to interpret the ENA observations of the flanks or the tail region. We use a simple model of the heliosphere to study the effects of the transport and loss mechanisms shaping the ion density distribution in the different regions.The important discovery by IBEX of the "ribbon" of enhanced ENA emision in the <6 keV energy range raises the question whether a similar structure can be present at higher energy. An enhancement in the energetic hydrogen flux was in fact observed by HSTOF in the region where the ribbon crosses its field of view. We discuss briefly the possibility of observing the ribbon in the HSTOF energy range. We also present a recently proposed explanation of the formation of the ribbon in which the ENA do not originate from the heliospheric pick-up ions.

Thursday, March 18, 2010: 15:15 - 15:40
Presenter: Mazelle, Christian

**Newborn and pickup ions in the environment of comets, Mars and Venus**

C. Mazelle, Centre d'Etude Spatiale des Rayonnements (CERS), UPS-CNRS, Toulouse, France

The neutral environment of a non-magnetized body of the solar system interacting with a fast flowing plasma like the solar wind will produce newborn ions through photo-ionisation, charge exchange or electron impact ionization and their subsequent pickup. The environment of a comet for instance is well-known as the ideal laboratory for studying the non collisional processes which will tend to assimilate such a new plasma population in the background plasma. This is performed mainly by the waves generated by the highly unstable newborn ion populations (ring-beam distributions) and these self-generated waves are then supposed to provide the appropriate diffusion via wave-particle interaction. These characteristic waves can then be used as a signature of the neutral environment even when experimental data neither on the neutrals nor on the ions are available. While large scale environment (as for highly active comets) allows the pitch-angle scattering to occur and produce nearly spherical shell distributions, this is not the case for a weakly active comet or the environment of a planet like Mars due to finite Larmor radius effect. Then the newborn ions velocity distributions will remain not only highly anisotropic (beam-like) but even also nongyrotropic. In the case of weakly active comets, the velocity distribution of the newborn ions has been predicted by integrating the Maxwell-Vlasov equation with appropriate source and loss terms and then compared to observations. The linear instability generated by this distribution has then been compared with the properties of the observed waves. Highly coherent waves at the proton cyclotron frequency both at Mars and Venus are the signatures of the existence of similar newborn ion distribution from the hydrogen exosphere of both planets.

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Thursday, March 18, 2010: 16:05 - 16:30
Presenter: Washimi, Haruichi

**Dynamic outer heliosphere and preliminary analysis of gcrs orbit**

Haruichi Washimi(1), Gary P Zank(1), Qiang Hu(1), Takashi Tanaka(2), Kazuoki Munakata(3)

(1) CSPAR, University of Alabama, Huntsville, AL, USA.
(2) Kyushu University, Fukuoka, Japan.
(3) Shinshu University, Matsumoto, Japan

We aim at realistic and time-varying modeling which should satisfy both Voyager 1 (V1) and Voyager 2 (V2) observed crossing times of the termination shock (TS) simultaneously, by performing three-dimensional MHD simulations which includes the effects of neutral particles. The short-term variations of the outer heliosphere is clarified in this analysis as following:
a) TS position increases every time when the solar-wind high-ram pressure pulse collides with the TS, b) a high magneto-sonic pulse is generated in the downstream side of the TS when the solar-wind high ram pressure pulse collides with the TS, c) fine structures of the heliosheath – magnetic wall and plasma sheet near the HP, and the thin current sheet embedded in the plasma sheet are identified, and the lower boundary of the plasma plays important role for the reflection of the magneto-sonic pulse and also probably for the particle acceleration, d) the TS position decreases when the reflected pulse collides with the TS, and e) the time-varying radial distance between V2 and reproduced TS positions seems consistent with the TS particle intensity profile during the period when the TSP was observed at V2. Under the given short- and long-term variations of electric and magnetic fields in the outer heliosphere, we analyze energetic charged-particle orbit to understand how GCRs come into the inner heliosphere passing across the heliopause. For this purpose an unstructured grid coordinate scheme simulation is provided, and test particle analyses under the given fields are performed. A preliminary result of the three-dimensional distribution of the charged particles in the 3D outer heliosphere is shown.

Thursday, March 18, 2010: 16:30 - 16:55
Presenter: Richardson, John

**Voyager observations and pickup ions**

John Richardson, MIT

Voyager 2 has seen effects of pickup ions since about 20 AU, first in the pressure-balance structures and then in the slowdown and heating of the solar wind. By the time V2 reached the ermination shock (TS) shock the speed had decreased by about 16% due to pickup ions. At the TS, most of the flow energy did not go into the thermal ions and is thought to have contributed to heating the pickup ions. This paper reviews previous pickup ion plasma work and sets limits for pickup ions in the heliosheath. We have also been looking at ICME shocks to see if pickup ions affect the heating at these shocks as well and will show these results. Reflected ions are seen at most, but not all interplanetary and planetary bow shocks and the presence of pickup ions may be a contributing factor.

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Thursday, March 18, 2010: 16:55 - 17:20
Presenter: Wang, Chi

**Propagation of interplanetary shocks from the inner to outer heliosphere**

Chi Wang(1), John D. Richardson(2)

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The solar wind in the outer heliosphere is fundamentally different from that in the inner heliosphere, since the influence of the local interstellar source becomes significant. We presented a multi-fluid MHD model, which takes into account the effects of pickup ions, to describe the solar wind in the outer heliosphere. Using observations from multiple spacecraft distributed throughout the heliosphere, we traced the propagation of ICMEs and their driven shocks from 1 AU to the location of Voyager 2. On October 16, 2001, Voyager 2 at 65 AU observed a strong shock with a speed jump over 100 km/3, the strongest shock recorded since 1991, but no single solar event was directly responsible for this shock. Instead, a series of solar events in April 2001 was responsible. The model results show that successive merging and interaction of relatively small interplanetary shocks could form a well-developed strong forward shock beyond 30 AU. In August 2007, Voyager 2 reached the termination shock and entered the heliosheath at a distance of about 84 AU. Due to the variations of the solar wind dynamic pressure or waves on the shock front, the termination shock crossed Voyager 2 multiple times. We examined the characteristics of the termination shock in detail. For two crossing events, the flow is found to be still supersonic with respect to the thermal ions downstream of the termination shock, probably due to the fact that most of the solar wind energy is transferred to pickup ions.

Thursday, March 18, 2010: 17:20 - 17:45
Presenter: Opher, Merav

**Global asymmetries in the heliosphere: Signature of the interstellar magnetic field**

M. Opher, F. Alouani-Bibi, V. Izmodenov, J. Richardson, T. Gombosi

In recent years it become clear that magnetic field effects, plays an important role in the Heliosphere, from shaping it and possible being responsible for the asymmetries observed in the Voyager data (e.g., Opher et al. 2007, 2009). However, the strength and orientation of the field in the local interstellar medium near the heliosphere has been poorly constrained. Previous estimates of the field strength range from 1.8-2.5 ορχιμG and the field was thought to be parallel to the Galactic plane or inclined by 38-60 ° (Lallement et al. 2005) or 60-90° (Opher et al. 2007) to this plane. These estimates relied either on indirect observational inferences or modeling in which the interstellar neutral hydrogen was not taken into account. We will discuss recent work that indicate that based on asymmetries detected by Voyager 1 and 2 and measurements of the deflection of the solar wind plasma flows in the heliosheath (Opher et al. 2009) indicate that the field strength in the local interstellar medium is strong, between 4-5 ορχιμG (Other works such as Izmodenov 2009; Pogorelov et al. 2009; Ratkiewickz et al. 2009 found similar strength). The field is tilted 20-30° from the interstellar medium flow direction (resulting from the peculiar motion of the Sun in the Galaxy) and is at an angle of about 30° from the Galactic plane. We will discuss the effect of such magnetic field in the global asymmetries of the heliosphere. We further will comment on the effect on asymmetries of our recent model of Kinetic-MHD model treating the neutrals in kinetic fashion (Alouani-Bibi et al. 2010). We will relate our findings with the most recent results of IBEX that indicate that the interstellar magnetic field has a strong signature in the emission of energetic neutrals.

NOTES

Friday, March 19, 2010: 8:00 - 8:25
Presenter: Intriligator, D.S. for Webber, W.R.

**Revisiting the Voyager 2-3 kHz radio emission**

W. R. Webber(1) and D. S. Intriligator(2)

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We have re-examined the relationships of the onset times of heliospheric kHz plasma wave emission reported by the Iowa Group during solar cycle #23, and the arrival of large shocks at V1 and V2 which are near the heliospheric termination shock at these times. The present paradigm, based on much larger kHz emissions observed in cycles #21 and 22, that these emissions only originate when a large shock reaches the heliopause, may need to be reconsidered in the light of these new comparisons.

Friday, March 19, 2010: 8:25 - 8:50
Presenter: Intriligator, Devrie

**Voyager 2 high energy ions near the termination shock**

D. S. Intriligator(1), J. Intriligator(1,2), W.D. Miller(1), W.R. Webber(3), R.B. Decker(4), W. Sun(1), T. Detman(1), M. Dryer(1), and C. S. Deehr(5)

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Voyager 2 was crossed by the termination shock on at least five occasions in August/September 2007 at ~ 84 AU. Near several of these crossings we found that in addition to the bulk convective plasma flow in the heliosheath there also appeared to be evidence of high energy plasma ions (Intriligator et al, *JGR*, in press, 2010). These high energy plasma ions may be pickup protons that either originated in the nearby solar wind or were accelerated from reflections off the termination shock. In either case, it is tempting to associate the presence of these high energy ions as an indication that Voyager 2 was in the vicinity of the termination shock. In this paper we show evidence for the presence of these high energy plasma ions when Voyager 2 was in the heliosheath from late November to mid-December 2007 and suggest that at this time the termination shock moved outward (away from the Sun) and again approached Voyager 2. To investigate the plausibility of this scenario, we employ 3D global modeling of solar events and the propagation of their associated interplanetary shocks from the Sun to Voyager 2.

NOTES

Friday, March 19, 2010: 8:50 - 9:15
Presenter: Cummings, Alan

**Voyager observations of accelerated pickup ions in the outer heliosphere**

Cummings, A.C.(1), Stone, E.C.(1), McDonald. F.B.(2), Heikkila, B.C.(3), Lal, N.(3), and Webber, W.R.(4)

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Pickup ions that become the high-energy anomalous cosmic rays (ACRs) observed at 1 AU begin as interstellar neutral gases that drift into the heliosphere, become ionized, and then are accelerated in the outer heliosphere. The source spectra of the higher-energy ACR component were not observed at either of the Voyager shock crossings and hence the location and mechanism of their acceleration are still to be determined. The particles may be accelerated along the flanks or tail of the shock or perhaps near the heliopause. A second distinct population of accelerated pickup ions has become apparent in the Voyager observations in the heliosheath. Low-energy termination shock particles appear to be accelerated at the termination shock by either classical diffusive shock acceleration, by a focused transport acceleration process, or by a nonlinear diffusive shock acceleration process. These particles are likely accelerated all along the termination shock, as they are observed at both Voyager 1 and Voyager 2. We will report on the latest observations of both of these accelerated pickup ion populations to gain further insight into their acceleration mechanisms and, in the case of the higher-energy ACRs, their source location.
This work was supported by NASA under contract NAS7-03001.

Friday, March 19, 2010: 9:15 - 9:40
Presenter: Kota, Jozsef

**Modeling Voyager-1 and -2 spectral differences along the blunt termination shock**

J. Kóta, J. Giacalone, and J.R. Jokipii, University of Arizona

Beside similarities, the energetic particle spectra seen by Voyager-1 and -2 showed distinct differences both before and after spacecraft's respective termination shock (TS) crossing. In particular, the post-TS spectrum was significantly harder at Voyager-2 than at Voyager-1: 40keV fluxes were higher at Voyager-1, while 0.5-1 MeV fluxes were higher at Voyager-2 (Decker et.al, 2008). It is conceivable that this difference is associated with the different locations of the two TS crossings. Voyager-1 was close to the nose, while Voyager-2 was more toward the flank, though the actual difference may have been smaller due to the asymmetry of the TS. Models including a blunt termination shock do predict less efficient acceleration at the nose, where the spiral field line first hits the shock and particles have had less time for acceleration (McComas and Schwadron, 2006; Kóta and Jokipii, 2004, 2006). We consider this model and apply our numerical 2-D code including the blunt TS. For the injection, we adopt the results of Giacalone and Decker (2010) obtained from hybrid simulations. We shall present numerical results and discuss their implications for injection and constrains for the transport parameters.

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Friday, March 19, 2010: 9:40 - 10:05
Presenter: Decker, Rob

**Variations of low-energy ion distributions measured in the heliosheath**

R. B. Decker (1), E. C. Roelof (1), S. M. Krimigis (1,2), and M.E. Hill (1)

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The LECP instruments on Voyagers 1 (V1) and 2 (V2) measure the intensities, energy spectra, and angular distributions of energetic ions and electrons. We summarize measurements of low-energy ions (28 keV - few MeV) made in the heliosheath (HSH) at V1 since 2004/351 (94-113 AU at latitude N35°) and at V2 since 2007/242 (84-91 AU at latitude S27-29°). This suprathermal ion population is the high-energy tail of pickup ion distributions that mediate termination shock (TS) structure and dominate the energy density of the HSH plasma. The core populations of the pickup ion distributions are not measured *in situ* in the HSH. However, their measured suprathermal tails provide absolute intensities and spectral indices that enable quantitative comparisons with models of pickup ion injection, heating, and acceleration at the TS and in the HSH, and with HSH ion distributions inferred from analyses of ENA intensities measured at spacecraft in the inner heliosphere. The angular distributions of the suprathermal ions also enable estimates of the plasma flow in the HSH (in the R-T plane). Recent results from the LECP data taken in the HSH include the following. (1) At V1 convective angular distributions of 40-140 keV ions show a steady decrease in the radial component of HSH plasma flow from ≈55-65 km/s in mid-2007 to ≈10-20 km/s in early 2010. (2) Although, on average, the intensities of low-energy HSH ions are comparable at V1 and V2, there are marked differences between the two spacecraft in the amplitudes and durations of intensity fluctuations. For example, during its first 1.5 years in the HSH, the V2/LECP measured quasi-recurrent (15-35 day) variations in the intensities and energy spectra of the suprathermal ions. Comparable variations have not been seen in the V1/LECP ions, which show relatively smooth intensities that are well fit by a power law with spectral index -1.5±0.1. Analysis indicates that the low-energy HSH ion intensity variations and differences thereof at the latitudes of V1 and V2 result from the different evolution in equatorward extensions of northern and southern polar coronal holes that produce stream interaction regions in the solar wind. These interaction regions and associated enhancements of low-energy ions accelerated at recurrent shocks can propagate into the outer heliosphere and into the TS/HSH. (3) Large increases in nearly radial anisotropies of >28 keV ions are measured at V2. During 2008.2- 2008.7 these increases were sporadic, but from 2009.3-onward the radial anisotropies became relatively steady. The onset of steady ion anisotropies is nearly coincident with the disappearance at V2 of 0.02-1.5 MeV electrons, the onset of the decreasing radial component of plasma flow measured by the V2 Plasma Science instrument, and the entry of V2 into southern polar coronal hole flow as indicted by the V2 Magnetometer. The enhanced V2 ion anisotropies are consistent with detection in the low-energy ion channels of protons >28 keV and helium ions >36 keV (9 keV/nuc) that are convected with the HSH plasma flow velocity.

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Friday, March 19, 2010: 10:30 - 10:55
Presenter: Desai, Mihir

**Acceleration of suprathermal and pickup ions near 1 au**

M. I. DESAI,(1, 2), F. ALLEGRINI(1, 2), H. KUCHAREK(3), E. MOBIUS(3), & G. M. MASON(4)

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We have surveyed the abundances of 0.25-0.8 MeV nucleon$^{-1}$ $He^+$, $^3He$, and heavy ions from C-Fe during 18 CME-driven interplanetary (IP) shocks observed near 1 AU by the ULEIS and SEPICA instruments on board the Advanced Composition Explorer between 1997 November and 2000 October. Our results show that each of the 18 IP shocks is accompanied by enhancements in the intensities of both $^3He$ and $He^+$ ions, showing for the first time, that individual IP shocks routinely accelerate ions from multiple sources, e.g., flares and pickup ions. Somewhat surprisingly and on a case-by-case basis, we also find that the abundances of $He^+$ and the heavier elements such as C-Fe (but not the $^3He$) are depleted systematically as a function of the ion's M/Q ratio when compared with those measured in the ambient suprathermal ion population upstream of the IP shocks. These results show that IP shocks accelerate ions via the same systematic rigidity-dependent mechanism wherein ions with higher rigidity or M/Q ratios are accelerated less efficiently than those with lower M/Q ratios. Finally, we investigate the relationship between the M/Q-dependence of the heavy ion abundances and the locally measured shock parameters and also explore why the $^3He$ abundance does not fit into the systematic M/Q-charge-dependent fractionation processes.

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Friday, March 19, 2010: 10:55 - 11:20
Presenter: Randol, Brent

**Pick-up ions measured with New Horizons/SWAP at 11 AU: Anisotropy, variability, and possible correlations with the solar wind**

Brent Randol(1,2), Heather Elliott(2), Dave McComas(2,1), Nathan Schwadron(3,2)

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(2) Southwest Research Institute
(3) Boston University

The Solar Wind Around Pluto (SWAP) instrument aboard the NASA spacecraft New Horizons measured ions from 3.5 eV/e to 7.5 keV/e in late 2008 in the solar wind in the ecliptic plane around 11 AU near the heliospheric nose direction. These data represent the first ever detailed measurements of interstellar pickup ions beyond the orbit of Saturn. First we discuss a continuous 8-hour interval in October, when the instrument was pointed out of the ecliptic, allowing us to observe interstellar pickup ions without contamination from the much brighter solar wind beam. We observe the characteristic cutoff in the pickup ion flux at about 4 times the bulk solar wind energy, with a partial “suprathermal tail” above that, as well as a ~4:1 anisotropy of sunward pickup ions. This anisotropy is nearly identical to the one found inside 5 AU with Ulysses SWICS. These new observations could indicate one or all of the following is occurring: there is an unknown source of background in the lower-energy data, the mean free path is much longer than previously thought, or the magnetic field at New Horizons is much more radial than we expect. Conversely, there could be some piece missing from the current pickup ion transport models. We also analyze the nominally ~1-day integrations of SWAP data following the higher-telemetry 8-hour interval. Although the solar wind beam dominates these observations, we still observe the pickup ion cutoff in almost all instances, as well as the sunward anisotropy and a suprathermal tail beyond the cutoff energy. However, we see significant variability within these phenomena. Also, we fit the distribution function of each species of ion with model functions and compute their densities in order to determine the correlation between the solar wind ions and the pickup ions. We find a fairly strong and possibly non-linear correlation.

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Friday, March 19, 2010: 11:20 - 11:45
Presenter: Raymond, John

**Pickup ions in supernova remnant shocks**

John Raymond, Harvard-Smithsonian Center for Astrophysics

Neutral particles passing through a fast shock become ionized downstream, so they should behave much like pickup ions. This paper will discuss the theoretical predictions for the velocity distribution for a mixture of pickup ions and ions that acquire a Maxwellian distribution at the shock. It will also present observations of the H alpha line profile in Tycho's Supernova Remnant that might be attributed to this effect. However, other interpretations are possible at this stage.

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Friday, March 19, 2010: 11:45 - 12:10
Presenter: Wood, Brian

**Lyman-alpha Absorption from Heliotail ENAs**

Brian Wood, Naval Research Laboratory, Space Science Division, Washington, DC 20375

Lyman-alpha Absorption from Heliotail ENAs The energetic neutral atoms (ENAs) that IBEX is currently studying are messengers from the termination shock and beyond. Their properties are determined in part by the properties of pickup ions in the solar wind, and on what happens to these ions when they encounter the termination shock. Ultraviolet spectra from the Hubble Space Telescope (HST) provide another way to study these ENAs, because they are capable of producing detectable absorption signatures in HST Lyman-alpha spectra of nearby stars. This broad, shallow absorption is only observed within 20 degrees of the downwind direction. This is consistent with the absorption originating from ENAs throughout the Sun's long heliotail, where only the downwind lines of sight through the heliotail build up enough column density of ENAs to yield detectable absorption. The absorption therefore represents the first real observational detection of the heliotail. I will summarize the relevant HST observations of the heliotail absorption, and place them in context with recent local ENA measurements from IBEX and Cassini.

Friday, March 19, 2010: 12:10 - 12:35
Presenter: Isenberg, P.A. for Smith, Charles

**Voyager and ACE observations of waves due to interstellar pickup H+ and He+**

C.W. Smith, C.J. Joyce, P.A. Isenberg, N. Murphy, and N.A. Schwadron

We have examined 2-sec Voyager-2 magnetic field data from shortly after launch until the end of 1979 when Voyager-2 was just beyond the encounter with Jupiter. This is the only useable Voyager data at this time resolution presently available. We have found one instance of low-frequency waves due to a combination of interstellar pickup H+ and He+ ions. This is the first report of waves due to interstellar pickup ions seen by the Voyager spacecraft and the first example of waves recognized as originating from interstellar He+. As with Ulysses observations of waves due to pickup H+, this instance is seen within a rarefaction interval possessing a nearly radial IMF. We compare the observation with predictions of quasilinear theory [Lee and Ip, 1987; Isenberg, 1995] and argue that there is sufficient time to produce observable levels of waves AND allow that same wave energy to drive turbulence that heats the solar wind in the outer heliosphere. We also explain why, at least in part, observations due to interstellar pickup ions are so few. As time permits, we will show an example of waves due to interstellar He+ observed by the ACE spacecraft as well.