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ORAL ABSTRACTS

Adhikari, Laxman	***The Interaction of Turbulence with Parallel and Perpendicular Shocks*** Laxman Adhikari, CSPAR, USA Gary P. Zank, UAH/CSPAR, USA Peter Hunana, UAH/CSPAR, USA Qiang Hu, UAH/CSPAR, USA Interplanetary shocks are common in the solar wind. Shocks are thought to be responsible for the amplification of turbulence as it is convected through a shock, as well as generating turbulence throughout heliosphere. Here, we apply the Zank et al. 2012 six coupled turbulence transport model equations to study the interaction of turbulence with parallel and perpendicular shock waves. For this, we model the 1D structure of a stationary perpendicular or parallel shock wave using a hyperbolic tangent function and the Rankine-Hugoniot conditions. Either six or four coupled 1D steady-state turbulence transport equations can describe the turbulence model. The turbulence transport equations are applied to parallel and perpendicular shock waves and solved using a 4th-order Runge Kutta method. We compare the model results against spacecraft observations of low-frequency turbulence upstream and downstream of shocks observed by the ACE spacecraft in the interplanetary medium. We identify six quasi-perpendicular and three quasi-parallel events in the ACE spacecraft data sets, and computed several turbulent parameters from the observations, such as the fluctuating magnetic and kinetic energy, the energy in forward and backward propagating modes, the total turbulent energy upstream and downstream of the observed shocks. We find that our corresponding predicted turbulence parameters for 1D steady state parallel and perpendicular shock waves are consistent with observations.
Bellan, Paul	***Radial Ejection Of Accretion Disk Angular Momentum Via The Electric Currents That Power Astrophysical Jets*** Paul M. Bellan, Applied Physics and Materials Science, Caltech, USA Two perplexing mysteries involve accretion disks. The first has to do with the increase of the kinetic energy L^2/(2mr^2) of angular momentum as the spin radius decreases. If angular momentum were conserved, the accreting gas spin energy would become infinite as the gas orbit radius decreased towards zero. Thus, angular momentum of the accreting gas must somehow be ejected. The second mystery is why stars with accretion disks typically have bi-directional plasma jets shooting away from the disk along the disk axis. I propose a model for resolving these mysteries [1]. Because of frequent inter-particle collisions, a clump of ions and the much larger number of adjacent neutral gas particles in an accretion disk behaves like a meta-particle having the charge of the ion and the mass of the neutral gas particles. The effective clump charge to mass ratio could easily be a billion times smaller than that of an ion in which case the clump cyclotron frequency would be comparable to the Kepler frequency. Detailed analysis shows that centrifugal force effectively ceases to exist when the cyclotron frequency is twice the Kepler frequency. Gravity is then unopposed in such critically-tuned clumps in which case they undergo magnetic braking and spiral in towards the star rather than orbit in the usual fixed-radius way. Because ionization is stratified, there will always be these critically tuned clumps. Furthermore, because the inward spirally clumps have electric charge, their accumulation at small radius produces a radially outward electric field causing the disk to behave like a battery with positive terminal near its axis and negative terminal near its rim. The battery, powered by the gravitational energy released by the inward spiraling clumps, drives electric currents that simultaneously drive the jets and transport angular momentum to near infinite radius. The radial angular momentum transport mechanism is analogous to an electric generator at small radius absorbing high spin-energy angular momentum and then transporting this angular momentum via electric current in wires to an electric motor at large radius that spins up fluid to create angular momentum with minimal spin-energy; magnetic forces associated with the electric currents in the wires accelerate plasma jets.
Ben-Jaffel, Lotfi	***The Voyager Ultraviolet Spectrometers*** Lotfi Ben-Jaffel, IAP-CNRS-UPMC, France During the last two decades, the Voyager 1 and 2 Ultraviolet Spectrometers (UVS) harvest covered EUV and FUV observations of the outer planets and their satellites, heliosphere sky-background in situ measurements (Lyman-a, Lyman-b, He 58.4 nm), and stellar spectrophotometry. Recently, sophisticated modeling of the sky background emission in the outer heliosphere was used to revise the UVS instruments calibration by no less than a factor 243% for V1 and 156% for V2 compared to the post-Jupiter encounter calibration. Because a strong modification of the UVS calibration has a much broader impact on many other topics than just the heliosphere problem, a reassessment is required. Here, we undertake a comprehensive investigation of the problem to show strong evidence for the stability of the instruments calibration. In that frame, both Voyager UVS almost certainly become one of the most stable EUV/FUV spectrographs of the history of space exploration.

Bertaux, Jean-Loup	***The Three Eyes of Ed Stone wide open on the Universe and a new Frontier.*** Jean-Loup Bertaux, LATMOS/CNRS/UVSQ, France I will first describe my early interaction with Jacques Blamont and Ed Stone in the context of Voyager payload selection, at that time Grand Tour, with some tumultuous payload re-arrangements. I will then focus on another great achievement of Ed Stone in the domain of Astronomy. In his position of Professor at Caltech, he became chair the Division of Physics, Maths, Astronomy. He was able to convince Howard Keck (a wealthy member of the Caltech Board) to fund the construction of Keck telescope at Mauna Kea, which became with 10 m diameter the largest telescope in the world (segmented technology). This project was followed by Keck-2 telescope, and now Ed Stone is dedicating strong efforts to establish the Thirty Meters Telescope (TMT) that will become the third eye of Ed Stone, wide open on the Universe. In 2004 I heard a speech of Ed Stone on the thema: « We need a new frontier ». I will argue that the search for bio-signatures and techno-signatures in exoplanets is indeed such a new frontier, calling for large telescopes on the ground and in space.
Boezio, Mirko	***The PAMELA Experiment: Cosmic Rays Deep Inside the Heliosphere*** M. Boezio, INFN, Sezione di Trieste, Italy on behalf of the "PAMELA Collaboration". It was the 15th of June of 2006 when the PAMELA satellite-borne experiment was launched from the Baikonur cosmodrome in Kazakstan. Since then, PAMELA has been making high-precision measurements of the charged component of the cosmic radiation opening a new era of precision studies in cosmic rays and challenging our basic vision of the mechanisms of production, acceleration and propagation of cosmic rays in the galaxy and in the heliosphere. The study of the time dependence of the various components of the cosmic radiations from the unusual 23rd solar minimum through the following period of solar maximum activity clearly shows solar modulation effects as well as charge sign dependence. PAMELA measurement of the energy spectra during solar energetic particle events fills the existing energy gap between the highest energy particles measured in space and the ground-based domain. Furthermore, providing pitch angle measurements, it allows the study of the effects of particle transport within interplanetary space over a broad range in energy.
Bucik, Radoslav	***Large-scale Coronal Waves in 3He-rich Solar Energetic Particle Events*** R. Bucik, University of Göttingen and Max Planck Institute for Solar System Research, Germany D. E. Innes, Max Planck Institute for Solar System Research, Germany G. M. Mason, Applied Physics Laboratory, Johns Hopkins University, USA M. E. Wiedenbeck, Jet Propulsion Laboratory, California Institute of Technology, USA Small 3He-rich (or impulsive) solar energetic particle (SEP) events have been commonly associated with EUV jets or narrow CMEs which may be signatures of magnetic reconnection involving open field lines. The elemental and isotopic fractionation in these events is thought to be caused by the processes (like MHD turbulence or reconnection-exhaust heating) confined to the flare sites. In this study we identify 30 impulsive SEP events from ACE at L1 during the solar minimum period 2007-2010 and examine their solar sources with high resolution STEREO EUV images. STEREO-A, leading the Earth with a rate of 22 degrees/year, provided for the first time a direct view on 3He-rich flares which are generally located on the Sun’s western hemisphere. Surprisingly, we find that about half of the events in this survey are associated with large-scale EUV coronal waves. We examine the relationship of the EUV waves to the accompanying energetic particles, including a detailed analysis of propagating wave fronts. The presence of EUV waves in these events may provide new insights on acceleration and transport of 3He-rich SEPs in solar corona.

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Burger, Adri	***Ab Initio Modulation Studies: Progress and Challenges*** Adri Burger, North-West University, South Africa Eugene Engelbrecht, North-West University, South Africa The Voyager spacecraft have over decades provided us with unique measurements, giving us a view of the heliosphere and beyond that may never be repeated. When these data are analysed in conjunction with long-term near-Earth observations, we gain a better understanding of how quantities like e.g. the magnetic variance behave as function of heliocentric radial distance. Such information is vital for models for turbulence transport which in turn feed into the diffusion tensor of the Parker Transport equation. In the ab initio approach to cosmic-ray modulation, we continuously attempt to use improved theoretical expressions for the elements of the diffusion tensor, restrain parameters and relax assumptions. Following a brief overview of progress made with our ab initio approach, we will discuss recent data analyses based on a second-order structure function approach. Key challenges for the ab initio approach include finding realistic expressions for all the elements of the diffusion tensor, and appropriate data for benchmarking turbulence transport models over several 22-year magnetic polarity cycles and throughout the heliosphere. IMP and ACE give us a 40-year timeline at Earth, and we show that while the variance of the normal component of the magnetic field follows the time-dependence of the magnetic field, the spectral index of the inertial range remains consistent with the Kolmogorov -5/3 value. We analyze 64-second resolution ACE data in field-aligned coordinates and show that if a composite slab/2D structure is assumed for the turbulence, the slab fraction varies significantly (and in a way apparently unrelated to solar activity) over the period 1998 to 2015. However, its mean value is consistent with the results of Bieber and co-workers, using Helios 1 and 2 data from the period prior to 1985 and a different analysis technique. We also show how the derived slab spectrum and 2D spectrum vary from 1998 to 2015. Our analysis of 48-second resolution Voyager 1 magnetic field data has not yet been completed, but the preliminary results show that beyond a few AU, the spectral index in the inertial range differs significantly from the Kolmogorov value. Large error bars preclude us from making more than qualitative statements about the validity of the composite slab/2D model as function of radial distance; it is neither ruled out nor confirmed. This work is based on research supported by South African National Research Foundation Grants 80824, 93592 and 96478.
Burlaga, Leonard	***Voyager 1Observations of the Interstellar Magnetic Field in the Outer Heliosheath*** L. F. Burlaga, NASA Goddard Space Flight Center, USA N. F. Ness, Catholic University of America, USA New observations of the magnetic field B from ≈ 2014.7 through 2015 together with the previous observations dating back to August 25, 2012 show that Voyager 1 has been observing draped interstellar magnetic fields in the outer heliosheath. During this interval, the direction of B has been nearly constant with no simple long term trend. A disturbed interval from 214.9126 to 2013.359 began with a shock or pressure wave followed by relatively strong but decreasing strength B. This interval was followed by a quiet interval from 2013.359 to 2014.643 with a more uniform and weaker B ($\langle B \rangle = 0.47 \pm 0.01$ nT) and very small amplitude fluctuations corresponding to Kolmogorov turbulence. The new observations show a similar pattern. A disturbed interval, beginning with the arrival of a weak shock or pressure wave on 2014.6458, contained relatively strong magnetic fields and oscillations in B with a 28-day period. This interval was followed on ≈2015.65 by a quiet interval containing weaker less variable magnetic fields lasting until at least the end of 2015. It is likely that the two disturbed intervals with strong magnetic fields and shocks were associated with sun/solar wind disturbances that impacted the heliopause and produced disturbances that propagated into the outer heliosheath. The two regions with relatively weak and less variable B might correspond to the relatively undisturbed “ground-state” of the outer heliosheath, viewed as the draped interstellar magnetic field and its turbulence. The direction of B in the first quiet interval was changing linearly and, if extrapolated to large distances, would pass through the center of the IBEX ribbon. We shall discuss whether this trend continues in the second quiet interval.

Chen, Bin	***Particle Acceleration by a Solar Flare Termination Shock*** Bin Chen, New Jersey Institute of Technology, USA Tim Bastian, National Radio Astronomy Observatory, USA Chengcai Shen, Harvard-Smithsonian Center for Astrophysics, USA Dale Gary, New Jersey Institute of Technology, USA Sam Krucker, University of California, Berkeley, USA Lindsay Glesener, University of Minnesota, USA A termination shock has long been postulated in the standard model of solar flares, formed by reconnection outflows impinging upon dense, closed magnetic loops in a cusp-shaped reconnection geometry. Unlike the well-accepted heliospheric termination shock, the existence of the solar flare termination shock and its role in particle acceleration have remained controversial. Using highly-sensitive and ultra-high-cadence radio imaging spectroscopic observations by the Karl G. Jansky Very Large Array, we present solid evidence of a termination shock in an eruptive flare and moreover, trace its morphology and dynamics in detail. The observed shock dynamics is closely associated with the upstream reconnection outflows, which is well reproduced by our numerical simulations. We further show that a disruption of the shock coincides with an abrupt reduction of the energetic electron population revealed by the concurrent RHESSI hard X-ray data. These results strongly suggest that a termination shock is responsible, at least in part, for accelerating energetic electrons in solar flares.
Cohen, Christina	***Energy and Charge-to-Mass Dependence of the Longitudinal Distribution of Solar Energetic Particles*** Christina Cohen, Caltech, USA Glenn Mason, JHUAPL, USA Richard Mewaldt, Caltech, USA Studies combining observations from near-Earth spacecraft and the twin STEREO spacecraft have resulted in a number of surprising results regarding the spread of solar energetic particles (SEPs) in longitude. The 7 February 2010 3He-rich event was observed by spacecraft spread over 136 degrees, extending far beyond the expected longitudinal extent of such events whose origins are compact flaring regions on the Sun. Intensities of 25 MeV protons from the 3 November 2011 SEP event increased abruptly at all three spacecraft with onsets occurring within 30 minutes of each other even though the spacecraft were roughly equally distributed in longitude around the Sun. These observations challenge our understanding of the transport of SEPs through the inner heliosphere. We have identified >40 multi-spacecraft events large enough to study the energy and species dependence of the SEP longitude distribution. While many transport mechanisms are governed by a particle's rigidity, other means of distributing particles in longitude are species independent. Thus it is instructive to examine the SEP longitude distribution as a function of particles' charge-to-mass (Q/M) ratios as well as particle energy. We find little organization with Q/M but some dependence on energy. These results will be discussed along with their implications for the dominant mechanism(s) for the longitudinal distribution of SEPs.
Consolini, Giuseppe	***On the Universality Character of Scaling Features and Intermittency at the Kinetic Scales.*** G. Consolini, INAF-IAPS, Italy F. Giannattasio, INAF-IAPS, Italy M.F. Marcucci, INAF-IAPS, Italy E. Yordanova, Swedish Institute for Space Physics, Sweden Z. Voros, Space Research Institute , Austrian Academy of Sciences, Austria M. Echim, IASB, Belgium In the last years the studies on the features of fluctuations at temporal and spatial scales below the ion(proton) gyro-period and gyro-radius have received a great interest. In this framework, controversial results have been recently reported on the occurrence of mono- or multi-scaling features of the magnetic field fluctuations at these scales and on the occurrence/meaning of intermittency. Here, we present results on the scaling features of magnetic field fluctuations at the non-MHD/kinetic scales in different turbulent space plasma environments. The possible universality character of the observed scaling features is also discussed. This work was supported by the European Community's Seventh Framework Programme ([FP7/2007-2013]) under Grant no. 313038/STORM

Cooper, John	***In Celebration of Professor Edward C. Stone: Eighty Years in the Heliosphere and Beyond*** John F. Cooper, Society of Ancient Cosmos Mariners, USA Nathan A. Schwadron, University of New Hampshire, USA Harlan E. Spence, University of New Hampshire, USA On behalf of the International Space Science Institute (ISSI) science team, Radiation Interactions at Planetary Bodies, and the venerable Society of Ancient Cosmos Mariners, we congratulate Professor Edward Stone on his 80th year within and virtually beyond the heliosphere. From his birth in Iowa to the present he has survived the rigors of exposure upon land, sea, and air to secondary radiation from the high-energy galactic cosmic rays and solar energetic particles. From the University of Chicago to the California Institute of Technology, from Earth orbit to the heliopause, Ed has sought the truths that are out there about the origins and transport of cosmic rays and energetic particles from sources far and near. He has found these truths with his many collaborators as a result of leadership or close involvement in many space investigations from OGO-2 to the twin Voyagers. And he has done this through many solar, geomagnetic, heliospheric, bureaucratic, and fiscal storms, refusing to yield in search of these great truths. Even when set back to desolate shores by cancellation of the NASA element for the International Solar Polar Mission, like Ulysses he pressed on and on to new adventures. Thus he has heeded Tennyson's immortal words from that one ancient mariner "to strive, to seek, to find, and not to yield". We review the evolution of the heliosphere, and his exploration thereof, over the past eighty years of his life and now beyond into time and the cosmos. Fare forward, Voyager!
Cummings, Alan	***Galactic Cosmic Rays in the Local Interstellar Medium: Voyager 1 Observations and Model Results*** A.C. Cummings, Caltech, USA E.C. Stone, Caltech, USA B.C. Heikkila, Goddard Space Flight Center, USA N. Lal, Goddard Space Flight Center, USA W. R. Webber, New Mexico State University, USA G. Jóhannesson, University of Iceland, Iceland I. V. Moskalenko, Stanford University, USA E. Orlando, Stanford University , USA T. A. Porter, Stanford University, USA We present observations of galactic cosmic rays (GCRs) from the Voyager 1 (V1) spacecraft that are representative of the local interstellar medium (LISM) and that help constrain new models of interstellar spectra over a broad energy range, which are also presented. We find the average radial gradient of protons over 3-346 MeV during a ~2.5 year period in the LISM is -0.009 ± 0.055 %/AU, consistent with zero and in agreement with some models but in disagreement with others. The V1 energy spectra define the newly-revealed, low-energy part of the local interstellar spectra of nuclei down to 3 MeV/nuc and of electrons down to 2.7 MeV. We find the interstellar spectra of H and He have the same shape from 3-346 MeV/nuc with a broad peak in the 10-50 MeV/nuc range. The H/He ratio is 12.2 ± 0.9 over 3-346 MeV/nuc. The interstellar electron spectrum from ~3-75 MeV is consistent with a power-law and exceeds the proton intensity below ~50 MeV. We find the B/C ratio is approximately independent of energy from ~8-100 MeV/nuc, which is difficult to match with the models. A new table of the GCR elemental source abundances from the new models is presented. These models of the LISM energy spectra of nuclei, together with an estimated LISM energy spectrum of GCR electrons, are used to estimate the cosmic-ray energy density and the ionization rate of atomic H in the local interstellar medium by nuclei above 3 MeV/nuc and by electrons above 3 MeV. We find that the total cosmic-ray energy density is in the range 0.83-1.02 eV/cm3, which includes a contribution of 0.040 eV/cm3 from electrons. The cosmic-ray ionization rate of atomic H is found to be in the range 1.51-1.64 x 10-17 s-1, which is a factor of more than 10 below the cosmic-ray ionization rate in diffuse interstellar clouds based on astrochemistry methods. We discuss possible reasons for this difference. Voyager data analysis is supported by NASA Grant NNN12AA01C. GALPROP development is supported by NASA Grants NNX13AC47G, NNX10AE78G, and NNX15AU79G.

Dalla, Silvia	***3D propagation of heavy ion Solar Energetic Particles*** S. Dalla, Univ Central Lancashire, UK M.S. Marsh, Met Office, UK P. Zelina, Univ Central Lancashire, UK T. Laitinen, Univ Central Lancashire, UK M. Battarbee, Univ Central Lancashire, UK In recent years, data from a variety of spacecraft including ACE and STEREO have been used to characterise heavy ion SEP properties over a wide range of elements and energies. Interpretation and modelling of these measurements usually assume that the particle's propagation is spatially 1D, along the magnetic field. In this work we model the trajectories of SEP Fe and O ions by means of a full orbit test particle model and show that their propagation takes place in 3D. A significant number of particles experience transport across the magnetic field due to guiding centre drift, associated with the curvature and gradient of the Parker spiral magnetic field. The amount of drift depends on the particles' mass-to-charge ratio and energy per nucleon. We derive intensity profiles that would be measured by a 1 AU observer and show that our model reproduces two key features of SEP heavy ion data: the decrease over time in the Fe/O ratio and the increase with energy of the average ionic charge state of Fe.
Decker, Robert	***Voyager 1 Measurements of Galactic Cosmic Ray Proton Anisotropies in the Local Interstellar Medium*** R. B. Decker, Johns Hopkins Applied Physics Laboratory, USA S. M. Krimigis, Johns Hopkins Applied Physics Laboratory, USA, and Academy of Athens, Greece M. E. Hill, Johns Hopkins Applied Physics Laboratory, USA E. C. Roelof, Johns Hopkins Applied Physics Laboratory, USA We describe angular distributions of galactic cosmic ray protons measured at Voyager 1 in the local interstellar medium. We focus on measurements made in 2012-2016.25, which includes Voyager 1's transition from the heliosheath to the interstellar medium and its heliopause crossing on 2012 day 238 at 121.6 AU. At Voyager 1, now (2016 day 75) at 134.3 AU and about 13 AU beyond the heliopause, intensities of low-energy ions and electrons and of anomalous cosmic rays, all of which were routinely measured in the heliosheath, remain at background levels. Intensities of galactic cosmic ray protons >211 MeV continue to show departures from isotropy, with broad (0.3-0.8 year) episodes of intensity depletions of protons gyrating nearly perpendicular to the magnetic field. Percentage intensity decreases during the three largest depletions, relative to the nearly flat intensities of cosmic rays propagating along the field, peak at -7% on 2013.35, at -3% on 2014.50, and at -9% on 2016.0. In the last case, the intensity decline to minimum lasted at least 9 months, and during 2016.0 to 2016.2 the anisotropy decreased from -9% to -4%. The two episodes in March-April 2013 and April-May 2014 when cosmic ray proton intensities showed small increases lasting 10-20 days indicate small energy boosts, produced possibly by magnetic disturbances from solar activity entering the interstellar medium [Gurnett et al., Ap. J., 809, 2015]. During these two periods intensities of cosmic ray protons with pitch angles nearer 90 deg were increased more than those with pitch angles nearer 0 deg and 180 deg.

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Desai, Mihir	***Systematic Charge-to-Mass Dependence of Heavy Ion Spectral Breaks in Large Gradual Solar Energetic Particle Events*** G. M. Mason, Johns Hopkins University/Applied Physics Laboratory, USA M. A. Dayeh, Southwest Research Institute, USA R. W. Ebert, Southwest Research Institute, USA D. J. McComas, Southwest Research Institute, USA G. Li, University of Alabama in Huntsville, USA C. M. S. Cohen, Caltech, USA R. A. Mewaldt, Caltech, USA N. A. Schwadron, University of New Hampshire, USA C. W. Smith, University of New Hampshire, USA We fit the ~0.1-500 MeV/nucleon H-Fe spectra in 46 large SEP events surveyed by Desai et al. (2015) with the double power law Band function to obtain a normalization constant, low- and high-energy parameters γa and γb; and break energy EB. We also calculate the low-energy power-law spectral slope γ1. We find that: 1) γa, γ1, and γb are species-independent, and the spectra steepen with increasing energy; 2) EB's are well ordered by Q/M ratio, and decrease systematically with decreasing Q/M, scaling as a power-law with index α that varies between ~0.2-3; 3) α is well correlated with Fe/O at ~0.16-0.23 MeV/nucleon, but not with the ~15-21 MeV/nucleon Fe/O and the ~0.5-2.0 MeV/nucleon 3He/4He ratios; 4) In most events: α<1.4, the spectra steepen significantly at higher energy with γb–γa>3, and O EB increases with γb–γa; and 5) Many extreme events (associated with faster CMEs and GLEs) are Fe-rich and 3He-rich, have large α≥1.4, flatter spectra at low and high energies with γb–γa<3, and EB that anti-correlates with γb–γa. The species-independence of γa, γ1, and γb and the systematic Q/M dependence of EB within an event, as well as the range of values for α suggest that the formation of double power-laws in SEP events occurs primarily due to diffusive acceleration at near-Sun CME shocks and not due to scattering in the interplanetary turbulence. In most events, the Q/M-dependence of EB is consistent with the equal diffusion coefficient condition while the event-to-event variations in α may be driven by differences in the near-shock wave intensity spectra, which are flatter than the Kolmogorov turbulence spectrum but weaker than for extreme events. The weaker turbulence allows SEPs to escape easily, resulting in weaker Q/M-dependence of EB (lower α values) and spectral steepening at higher energies. In extreme events, the flatter spectra at high and low energy and stronger Q/M-dependence of EB (larger α values) occur due to enhanced wave power, which also enables the faster CME shocks to accelerate flare suprathermals more efficiently than ambient coronal ions.
Drake, James	***Turbulence in the Heliospheric Jets*** J. F. Drake, University of Maryland, USA M. Swisdak, University of Maryland, USA M. Opher, Boston University, USA The conventional picture of the heliosphere is that of a comet-shaped structure with an extended tail produced by the relative motion of the sun through the local interstellar medium (LISM). Recent MHD simulations of the global heliosphere have revealed, however, that the heliosphere drives magnetized jets to the North and South similar to those driven by the Crab Nebula and other astrophysical objects [1,2]. These simulations reveal that the jets become turbulent with scale lengths as large as 100AU. An important question is what drives this large-scale turbulence, what are the implications for mixing of interstellar and heliospheric plasma and does this turbulence drive energetic particles? An analytic model of the heliospheric jets in the simple limit in which the interstellar flow and magnetic field are neglected yields an equilibrium state that can be analyzed to explore potential instabilities [3]. Preliminary calculations suggest that because the axial magnetic field within the jets is small, the dominant instability is the sausage mode, driven by the azimuthal solar magnetic field. Other drive mechanisms, including Kelvin Helmholtz are also being explored. [1] Opher et al ApJ Lett. 800, L28, 2015 [2] Polgorelov et al ApJ Lett.812,L6, 2015 [3] Drake et al ApJ Lett. 808, L44, 2015

Effenberger, Frederic	***Energetic Particle Confinement and Release in Solar Flare Loops and their Coronal Signatures*** Frederic Effenberger, Department of Physics and KIPAC, Stanford University, USA Vahe' Petrosian, Department of Physics and KIPAC, Stanford University, USA Fatima Rubio da Costa, Department of Physics and KIPAC, Stanford University, USA Particle acceleration and transport effects in solar flares are an important topic for advancing our understanding of fundamental plasma processes in the heliosphere. The properties of hard X-ray emission from solar flares can provide insights into the behavior of non-thermal particles, particularly electrons. Because of limited dynamic ranges of X-ray telescopes, oftentimes at high energies the bright emission from the chromospheric footpoints of a flare loop prevents a detailed analysis of the relatively weaker coronal loop-top source. As such, flares with footpoints occulted by the solar limb are extremely valuable, as they can potentially reveal the loop-top emission in greater detail. In some of the cases, this also allows us to investigate the spatial separation between thermal and non-thermal emissions. In addition, they can provide the most direct information on the spectrum of the accelerated electrons. We will present results of a survey of footpoint-occulted flares observed with the Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI). We show results from two forward fitting approaches to the loop-top spectra with a thermal plus a power-law component and a kappa distribution and electron spectra obtained directly from regularized inversion. We compare our results with selected cases of on-disk flares where imaging spectroscopy is available. Our findings will be discussed in the context of our modeling efforts, which are aimed at a detailed understanding of energetic particle acceleration and transport in solar flares. These models include effects of pitch-angle scattering due to the interaction of the particles with local turbulence and large scale magnetic field focusing from field-line convergence towards the footpoints of the loop.
Ferriere, Katia	***New probes of the Interstellar Magnetic Field*** Katia Ferriere, IRAP (OMP), Universite de Toulouse, CNRS, France I will review our observational knowledge of the interstellar magnetic field of our Galaxy. I will first describe the main methods traditionally used to probe the interstellar magnetic field, and I will explain what the different methods have taught us regarding its strength, direction, and spatial distribution. I will then describe a new method, known as rotation measure synthesis or Faraday tomography, which combines synchrotron emission and Faraday rotation, and I will illustrate the potential of this method with a couple of examples.
Fichtner, Horst	***Testing the H-wave Hypothesis for the Origin of the IBEX Ribbon*** Horst Fichtner, Institut fuer Theoretische Physik, Ruhr-Universitaet Bochum, Germany Adama Sylla, Institut fuer Theoretische Physik, Ruhr-Universitaet Bochum, Germany The Interstellar Boundary Explorer (IBEX) spacecraft maps the neutral atom fluxes across the whole sky. Thereby it is indirectly mapping the structure of the outer heliosphere and the (very) local interstellar medium. A particularly interesting feature in the IBEX-Hi all-sky maps of the differential flux of Energetic Neutral Atoms (ENAs) in the 0.7 to 4.3~keV range is the so-called ribbon, i.e. a factor of two to three enhancement in a twenty to thirty degree wide band across the sky. Amongst other hypotheses it has been argued that this ribbon may be related to a neutral density enhancement, a so-called H-wave, in the local interstellar medium. By employing an analytical model of the large-scale structure of the heliosphere it is demonstrated that the H-wave scenario for the ribbon formation leads to results that are fully consistent with the observed location of the ribbon in the full-sky maps at all energies detected with IBEX-Hi.
Fisk, Len	***The Fisk and Gloeckler Model for the Nose Region of the Heliosheath: Another Model for Ed Stone to Test*** L.A. Fisk, University of Michigan, USA G. Gloeckler, University of Michigan, USA Ed Stone has always been receptive to new ideas, including controversial ones, provided that the idea can be tested by observations. This talk will discuss the latest controversial idea for Ed to test: the Fisk and Gloeckler (F and G) model for the nose region of the heliosheath, which concludes that Voyager 1 remains in the heliosphere and is not in the local interstellar medium, and that the nose region of the heliosheath is a very different place from what others have considered, and it can be argued, a more interesting place than others have imagined. The test of the model is that within this year, Voyager 1 should encounter another current sheet, due to the reversal of the magnetic field of the Sun, thereby establishing conclusively that Voyager 1 remains in the heliosphere. If or when the current sheet is crossed, it will be appropriate to extend the F and G model. A preview will be provided of these extensions and the interesting properties and physical processes that result for: (1) the region inside the heliocliff; (2) the heliocliff; (3) the region between the heliocliff and the actual heliopause; and (4) the heliopause.

Florinski, Vladimir	***The Ribbon of the Rings: The Stability of the Rings*** Vladimir Florinski, University of Alabama in Huntsville, USA Jacob Heerikhuisen, University of Alabama in Huntsville, USA Jacek Niemiec, Institute of Nuclear Physics PAN, Poland Unlike the One Ring, which was very refractory (and stable over thousands of years), the ion rings injected in interstellar space from charge exchange between hydrogen atoms of solar-wind and heliosheath origin are relatively short lived. Kinetic instabilities tend to incite scattering of the initial ring leading to isotropization on timescales short comparable with the time necessary to undergo another charge exchange to produce an energetic atom traveling back toward the Sun, which is required by the leading theory of the IBEX ribbon. We performed a careful study of the three competing instabilities operating under the conditions prevalent in the outer heliosheath using dispersion analysis, hybrid simulations, and full PIC simulations, for a range of possible pickup ion distributions, both idealized and based on Monte-Carlo models of hydrogen transport in and around the heliosphere. We obtained an excellent agreement between hybrid and PIC results for the common set of parameters, semonstrating that electron kinetics play negligible role in the development of low-frequency ion instabilities. Unexpectedly, narrow rings are more stable in the outer heliosheath then broader rings for pickup angles close to 90 degrees because of the so-called "stability gap". For oblique pickup angles the "partial shell" distribution is more stable away from the ribbon direction, owing to spatial transport along the magnetic field lines. We also discuss the effects of the inner heliosheath "halo" population of energetic hydrogen atoms on the stability properties of the ring.
Frisch, Priscilla	***The Heliosphere and the Surrounding Magnetoionic Medium*** P. C. Frisch, U.Chicago, USA B-G Andersson, USRA, SOFIA, USA A. Berdyugin, U.Turku, Finland H. O. Funsten, LANL, USA A. M. Magalhaes, U. Sao Paulo, Brazil D. J. McComas Princeton U., USA V. Piirola, U.Turku, Finland N. A. Schwadron, U. New Hampshire, USA D. B. Seriacopi, U. Sao Paulo, Brazil J. D. Slavin, SAO-Harvard, USA S. J. Wiktorowicz, Aerospace, USA The interstellar medium surrounding the heliosphere is part of the large-scale magnetoionic medium that can be mapped throughout low density regions of the galaxy. Charged gas and dust in the local ISM couple closely to the interstellar magnetic field (ISMF). This ISMF can be traced from the IBEX Ribbon out into interstellar space using starlight polarized by magnetically ordered dust grains. Looking at the local magnetoionic medium as an integrated system, we find that (1) the ISMF orders the kinematics of local clouds and the alignment of dust grains in those clouds; (2) low magnetic turbulence of the local ISMF explains the connectivity between the IBEX Ribbon magnetic field and the deep space magnetic field detected through polarized starlight; (3) a nearby filament-like dust structure is symmetric with respect to the heliospheric B-V plane and traces the velocity of the LIC interaction with the heliosphere; (4) the location of the Sun in a fragment of an ancient superbubble shell would explain the ISMF configuration and shock-like interactions between nearby interstellar clouds.

Giacalone, Joe	***A New Model for the Heliosphere's "IBEX Ribbon"*** Joe Giacalone, Dept. of Planetary Sciences, University of Arizona, USA Randy Jokipii, Dept. of Planetary Sciences, University of Arizona (USA) We present a model for the narrow, ribbon-like enhancement of energetic-neutral-atoms (ENA) coming from the outer heliosphere known as the "IBEX ribbon". We show that pre-existing, turbulent, small-amplitude fluctuations in the magnitude of the local interstellar magnetic field can efficiently trap secondary pickup protons, produced by charge-exchange between fast-moving solar-wind neutral atoms and the cold interstellar gas, with initial pitch angles near ninety degrees. This leads to a narrow region of enhanced pickup-proton intensity in the local interstellar medium, which ultimately is the source region of the IBEX-ribbon-producing particles. This trapping results mostly from magnetic mirroring in the small-amplitude magnetic-field magnitude fluctuations. The analytically estimated width of the resulting ribbon of emission is consistent with observations. We also present results from a numerical model that are generally also consistent with the observations. Our interpretation relies only on the pre-existing turbulent interstellar magnetic field to trap the pickup protons. This leads to a broader local pitch-angle distribution compared to that of a ring. Our numerical model also predicts the ribbon is double peaked with a central depression. This is a further consequence of (primarily) magnetic mirroring of pickup ions with pitch-angles close to ninety degrees in the pre-existing, turbulent interstellar magnetic field.
Gloeckler, George	***Solar Wind and Pickup Proton Distributions in the Heliosheath Nose and Tail*** George Gloecker, University of Michigan, USA, and Johannes Geiss Fellow, International Space Science Institute, Bern, Switzerland Len Fisk, University of Michigan, USA From the latest published differential intensities of energetic neutral hydrogen measured by IBEX, we determine the average radial velocity distributions of solar wind and pickup protons in the heliosheath in four view directions of IBEX: tail, Voyager 1, Voyager 2, and ribbon directions. We find that both the solar wind and pickup proton distributions have strong -5 power law super-tails similar to what is observed in the most powerful acceleration events in the suprathermal solar wind. Applying pressure balance requirements, we also determine the width of the heliosheath and the density and radial component of the solar wind speed in each of the four directions. For example, we find that in the heliosheath between the Termination Shock and 122 AU explored by Voyager 1 the average solar wind density, thermal speed, and radial speed are 0.02 cm^-3, 25 km/s, and 17 km/s, respectively. The thermal and ram pressures of the solar wind with its super -5 tail are 6x10^-13 and 1.1x10^-13 dyne/cm^2, respectively. The pickup proton thermal pressure amounts to 5.5x10^-13 dyne/cm^2, while the measured greater than 40 keV TSP plus ACR pressure is 7.8x10^-13 dyne/cm^2. The magnetic pressure of only 0.4x10^-13 dyne/cm^2 makes the smallest contribution to the total pressure of 2.09x10^-12 dyne/cm^2. The most likely values for local interstellar parameters are: proton density of 0.05 cm^-3, neutral hydrogen density of 0.19 cm^-3, and magnetic field strength of 0.58 nT.
Golla, Thejappa	***The Probability Distributions of Langmuir Wave Packets Associated with Solar Type III Radio Bursts and Theoretical Implications*** G. Thejappa, Department of Astronomy, University of Maryland, USA R. J. MacDowall, NASA/GSFC, USA The energetic electrons accelerated during solar flares form bump-on-tail distributions. These electron beams are known to travel large distances from the base of the corona all the way to 1 AU and beyond exciting Langmuir waves on their way at local electron plasma frequencies. These Langmuir waves are known to get converted into fast drifting radio emissions known as the solar type III radio bursts at the fundamental and second harmonic of the electron plasma frequency. It is suspected that some non-linear processes prevent the quasi-relaxation of the electron beams in the solar atmosphere, as well as convert the Langmuir waves into escaping electromagnetic radio emission. The WAVES experiment of the STEREO spacecraft is providing the high quality in situ high time resolution measurements of the Langmuir wave fields associated with type III radio bursts, providing an unique opportunity to identify and understand these nonlinear processes. The normalized peak intensities, wave numbers and spectral structures of these wave packets provide the crucial information of the nonlinear processes. We have conducted a systematic analysis of these in situ high time resolution wave measurements and determined their three dimensional relative peak intensities and spectral structures. Using the frequency drifts of type III bursts, we have estimated the velocities of the electron beams; these velocities are used to estimate the wave numbers of the observed Langmuir waves. We show that (1) the boxplots and the distributions of the peak intensities of the Langmuir waves are right skewed with one or more outliers, (2) these distributions can not be fitted with known distributions, such as the beta, gamma, lognormal or normal distributions, which implies that the observed Langmuir wave spikes do not correspond to field structures generated due to the trapping in the random background fluctuations, instead, they probably correspond to the spikes trapped in the self-generated density holes, and (3) the spectra of the wave packets corresponding to outliers of these distributions contain the sidebands corresponding to oscillating two stream instability (OTSI); these wave packets easily satisfy the threshold conditions for the OTSI. The implication of this is that the OTSI and related strong Langmuir turbulence processes play important roles in the beam stabilization as well as in conversion of Langmuir waves into escaping radiation.

Gruntman, Mike	***Ionization of Interstellar Hydrogen Beyond the Termination Shock*** Mike Gruntman, University of Southern California, USA Models of solar wind interaction with the surrounding interstellar medium often disregard ionization of interstellar hydrogen atoms beyond the solar wind termination shock. If and when included, the effects of ionization in the heliospheric interface region are often obscured by complexities of the interaction. This work assesses the importance of interstellar hydrogen ionization in the heliosheath. Photoionization could be accounted for in a straightforward way. At the same time, electron impact ionization is largely unknown because of poorly understood energy transfer to electrons at the termination shock and beyond. We first estimate the effect of photoionization and then use it as a yardstick to assess possible effects of electron impact ionization. The physical estimates show that ionization may lead to significant mass loading in the inner heliosheath which would slow down plasma flows toward the heliotail and deplete populations of nonthermal protons, with the corresponding effect on heliospheric fluxes of energetic neutral atoms.
Gurnett, Don	***Shocks and Associated Effects in the Nearby Interstellar Medium*** D. A. Gurnett, University of Iowa, USA W. S. Kurth, University of Iowa, USA, E. C. Stone, California Inst. of Technology, USA A. C. Cummings, California Inst. of Technology, USA S. M. Krimigis, Applied Physics Laboratory/JHU, USA R. B. Decker, Applied Physics Laboratory/JHU, USA N. F. Ness, Catholic University of American, USA L. F. Burlaga, NASA Goddard Space Flight, USA The Voyager 1 spacecraft crossed the heliopause into the nearby interstellar plasma on or about August 25, 2012. In the nearly four years that the spacecraft has been in the nearby interstellar space four notable disturbances have been observed, each apparently associated with a shock wave propagating outward from an energetic solar event, i.e., solar mass ejections. The primary means of identifying these events is from electron plasma oscillations detected by the plasma wave instrument (PWS), oscillations that are believed to be produced by electron beams propagating upstream from an approaching shock. The first of these PWS events occurred from Oct-Nov 2012, the second from April-May 2013, the third from Feb-Nov 2014, and the fourth from Sept-Nov 2015. In the first and third events, the causative shock was clearly identified in the magnetometer (MAG) data. In the third event no shock was detected in the MAG data, and for the fourth event we are still awaiting the MAG data. In each of the four events, a marked decrease in the flux of energetic particles was detected at 90-degree pitch angles by the low energy charged particle (LECP) and cosmic ray (CRS) detectors. These depressed 90-degree intensities occurred as much as 30 to 100 days before the arrival of the shock inferred from the MAG and PWS data. Only very minor effects were observed in the LECP and CRS isotropic intensities. The decrease in the 90-degree energetic particle intensities before the arrival of the shock appears to be due to a reconfiguration of the interstellar magnetic field that is associated with the passage of the shock, the details of which are not completely understood. Other more detailed effects that are unique to each event are also described.

Hill, Matthew	***Pickup Ions, Suprathermal & Energetic Particles, and Cosmic Rays Measured Across the Heliosphere with the Voyager 1 & 2/LECP, New Horizons/PEPSSI, Cassini/MIMI/CHEMS & LEMMS, and Juno/JEDI Cohort of Instruments: First Report*** M.E. Hill, Johns Hopkins University Applied Physics Laboratory, USA P. Kollmann, Johns Hopkins University Applied Physics Laboratory, USA R.B. Decker, Johns Hopkins University Applied Physics Laboratory, USA L.E. Brown, Johns Hopkins University Applied Physics Laboratory, USA G. Clark, Johns Hopkins University Applied Physics Laboratory, USA D.K. Haggerty, Johns Hopkins University Applied Physics Laboratory, USA D.C. Hamilton, University of Maryland, Department of Physics, USA S.M. Krimigis, Johns Hopkins University Applied Physics Laboratory, USA M. Kusterer, Johns Hopkins University Applied Physics Laboratory, USA B.H. Mauk, Johns Hopkins University Applied Physics Laboratory, USA R.L. McNutt Jr., Johns Hopkins University Applied Physics Laboratory, USA D.G. Mitchell, Johns Hopkins University Applied Physics Laboratory, USA E.C. Roelof, Johns Hopkins University Applied Physics Laboratory, USA J.D. Vandegriff, , Johns Hopkins University Applied Physics Laboratory, USA We report a new endeavor to uniquely combine a set of ion measurements from across the heliosphere to study particle dynamics across a large range of energies. Such multipoint measurements are key to disentangling spatial and temporal variations in heliospheric particle populations such as interstellar pickup ions (IPUIs) and their accelerated suprathermal (ST) tails, energetic particles (EPs) such as those energized at local plasma shocks, and the remotely accelerated anomalous and galactic cosmic rays (ACRs and GCRs). With the Low Energy Charged Particle (LECP) instruments on Voyager 1 and Voyager 2, the Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI) instrument on New Horizons, and the Magnetospheric Imaging Instrument (MIMI) suite on Cassini (specifically the CHEMS and LEMMS sensors), we have five long-term (and continuing) data sets in the heliosphere. The Jovian Energetic-Particle Detector Instruments (JEDI) on Juno also provide particle measurements during the 2012-2016 cruise to Jupiter; Jupiter orbit insertion is July 4, 2016, after which Juno will not return to the solar wind (SW). The enduring Voyager spacecraft have ranged far, from 1 to 135 AU over the 1977–2016 period. Cassini cruised from 1 to 9 AU during 1997–2004 and has orbited Saturn since (sometimes in the solar wind), while New Horizons traveled from 1 to 35 AU during the 2006 to 2016 period. The populations and energies covered by these instruments include IPUIs & ST ions (~1 – 200 keV/nuc, CHEMS & PEPSSI; down to ~8 keV, JEDI), low-energy EPs (~30 keV – 1 MeV, LEMMS, PEPSSI, LECP, & JEDI), and high-energy EPs, ACRs, and GCRs (~1-150 MeV, LEMMS; >~20 MeV, PEPSSI; ~1-40 MeV/nuc, >70 MeV, >200 MeV, LECP; > ~50 MeV, JEDI), often with elemental composition. Additionally, these instruments provide some SW speed determination capability, either through the IPUI spectral cutoff or Compton-Getting anisotropy methods (this capability is still under investigation with JEDI). New Horizons and V2 have dedicated plasma instruments with extensive SW datasets while V1, Juno and Cassini have very limited direct plasma measurements of the SW. By bringing together these measurements for the first time, a new avenue for understanding particle origins, acceleration, and transport in the heliosphere has been opened.
Ho, George	***Multi-spacecraft Observations of Energetic Particle Events from 0.3 to 1.0 AU*** George C. Ho, The Johns Hopkins University Applied Physics Laboratory, USA David Lario, The Johns Hopkins University Applied Physics Laboratory, USA The propagation and radial evolution of solar energetic particle (SEP) events can only be studied by multiple-point simultaneous in-situ measurement within the heliosphere. The MErcury Surface Space ENvironmen GEochemistry and Ranging (MESSENGER) mission, a scientific investigation of the planet Mercury, provided us invaluable particle and field measurement inside 0.4 AU from 2010 to its mission completion in April 2015. On 14 August 2010, a series of solar flares and coronal mass ejections have been observed by multiple in-situ instruments throughout the heliosphere. In a period of less than 5 days, an active region (AR 1099) on the western limb of the Sun produced two SEP events and associated coronal mass ejections (CMEs). During that time, the MESSENGER spacecraft was cruising near its perihelion distance (~0.3 AU) at W110 relative to the Earth-Sun line, and the STEREO Ahead spacecraft was at W80. Together with the ACE spacecraft, the particle instruments on these probes measured the associated SEPs and the plasma and field instruments detected the associated interplanetary CMEs. In this paper, we report the first multi-spacecraft observations of these recent events, and we discuss the propagation and transport of SEPs from 0.3 to 1 AU.

Hunana, Peter	***Magnetohydrodynamics with temperature anisotropy.*** Peter Hunana, University of Alabama, Huntsville, USA Gary P. Zank, University of Alabama, Huntsville, USA Melvyn L. Goldstein, NASA Goddard, Greenbelt, USA Laxman Adhikari, University of Alabama, Huntsville, USA Temperature anisotropy effects and associated micro-instabilities have an important implications for the evolution of the solar wind flow. For example, observational studies showed that the solar wind plasma data is bounded by the mirror and firehose instabilities thresholds and it is often believed that these instabilities are of a purely kinetic nature. We will discuss fluid models with various degrees of complexity that generalize the usual magnetohydrodynamic description (CGL, Hall-CGL, Hall-FLR-CGL, higher order fluid models with heat flux fluctuations, Landau fluid models) and we will clarify which effects are important to capture the mirror and firehose instabilities in a fluid formalism.
Intriligator, Devrie	***The Sun's Dynamic Influence on the Outer Heliosphere, the Heliosheath, and the Local Interstellar Medium*** Devrie S. Intriligator, Carmel Research Center, Inc., USA Wei Sun, Univ. of Alaska, Fairbanks, USA Thomas Detman, Carmel Research Center, Inc., USA W. David Miller, Carmel Research Center, Inc., USA James M. intriligator, Carmel Research Center, Inc., USA; Bangor Univ., UK William R. Webber, New Mexico State Univ., USA Murray Dryer, Carmel Research Center, Inc., USA Charles Deehr, Univ. of Alaska, Fairbanks, USA George Gloeckler, Univ. of Michigan, USA We and the heliophysics community are indebted to Ed Stone for his many important and significant contributions including those associated with ACE and Voyager. His tireless efforts have helped make available vast arrays of data that serve to extend our knowledge of the universe. Using 3D time-dependent modeling starting near the Sun (at 2.5 Rs) we simulate impulsive time-dependent solar events. Because pre-existing solar wind (SW) background conditions have a strong influence on the propagation of such shock waves, the simulated solar events are introduced "into" the time-dependent context of a slowly evolving background ambient SW. We then propagate these events to various locations to compare them with available in-situ spacecraft (s/c) measurements. We use two simulation models. The HHMS-PI (Hybrid Heliospheric Modeling System with Pickup protons) is a numerical magnetohydrodynamic SW simulation model. The HAFSS (HAF Source Surface) model is a kinematic model. We show comparisons of our simulation results with ACE, Ulysses, and Voyager s/c observations. Through the agreement found with these comparisons we demonstrate that both models (HHMS-PI and HAFSS) are well-suited for such analyses. For example, our models naturally reproduce the dynamic 3D spatially asymmetric effects observed throughout the heliosphere. The models also capture some important elements of propagating shocks (and their various attendant phenomena) throughout the outer heliosphere, the heliosheath, and the local interstellar medium.

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Isenberg, Philip	***Estimating the Shape of the Heliopause from IBEX Observations of Secondary Neutral Helium*** Philip A. Isenberg, Space Science Center, University of New Hampshir, USA Harald Kucharek, Space Science Center, University of New Hampshire, USA Jeewoo Park, Space Science Center, University of New Hampshire, USA A particular strength of the IBEX mission, as a set of imaging detectors, is the ability to remotely measure large-scale structures as they influence the neutral component of the nearby interstellar medium. Here, we assume that the observed irregular cloud of inflowing neutral He originates from a single distant population, as opposed to other interpretations of a separate "warm breeze". In this case, the structure of this cloud contains information on the deflection of the interstellar plasma by the obstacle of the heliopause. The combination of external forces (due to the tilted interstellar magnetic field) and internal forces (from non-spherically-symmetric solar wind and heliosheath pressures) create an obstacle in the interstellar flow which is non-axisymmetric, with different degrees of curvature along different azimuthal directions from the nose. By comparing the shape of the secondary He cloud to models of charge-exchange emission from the deflected plasma, we can construct a heliopause shape directly derived from the IBEX measurements. Ideally, the complexity of the model should not exceed the level of observational detail. Thus, a somewhat crude model of the plasma flow should be sufficient to yield a useful representation of the low resolution He observations. We make two substantial simplifications in our plasma model: First, rather than dealing with a single complicated obstacle, we obtain the deflected flow field due to a number of axi-symmetric obstacles with different curvatures, and take the resulting flows to describe the plasma behavior in the different angular ranges about the nose. Second, since the effects of the anisotropic interstellar magnetic pressure are already accounted for in the irregular obstacle shape, we solve a gas-dynamic flow equation which incorporates the magnetic field into an isotropic effective plasma temperature. We will describe this model and present preliminary results. We expect this information, obtained from direct modeling of the observations, to constrain and guide the forward modeling efforts which address this question with detailed global MHD-kinetic computations.
Jokipii, Jack (Randy)	***Charged-Particle Acceleration at Heliospheric Shocks and Elsewhere*** J. R. Jokipii, University of Arizona, USA Energetic charged particles are observed in heliospheric locations ranging from the solar wind to the heliosheath and beyond. Diffusive shock acceleration, introduced some decades ago and was for a long time the mechanism of choice. Observations at the termination shock, beginning a decade ago showed complexity which required either modification of the initial simple models of shock acceleration or the introduction of new mechanisms.. The new mechanisms range from the introduction of non-planar shock geometries to entirely different mechanisms, such as reconnection or various forms of compression. In this talk, observational constraints such as the acceleration rate and temporal/spatial variations, will be compared with the various scenarios for acceleration.

Kollmann, Peter	***Interstellar pickup ions in the outer heliosphere*** P. Kollmann, JHU/APL, USA M. E. Hill, JHU/APL, USA R. L. McNutt, Jr., JHU/APL, USA R. Decker, JHU/APL, USA J. Vandegriff, JHU/APL, USA L. E. Brown, JHU/APL, USA M. Kusterer, JHU/APL, USA Interstellar gas that approaches the Sun is ionized and accelerated by the convective electric field to solar wind speeds, yielding interstellar pickup ions with a suprathermal tail in their energy distributions. Here we use New Horizons/PEPSSI and Cassini/CHEMS data in the keV to hundreds of keV range acquired outside of 5 astronomical units (AU) from the Sun to study these ions. Although PEPSSI does not directly distinguish species at the lowest energies, we show that ion counts in that range are dominated by pickup-helium. The most dominant parameter organizing the distribution of H+ and He+ in the spacecraft frame is the cone angle relative to the Sun. Cassini and New Horizons can measure a large range of these angles since they are often 3-axis stabilized. Transformation of the distribution into the co-moving frame of reference reveals that the distribution at these relatively large distances to the Sun is to first order isotropic. "Typical" distributions show a sharp drop at about twice the solar wind speed, followed by a suprathermal population that can be described by a power law. It has been known that the overall distribution can look shallower for example near shocks of the solar wind, when the population of suprathermal particles becomes more intense. Such shallow distributions are commonly measured by CHEMS and PEPSSI. We study the relative amplitude of the suprathermal particles over the solar cycle while CHEMS stays around 10 AU and PEPSSI moves towards 30 AU and beyond.
Kota, Jozsef	***On the Role Particle Drifts in the Heliosphere*** Jozsef Kota, University of Arizona, USA The importance of particle drifts in the non-uniform heliospheric magnetic field (HMF) was recognized by Jokipii, Levy and Hubbard (1977) and confirmed by Voyager observations by Cummings, Stone, and Webber (1987). Yet, drifts are often debated or ignored. In the talk I overview some features of particle drifts in the inner and outer Heliosphere, and bring arguments that drift is just as important as convection and should be treated in the same way. The possible role of particle drifts near the heliopause will be discussed. In the conventional picture of the heliosphere, positive and negative magnetic sectors are stacked closely because of the slow movement of the wind near the stagnation region. The recent model of Opher et al. (2015) is different and the HCS may retain a recognizable large-scale structure near the Heliopause (HP). The large scale drift pattern will be presented in a simple toy model similar to that of Drake, Swisdak, and Opher (2015) and possible implications for ACRs, GCRs, and TeV anisotropies will be discussed.
Krasnoselskikh, Vladimir	***Probabilistic Model of Beam - Plasma Interaction in Randomly Inhomogeneous Solar Wind*** Krasnoselskikh, Vladimir, LPC2E/ CNRS -University of Orleans, FRANCE Voshchepynets, Andrii, LPC2E/CNRS-University of Orleans, FRANCE In this presentation we describe the effects of plasma density fluctuations in the solar wind on the relaxation of the electron beams ejected from the Sun. The density fluctuations are supposed to be responsible for the changes in the local phase velocity of the Langmuir waves generated by the beam instability. Changes in the wave phase velocity during the wave propagation can be described in terms of probability distribution function determined by distribution of the density fluctuations. Using these probability distributions we describe resonant wave particle interactions by a system of equations, similar to well known quasi-linear approximation, where the conventional velocity diffusion coefficient and the wave growth rate are replaced by the averaged in the velocity space. It was shown that the process of relaxation of electron beam is accompanied by transformation of significant part of the beam kinetic energy to energy of the accelerated particles via generation and absorption of the Langmuir waves. We discovered that for the very rapid beams with beam velocity $V_b > 15 v_T$, where v_T is a thermal velocity of background plasma, the relaxation process consists of two well separated steps. On first step the major relaxation process occurs and the wave growth rate almost everywhere in the velocity space becomes close to zero or negative. At the seconde stage the system remains in the state close to state of marginal stability enough long to explain how the beam may be preserved traveling distances over 1 AU while still being able to generate the Langmuir waves.

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Krimigis, Stamatios	***11 years of ENA imaging with Cassini/INCA and in-situ ion Voyager1 & 2/LECP measurements*** S. M. Krimigis, JHU/APL, MD, USA K. Dialynas, Athens Academy, Greece D. G. Mitchell, JHU/APL, MD, USA R. B. Decker, JHU/APL, MD, USA E. C. Roelof, JHU/APL, MD, USA Discovery of the reservoir of ions and electrons that constitute the heliosheath (HS) by V1 and V2 after crossing the termination shock (TS) north and south of the ecliptic plane at 94 and 84 AU, respectively, was followed by the identification by Cassini/INCA of a high intensity, relatively wide (about 50 to 100 deg FWHM) ENA region that wraps around the celestial sphere in ecliptic coordinates, commonly known now as “Belt”. Our analyses have provided evidence that the Belt is a relatively stable feature as a function of energy, and corresponds to a reservoir of particles that exist within the HS, constantly replenished by new particles from the solar wind. These ENAs appear to be associated with a region of enhanced particle pressure that is formed between the TS and the heliopause (HP) and contributes to balancing the pressure of the interstellar magnetic field (ISMF). This region points toward a nearly symmetric HS with little magnetosphere-type tail, and behaves as a diamagnetic bubble. The overlapping agreement between the 5-55 keV power law ENA energy spectra and those of more than 28 keV Voyager ions revealed that the ISMF was nearly twice what was previously assumed (up to 0.64 nT) in order to balance the nonthermal pickup ion (PUI) pressure in the heliosheath. This was actually verified by the V1 magnetic field measurements upon crossing the heliopause. Furthermore, comparison of remotely-sensed ENAs with the in-situ ions in the V1 and V2 pixels produced an accurate (with only a month offset) prediction of V1 crossing from the HP (at ~122 AU; HS thickness of LV1 about 30 AU) while predicting that the heliosheath must be about twice as thick along the Voyager-2 LOS (LV2 about 71(+30, −15) AU). Our most recent analyses have examined the details of the evolution of the yearly-integrated 5-55 keV ENA images from 2003 to 2014, i.e. during the declining phase of SC23 and onset of SC24, compared with the histories of in situ "ground truth" ion intensities in overlapping energy bands provided by Voyager, prove that the 11-year “breathing mode” of the global heliosphere, manifested by the outward propagating changes of the solar wind (SW) through the solar cycle (SC), is reflected in the remote-sensed INCA/ENAs (promptly, within about 1.5-2 years time delay). The convergence between ENAs and ions points to the heliosheath (HS) as the obvious source of the measured keV ENAs. Thus INCA measurements are essential in constructing future sophisticated global heliosphere models.
Kucharek, Harald	***The Interaction of Heavy Interstellar Neutral Atoms with the Global Heliosphere*** Harald Kucharek, University of New Hampshire, NH, USA Jeewoo Park, University of New Hampshire, NH, USA Philip Isenberg, University of New Hampshire, NH, USA Eberhard Moebius,University of New Hampshire, NH, USA The interaction of the solar wind with the ionized as well as the neutral component of the local interstellar medium determines the size and the shape of the heliosphere. The size and the shape of the heliosphere determine the flow of the interstellar gas around it. Although neutral, singly charge hydrogen, and electrons are the major constituents the local interstellar medium also contains heavier elements. In contrast to the interstellar medium which shows low charge states, the solar wind shows high charge states due to intense ionization of the Sun corona. Only the neutral component provides us with information on the properties of the interstellar medium. IBEX observations of the interstellar gas flow in the inner heliosphere provide the most detailed information about the physical conditions of the surrounding interstellar medium and the interaction of this flow with the outer heliosheath. An extremely important diagnostic tool is the so-called secondary component of the interstellar neutral gas flow that originates from charge exchange interstellar neutrals with outer heliosheath ions, which are diverted around the heliosphere. In order to investigate flow patterns around the heliosphere we have determined the relative intensity of secondary He and O flow and the distributed flux with respect to the primary component in different flow directions. We have observed significant differences in the observed flux in different directions, which can be due to different flow patterns of the interstellar neutral gas flow around the outer heliosheath and thus provide us information on the shape of the heliosphere. We will discuss potential implications these intensity differences on the global shape of the heliosphere.

Lallement, Rosine	***Bipolar Wind from the Milky Way Centre: Heliospheric Science at the Galactic Scale?*** Rosine Lallement, CNRS, GEPI/Observatoire de Paris, France All the physical processes at work in the heliosphere and that Ed Stone has so largely contributed to elucidate are now thought to be present at the Galactic scale in the Milky Way. Following the discovery of the so-called gigantic «Fermi bubbles», and in the light of diffuse X-ray, sub-mm and IR emission data, it seems increasingly likely that the Milky Way center is the source of large scale AGN-type ejections or starburst episodes/Galactic wind launches, as seen in external galaxies. Whatever are the exact nature and timescale of the phenomenon, it must impact the cosmic-ray distribution in space and energy. After an introduction I will focus on new results of joint XMM-Newton and ground-based observing programs that clearly demonstrate that the North Polar Spur (NPS), the most conspicuous feature in the diffuse X-ray sky, originates at least several hundreds of parsecs away from the Sun, with strong evidence for an even more distant origin, and likely in relation with a large-scale Galactic wind. Such a link between the NPS/Loop1 and the Galactic wind/Fermi bubbles will also modify our view of the solar neighborhood.
Landi, Enrico	***In-situ and Remote Sensing Studies of Solar Wind Origin and Acceleration*** Enrico Landi, University of Michigan, USA In this talk I will describe the results of a combined approach that includes 1) in-situ measurements of wind properties from Ulysses and ACE, 2) remote sensing observations from SoHO and Hinode, and 3) the Michigan 3D MHD global model, aimed at answering the two fundamental questions: how is the solar wind accelerated? Where are the source regions of the solar wind? Our results indicate that there are two types of solar wind, coming from two different sources: a wind from coronal holes, traveling at all speeds, and wind coming from closed magnetic loops, opened by reconnection, confined to speeds lower than 450 km/s. Both types of wind are accelerated and heated by magnetic wave pressure gradients and wave dissipation.
Laurenza, Monica	***The Weibull functional form for the energetic particle spectra at interplanetary shock waves*** M, Laurenza, INAF-IAPS, Italy G. Consolini, INAF-IAPS, Italy M Storini, INAF-IAPS, Italy G. Pallocchia, INAF-IAPS, Italy A. Damiani, Japan Agency for Marine-Earth Science and Technology, Japan Various highly dynamic processes in the magnetized coronal and interplanetary plasmas can produce major acceleration of charged particles to considerable non-thermal energies. In particular, high energy particles can be produced by shock waves in the heliospheric environment, such as solar energetic particles, the energetic storm particle (ESP) events, related to transient interplanetary shock waves, and those associated with the shocks bounding corotating interaction regions (CIRs), produced by the interaction between fast and slow solar wind streams. The kinetic energy spectra of several energetic particles enhancements at interplanetary shocks have been investigated through the Shannon's differential entropy, as proposed by [1]. Data from LET and HET instruments onboard the STEREO spacecraft were used to cover a wide energy range from ~ 4 MeV to 100 MeV, as well as EPAM data, on board the ACE spacecraft, respectively, in the lower energy range 0.047 – 4.75 MeV. The spectral features were found to be consistent with the Weibull like shape. Comparison of results obtained for energetic particles accelerated at CIRs, are presented and discussed in the framework of shock acceleration theories.

le Roux, Jakobus	***Diffusive Shock Acceleration Coupled with Downstream Acceleration of Energetic particles due to Small-scale Flux-rope Dynamics at Heliospheric Shocks*** Jakobus le Roux, U. of Alabama, USA Gary Zank, U. of Alabama, USA Gary Webb, U. of Alabama, USA Olga Khabarova, IZMIRAN, Russia Computational and observational evidence is accruing for the existence of small-scale flux ropes behind heliospheric shocks. Flux ropes can be formed, either by the emittance of vorticity by shocks, or by magnetic reconnection at primary current sheets located downstream. This led Zank et al. (2015) to investigate a new paradigm whereby energetic particle acceleration near shocks is a combination of diffusive shock acceleration (DSA) with downstream acceleration by many small-scale contracting and reconnecting (merging) flux ropes. By using a model in which flux-rope acceleration involves a first order Fermi mechanism due to the mean compression of numerous contracting flux ropes, Zank et al. (2015) provide theoretical support for observations that (i) power-law spectra of energetic particles downstream of heliospheric shocks can be harder than predicted by DSA theory and, (ii) that energetic particle intensities often peak behind shocks instead of at shocks as predicted by DSA theory. In this talk, results will be reported of a more extended kinetic theory transport formalism for energetic particle acceleration by small-scale flux ropes, developed by le Roux et al. (2015), that were used to explore this paradigm further. We will discuss how second order Fermi acceleration, related to the variance in the electromagnetic fields produced by downstream small-scale flux-rope dynamics, can potentially modify the standard DSA model. The results show that this approach can potentially (i) reproduce the observations mentioned above, thus providing further support for the new paradigm, and (ii) generate acceleration associated with compressible flux-rope dynamics that tends to be more efficient than acceleration involving incompressible flux-rope dynamics in modifying the DSA spectrum of energetic particles.
Lee, Martin	***The "Pump Mechanism" of Fisk and Gloeckler and the Acceleration of Suprathermal Ion Populations in the Heliosphere*** Martin Lee, UNH, USA The basic physics of the pump mechanism as defined by Fisk and Gloeckler (2014) is first described, followed by their traditional derivation of the pump mechanism transport equation based on the Parker equation. The pump mechanism transport equation naturally produces an omnidirectional distribution function that is a power law with index -5. Some inconsistencies in the pump mechanism and its derivation are then highlighted, particularly as applied to suprathermal particle populations in the heliosphere. Finally, an alternate explanation for the commonly observed power law with index -5 is presented.
Leske, Richard	***Updated Measurements of the Isotopic Composition of Solar Energetic Particles from ACE/SIS Through Solar Cycle 24*** R. A. Leske, C. M. S. Cohen, R. A. Mewaldt, A. C. Cummings, and E. C. Stone, California Institute of Technology, USA M. E. Wiedenbeck, Jet Propulsion Laboratory, Caltech, USA T. T. von Rosenvinge, NASA/Goddard Space Flight Center, USA In addition to measuring elemental composition and spectra of solar energetic particles (SEPs), the Solar Isotope Spectrometer (SIS) onboard NASA's Advanced Composition Explorer (ACE) spacecraft is capable of high-resolution measurements of the isotopic composition of SEPs at energies >20 MeV/nucleon. During solar cycle 23, we obtained SEP isotope measurements of C, O, Ne, Mg, Si, S, Ar, Ca, Fe, and Ni in up to ~40 large events. The present solar cycle 24 has been characterized by fewer large SEP events with hard energy spectra, nevertheless there have been several events with sufficient intensity at high energies for SIS to determine the heavy ion isotopic composition with reasonable statistical accuracy. We review the isotopic measurements from the previous cycle and update them with values from the largest events of this cycle. We find that isotopic composition is highly variable from one SEP event to another due to mass fractionation during particle acceleration and/or transport. Various isotopic and elemental enhancements are well correlated with each other, allowing us to devise empirical corrections to account for the compositional variability and obtain estimates of the solar coronal isotopic abundances. We compare the solar values and their uncertainties inferred from SEPs with those available from solar wind and meteoritic measurements and find generally good agreement.

Linsky, Jeffrey	***Visualizing the Three-dimensional Structure of the Local Interstellar Medium and Possible Physical Causes for this Structure*** Jeffrey L. Linsky, Univ. of Colorado, USA Seth Redfield, Wesleyan Univ., USA Max Schwarz, Univ. of Colorado, USA Analysis of high-resolution interstellar absorption lines observed in the ultraviolet spectra of nearby stars provides the basis for identifying 15 partially ionized "clouds" of interstellar gas located within 15 parsecs of the Sun and likely closer. We show visualizations of these clouds as seen from different directions. The presence of discrete clouds implies one or more physical processes that establish these structures and the presence of gas with very different properties between these clouds. While classical models of the interstellar medium based on the assumptions of pressure and ionization equilibrium in a nonmagnetic medium are not consistent with observations, dynamical simulations without these assumptions are likely more realistic. Possible physical processes that could structure the clouds include magnetic fields, extreme-ultraviolet radiation, Stromgren spheres, and instabilities in a recombining plasma following supernova events. We describe the available evidence concerning these processes. The properties of the intercloud medium are not yet established, but there are limits that can be placed on these properties.
Luhmann, Janet	***STEREO and ACE SEP Science- Transforming Space Weather Prospects*** J.G. Luhmann, SSL, University of California, Berkeley, USA M.L. Mays, CUA, USA D. Odstrcil, GMU, USA Yan Li, SSL, USA H. Bain, SSL, USA R.A. Mewaldt, Caltech, USA R.A. Leske, Caltech, USA C.M.S. Cohen, Caltech, USA STEREO and ACE together transformed our ability to study the heliosphere at 1 AU, and have been particularly effective in providing insights on solar energetic particle (SEP events) at Earth's orbit. While in the past it was necessary to take advantage of more serendipitous multipoint observations, or those with a variety of heliocentric distance viewpoints, the consistent records we now have from these spacecraft (in spite of the recalcitrant Sun during STEREO's initial years) have provided a data base of unprecedented potential. These data are of particular value in diagnosing the idiosyncracies of local SEP event behavior, including their sometimes surprisingly broad longitudinal reach as well as their solar/coronal activity associations. The result has been a revitalized industry in global modeling of SEPs' behavior, with the prospect of finally having this important element of space weather in the forecasting game. Ed Stone's contributions to STEREO instrumentation and science through his team at Caltech and his creation of the unfailingly reliable ACE mission have allowed this development to occur - one of his many gifts to us as a scientist, colleague and unequaled leader in the field of space physics.
Manchester, Ward	***Simulating CME-Driven Shocks and Implications for SEPs*** Ward Manchester, University of Michigan, USA Coronal mass ejections (CMEs) are large-scale magnetically driven eruptions in which a portion of the solar corona is expelled into interplanetary space. CMEs significantly faster than the solar wind drive forward shocks where it is believed energetic particle acceleration occurs giving rise to long-duration events. Here, we compare simulation results and observations of fast CMEs. Particular attention is given to the CME-driven shock geometry and its detailed structure and evolution. We identify shock fronts in images produced by the Large Angle Spectrometric Coronagraph (LASCO) C3, and find that the model can reproduce the shock giving good agreement with both the general morphology of the shock front and the quantitative brightness. Our results demonstrate the process by which shock geometry is largely determined by shock speed and interaction with the ambient solar wind. We then consider the evolution of the shock front along the magnetic field line connected to the Earth and determine if there are any discernible relationships to the energetic particle distribution.

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McNutt, Ralph	***Making Interstellar Probe Real*** Ralph L. McNutt, Jr., The John Hopkins University Applied Physics Laboratory, USA Thomas H. Zurbuchen, University of Michigan, USA The science community has been discussing a dedicated Interstellar Probe mission since 1971. While there has been general concurrence on the science and measurement requirements, measurement and implementation details have evolved with technologies and scientific understanding of near-interstellar space. That understanding has been enabled by the in situ measurements by the Voyager 1 and 2 spacecraft as the Voyager Interstellar Mission (VIM), and complementary remote imaging of energetic neutral atoms (ENAs) by the Ion Neutral CAmera (INCA) on Cassini, from its vantage point at Saturn, and from the Interstellar Boundary Explorer (IBEX) in Earth orbit. The remote observations are leading to a much better understanding of the constraints on the overall global interaction of the solar wind with the very local interstellar medium (VLISM), but discrepancies with current models remain. Thus, reaching large heliocentric distances is an even more compelling driver than heretofore for an Interstellar Probe, but reliance on advanced technologies, which have not matured or have fallen short of expectations have hindered serious planning to date for a near-term mission. Regardless of the propulsive means, what has emerged is a requirement for a small, properly instrumented, extremely capable spacecraft, not unlike the New Horizons spacecraft (< 500 kg launch mass), which recently flew by Pluto. A consensus on the driving science, corresponding required measurements, and the best means for obtaining the requisite data are necessary to bound the solution space for a mission, which can be carried out with current technologies. Appropriate instrumentation must be accommodated within realistic mass and power allocations on the spacecraft, which will also have a lifetime requirement of as much as 30 years prior to launch, far in excess of previous mission requirements, e.g., five years for Voyager. The Committee on Space Research (COSPAR) has recently established a new Panel on Interstellar Research (PIR) to consider the next steps toward finally making such a dedicated Interstellar Probe mission a reality. Crucial tasks are to build consensus amongst the international scientific community for the appropriate scientific campaigns and measurements to be carried out for such a mission, taking into account the new and continuing findings from the outer solar system and beyond.
Mewaldt, Richard	***Long-Term Variations in the Solar Energetic Particle He/H Ratio*** R. A. Mewaldt, Caltech, USA C. M.S. Cohen, Caltech, USA G. M. Mason, JHU/APL, USA It is well-known that the solar-wind He/H ratio varies over the solar cycle, with larger values generally present at solar maximum. However, it is also evident that the solar-wind He/H ratio at successive solar maxima has been declining since ~1990. We report preliminary results of a survey of the He/H ratio in solar energetic particle (SEP) events over the years from ~1973 to 2015, based on data from instruments on IMP-7&8, ACE, and STEREO. We also discuss possible causes of such variations in SEPs.
Moebius, Eberhard	***Interstellar Flow Longitude from Pickup Ion Cut-off Observations at with STEREO and ACE*** Eberhard Moebius, Martin A. Lee, Space Science Center & Department of Physics, University of New Hampshire, U.S.A. George Gloeckler, Department of Atmospheric, Oceanic, & Space Sciences, University of Michigan, U.S.A. Christian Drews, Institut für Experimentelle und Angewandte Physik, Christian-Albrecht-Universität, Kiel, Germany The precise determination of the interstellar neutral (ISN) flow direction is important in several ways. As a cardinal axis of the heliosphere it has strong leverage on the plane subtended by the ISN velocity and interstellar magnetic field vector, which controls the shape of the heliosphere and its interaction with the interstellar medium. The observation of the ISN flow through the heliosphere for several decades has initiated a discussion about potential temporal variations of the ISN flow. To tackle these questions, a precision measurement of the ISN flow velocity vector is needed over a long time period. Recent efforts to obtain a consistent ISN vector and temperature with Ulysses and IBEX point to remaining uncertainties and potential systematic effects. In particular, IBEX measurements provide a very precise relation between ISN flow longitude and speed via the hyperbolic trajectory equation, but they contain larger uncertainties along the parameter tube defined by this relation. Complementary to this result, observations of the pickup ion (PUI) cut-off variation with ecliptic longitude at 1 AU can provide a determination of the flow longitude with high precision. The interstellar PUI cut-off speed is a function of the ratio of the radial ISN flow component and the solar wind speed at the observer location, symmetric about the ISN flow direction. The cut-off speed is much less sensitive to systematic effects on PUIs, such as variations in the solar wind parameters, ionization, and transport. We compare STEREO PLASTIC and ACE SWICS observations with a simple analytic model of the cut-off and perform a Pearson correlation analysis of the cut-off as a function of ecliptic longitude with its mirrored function and obtain the symmetry axis with a statistical uncertainty <0.1o. As one way to test how this value varies due to remaining systematic influences we exploit multi year and location ACE SWICS and STEREO PLASTIC samples.

Mueller, Hans	***Ab-initio Calculation of Primary and Secondary Neutral Helium from the Outer Heliosphere, bserved close to the Sun*** Hans Mueller, Dartmouth College, USA Brian Wood, Naval Research Lab, USA Eberhard Moebius, UNH, USA An accurate, analytic heliospheric neutral test-particle code for helium atoms from the interstellar medium (ISM) is coupled to global heliospheric models dominated by hydrogen and protons from the solar wind and the ISM. This coupling allows for ab-initio estimates of charge exchange losses of primary interstellar helium as they travel to the inner heliosphere to be measured, for example, by IBEX. It also enables the forward-calculation of secondary helium neutrals produced predominantly upwind of the heliopause. The distributions and fluxes of primary and secondary helium neutrals in the heliosphere, especially in the innermost heliosphere, are characterized and discussed briefly.
Oka, Mitsuo	***Particle Acceleration in Solar Flares and Terrestrial Substorms*** Mitsuo Oka, UC Berkeley, USA Particles are accelerated to very high, non-thermal energies during explosive energy-release phenomena such as solar flares and terrestrial substorms. While it has been established that magnetic reconnection plays a key role in these phenomena, the precise mechanism of particle acceleration is still being discussed from both theoretical and observational points of view. In order to constrain theories, it is important to characterize the observed forms of energy spectra using quantities such as density, temperature and power-law spectral index. These quantities would further enable us to discuss how particle energies are partitioned between thermal and non-thermal components. Here we show, based on a compilation of previously reported observations, that the power-law spectral index k may have a lower-limit at $k \sim 4$ in both solar flares and terrestrial substorms (i.e., $k > 4$), where k is defined in a form of the kappa distribution. This is in stark contrast to the case of particle acceleration at shocks (such as interplanetary shocks and the terrestrial bow shock) whose power-law spectral index (when properly converted to that of the kappa distribution) often exceeds the limit (i.e., $k < 4$). The result of this review suggests that explosive energy-release phenomena such as solar flares and terrestrial substorms are not as efficient as shocks in terms of converting upstream energies to non-thermal particle energies at least in the heliospheric, non-relativistic environment of plasmas.
Opher, Merav	***Reconnection "hot spots" and their impact on the large-scale draping of the interstellar magnetic field*** M. Opher, J. F. Drake, B. Zieger, G. Toth Based on the difference between the orientation of the interstellar and the solar magnetic fields, there was an expectation by the community that the magnetic field direction will rotate dramatically across the heliopause (HP). With the crossing of Voyager 1 into the interstellar space the question arose why there was no significant rotation in the direction of the magnetic field across the HP. Recently we proposed a scenario (Opher et al. 2015) that the structure of the heliosphere might be very different than we previously thought. The standard picture of the heliosphere is a comet-shape like structure with the tail extending for 1000's of AUs. This standard picture stems from a view where magnetic forces are negligible and the solar magnetic field is convected passively down the tail. We showed (Opher et al. 2015, Drake et al. 2015) that the magnetic tension of the solar magnetic field plays a crucial role on organizing the solar wind in the heliosheath into two jet-like structures. The two heliospherc jets are separated by the interstellar medium that flows between them. The heliosphere then has a ``croissant"-like shape where the distance to the heliopause downtail is almost the same as towards the nose. Here we present the consequence of this "croissant-like structure" on the draping and reconnection of the interstellar magnetic field across the HP. We show that there are locations around the heliopause where active reconnection is taken place, called "hot-spots". These "hot spots" control the draping and the orientation of the interstellar magnetic field (BISM) ahead of the heliopause. The BISM twists as it approaches the HP and acquires a strong T component (East–West) as shown in Opher & Drake (2013). Only beyond some significant distance outside the HP is the direction of the interstellar field distinguishably different from that of the Parker spiral.

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Pierrard, Viviane	***Kinetic Aspects in Solar Wind Modelling*** Viviane Pierrard, Royal Belgian Institute for Space Aeronomy and Univeristy Catholique de Louvain, Belgium A kinetic solar wind model has been developed to study physical mechanisms and for space weather predictions. Photospheric magnetograms serve as observational input in semi-empirical coronal models for estimating the plasma characteristics up to low heliocentric distance. The results serve to constrain the parameters used in a three-dimensional exospheric kinetic solar wind model based on kappa velocity distribution functions for the electrons. A full MHD model is also employed for computing the evolution of the solar wind macroscopic variables up to 1AU and compare the results. We compare solar wind advantages and complementarity in modelling efforts with both magnetohydrodynamic (MHD) and kinetic treatments. Velocity distributions functions in the corona are used as boundary conditions to determine the solar wind solution and parameters are estimated to obtain the best comparison with available observations at the Earth. The kinetic description shed light on processes such as coronal heating and solar wind acceleration, that naturally appear by inclusion of suprathermal electrons in the model. We are focusing on the profile and variation of solar wind parameters, such as the solar wind speed and density at 1 AU, on characterising the slow and fast source regions of the wind and on comparing its features with results of exospheric models in similar conditions. In order to compare MHD and kinetic approaches with observations, we start from similar boundary conditions at the exobase (around 2.5 solar radii) and propagate the global kinetic solution up to 1AU. The variations of the VDF as a function of the radial distance are also studied with data of different spacecraft. Furthermore, we are interested in examining the existence of an empirical relation between the solar wind speed and the close-to-sun magnetic field information. Following the reverse process, i.e starting from observations at 1AU and assuming kappa velocity distribution functions for the electrons, we try to improve the close-to-sun boundary conditions for both models.
Pogorelov, Nikolai	***The Heliosphere and Its Effect on the Local Interstellar Medium*** Nikolai Pogorelov, University of Alabama in Huntsville, USA Matthew Bedford, University of Alabama in Huntsville, USA Jacob Heerikhuisen, University of Alabama in Huntsville, USA Harald Kucharek, University of New Hampshire, USA Alexandre Lazarian, University of Wisconsin, USA Vadim Roytershteyn, Space Research Institute, USA Gary Zank, University of Alabama in Huntsville, USA Ming Zhang, Florida Institute of Technology, USA The presence of the heliosphere affects the properties of the local interstellar medium (LISM) in its vicinity. This effect is two-fold. From he Voyager spacecraft perspective, the heliopause draping by the interstellar magnetic field (ISMF) is important. However, a larger scale modification to the LISM is due to the presence of the heliotail. Its presence is seen in IBEX data. The heliotail is likely to be affecting the anisotropy of 1-10 TeV galactic cosmic rays. On the other hand, the heliopause is a surface of equal total (thermal and magnetic) pressure and herefore influences the solar wind flow inside the heliosphere. We discuss both macroscopic and iscroscopic phenomena near the heliopause: the variation of the ISMF angles as Voyager 1 penetrates deeper into the LISM, pickup ion behavior, the heliopause instability, and the nature of the bow wave. It is shown that Voyager 1 observations during its crossing of the heliopause structure are supported by numerical simulations. We also demonstrate that the heliotail is very long, which is necessary to account for its effect of high-energy cosmic rays. We also show that the solar wind collimation by the Parker's spiral heliospheric field is absent when solar cycle effects are taken into account. As a result, the solar wind density increases toward the solar equatorial plane.
Potgieter, Marius	***Drift effects during the quiet solar modulation period up to 2009*** Marius Potgieter, Centre for Space Research, North-West University, South Africa. Etienne Vos, Centre for Space Research, North-West University, South Africa. The onset of solar cycle 24 was expected to start at the end of 2008, following the familiar 11-year solar activity cycle. However, solar minimum modulation conditions were prolonged until the end of 2009, producing a remarkable decrease in the heliospheric magnetic field magnitude and modulation conditions significantly different from previous minimum epochs. Fortunately, this unique minimum has been observed by the PAMELA detector, measuring cosmic ray protons, electrons and positrons, among others. A comprehensive numerical model is used to reproduce the observed increases in proton, electron and positron spectra from mid-2006 to the end of 2009, taking into account all modulation parameters self consistently. Clear evidence is found in comparison with our modelling, that charge-sign dependent modulation had occurred during this exceptional solar minimum period. Drift effects were found less pronounced compared to previous solar minimum activity periods; the reasons will be illustrated and discussed.

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Raeder, Jimmy	***Sub-Auroral Polarization Streams - A Complex Interaction Between the Magnetosphere, Ionosphere, and Thermosphere*** Joachim Raeder, UNH, USA Doug Cramer, UNH, USA Joseph Jensen, UNH, USA Frank Toffoletto, Rice U., USA Stanislav Sazykin, Rice U., USA Hien Vo, Turabo U., Puerto Rico Sub-Auroral Polarization Streams (SAPS), also known as Sub-Auroral Ion Drifts (SAIDs), are fast westward flows in the ionosphere that occur at latitudes lower than auroral precipitation, and well separated from the high-latitude convection pattern. Although SAPS were first observed in the ionosphere, they can also be seen in the magnetosphere and are believed to be driven by a combination of region-2 currents and low ionospheric conductance. SAPS are thus governed both by magnetosphere and ionosphere processes and require self-consistently coupled models of the outer magnetosphere, the inner magnetosphere and the ring current, and the ionosphere-thermosphere system. Here, we present first results from the OpenGGCM-RCM coupled model, which includes all of the required physical processes and feedbacks. In particular, the ionospheric conductance is computed self-consistently from both magnetosphere electron precipitation, solar ionization, and ionospheric chemistry within the fully dynamical CTIM sub model of OpenGGCM. Furthermore, CTIM includes the recombination feedback of streaming ions. We focus on the GEM-CEDAR storm events of 2013-03-17, 2011-04-27, 2012-05-07, and 2012-09-02. We show that the coupled model produces SAPS that compare well with data in terms of location, extent, and magnitude. By modifying the conductances in the code we evaluate the potential positive feedback process of the ionospheric conductance on SAPS.
Ratkiewicz, Romana	***The Local Interstellar Magnetic Field and the IBEX Ribbon*** Romana Ratkiewicz, Institute of Aviation and Space Research Center, PAS, Poland The Interstellar Boundary Explorer (IBEX) discovered a region of enhanced energetic neutral atom (ENA) emission seen in all sky maps as a ribbon. The enhanced fluxes of ENAs are between 2 and 3 times greater than adjacent regions of the sky. The ribbon itself was not predicted by any models of the heliospheric interface. In this talk we present some arguments to show that it was possible to predict the IBEX ribbon. We study the effects of the strength and direction of the local interstellar magnetic field (ISMF) on the heliosphere geometry that generates the locus of points associated with the position of the IBEX ribbon. MHD heliosphere models are run for a variety of ISMF parameters to specifically study the correlation between locations of maxima of the ISMF magnitude along the field lines and places where the local ISMF B is perpendicular to radial vectors r from the Sun, i.e., $B \cdot r = 0$. The study confirms the existence of a strong physical relationship between the ribbon and the ISMF.
Reames, Donald	***Element Abundances and Source Plasma Temperatures of Solar Energetic Particles*** D. Reames, U. of Maryland, USA It was observed 30 years ago by Breneman and Stone (1985) that the enhancement or suppression of element abundances in large solar energetic-particle (SEP) events varies as a power of the mass-to-charge ratio, A/Q, of the elements. Since Q during acceleration or transport may depend upon the source plasma temperature T, the pattern of element enhancements can provide a best-fit measure of T. The small SEP events we call 3He-rich or “impulsive” show enhancements, relative to coronal abundances, rising as the 3.6 power of A/Q, on average, to a factor of ~1000 for (75<Z<83)/O and temperature in the range 2-4 MK. This acceleration is believed to occur in islands of magnetic reconnection on open field lines in solar flares and jets. It has been recently been found that the large shock-accelerated “gradual” SEP events have a broad range of source plasma temperatures; 64% have coronal temperatures of T < 1.6 MK, while 24% have T ~ 3 MK, the latter suggesting a seed population dominated by residual impulsive suprathermal ions. Most of the large event-to-event abundance variations and their time variation are largely explained by variations in T magnified by A/Q-dependent fractionation during transport. However, the non-thermal variance of impulsive SEP events (~30%) exceeds that of the ~3MK gradual events (~10%) so that many impulsive events must be averaged to form the seed population for the shock acceleration.

Redfield, Seth	***A Three-Dimensional Model of the Interstellar Medium Surrounding the Sun and Nearby Stars*** Seth Redfield, Astronomy Department and Van Vleck Observatory, Wesleyan University, USA Jeffrey L. Linsky, JILA, University of Colorado and NIST, USA The Sun and nearby stars are surrounded by warm, partially ionized gas. This material dictates the structure of the heliosphere and astrospheres around other stars. Therefore, a thorough understanding of the physical properties of the surrounding local interstellar medium (LISM) is critical. The ISM displays dramatic variations in properties (e.g., density, relative velocity, turbulence, temperature, ionization), which argues for comparably dramatic variations in the heliosphere and astrospheres. I will review the attributes of the local ISM as revealed by high resolution spectroscopic observations of nearby stars. These observations provide important independent measurements of the properties of the LISM directly beyond the heliosphere, and are the only way in which the surrounding ISM properties can be derived for nearby stars, or for the Sun in its recent past or near future. I will review recent work to evaluate the morphology of the LISM, and present work that argues for a suite of related, but differentiated structures.
Reisenfeld, Daniel	***Tracking the Solar Cycle Through IBEX Observations of Energetic Neutral Atom Flux Variations at the Heliospheric Poles*** Daniel B. Reisenfeld, University of Montana, USA Maciej Bzowski, Polish Academy of Sciences, Poland Herbert O. Funsten, Los Alamos National Laboratory, USA Stephen A. Fuselier, Southwest Research Institute, USA Paul H. Janzen, University of Montana, USA N. Karna, GSFC, USA Marzena A. Kubiak, Polish Academy of Sciences, Poland David J. McComas, Southwest Research Institute, USA Nathan A. Schwadron, University of New Hampshire, USA Justyna M. Sokol, Polish Academy of Sciences, Poland With seven years of IBEX observations, we can now trace the time evolution of heliospheric ENAs through over half a solar cycle. At the north and south ecliptic poles, the spacecraft attitude allows for continuous coverage of the ENA flux; thus, signal from these vantages have much higher statistical accuracy and time resolution than anywhere else in the sky. By comparing the solar wind dynamic pressure measured at 1 AU with the heliosheath plasma pressure derived from the observed ENA fluxes, we show that the heliosheath pressure measured at the poles correlates well with the solar cycle. The analysis requires time-shifting the ENA measurements to account for the travel time out and back from the heliosheath. The time shifts at the north pole range from 5.1 years at 700 eV, the low end of the IBEX-Hi energy range, to 3.2 years at 4.3 keV, the top IBEX-Hi energy. For the south pole, the best-fit time shifts range from 4.1 to 2.6 years across the IBEX-Hi energy range. These time shifts assume a common mean distance to the ENA source region for all energies, which allows us to estimate the scale size of the heliosheath in the polar directions. For the north pole, we estimate a distance to the ENA source region of 220 AU, and in the south, a distance of 190 AU. This is consistent with an asymmetric heliosphere model. We also find a good correlation between the solar cycle and the ENA energy spectra at the poles. In particular, the ENA flux for the highest IBEX energy channel (4.3 keV) quite closely tracks the areas of the polar coronal holes (PCHs), in both the north and south, consistent with the notion that polar ENAs at this energy form from pick up ions of the high speed wind (~700 km/s) that emanates from PCHs.
Richardson, John	***Plasma, Pressure Pulses, and HCS Crossings in the Heliosheath*** John Richardson, MIT, USA Heliosheath plasma data from Voyager 2 is available since 2007. The recent observations and evolution of plasma through the heliosheath and with solar cycle are discussed. V1 data show substantial activity in the local interstellar medium driven by shocks. We discuss the origins and frequency of these shocks based on V2 observations of pressure pulses in the solar wind and heliosheath. The role of reconnection in the heliosheath is an active topic. The observed heliosheath crossing frequency will be compared to the expected frequency based on the observed solar tilt and heliosheath flows.

Roelof, Edmond	***Evidence from Voyager 1/2 that Anomalous Cosmic Rays are Accelerated in the Heliosheath Reservoir*** Edmond C. Roelof, Johns Hopkins U./Applied Physics Lab., USA Stamatios M. Krimigis, Johns Hopkins U./Applied Physics Lab., USA, and Academy of Athens, Greece Matthew E. Hill, Johns Hopkins U./Applied Physics Lab., USA Robert B. Decker, Johns Hopkins U./Applied Physics Lab., USA The huge volume of the heliosheath (at least that which has been sampled by the pair of Voyager spacecraft, VGR1 and VG2), is a “reservoir” filled with energetic particles, up to and including anomalous cosmic ray (ACR) ions (H, He, C, O) in the 100MeV-range of total energy. The ACR intensities continued to increase after the Voyagers crossed the heliospheric termination shock, and the VGR1 ACR intensities maximized just before they essentially disappeared upon crossing the heliopause into the interstellar medium (where only galactic cosmic rays of these species were detected at much lower intensities). Evidence, both observational and theoretical, is presented that the ACRs are being accelerated within the heliosheath itself. As predicted, a striking ordering of the ACR composition is obtained when computed in terms of total ion energy/charge (or equivalently, total energy, since almost all ACRs have charge +1 because of their origins as interstellar pickup ions). All four ACR species with common total energy ranges exhibited proportional intensity histories throughout VGR1’s 8-year (94-121 AU) transit of the heliosheath. The signature (and site) of the acceleration mechanism is identified as the nearly linear decrease of the radial component of the VGR1 plasma velocity over 2.5 years (104.0-113.2 AU), in quantitative agreement with the predictions of the with the reservoir transport equation [Roelof, AIP Conf. Proc., 1500, 174-185, 2012] and the newly proposed acceleration mechanism of “transverse plasma compression” [Roelof, IOP J. Phys., Conf. Series, 642, (2015), doi:10.1088/1742-6596/642/1/012024]. Although the ACR intensities at VGR2 have been similarly well-ordered in total energy, the corresponding signature of a gradient in the radial plasma velocity of the acceleration mechanism has not yet been obvious in the VGR2 data, perhaps because VGR2 (near 100 AU from the Sun) is only part way to the heliopause, and because the signature may be masked by the greater temporal intensity variations (compared to those measured by VGR1).
Salem, Chadi	***Solar Wind Electron Thermodynamics: Microphysical Processes and Their Role in the Evolution of the Solar Wind*** Chadi S. Salem, Space Sciences Laboratory, University of California Berkeley, USA Marc Pulupa, Space Sciences Laboratory, University of California Berkeley, USA Stuart D. Bale, Space Sciences Laboratory, University of California Berkeley, USA We present a review of our latest work based on statistical analysis of solar wind electrons at 1AU using a newly developed dataset of (several years of) accurate measurements of core, halo and strahl electron parameters from the 3D-Plasma experiment on Wind. We investigate the properties of these different populations and the physical processe(s) that likely act to control and regulate them. We review new results obtained on (1) the electron temperature anisotropies and their variation with collisions and/or solar wind fluctuations and instabilities, (2) the properties of core and halo drifts in the solar wind proton frame, (3) the electron heat flux, and (4) the electron strahl. These new observations emphasize the non-negligible role of Coulomb collisions in shaping the electron distribution function and regulating of the thermal and supra thermal electrons, but that the solar wind electron expansion and compression are limited fundamentally by some instabilities under certain conditions.
Savage, Sabrina	***Observational Signatures of Magnetic Reconnection in the Extended Corona*** Sabrina Savage, NASA/MSFC, USA Daniel Seaton, University of Colorado, USA Matthew West, Royal Observatory of Belgium, Belgium Observational signatures of reconnection have been studied extensively in the lower corona for decades, successfully providing insight into energy release mechanisms in the region above post-flare arcade loops and below 1.5 solar radii. During large eruptive events, however, energy release continues to occur well beyond the presence of reconnection signatures at these low heights. Supra-arcade downflows (SADs) and downflowing loops (SADLs) are particularly useful measures of continual reconnection in the corona as they may indicate the presence and path of retracting post-reconnection loops. SADs and SADLs have been faintly observed up to 18 hours beyond the passage of corona mass ejections through the SOHO/LASCO field of view, but a recent event from 2014 October 14 associated with giant arches provides very clear observations of these downflows for days after the initial eruption. We report on this unique event and compare these findings with observational signatures of magnetic reconnection in the extended corona for more typical eruptions.

Scherer, Klaus	***Heliosphere vs astrosphere*** K. Scherer, H. Fichtner, J. Kleimann, RUB, Germany D. Bomans, K. Weis, AIRUB, Bochum, Germany S.E.S. Ferreira, A. van der Schyff, NWU, South Africa The heliosphere is a special astrosphere. While the former is well explored by fleet of spacecraft, informations of the latter can only become availanle by remote observations. Especially, bow shocks around hot stars can be observed in the H-alpha light. For the heliosphere sophistacted models exist, including ions and neutrals, the models of astrospheres includes only ions and cooling functions. We compare here these different models and discuss commonalities and differences. Furthermore, we show that different astrospherical observational features are due to projection effects.
Schlickeiser, Reinhard	***Cosmic rays and MHD turbulence generation in interstellar molecular clouds*** R. Schlickeiser, Ruhr University Bochum, Germany M. Caglar, Ruhr-University Bochum, Germany A. Lazarian, University of Wisconsin-Madison, USA The diffusive propagation of nonrelativistic cosmic ray (CR) protons undergoing energy losses by ionization in a dense homogeneous infinitely extended interstellar molecular cloud (MC) is investigated in a spatially one-dimensional geometry. The steady-state transport equation for the differential number density of nonrelativistic CR protons is solved with the boundary condition that at the edge of cloud it agrees with the interstellar CR number density. The derived CR proton density distribution in the MC sensitively depends on two characteristic length scales determined by the ratio of the time scales for diffusive propagation and ionization losses. In the edge region $0\le Z\le Z_0=1.47\cdot 10^{-4}$ pc the ionization time scale is much longer than the diffusion time scales for all CR momenta, so here the CR proton density distribution equals the incoming interstellar CR proton distribution. For intermediate penetration depths $Z_0<Z\le Z_1=2.33$ pc only CR with low momenta are affected by the ionization losses, whereas at large penetration depths $Z>Z_1$ CRs at all momenta are affected by the ionization losses. This leads to different momentum spectra and spatial distributions of the CR protons and their total density in these three regions. With the derived CR proton density distribution in the MC the gas ionization and heating rate by CRs in the MC are calculated. They are largest at the edge of the MC, decrease slightly at intermediate depths $Z_0<Z\le Z_1$, whereas at large penetration depths $Z>Z_1$ they are strongly reduced $\propto (Z/Z_1)^{-1.12}$ compared to the edge values. Apparently, nonrelativistic CR protons ionize and heat the gas in the MC efficiently only at penetration depths smaller than Z_1. Moreover, the generation of parallel propagating slab MHD waves due to the streaming instability, caused by the CR spatial gradient, and the Compton-Getting instability, caused by CR momentum gradient, is investigated. The Compton-Getting anisotropy always leads to a damping rate, while the streaming rate is positive for forward moving and negative for backward moving Alfven waves. Neglecting spontaneous wave emission, Landau damping, cascading effects and ion-neutral damping, it is shown that at small penetration depth $Z<Z_0$ no forward moving Alfven waves are generated by the streaming instability, as here the CR distribution function has not developed any spatial gradient. In contrast, due to the strong CR spatial gradient effficient generation of forward moving Alfven waves occurs at large penetration depths $Z>Z_1$ with a wavenumber intensity spectrum $\propto k^{-2}$. By integrating over all wavenumbers it is found that one half of the energy density of incoming interstellar nonrelativistic CRs is converted into Alfvenic turbulence by the streaming instability at large penetration depths, giving rise to a total strength of fluctuating magnetic fields in the form of forward propagating Alfven waves of $|\delta B^f|=0.88 \; \mu $G. Consequently, nonrelativistic CRs inside MCs lose energy by ionizing and heating the molecular gas at small penetration depths $Z<Z_1=2.33$ pc, whereas at large penetration depths $Z>Z_1$ they are collectively dissipated by the streaming instability. MCs with thicknesses much greater than Z_1 are an efficient sink of nonrelativistic CRs.

Schwadron, Nathan	***Opening a New Window on Our Global Heliosphere - IBEX, the Voyagers, and the Next Steps in Exploring this Vast Frontier*** N. A. Schwadron, UNH, and the IBEX Team Our piece of cosmic real-estate, the heliosphere, is the domain of all human existence - an astrophysical case-history of the successful evolution of life in a habitable system. By exploring our global heliosphere and its myriad interactions, we develop key physical knowledge of the interstellar interactions that influence exoplanetary habitability as well as the distant history and destiny of our solar system and world. IBEX was the first mission to explore the global heliosphere and in concert with Voyager 1 and Voyager 2 is discovering a fundamentally new and uncharted physical domain of the outer heliosphere. The enigmatic IBEX ribbon was an unanticipated discovery demonstrating that much of what we know or think we understand about the outer heliosphere needs to be revised. The next quantum leap enabled by IMAP will open new windows on the frontier of Heliophysics at a time when the space environment is rapidly evolving. IMAP, like ACE before it, will be a keystone of the Heliophysics System Observatory by providing comprehensive cosmic ray, energetic particle, pickup ion, suprathermal ion, neutral atom, solar wind, solar wind heavy ion, and magnetic field observations to diagnose the changing space environment and understand the fundamental origins of particle acceleration. In this talk, we will review recent discoveries of IBEX and their relation to measurements by Voyager 1 and Voyager 2. We will discuss new analyses of IBEX measurements of interstellar neutral matter, which reveal the influences of interstellar structure influenced by the external interstellar magnetic field.
Scudder, Jack	***A Generic Origin for Non-thermal Velocity Distributions in Astrophysical Plasmas*** Jack D. Scudder, University of Iowa, USA A general argument is presented that the natural, lowest order description of an astrophysical plasma is that it is non-thermal. Properties of these non-thermal distributions are shown to be functions of the dimensionless parallel electric field that permeate astrophysical plasmas. The lowest order properties of the non-thermal electron distributions are quantitatively derived and shown to be strongly organized through their common dependence on this parallel electric field. These correlations are precisely those unexplained, but ubiquitous properties documented with in situ solar wind observations, including the number fraction of particles that are observed to be non-thermal, the energy where the spectrum transitions to non-thermal behavior, as well as their partial pressures, mean energies and their flow of heat. The electron supra thermal morphology is more widely documented in the solar wind than the ion behavior, but the recent discussions by Gloeckler and Fisk of proton supra thermal tails with distinctive termination signatures are also part of this same behavior and explanation. This general argument also suggests that the regimes where Maxwellians should be expected are those where the dimensionless parallel electric field is negligible, as would occur in a plasma without gradients - which is not a very astrophysical plasma! The analysis also shows that the non-thermal character of the plasma is spatially dependent on the variability of the dimensionless parallel electric field. The realization that Maxwellians do not have a privileged status in astrophysical plasmas impacts: (i) the interpretation of nearly every photon collected in astrophysics; (ii) the first stage of promoting particles from the thermal pool to energies where more esoteric accelerations are possible; (iii) implies that the analogue of the continuum fluid equations may be closed in different ways than those predicated on near Maxwellian behavior. Among the phenomena understood from in-situ observations that behave like (i) were the Voyager discussion of ionization equilibrium in Io's torus; or of type (iii) are Io's torus as mapped by Ulysses quasi-thermal noise receiver, the Polar Rain in magnetized planets, the ionospheres of visited planets, and the "heating" of the solar corona and the coronae of all main sequence stars if non-thermals were known to be present.

Song, Paul	***Effect of Interstellar Neutrals on Forming the Termination Shock*** V. M. Vasyliūnas, Space Science Laboratory and Department of Physics, University of Massachusetts Lowell, USA, and Max-Planck-Institut für Sonnensystemforschung, Göttingen,Germany P. Song, Space Science Laboratory and Department of Physics, University of Massachusetts Lowell, USA The interstellar medium in the vicinity of the Sun is partially ionized, with an appreciable and possibly dominant population of neutral particles. Not subject to electromagnetic forces, neutral particles can move freely through the heliopause, hence the neutral density inside remains at nearly its interstellar value, down to distances of some ~ 5-10 AU. The plasma density, on the other hand, is greatly lowered by the expanding solar wind, which also sweeps any interstellar plasma out of the heliosphere. As a result, the medium (viewed as one fluid) in the outer solar wind and in the heliosphere is very weakly ionized. Although it is also only weakly collisional, the rate and properties of collisional processes are sufficient for neutrals to have a major effect on solar wind plasma. Photoionization, charge exchange, and consequent ion pickup affect continuity, momentum, and energy equations for both plasma and neutrals. We analyze self-consistently the two-fluid equations and Maxwell's equations for the combined medium. The solar wind decelerates and becomes hotter gradually before it undergoes a shock transition. The location of the shock is constrained to a relatively narrow range of distances (around 80-100 AU) by the interaction with interstellar neutral and depends only weakly on the heliopause.
Stone, Edward C.	***Voyager Explores the Edge of Interstellar Space*** Edward C. Stone, California Institute of Technology, USA After a thirty-five year journey, Voyager 1 began exploring the region where the interstellar and solar winds strongly interact and a "wall" of H atoms forms. The interstellar plasma density is ~100 times that in the outer heliosphere, and the intensity of galactic cosmic rays is ~4 times the highest level observed at 1 AU, with transient variations caused by the arrival of Merged Interaction Regions originating at the sun. Although the interstellar magnetic field is wrapped around the heliosphere, the turbulence in the field is <1% of the average field, leading to extremely weak cosmic ray scattering rates and pitch angle anisotropies that persist for months. Voyager 2 continues to explore the outer regions of the heliosphere where the solar wind flow has turned as it approaches contact with the interstellar wind.
Verkhoglyadova, Olga	***Driving of the Earth's thermosphere and ionosphere by the solar wind structures*** O.P. Verkhoglyadova, A.J. Mannucci, B.T. Tsurutani, X. Meng, A. Komjathy Jet Propulsion Laboratory, California Institute of Technology, USA M.G. Mlynczak, NASA Langley Research Center, USA L.A. Hunt, Sciences Systems and Applications, Inc., USA L.J. Paxton, Applied Physics Laboratory, Johns Hopkins University, USA We discuss causal relationships between interplanetary transient structures (parts of CMEs or high-speed-streams) and efficiency of solar wind coupling with the ionosphere-thermosphere (IT). Detailed analyses are presented for the St. Patrick's Day storms intervals of 74 – 80 DOY in 2013 and 2015. Empirical and modeling estimates of energy transport into the IT system are presented. We focus on dynamics of IT parameters over the course of the geomagnetic storms. We utilize measurements of the ionospheric total electron content from the Global Navigation Satellite Systems' (GNSS) to describe storm-time ionospheric dynamics. TIMED/SABER measurements of thermospheric radiative cooling during these events has been analyzed. Based on these datasets we emphasize distinct IT responses to external driving by sheaths antisunward of the ICME, the coronal loops, magnetic clouds and plasma discontinuities portion of the ICMEs, and high-speed streams (HSSs) emanating from coronal holes.
Verscharen, Daniel	***Isotropization of the Solar Wind through Plasma Instabilities induced by Compressive Fluctuations*** Daniel Verscharen, Space Science Center, University of New Hampshire, USA Benjamin D. G. Chandran, University of New Hampshire, USA Compressive fluctuations are a minor yet significant component of solar-wind turbulence. In-situ observations indicate that about ten percent of the energy of turbulent fluctuations is associated with compressive slow magnetosonic modes. Slow-mode fluctuations lead to changes in beta and in the temperature anisotropy of all plasma species. If the amplitude of the compressive fluctuations is large enough, the anisotropy crosses one or more instability thresholds for anisotropy-driven micro-instabilities. We explore the ansatz that these instabilities reduce the equilibrium temperature anisotropy. We discuss this collisionless isotropization mechanism and analytically quantify the reduced anisotropy as a function of the wave amplitude. We determine the relevant wave-polarization properties using magnetohydrodynamics (MHD) to describe the large-scale fluctuations. We then calculate the changes in beta and in the plasma anisotropy using numerical solutions to the hot-plasma dispersion relation. We visualize these effects by illustrating the particle distribution functions associated with various plasma modes. We find that this mechanism successfully explains the observation that the solar wind is more isotropic than predicted by the double-adiabatic model.

Wang, Chi	***SMILE (Solar wind Magnetosphere Ionosphere Link Explorer): A New Mission to Image the Magnetosphere*** Chi Wang, NSSC-CAS, China G. Branduardi-Raymont, MSSL-UCL, UK and the SMILE Team SMILE is a novel space mission, currently under development, dedicated to study the dynamic coupling of the solar wind with the Earth's magnetosphere in a global way never attempted so far. From a highly inclined elliptical Earth orbit, SMILE will obtain X-ray images of the magnetosheath and polar cusps simultaneously with UV images of the Northern aurora, while also carrying out in situ solar wind/magnetosheath plasma and magnetic field measurements. Remote sensing of the magnetosphere with X-ray imaging is now possible thanks to the relatively recent discovery of solar wind charge exchange (SWCX), which were first observed at comets, and subsequently found to occur in the vicinity of the Earth's magnetosphere. SMILE will turn what is unwanted background for astronomical observations into a diagnostic tool for the study of solar-terrestrial interactions, enabling us to trace and link the processes of solar wind injection in the magnetosphere with particle precipitation into the cusps and the aurora. SMILE is the first fully collaborative space mission from inception to implementation and operations between European Space Agency (ESA) and the Chinese Academy of Sciences (CAS). It was approved by ESA and CAS in 2015, and is expected to be launched in 2021 ~ 2022. This talk will present the science that SMILE will deliver and its impact, model simulations, and will provide an overview of its payload and of the mission's development.
Whittlesey, Phyllis	***Modification of Velocity Power Spectra by Thermal Plasma Instrumentation*** P.L. Whittlesey, G. P. Zank, J. W. Cirtain, K. H. Wright Jr. The upcoming Solar Probe Plus mission (Launch 2018) will launch with the newest and fastest space plasma instrumentation to date. The Solar Wind Electrons, Alphas, and Protons (SWEAP) instrument suite, which measures thermal plasma, will make measurements faster than the local gyro-frequency and proton plasma frequency. By developing an end-to-end computer model of a SWEAP instrument, this work explores the specific instrumental effects of thermal space plasma measurement, particularly in the reproduction of velocity power spectra, or Power Spectral Densities (PSDs). This model reproduces the slowest measurement cadence of the Solar Probe Cup (SPC), a Faraday cup (FC) style instrument on that will measure thermal plasma density, velocity, and temperature on SPP. By using the calibrated model to model measurement of fully determined and synthetic turbulent time series data, a consistent underestimation of the velocity power spectral indices has been quantified, with possible implications for previous missions flying similar instrumentation.

Wiedenbeck, Mark	***Constraints on the Acceleration and Transport of Galactic Cosmic Rays from Abundance Measurements of Radioactive Nuclides*** M. E. Wiedenbeck, JPL/Caltech, USA W. R. Binns, Washington Univ., USA M. H. Israel, Washington Univ., USA E. R. Christian, NASA/GSFC, USA A. C. Cummings, Caltech, USA G. A. de Nolfo, , NASA/GSFC, USA A. W. Labrador, Caltech, USA R. A. Leske, Caltech, USA R. A. Mewaldt, Caltech, USA E. C. Stone, Caltech, USA T. T. von Rosenvinge, NASA/GSFC, USA The galactic cosmic rays arriving at Earth include a number of radioactive nuclides that provide information about time scales associated with the acceleration and transport of these particles in the Galaxy. The primary, beta-decay nuclide 60Fe is synthesized in supernovae explosions of massive stars and ejected into the interstellar medium (ISM). It decays between the time of its synthesis and its acceleration, and also during its propagation at high energies in the ISM (Binns et al. 2016). In contrast, 59Ni is a dominantly primary nuclide that can decay only by orbital electron capture (ec). It can decay prior to its acceleration, but at high energies it is stripped of its orbital electrons and becomes stable. Thus its abundance is a probe of the time between nucleosynthesis and acceleration (Wiedenbeck et al. 1999). There are several radionuclides that can decay by beta-particle emission that are produced primarily by fragmentation of heavier nuclides during transport in the Galaxy, including 10Be, 26Al, 36Cl, and 54Mn. These secondary clocks probe the cosmic-ray residence time in the Galaxy (Yanasak et al. 2001 and references therein). Finally, a number of secondary nuclides that can decay only by orbital electron capture (e.g., 7Be, which has a laboratory halflife of 53 days) are observed in cosmic rays in spite of a mean residence time in the Galaxy that exceeds 10 Myr because the bare nuclei are effectively stable. These ec secondaries can provide some indication of the history of energy changes that cosmic rays experience because the probability that an energetic nucleus can attach an electron from the medium in which it is propagating and retain it long enough to undergo ec decay is a strong function of energy. The Cosmic Ray Isotope Spectrometer (CRIS) on NASA's Advanced Composition Explorer (ACE) spacecraft combines excellent mass resolution and background rejection with a large geometrical factor and a long exposure time to make abundance measurements of radioactive cosmic-ray nuclides in each of these categories. We will review the radionuclide measurements that have been made to date using ACE/CRIS and discuss their implications for our understanding of cosmic-ray acceleration and transport time scales.
Wood, Brian	***Observational Constraints on Astrospheric Structures from the Hubble Space Telescope*** Brian E. Wood, Naval Research Laboratory, USA Hans-Reinhard Mueller, Dartmouth College, USA Graham M. Harper, University of Colorado, USA Ultraviolet spectroscopy from the Hubble Space Telescope (HST) provides a unique way to detect and probe the characteristics of stellar astrospheres, including the heliospheric structure surrounding our own Sun. Lyman-alpha absorption has been observed from the "hydrogen wall" region outside the heliopause, and from the heliotail, representing the most distant regions of the heliosphere ever probed observationally. Hydrogen wall absorption has also been observed around other Sun-like stars, representing the first method by which solar-like coronal winds can be detected around other stars. Finally, Mg II absorption has been used to detect astrospheric structures around red giant stars, with indications that their termination shocks can be radiative shocks, with hydrogen Lyman lines providing the radiative cooling. We report on recent HST observations that have provided new detections of red giant astrospheres.

15th ANNUAL INTERNATIONAL ASTROPHYSICS CONFERENCE
ORAL ABSTRACTS

Wurz, Peter	***Investigating the Heliospheric Boundary at Energies down to 10eV with Neutral Atom Imaging by IBEX.*** P. Wurz and A. Galli, Physics Institute, University of Bern, Switzerland N.A. Schwadron, H. Kucharek, and E. Möbius, University of New Hampshire, USA M. Bzowski, J. M. Sokol, and M. A. Kubiak, Space Research Centre, Polish Academy of Sciences, Poland S. A. Fuselier and D. J. McComas, Southwest Research Institute, University of Texas, USA The Interstellar Boundary Explorer mission (IBEX) investigates the heliospheric boundary by imaging energetic neutral atoms (ENA) from Earth orbit in the energy range from 10eV to 6keV. The IBEX-Lo camera covers the lower energy range from 10eV to 2keV, whereas IBEX-Hi covers the range from 300eV to 6keV. Full sky maps of the distributed ENA flux are available down to 100eV, and maps for the ram direction down to 10eV. The IBEX ribbon of enhanced ENA intensities is most prominent at solar wind energies (1-2keV) and has been observed to disappear at 100eV. ENA energy spectra down to 10eV can be derived at selected locations in the sky. The inflow of interstellar gas, which is discussed separately, is the dominant signal in the energy range below 100eV during the spring observation periods, masking all other signals in the same hemisphere. The fall signal from the inflow of interstellar gas is expected to be weak because the spacecraft is moving away from the interstellar gas during that period. So far, attempts to identify this fall signal in the ENA maps have not been successful.
Ye, Junye	***The Effects of a Turbulent Solar Wind Magnetic Field and Termination Shock Structure on Interstellar Pickup Ion Acceleration Using a Focused Transport Approach*** Junye Ye, University of Alabama in Huntsville, USA Jakobus le Roux, University of Alabama in Huntsville, USA We study the physics of locally born interstellar pickup proton acceleration at the nearly perpendicular solar wind termination shock (SWTS) in the presence of random magnetic field spiral angle and magnitude fluctuations using a focused transport model. Guided by Voyager 2 observations, the spiral angle and magnitude variations are modeled with a q-Gaussian and a log-normal distribution, respectively. The spiral angle fluctuations, which are used to generate perpendicular diffusion of pickup protons across the SWTS, play a key role in enabling efficient injection and rapid diffusive shock acceleration (DSA) when these particles follow field lines. Our simulations suggest that variation of both the shape (q-value) and the standard deviation (sigma-value) of the q-Gaussian distribution significantly affect the injection speed, pitch-angle anisotropy, radial distribution and the efficiency of DSA of pickup protons at the SWTS. For example, increasing q and especially reducing sigma enhances the DSA rate. Likewise, variation in the statistics of the magnetic field strength was found to significantly impact the characteristics of pickup ion acceleration by the SWTS. Statistical variation of shock compression ratio modeled as a q-Gaussian distribution is also studied. Our results suggest that increasing sigma-value of the compression ratio PDF results in more efficient DSA of pickup protons at the SWTS.
Yoon, Peter	***Theoretical Considerations in Modeling the Non-Thermal Properties of the Solar Wind Electrons*** Peter H. Yoon, Institute for Physical Science and Technology, University of Maryland, USA The solar wind is made of energetic ions and electrons streaming outward from the Sun. In theoretically modeling the behavior of the solar wind, the consideration of plasma kinetic theory is essential. To model the quasi-static behavior of the solar wind electron velocity distribution function, which is often described by the kappa distribution, a steady-state self-consistent solution of coupled particle and wave kinetic equations is obtained. According to such a solution, the non-thermal (halo plus super-halo) solar wind electron component maintains dynamical equilibrium with the self-generated electrostatic (Langmuir) fluctuations. Previously it was thought that electromagnetic fluctuations with whistler frequency range were also important in maintaining the overall dynamical steady state [Kim et al., 2015; Yoon et al., 2015], but the latest finding shows that the influence of whistler turbulence is minimal. The Voyager spacecraft has shown that there exists a background component of protons with an inverse power law velocity distribution of spectral index of minus 5 [Fisk and Gloeckler, 2008]. The non-thermal electrons in the solar wind, especially the highly energetic component known as the super-halo [Wang et al., 2015], appears to be analogous to the suprathermal proton distribution.

Zank, Gary	***Particle Acceleration at Shock Waves and Downstream Small-Scale Flux Ropes*** G.P. Zank, University of Alabama in Huntsville, USA P. Hunana, University of Alabama in Huntsville, USA O. Khabarova, IZMIRAN, Russia P. Mostafavi, University of Alabama in Huntsville, USA J. le Roux, University of Alabama in Huntsville, USA G.M. Webb, University of Alabama in Huntsville, USA Gang Li, University of Alabama in Huntsville, USA A.C. Cummings, California Institute of Technology, USA E.C. Stone, California Institute of Technology, USA R.B. Decker, Applied Physics Lab., Johns Hopkins University, USA An emerging paradigm for the dissipation of magnetic turbulence in the supersonic solar wind is via localized small-scale reconnection processes, essentially between quasi-2D interacting magnetic islands or flux ropes. Charged particles trapped in merging magnetic islands can be accelerated by the electric field generated by magnetic island merging and the contraction of magnetic islands. We discuss the basic physics of particle acceleration by single magnetic islands and describe how to incorporate these ideas in a distributed “sea of magnetic islands” by developing a transport formalism. We discuss particle acceleration in the supersonic solar wind and extend these ideas to particle acceleration at shock waves. Shock waves generate naturally vortical turbulence and particle acceleration at shocks is likely therefore to be a combination of classical diffusive shock acceleration and acceleration by downstream magnetic islands or flux ropes. These models are appropriate to the acceleration of both electrons and ions. We describe model predictions and supporting observations made at the heliospheric termination shock and in the vicinity of the heliospheric current sheet.
Zelina, Peter	***Time dependence of heavy ion ratios in SEP events*** Peter Zelina, University of Central Lancashire, United Kingdom Silvia Dalla, University of Central Lancashire, United Kingdom Eruptive events such as solar flares and coronal mass ejections can accelerate ions and electrons into the heliosphere, causing solar energetic particle (SEP) events. Time resolved in situ measurements show that heavy ion ratios, e.g. Fe/O, are not constant but exhibit temporal evolution over the duration of an SEP event. In the case of Fe/O, the ratio is observed to decrease by as much as 2 orders of magnitude, but other ratios may show less temporal variation or even increase over time. What causes the ratio abundances to change over time? Is there a parameter that is ordering the observed behaviour? In this work, we systematically characterise the decreases (increases) of heavy ion ratios in several SEP events. We consider several pairings of elements and automatically determine the decay/increase time constant B describing their ratio's evolution. We find that B scales with the ratio of M/Q values of the two elements. In some SEP events, we find that time dependences of X/H, where X stands for an abundant SEP element, do not follow the same trend as ratios with respect to other ions. We discuss possible causes of the time dependence of elemental ratios within the context of our observational results.
Zhang, Ming	***The heliosphere as seen in TeV cosmic rays*** Ming Zhang, Department of Physics and Space Sciences, Florida Institute of Technology, USA Nikolai Pogorelov, Center for Space Plasma and Aeronomic Research and Department of Space Sciences, University of Alabama in Huntsville, USA Measurements from several cosmic ray air shower experiments reveal that the directional variation (anisotropy) of TeV cosmic ray flux does not agree with a dipole pattern commonly expected from the Compton-Getting effect due to the motion the heliosphere relative to the local interstellar plasma or from the diffusion of cosmic rays in Galactic magnetic fields. TeV cosmic ray anisotropy maps often show fine features, some of which are slightly time dependent. Since the gyroradii of these particles are comparable to the size of the heliosphere, and they are also slightly bended by the solar coronal magnetic field, it is expected that electric and magnetic fields of the heliosphere may distort the pattern of cosmic ray anisotropy that one would see in the local interstellar medium without the presence of the heliosphere. Therefore, these features of cosmic ray anisotropy can be used to explore large-scale magnetic field structures from the solar corona to the local interstellar medium. We have developed a method of mapping cosmic ray anisotropy using Liouville’s theorem. In this paper, we show how to use cosmic ray anisotropy features to determine the direction of the local interstellar magnetic field, the hydrogen deflection plane, the size and shape of the heliotail, and some possible geometry of the heliosphere bow wave.

Zheng, Jinlei	***Observations and Analysis of Small-scale Magnetic Flux Ropes in the Solar Wind*** Jinlei Zheng, Department of Space Science, University of Alabama in Huntsville, USA Qiang Hu, Center for Space Plasma and Aeronomic Research and Department of Space Sciences, University of Alabama in Huntsville, USA The small-scale magnetic flux ropes (of duration ranging from a few minutes to a few hours) in the solar wind have the typical topology of winding field lines around a central axis, which is similar to the large-scale flux ropes, i.e., magnetic clouds. However, accumulating evidence suggests that their plasma characteristics, origin, formation mechanism and evolution are different from those of large-scale flux ropes. The small-scale flux ropes are intensively studied in recent years, since they affect particle transport and energization, and are considered as the potential source of local acceleration. The Grad-Shafranov reconstruction technique is a tool to reconstruct the two and a half dimensional field structure based on in-situ measurements captured by an observing platform moving past it. In this study, we reconstruct the flux rope structures in two cases using the Grad-Shafranov reconstruction approach. In one case, a twin flux rope structure at 1 AU occurring on 2002 February 1 and two following single flux rope structures are identified behind an interplanetary shock. In the other case, we reconstruct the flux rope structures occurring on 1998 March 25 and 26 at 1 AU in the ambient solar wind. The associated energetic particle signatures and the possible origin of these flux rope structures will be discussed.
Zieger, Bertalan	***Dispersive Magnetosonic Waves and Turbulence in the Heliosheath*** Bertalan Zieger, Boston University, USA Merav Opher, Boston University, USA Gabor Toth, University of Michigan, USA Recently we demonstrated that our three-fluid MHD model of the solar wind plasma (where cold thermal solar wind ions, hot pickup ions, and electrons are treated as separate fluids) is able to reconstruct the microstructure of the termination shock observed by Voyager 2 [Zieger et al., 2015]. We constrained the unknown pickup ion abundance and temperature and confirmed the presence of a hot electron population at the termination shock, which has been predicted by a number of previous theoretical studies [e.g. Chasei and Fahr, 2014; Fahr et al., 2014]. We showed that a significant part of the upstream hydrodynamic energy is transferred to the heating of pickup ions and "massless" electrons. As shown in Zieger et al., [2015], three-fluid MHD theory predicts two fast magnetosonic modes, a low-frequency fast mode or solar wind ion (SW) mode and a high-frequency fast mode or pickup ion (PUI) mode. The coupling of the two ion populations results in a quasi-stationary nonlinear mode or oscilliton, which appears as a trailing wave train downstream of the termination shock. In single-fluid plasma, dispersive effects appear on the scale of the Debye length. However, in a non-equilibrium plasma like the solar wind, where solar wind ions and PUIs have different temperatures, dispersive effects become important on fluid scales [see Zieger et al., 2015]. Here we show that the dispersive effects of fast magnetosonic waves are expected on the scale of astronomical units (AU), and dispersion plays an important role producing compressional turbulence in the heliosheath. The trailing wave train of the termination shock (the SW-mode oscilliton) does not extend to infinity. Downstream propagating PUI-mode waves grow until they steepen into PUI shocklets and overturn starting to propagate backward. The upstream propagating PUI-mode waves result in fast magnetosonic turbulence and limit the downstream extension of the oscilliton. The overturning distance of the PUI-mode, where these waves start to propagate backward, depends on the maximum growth rate of the PUI-mode. We discuss our simulations in light of the Voyager 2 observations in the heliosheath.
Zirnstein, Eric	***Local Interstellar Magnetic Field Determined from the IBEX Ribbon*** E. J. Zirnstein, Southwest Research Institute, USA J. Heerikhuisen, Department of Space Science, University of Alabama in Huntsville, USA H. O. Funsten, Los Alamos National Laboratory, USA G. Livadiotis, Southwest Research Institute, USA D. J. McComas, Southwest Research Institute, USA N. V. Pogorelov, Department of Space Science, University of Alabama in Huntsville, USA The solar wind emanating from the Sun interacts with the local interstellar medium (LISM), forming the heliosphere. Hydrogen energetic neutral atoms (ENAs) produced by the solar-interstellar interaction carry important information about plasma properties from the boundaries of the heliosphere, and are currently being measured by NASA's Interstellar Boundary Explorer (IBEX). IBEX observations show the existence of a "ribbon" of intense ENA emission projecting a circle on the celestial sphere that is centered near the local interstellar magnetic field (ISMF) vector. Here we show that the source of the IBEX ribbon as a function of ENA energy outside the heliosphere, uniquely coupled to the draping of the ISMF around the heliopause, can be used to precisely determine the magnitude and direction of the pristine ISMF far from the Sun. We find that the ISMF vector is offset from the ribbon center by ~8 deg. toward the direction of motion of the heliosphere through the LISM, and their vectors form a plane that is consistent with the direction of deflected interstellar neutral hydrogen, thought to be controlled by the ISMF. Our results yield draped ISMF properties close to that observed by Voyager 1, the only spacecraft to directly measure the ISMF close to the heliosphere.

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