SOLAR WIND 12

Twelfth International Solar Wind Conference

21-26 June 2009

SAINT-MALO, France

ABSTRACTS

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Notes: The content of this abstract book was fixed on May 7th, 2009. As usual, (minor) changes in the program may still occur. Abstracts and list of participants inputs have been imported "raw" from the web and are thus given under the sole responsability of their autors.

Remarques: Le contenu de ce recueil de résumés a été arrêté au 7 mai 2009. Comme il se doit, des changements (mineurs) peuvent avoir lieu. Les résumés et les coordonnées des participants sont directement issus de la Toile et sont donc donnés sous la seule responsabilité de leurs auteurs.

CONFERENCE OVERVIEW

Sunday, June 21	4:00 - 6:00 pm	Registrations
	6:00 - 8:00 pm	Welcome cocktail and setting posters of sessions 1 & 2
Monday, June 22	8:00 am ...	Registrations
	8:45 - 9:00 am	Welcome address
	9:00 - 9:40 am	Opening Talk
	9:40 - 10:50 am	1 - CORONAL HEATING AND ACCELERATION OF THE FAST SOLAR WIND
	Coffee break...	and Poster viewing (sessions 1 & 2)
	11:50 am - 12:30 pm	1 - CORONAL HEATING AND ACCELERATION OF THE FAST SOLAR WIND
	Lunch	at the *Palais du Grand Large*
	2:00 - 3:00 pm	1 - CORONAL HEATING AND ACCELERATION OF THE FAST SOLAR WIND
	3:00 - 3:50 pm	2 - PHYSICAL PROCESSES IN THE SOLAR WIND
	Coffee break...	and Poster viewing (sessions 1 & 2)
	4:50 - 6:00 pm	2 - PHYSICAL PROCESSES IN THE SOLAR WIND
	6:00 - 7:30 pm	Poster viewing (sessions 1 & 2)
Tuesday, June 23	8:30 - 10:20 am	2 - PHYSICAL PROCESSES IN THE SOLAR WIND
	Coffee break...	poster viewing (session 1 & 2) and poster removal
	11:10 am - 12:30 pm	2 - PHYSICAL PROCESSES IN THE SOLAR WIND
	Lunch	at the *Palais du Grand Large*
	2:00 - 3:00 pm	2 - PHYSICAL PROCESSES IN THE SOLAR WIND
	3:00 - 3:50 pm	3 - SLOW WIND STREAMS, CMEs & 3D-STRUCTURE OF THE CORONA AND HELIOSPHERE
	Coffee break...	and setting posters of sessions 3 to 6
	4:20 - 6:10 pm	3 - SLOW WIND STREAMS, CMEs & 3D-STRUCTURE OF THE CORONA AND HELIOSPHERE
	6:10 - 7:30 pm	Poster viewing (sessions 3 to 6)

CONFERENCE OVERVIEW

Wednesday, June 24	8:30 - 10:20 am	3 - SLOW WIND STREAMS, CMEs & 3D-STRUCTURE OF THE CORONA AND HELIOSPHERE
	Coffee break…	Poster viewing (sessions 3 to 6)
	11:20 - 11:40 am	3 - SLOW WIND STREAMS, CMEs & 3D-STRUCTURE OF THE CORONA AND HELIOSPHERE
	11:40 am - 12:40 pm	1- CORONAL HEATING AND ACCELERATION OF THE FAST SOLAR WIND
	Lunch	at the *Palais du Grand Large*
	3:30- 9:00 pm	Excursion to the *Mont Saint-Michel*
Thursday, June 25	8:30 - 10:10 am	4 - SOLAR WIND THROUGH ITS INTERACTION PROCESSES WITH SOLAR SYSTEM OBJECTS & DUST
	Coffee break…	and Poster viewing (sessions 3 to 6)
	11:10 am - 12:20 pm	4 - SOLAR WIND THROUGH ITS INTERACTION PROCESSES WITH SOLAR SYSTEM OBJECTS & DUST
	Lunch	at the *Palais du Grand Large*
	2:00 - 4:00 pm	5 - ENERGETIC PARTICLES & FRONTIERS OF THE HELIOSPHERE
	Coffee break…	and Poster viewing (sessions 3 to 6) and poster removal
	5:00 - 6:10 pm	5 - ENERGETIC PARTICLES & FRONTIERS OF THE HELIOSPHERE
	7:30 pm	Cocktail at the *Palais du Grand Large*
	8:30 pm	Conference dinner at the *Palais du Grand Large*
Friday, June 26	8:30 - 10:10 am	5 - ENERGETIC PARTICLES & FRONTIERS OF THE HELIOSPHERE
	Coffee break	
	10:30 am - 12:50 pm	6 - OPEN SESSION (including SOLAR CYCLES STUDIES)
	1:00 pm	End of the Conference

Program & Contents

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Session 4: Solar Wind through its Interaction Processes with Solar System Objects and Dust

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Opening Talk

THE SOLAR WIND IN ASTROPHYSICAL CONTEXT

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Since its discovery nearly 50 years ago, the concept of the solar wind, and the subsequent studies of the underlying physics of coronal heating and expansion, have had a significant impact on a broad array of research in astrophysics. The notion of a steady "wind" outflow is now routinely applied to stars throughout the HR diagram, to stellar and galactic accretion disks, and even to whole galaxies or galaxy clusters. The wind driving mechanisms are likewise diverse, but can generally be divided between thermal, pressure-driven expansion analogous to the solar wind, and momentum-driven outflows, in which a direct force, e.g. due to radiative scattering, lifts the flow against gravity. To give a broader astrophysical context to the detailed discussion of the solar wind at this meeting, this talk will outline some key physical commonalities and differences among these various types of astrophysical outflows.

Session 1:
Coronal Heating and the Acceleration of the Fast Solar Wind

REVIEW OF HEATING RELEVANT CORONAL AND SOLAR WIND OBSERVATIONS AND THEORIES

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Remote spectroscopic observations of the solar corona and in situ particle measurements have led to a new understanding of how the fast solar wind is driven. An overview over the present knowledge of the fast solar wind, derived from observations and basic theoretical considerations will be given. The most recent observations from e.g. Hinode and other spacecraft will be included and compared with results derived from previous coronal and in situ observations. The talk will concentrate on the steady, fast solar wind flow originating from polar coronal holes.

UPWARD PROPAGATION OF ALFVéN WAVES LAUNCHED BY SMALL-SCALE MAGNETIC RECONNECTION IN THE CHROMOSPHERE

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The Alfvén wave is believed to play a crucial role in heating the solar corona and accelerating the solar wind. How it is excited is a long-standing puzzle in solar physics. Magnetic reconnection is supposed to be a possible cause for the wave excitation. However, such supposition needs to be confirmed by direct observation.

Here, we report the observation of Alfvén wave excitation due to small-scale magnetic reconnection, based on SOT measurements in the Ca II line. We find in two cases that Alfvén waves were excited intermittently by small-scale (<2") reconnection events. The transverse disturbances occurred in impulses rather than continuous oscillations, and the Alfvén waves propagated upward along the spicule with phase speeds ranging between 40 and 80 km/s in the height interval below 10 Mm.

The ultimate driver launching the Alfvén waves in these two cases is considered to be magnetic reconnection. There are some detailed differences in the excitation mechanisms for the two cases. In Case-I, the Alfvén wave seems to be initiated by a pressure impulse which impacts on the open field line as the mass was released from the heated closed loop. In Case-II, the Alfvén wave seems to be launched by a jump of the foot of the open field line due to interchange reconnection.

The wave-energy flux densities in these two cases are estimated. For Case-I in an active region, the Alfvén wave energy flux density is estimated to be able to heat most of the individual flux channel in the active corona. For Case-II in a coronal hole, the estimated wave energy flux density seems large enough to drive the solar wind in the individual flux channel in the coronal hole.

Our findings support the conjecture that Alfvén waves can be excited by small-scale magnetic reconnection in the solar chromosphere, provide solid evidence for a solar wind driven by Alfvén waves, and develop new perspectives for future solar wind models involving magnetic reconnection in the solar chromosphere.

MORE THAN MASS PROPORTIONAL HEATING OF HEAVY IONS BY COLLISIONLESS QUASI-PERPENDICULAR SHOCKS IN SOLAR CORONA

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The heating of the solar corona to temperatures of the order of 10^6 K and more is one of the fundamental problems of solar physics. Beside the high temperatures, Soho/UVCS observations have shown that heavy ions in polar corona, like O^{5+} and Mg^{9+}, are heated more than protons, and that heavy ion heating is more than mass proportional; further, the perpendicular temperatures are much larger than parallel temperatures. Shock waves are common in the corona. Here, we propose a new model which shows that the more than mass proportional heating of heavy ions in coronal holes is due to the ion reflection at supercritical quasi-perpendicular shocks and to the ion acceleration by the $\mathbf{V} \times \mathbf{B}$ electric field in the shock frame. We consider that small scale plasma jets are formed in the reconnection regions in the solar corona and chromosphere. Such jets give rise to fast mode shock waves when they interact with the ambient plasma. On the terrestrial bow shock, the quasi-perpendicular and the quasi-parallel portions of the supercritical shock are routinely observed by spacecraft. Ion reflection can be considered to be the main mechanism by which collisionless shocks convert the flow directed energy into heat, while the electrons are heated much less.

The acceleration due to motional electric field is perpendicular to the magnetic field, in agreement with Soho/UVCS observations, and is more than mass proportional with respect to protons, because the heavy ion orbit is mostly upstream of the quasi-perpendicular shock foot. A single shock encounter is sufficient to bring the chromospheric plasma to coronal temperatures. Studies of collisionless shocks in the solar wind can be very helpful, as in some cases α particles are observed to be specularly reflected at the Earth's bow shock. On the other hand, more studies are needed to understand the processes which actually lead to heavy ion reflection under variable solar corona conditions. This would give a prime contribution to the understanding of heavy ion heating in the solar corona.

SOLAR WIND ACCELERATION: MECHANISMS AND SCALING LAWS

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Dipartimento di Astronomia e Scienza dello Spazio, Università di Firenze

Over the past several years, a number of scaling laws concerning the asymptotic solar wind speed have been presented in the litterature (see e.g. Fisk, 2003, Schwadron and McComas 2003, Suzuki 2006), all derived by the basic conservation laws for mass, momentum and energy and taking into account one or more observational constraints coming from remote sensing observations of the corona and in-situ measurements of the wind. Here I will review theories of solar wind acceleration based on conservation principles, pointing out limitations and pitfalls in such arguments, and then discuss the most promising acceleration mechanisms, from Alfvén waves and turbulence to compressive modes, shock formation, magnetic and "interchange" reconnection.

References

Fisk, L.A., Acceleration of the solar wind as a result of the reconnection of open magnetic flux with coronal loops, JGR A 108, 1157, doi:10.1029/2002JA009284, 2003
Schwadron, N.A. and McComas, D.J., Solar Wind Scaling Law, ApJ 599, 1395-1403, 2003
Suzuki, T.K., Forecasting solar wind speeds, ApJ 640:L75-L78, 2006

QUASI-PERIODIC FLUCTUATIONS DETECTED IN MARS-EXPRESS CORONAL RADIO SOUNDING OBSERVATIONS

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Spectral analysis of the high-quality dual-frequency data obtained with the radio sounding experiment MaRS on Mars Express has revealed a quasi-periodic component (QPC) at heliocentric distances from 4 to 8 solar radii, which is most probably associated with MHD waves in the solar corona. The QPC typically appears as a broad maximum centered at temporal frequencies in the range 3 mHz $< \nu <$ 5 mHz and can sometimes be as much as four times stronger than the background power-law spectrum at the same frequency. Occurring sporadically, the QPC power level can increase rapidly within about 30 minutes, only to vanish again on the same time scale. Two distinct QPCs are evident in a few selected spectra, possibly a main wave and its second harmonic. It is conjectured that MHD waves with periods near 4 minutes ($\nu \approx 4$ mHz) are continuously present in the solar wind acceleration region and can be occasionally detected in radio sounding data under conditions with a favorable observational geometry.

PROPERTIES OF MAGNETIC RECONNECTION IN MHD TURBULENCE

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Magnetic reconnection in turbulence has been investigated [1] through simulations of compressible and incompressible, two-dimensional, Magnetohydrodynamics (MHD). Reconnection between magnetic islands, different in size and energy, occurs locally and sporadically in time. The associated reconnection rates are distributed over a wide range of values and scale with the geometry of the diffusion region. Matching classical turbulence analysis with the Sweet-Parker theory, the main statistical features of these multi-scale reconnection events are identified. Magnetic reconnection in turbulence can be described through an asymmetric Sweet-Parker model, in which the parameters that control the reconnection rates are determined by turbulence itself. This new and general perspective on reconnection is relevant in space and astrophysical systems, where plasma is generally in a fully nonlinear regime.

[1] S. Servidio et al, PRL, in press (2009).

DEMONSTRATIONS THAT THE SOLAR WIND IS NOT ACCELERATED BY WAVES OR TURBULENCE

D. Aaron Roberts
NASA Goddard Space Flight Center

The present work uses both observations and theoretical considerations to show that hydromagnetic waves, whether turbulent or not, cannot produce the acceleration of the fast solar wind and the related heating of the open solar corona. Waves do exist, and can play a role in the differential heating and acceleration of minor ions, but their amplitudes are not sufficient to power the wind, as demonstrated by extrapolation of magnetic spectra from Helios and Ulysses observations. Dissipation mechanisms invoked to circumvent this conclusion cannot be effective for a variety of reasons. In particular, turbulence does not play a strong role in the corona as shown by both observations of coronal striations and theoretical considerations of line-tying to a nonturbulent photosphere, nonlocality of interactions, and the nature of the kinetic dissipation. In the absence of wave heating and acceleration, we suggest that the chromosphere and transition region become the natural source of open coronal energization through the production of nonthermal particle distributions.

VELOCITY DISTRIBUTION FUNCTIONS OF THE SOLAR WIND PARTICLES

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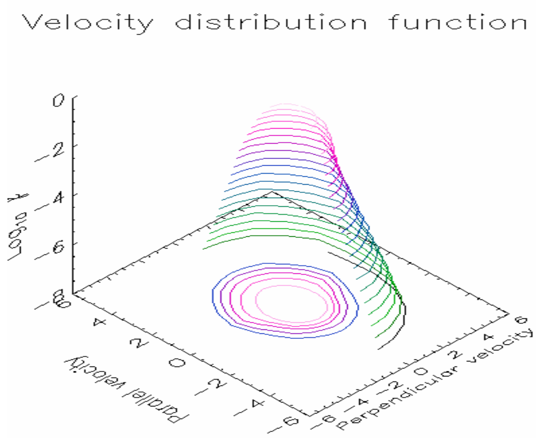
Recent kinetic models of the solar corona and of the solar wind will be presented with emphasis on the characteristics of the particle velocity distribution function (VDF). ULYSSES and WIND have observed that the VDF of the solar wind particles deviate significantly from Maxwellians. Using exospheric collisionless models based on the solution of Vlasov equation, we show that the presence of suprathermal electrons increases the electrostatic potential and then accelerates the solar wind to higher bulk velocities. The effects of the Coulomb collisions are also studied with kinetic solar wind models based on the solution of the Fokker-Planck equation. Such models show the transformation of the velocity distribution function of the particles in the transition region between the collision-dominated region in the corona and the collisionless region at larger radial distances. In the proton velocity distributions, extended anti-sunward tails and beams are often observed in the fast solar wind. We suggest that they can be created and maintained by kinetic Alfven waves (KAWs). KAWs carry a field-aligned potential well propagating with a near-Alfven velocity along the background magnetic field. We show that the protons trapped in the potential well can form observed proton beams and tails. The energy reservoir for these KAWs can be provided by large-scale MHD Alfven waves reducing their cross-field wavelengths via nonlinear interactions (turbulent cascades) or via phase-mixing in shear plasma flows. The velocity distribution functions of minor ions in the solar wind will also be presented. Due to their different masses and charges, heavy solar ions provide invaluable information on the physical mechanisms responsible for the heating of the corona and for the solar wind acceleration. In exospheric models, the heavy ions are accelerated to high bulk velocities at large radial distances if their coronal temperatures are more than proportional to their mass. Such heating can be obtained by the velocity filtration effect that accounts for the dispersion of ion velocity increasing with altitude in the corona. The kinetic filtration theory predicts ion coronal temperatures which are more than proportional to the mass of the ions, with a small correction for the charge state.



KINETIC AND HYDRODYNAMIC REPRESENTATIONS OF CORONAL EXPANSION AND THE SOLAR WIND

Eugene N. Parker
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The small number density of the interplanetary plasma suggests that the overall dynamics of the plasma may be approximated by the outward flight of freely moving ions and electrons evaporating from an exosphere at which the thermal velocity distributions are Maxwellian. The evaporating ions and electrons are constrained by a radial electric field to move together, preserving charge neutrality. The traditional treatment of this kinetic mass loss from the Sun provided only a tenuous subsonic outflow of plasma, which was hardly surprising because together the ions and electrons move adiabatically once they have evaporated from the exosphere. Some years ago Lemaire and Scherer re-examined the kinetic evaporation formulation and found that the traditional treatment employed an electric field some 20 – 40 percent too weak to force equality of the escaping ion and electron fluxes. Using the correct electric field their numerical computation of the individual particle trajectories provided a net supersonic wind, similar to the observed quiet day solar wind. The challenge, then, is to understand why the Lemaire – Scherer evaporation is so different from the traditional subsonic wind, keeping in mind that the electric field holds the ions and electrons together but gives no net lift. The question is readily answered by (a) taking advantage of the smallness of the electron-proton mass ratio m/M and (b) noting that the large-scale bulk motion of a collisionless gas conforms to the familiar hydrodynamic equations. It turns out that, in the limit of small m/M, the electrons form an isothermal atmosphere extending to infinity, from which the supersonic outflow follows directly from the hydrodynamic equations.

HALF A CENTURY OF KINETIC SOLAR WIND MODELS

Joseph F. Lemaire
Belgian Institute for Space Aeronomy, Brussels

I will show that kinetic descriptions of this coronal expansion are not giving meaningless results, as long believed within the MHD community due to a shortcoming of the exospheric "solar breeze model". Indeed, when a correct and self-consistent polarization electric potential distribution is used in exospheric models of the outer corona, (instead of the usual Pannekoek-Rosseland E-field generally assumed)a supersonic expansion velocity is readily obtained at 1 AU. The average of protons velocity or plasma bulk velocity predicted by the "reformed exospheric models" are in good agreement with the quiet solar wind observations. Even the plasma density and the omnidirectional (pitch angle averaged) temperatures of the electrons and protons are in remarkable agreement with the values measured at 1 AU. The remarkable results of these reformed coronal evaporation models are challenging those obtained with single and two-fluid hydrodynamic models for the solar wind expansion. The self-consistent electric potential distribution in Lemaire-Scherer's exospheric models of the corona is determined as the solution of the quasi-neutrlity condition with the additional constrain that the evaporation flux of the thermal electrons is precisely equal to that of the protons accelerated out of the corona by the electrostatic force. I will show that the radial component of Lemaire-Scherer's electrostatic field distribution is everywhere larger then the Pannekoek-Rosseland's electric field. This charge separation electric filed compares quite well with that deduced from electron density profiles obtained below 20 RS from eclipse observations.

Various improvements of exospheric models introduced to obtain bulk velocities larger than 700 km/s, observed in fast speed solar wind streams, will also be presented and discussed (e.g. non-maxwellian velocity distribution functions with supra-thermal tails; exobase levels at lower altitudes as expected in coronal holes, spiral magnetic field distributions, . . .). Improvements proposed to reduce the excessive anisotropies of the electron and proton temperatures which are predicted by exospheric (collisionless) models of the solar wind, will be described and discussed (e.g. spiral IMF; Fokker-Planck approach...).

The complementarities of hydrodynamic and kinetic models will be outlined.

Posters of session 1

ANALYSIS OF NON-STEADY RECONNECTION PROCESSES FROM THE LOW CORONA TO THE SOLAR WIND: MHD AND KINETIC SIMULATIONS

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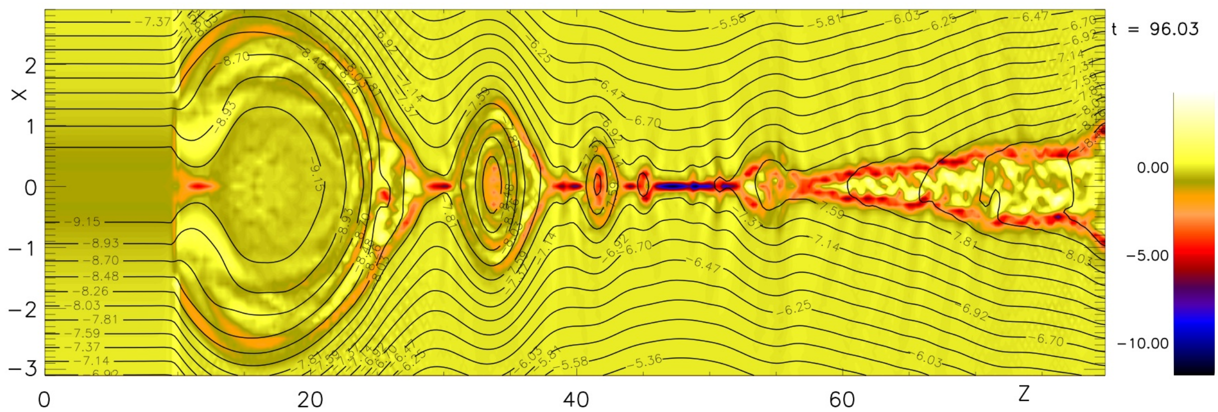
Within the solar environment, magnetic reconnection is often invoked to explain and/or model several phenomena ranging from the triggering of solar explosive events to less dramatic processes like solar wind dynamics and coronal heating. A strong interest is currently focused on three main aspects: the possibility of a natural transition between different reconnection regimes in magnetohydrodynamics, that is the onset of a spontaneous fast reconnection without invoking anomalous enhancements of plasma's local resistivity; the conditions for the development of a multiple small-scale reconnection process leading to a macroscopic turbulent state; the effect of magnetic reconnection on ions' distributions in a multi-species plasma. In compressible conditions, the presence of a density variation, and so the corresponding sensitive variation of the plasma beta, does influence the onset and the evolution of the reconnecting field lines, the resulting jet formation, its acceleration, and the final state the system is driven into. The understanding of a self-feeding slow-fast reconnection mechanism in the solar atmosphere as well as its macroscopic evolution is the first and fundamental step to produce realistic models of all those phenomena requiring fast (and high power) triggering events. On the one hand, this work presents a two-dimensional numerical analysis of such a picture: an initial force-free current-sheet located in a medium with a strong density variation, resembling the solar atmosphere from the high Chromosphere up to the low Corona, is properly perturbed. Its evolution is followed throughout a spontaneous two-staged reconnection process. A final macroscopic chaotic state is reached as shown in the attached figure representing the out-of-plane current density (in color) and the magnetic vector potential (solid black lines). The main features of a naturally-evolving slow-fast reconnection regime transition in MHD is analyzed. On the other hand, we present pic simulations' preliminary results of the effects of magnetic reconnection on a multi-species plasma and we focus in particular on helium/hydrogen distributions in the slow component of the solar wind.



PARALLEL AND PERPENDICULAR ENERGY CASCADES IN THE TURBULENT SOLAR CORONA AND SOLAR WIND

Benjamin D. G. Chandran
Department of Physics and Space Science Center, University of New Hampshire

Observations of perpendicular ion heating and energetic particle scattering suggest that a "parallel energy cascade" may be operating in the solar corona and solar wind, whereby wave-wave nonlinearities generate a population of small-scale fluctuations that vary more rapidly along the background-magnetic-field direction than in the directions perpendicular to the background magnetic field. This suggestion from observations is seemingly at odds with theoretical studies of incompressible MHD turbulence, which find that wave-wave nonlinearities generate small-scale structures that vary most rapidly perpendicular to the (local) background magnetic field. However, because the corona and solar wind are compressible plasmas, the energy cascades in the corona and solar wind differ significantly from the incompressible case. In this presentation, weak-turbulence theory is used to investigate interactions among Alfven waves and fast and slow magnetosonic waves in collisionless, compressible, low-beta plasmas. The wave kinetic equations are derived from the equations of magnetohydrodynamics, and extra terms are then added to model collisionless damping. These equations are then used to provide a quantitative description of a variety of nonlinear processes, including parallel and perpendicular energy cascade, energy transfer between wave types, phase mixing, and the generation of backscattered Alfven waves.

CORONAL LINE WIDTHS: ALFVEN WAVES, ION-CYCLOTRON WAVES, AND PREFERENTIAL HEATING

Laurent Dolla and Jacques Solomon
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Institut d'Astrophysique Spatiale (Orsay)

Alfvén waves and ion-cyclotron absorption of high-frequency waves are frequently brought into models devoted to coronal heating and fast solar-wind acceleration. Signatures of ion-cyclotron resonance have already been observed in situ in the solar wind (HELIOS spacecrafts) and in the upper corona (UVCS/SOHO remote-sensing results). We observed emission line profiles with SUMER/SOHO in the lower corona (below 1.5 solar radii) above a polar coronal hole, to infer ion temperatures and investigate the presence of any preferential heating. The value of the so-called "non-thermal" (or "unresolved") velocity, potentially related to the amplitude of Alfvén waves propagating in the corona, was constrained using the line width gradient and a density diagnostic. Taking into account the effect of instrumental stray light before analysing the line profiles, we rule out any direct evidence of damping of the Alfvén waves up to 1.25 solar radii. We then show that ions with the lowest charge-to-mass ratios are preferentially heated, thus providing observational constraints for models.

SOLAR WIND SPEED AND TEMPERATURE RELATIONSHIP

Heather A. Elliott (1), David J. McComas (1), and William H. Matthaeus (2)
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A few studies of solar wind proton temperature and solar wind speed have found a break in the curve at 450 km/s. Here we at the OMNI2 measurements from 1963 to 2009, and show that the only clear break in the temperature speed curve occurs in 2003 at 550 km/s coincident with a large polar coronal hole extension and another large low latitude hole. Instead of standard scatter plots, we create 2-dimensional bins in both temperature and speed and show the number of points in color. These color plots allow the true curve shape to be revealed since they clearly show where the majority of the points lie. We look at each year individually and find changes in the slope; however, most of the data is well represented by a simple linear fit.

THE ATMOSPHERIC IMAGING ASSEMBLY (AIA) OF THE SOLAR DYNAMICS OBSERVATORY (SDO)

Leon Golub(1), Ed DeLuca(1), Paola Testa(1), Mark Weber(1), Joan Schmelz(1,2), and Peter Beiersdorfer(3)
(1) Harvard-Smithsonian Center for Astrophysics
(2) University of Memphis
(3) Lawrence Livermore National Lab

The AIA is a set of telescopes that will image the solar atmosphere at wavelengths from the UV to the soft x-ray, providing full disk observations continuously in eight spectral channels. The coronal channels will record ionization stages of iron from Fe VIII through Fe XXIV, providing the most complete coverage of the hot corona ever obtained. In addition to the completeness of the spatial and spectral coverage, the AIA will also image two wavelength channels which have never before been seen: 94 Å and 131 Å. The 94 Å channel is centered on the Fe XVIII emission line, formed at log T≈6.9. This will show the locations and variability of hot plasma with very high sensitivity, where that plasma is present; it will also show the cooler corona at log T≈5.9 when there is little hot plasma present. Thus there will be a background quiet-corona image, with occasional dramatic appearances of hot plasma, either in nanoflares or in larger flare and CME events. The 131 Å channel will show similar behavior, with a transition region image in Fe VIII present at all times, and flare plasma showing brightly in a complex of high-excitation iron lines, when there is localized heating. We expect that these new channels, coupled with the coverage provided by the He II, Fe IX, Fe XII+XXIV, Fe XIV and Fe XVI channels, will provide unprecedented capability to study the full range of solar activity, from coronal holes and bright points, to polar jets, emerging flux, reconnection, flares and coronal mass ejections (CMEs) and the related waves, oscillations and dimmings. In particular, the 193 Å channel has been optimized to provide higher sensitivity to flare plasma than is usually seen in this channel, since we have found that the hot component is often readily determined from its spatial and temporal behavior. We expect that this will be a fruitful line of investigation with three different channels, covering a broad range of temperatures, exhibiting this behavior.

QUASILINEAR PROTON HEATING AND WAVE GENERATION DRIVEN BY AN UNBALANCED TURBULENT CASCADE

Philip A. Isenberg, Bernard J. Vasquez, Benjamin D. G. Chandran and Peera Pongkitiwanichakul
Department of Physics, University of New Hampshire, Durham NH 03824, USA

The resonant cyclotron interaction of coronal hole protons with anti-sunward propagating Alfvén-ion cyclotron waves primarily heats only the sunward portion of the proton velocity distribution. The resulting skewed distribution is unstable to the generation of sunward-propagating waves. This combined heating and wave generation control the evolution of coronal hole protons under the conditions assumed by most wave-driven or turbulence-driven models of solar wind generation. Additionally, we expect this quasilinear transfer of fluctuation energy from outward- to inward-propagating modes to have a strong influence on turbulent cascades in the “unbalanced” situation expected when the ultimate energy source is below the corona. We present self-consistent numerical solutions of the quasilinear equations describing the wave-particle interaction: proton diffusion in the wave fields and the back-reaction of wave growth or damping by the proton scattering. Our first investigations consider a spatially homogeneous system. Application of these results to turbulent evolution and to solar wind generation in the expanding coronal hole will be discussed.

IMPROVING THE MODEL OF THE FAST SOLAR WIND: THE CORONAL ORIGIN

Philippe Lamy (1), Serge Koutchmy (2) and Antoine Llebaria (1)
(1)Laboratoire d’Astronomie Spatiale, CNRS, Marseille (France)
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We use both C2 and C3-LASCO coronagraphic observations and well-calibrated eclipse observations performed during minima of solar activity to construct a mean radial profile of the electron density typical of the broad Polar Regions (i.e., outside the helio-sheet) where the wind is everywhere fast. When possible, our measurements are combined with those of Ulysses, solar wind densities and velocities, obtained over the same Polar Regions. We pay attention to a possible N-S asymmetry and evaluate where the acceleration through the sonic point is occurring. We also discuss the possible origin of the supplied additional energy from transverse waves observed in the low corona.

LARGE-SCALE ENERGY BALANCE AND MHD TURBULENCE IN SOLAR CORONAL STRUCTURES.

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The dynamics of fluctuations in a closed coronal structure is regulated by two phenomena: the resonance excited by motions at the loop basis, that stores energy within the loop, and nonlinear couplings, that move energy towards smaller scales. The energy balance is analytically evaluated taking into account longitudinal inhomogeneities of the structure. The spatial form of resonant eigenmodes and the corresponding eigenfrequencies are calculated. A scaling law is derived for the input energy flux, that turns out to be independent of nonlinear couplings and is mainly determined by slow (DC) fluctuations, though a contribution comes also from non-zero frequency (AC) motions. The nonlinear flux is due to interactions between eigenmodes at different perpendicular wavelengths, but with the same parallel profile. The energy balance allows for an estimation of velocity fluctuations that in agreement with measures of nonthermal velocity in the solar corona. The fluctuation spectrum is formed by an injection range at large scales, a pre-inertial range where magnetic energy dominates kinetic energy, an inertial range where the turbulence behaves as in an unbounded system, and a dissipative range. These results are confirmed by a numerical model (hybrid shell model) of the turbulence derived within the reduced MHD and based on a shell technique.

ION DISTRIBUTIONS IN CORONAL HOLES AND FAST SOLAR WIND

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We performed 1D hybrid simulations to investigate the non-linear kinetic behavior of the tenuous collisionless plasma in coronal holes and fast solar wind. Initially isotropic ion distributions are reshaped via wave-particle interactions with resonant daughter waves that are born by parametrically unstable large-amplitude Alfvén-cyclotron waves. Decay processes lead to the formation of both acoustic and electromagnetic micro-turbulence, which influences the motion of the ions via Landau damping and pitch-angle scattering. This causes anisotropies in the ion distributions, resulting in differential streaming and formation of ion beams. Due to their low mass densities and charge-to-mass ratios heavy ions are preferentially heated and more anisotropic than protons. We make a further study of the relation between ion anisotropies and relative drift speeds. The model results quantitatively agree with recent analysis based on in-situ solar wind observations, showing compelling evidence for a parallel heating in addition to cyclotron damping.

THE ACCELERATION OF THE FAST SOLAR WIND

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The acceleration of the fast solar wind in a non-homogeneous coronal hole is studied with 2.5D multi-fluid model that includes a spectrum of resolved Alfvén and fast magnetosonic waves. The heating by the resonant high end of the spectrum is considered with 2D hybrid model. The effect of polar plumes on acceleration by the spectrum of obliquely propagating waves is studies. The compositional variation of the fast solar wind is considered by including heavy ions as coupled fluids. It was found that the solar wind protons are accelerated to fast wind speed within $10R_s$ - in agreement with observations. The acceleration of He^{++}, and heavier ions requires the addition deposition of momentum and heat to match the high speed of these ions compared to protons observed at 1AU. The preferential heating of heavy ions by the resonant ion-cyclotron waves is studied with 2D hybrid model, and the results are incorporated empirically into the multi-fluid model.

CORONAL INFLOWS AND GIANT POLAR PLUMES

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We present two numerical models and the simulation of giant plumes and coronal flows. The first model is 1D and includes both the solar wind and the dense chromospheric layers. Plumes, inflows and outflows are generated by varying the flux-tube expansion rate (thus mimicking reconnection happening near coronal hole boundaries) and/or the mechanical heating flux parameters (*e.g* changing the altitude at which most heat is deposited).

The second one is a 2.5D axisymmetric model of an isothermal corona and slow solar wind. A plume is generated just above a small magnetic bipole embedded in an unipolar flux region which is perturbed by alfvén waves injected from the coronal base.

The boundary conditions are transparent in both cases.

THEORY OF INCOMPRESSIBLE MHD TURBULENCE WITH CROSS-HELICITY, ANISOTROPY, AND SCALE DEPENDENT ALIGNMENT

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Understanding the solar wind and the physical processes associated with solar wind fluctuations is important not only in space physics but also in astrophysics. Because the solar wind is the only astrophysical plasma accessible to in-situ spacecraft measurements, solar wind plasma and magnetic field data are our primary guide and testing ground for theories of turbulence in collisionless astrophysical plasmas. Such theories are important because they help codify our knowledge and understanding of solar wind turbulence and describe in a simple way how turbulent plasma physical processes work.

Recent phenomenological theories of incompressible MHD turbulence take the anisotropy of the fluctuations into account by assuming a balance between the nonlinear eddy turnover time and the Alfvén wave period. This is the concept of critical balance of Goldreich & Sridhar (1995, 1997) which is also implicit in the work of Higdon (1984). The theory of Goldreich & Sridhar (1995) predicts a perpendicular energy spectrum proportional to $k_\perp^{-5/3}$ and a scale dependent anisotropy of the form $k_\parallel \propto k_\perp^{2/3}$. High resolution direct numerical simulations of incompressible MHD turbulence in three dimensions have provided some preliminary support for this scaling.

These simulations also indicate that when the background magnetic field is strong the energy spectrum has a power-law exponent closer to 3/2 than 5/3. To explain this, a new theory was developed by Boldyrev (2005, 2006) who introduced the idea that velocity and magnetic field fluctuations are aligned with some small angle θ and that this alignment angle is scale dependent so that it decreases as the lengthscale of the fluctuations decrease throughout the inertial range. This alignment effect reduces the nonlinear interactions causing a perpendicular energy spectrum proportional to $k_\perp^{-3/2}$ and anisotropy of the form $k_\parallel \propto k_\perp^{1/2}$. Evidence for this alignment effect has been obtained by Boldyrev and his colleagues using 3D numerical simulations and by Podesta et al. (2008, 2009) using solar wind data from the *Wind* spacecraft.

Although the 5/3 scaling of the Goldreich & Sridhar theory and the 3/2 scaling of the Boldyrev theory are similar to the scalings in the well known theories of Kolmogorov in hydrodynamics and Kraichnan in MHD, it is important to emphasize that the Kolmogorov and Kraichnan theories assume isotropic wavevector spectra whereas the more recent theories of Goldreich & Sridhar and Boldyrev do not. This is important in plasma astrophysics where the turbulence is usually anisotropic due to the presence of large scale magnetic fields.

Although it is of interest to apply phenomenological theories such as those of Goldreich & Sridhar (1995) and/or Boldyrev (2006) to the study of solar wind turbulence, it is important to realize that these theories are valid only when the cross-helicity vanishes. In the solar wind the normalized cross-helicity is often non-zero and appropriate generalizations of these theories are needed. The theory of Goldreich & Sridhar (1995) has been generalized to turbulence with non-zero cross-helicity by Lithwick et al. (2007) and other theories of turbulence with cross-helicity have been developed by Beresnyak & Lazarian (2008) and Chandran (2008). Generalizations of Boldyrev's theory have been discussed by Perez & Boldyrev (2009) and also by Podesta & Bhattacharjee (2009). This talk will describe the interplay between theory, simulations, and solar wind observations that led to the development of the theory of Podesta & Bhattacharjee (2009).

Solar wind observations by Marsch & Tu (1990) and more recent observations from the *Wind* spacecraft often show that the normalized cross-helicity σ_c is approximately constant in the inertial range. This means the normalized cross-helicity has the special property that it is approximately *scale invariant*. Further support for this comes from 3D simulations of incompressible MHD turbulence by Perez & Boldyrev (2009). Solar wind data also shows that outward propagating Alfvénic fluctuations are observed to occur more frequently than inward propagating fluctuations. If p and q are the probabilities to observe outward and inward propagating fluctuations, respectively, then this is equivalent to the statement $p > q$. Using these observational facts together with Boldyrev's hypothesis of a scale dependent alignment of velocity and magnetic field fluctuations, a theory is constructed that reduces to the theory of Boldyrev (2006) when the cross-helicity vanishes $\sigma_c = 0$. The perpendicular energy spectra of the two Elsasser fields are both proportional to $k_\perp^{-3/2}$ and have a scale dependent anisotropy of the form $k_\| \propto k_\perp^{1/2}$. The theory generalizes the theory of Perez & Boldyrev (2009) in a significant way by taking into account the observational parameters p and q.

EVOLUTION OF ION CYCLOTRON WAVES IN THE SOLAR WIND FROM 0.3 TO 1 AU

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We have observed the strong ion cyclotron waves (ICWs) in the solar wind near 0.3, 0.7, and 1 AU, by using the high-resolution magnetometer data from Helios, Venus Express, and STEREO spacecraft. These waves are circularly-polarized transverse waves, propagating nearly parallel to the magnetic field, and below the local proton gyro-frequency in the solar wind frame. Because their maximum perturbation direction is almost perpendicular to the plane containing the magnetic field and the direction of propagation, these waves should be intrinsically all left-handed polarized waves. Since they often appear when the field and solar wind velocity is almost parallel, and their wave frequency in the spacecraft frame is larger than the local proton gyrofrequency, the possibility of local generation from pickup ions is eliminated. In our scenario, these ICWs are generated closer to the Sun and carried out by the super-Alfvénic solar wind. We analyze the wave properties of each event to obtain the statistics of the wave properties at each heliocentric distance. Since the ion cyclotron waves are damped when they approach the local proton and helium gyrofrequencies, the decrease of the wave frequency and wave power with radial distance helps us estimate their amplitude nearer the Sun and their potential contribution to the solar wind acceleration.

DEVELOPMENT OF SOLAR WIND MODEL DRIVEN BY EMPIRICAL HEAT FLUX AND PRESSURE TERMS

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We are developing a time stationary self-consistent 2D MHD model of the solar corona and solar wind as suggested by Sittler et al. (2003). Sittler & Guhathakurta (1999) developed a semi-empirical steady state model (SG model) of the solar wind in a multipole 3-streamer structure, with the model constrained by Skylab observations. Guhathakurta et al. (2006) presented a more recent version of their initial work. Sittler et al. (2003) modified the SG model by investigating time dependent MHD, ad hoc heating term with heat conduction and empirical heating solutions. Next step of development of 2D MHD models was performed by Sittler & Ofman (2006). They derived effective temperature and effective heat flux from the data-driven SG model and fit smooth analytical functions to be used in MHD calculations. These solutions used the energy equation and not a polytrope. Improvements of the Sittler & Ofman (2006) results now show a convergence of the 3-streamer topology into a single equatorial streamer at altitudes $>$ 2 RS. This is a new result and shows we are now able to reproduce observations of an equatorially confined streamer belt. In order to allow our solutions to be applied to more general applications, we extend that model by using magnetogram data and PFSS model as a boundary condition. We choose solar minimum magnetogram data since during solar maximum the boundary conditions are more complex and the coronal magnetic field may not be described correctly by PFSS model. As the first step we studied the simplest 2D MHD case with variable heat conduction, and with empirical heat input combined with empirical momentum addition for the fast solar wind. We use realistic magnetic field data based on NSO/GONG data, and plan to extend the study to 3D. This study represents the first attempt of fully self-consistent realistic model based on real data and including semi-empirical heat flux and semi-empirical effective pressure terms.

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SIGNATURE OF MASS SUPPLY TO QUIET CORONAL LOOPS

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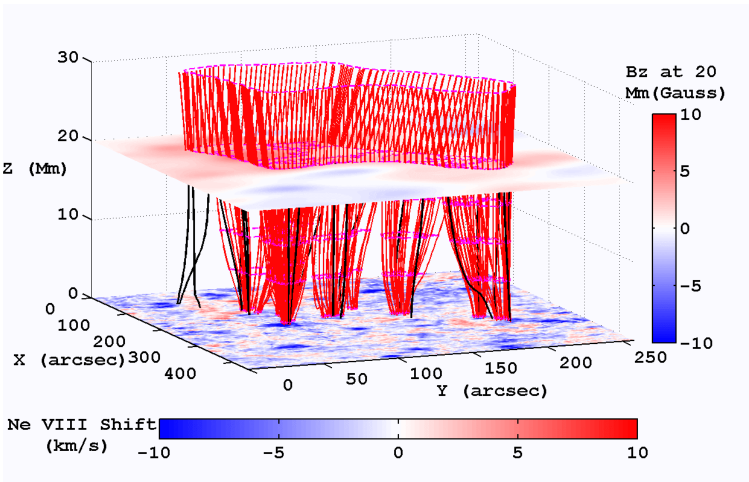
The physical implication of large blue shift of Ne VIII in the quiet Sun region is investigated. We compare the significant Ne VIII blue shifts, which are visible as large blue patches on the Doppler-shift map of a middlelatitude quiet-Sun region observed by SUMER, with the coronal magnetic-field structures as reconstructed from a simultaneous photospheric magnetogram by means of a force-free-field extrapolation. We show for the first time that coronal funnels also exist in the quiet Sun. The region studied contains several small funnels that originate from network lanes, expand with height and finally merge into a single wide open-field region. However, the large blue shifts of the Ne VIII line are not generally associated with funnels. A comparison between the projections of coronal loops onto the horizontal plane and the Ne VIII dopplergram indicates that there are some loops that reveal large Ne VIII blue shifts in both legs, and some loops with upflow in one and downflow in the other leg. Our results suggest that strong plasma outflow, which can be traced by large Ne VIII blue shift, is not necessarily associated with the solar wind originating in coronal funnels but appears to be a signature of mass supply to coronal loops. Under the assumption that the measured Doppler shift of the Ne VIII line represents the real outflow velocity of the neon ions being markers of the proton flow, we estimate the mass supply rate to coronal loops to be about $10^{34}\mathrm{s}^{-1}$.



A POSSIBLE SOURCE OF MASS SUPPLY TO SLOW SOLAR WIND: SPATIALLY INTERMITTENT EJECTION OF CORONAL FINE STRUCTURES

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The origin of the slow solar wind is a long standing question and being widely discussed. Recently, the possibility was suggested that active regions can lead to enhanced plasma outflow in the neighbouring small coronal holes (Habbal et al. 2008). However, neither has an observation on the mass supply to that outflow from the boundary between closed and open field regions nor a discussion of the related physical process been presented so far. It was reported, though, that continuous plasma outflow was observed from this kind of boundary region by XRT/Hinode. Here we present a joint data analysis to show that the spatially intermittent material ejection within a coronal fine structure could be the basic mode of mass supply to the outflow from this kind of solar regions. We used observations from TRACE in Fe 171Å, and from XRT, SOT and EIS on Hinode. We identified two kinds of coronal fine structures, which propagated outwardly for a few minutes along some long lasting pre-existing emission structures. The type-I structure is of relatively weak intensity and characterized by an average ejection velocity ranging from 70 km/s to 110 km/s, at the extension distance around 40 arcsec. The type-II structure is of strong intensity and characterized by an average ejection velocity ranging from 20 km/s to 40 km/s, at the extension distance of about 20 arcsec. These ejection events occurring on extended coronal fine structures may be understood as representing a mass-filling process, perhaps following small-scale magnetic reconnection. Apparently, it took place in the low corona or transition region, since the long-time pre-existing structures as seen in the Fe 171Å image did not change their topologies during these events. From such intermittent fine-structure-extension events, we can estimate the mass supply rate due to reconnection in the boundary region between an active region and a coronal hole. We also evaluate the importance of this mass-supply mechanism for the origin of the slow solar wind.

COUPLING PHOTOSPHERE AND CORONA : LINEAR AND TURBULENT REGIMES

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In a recent work Grappin, Aulanier & Pinto (2008) have shown that low-frequency movements can be transmitted from one footpoint to the other along a magnetic loop, thus mimicking a friction effect of the corona on the photosphere, and invalidating the line-tying approximation.

We consider here successively the effect of high frequencies and turbulent damping on the process. We use a very simple atmospheric model which allows to study analytically the laminar case, and to study the turbulent case both using simple phenomenological arguments and a more sophisticated turbulence model for Alfvén waves propagating along magnetic loops (Buchlini & Velli 2007).

We find that, except when turbulent damping is such that all turbulence is damped during loop traversal, coupling still occurs between distant footpoints, and moreover the coronal field induced by photospheric movements saturates at finite values to the finite transmission of the signal.

ON A SELF CONSISTENT TURBULENT HEATED SOLAR WIND

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We present results from a self consistent model of the fast solar wind, in one dimension, in which both heating and acceleration are provided by a phenomenological model of turbulent dissipation sustained by the reflection of Alfvén waves [1]. In seeking stationary solution of the coupled equations of wave propagation and dissipation, momentum and energy for the bulk flow, solved via an iterative procedure, we find that:
1) Despite turbulent dissipation accounts for almost all the heating necessary to sustain a fast wind, some more physics must be added to the model in order to obtain a stationary solution.
2) An independent ad-hoc heating, which we take in the form of a gaussian function centered inside the sonic point (mimicking the contribution of compressible fluctuations), stabilizes the system, yielding good solutions in which the less the contribution of the ad-hoc function, the better the wind and temperature profiles are reproduced.

In the present work we explore the effect of heat conduction (see also [2]) that can result in a convergence of the model, showing for the first time the temperature, density and velocity profiles of a purely turbulent heated solar wind.

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TURBULENCE IN THE SUB-ALFVÉNIC SOLAR WIND DRIVEN BY REFLECTION OF LOW-FREQUENCY ALFVÉN WAVES

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We study the formation and evolution of a turbulent spectrum of Alfvén waves driven by reflection off the solar wind density gradients, starting from the coronal base up to 17 solar radii, well beyond the Alfvénic critical point, and using a 2D shell model to describe nonlinear interactions. We find that the turbulent spectra are influenced by the nature of reflected waves. Close to the base, these give rise to a flatter and steeper spectrum for the outgoing and reflected waves respectively. At higher heliocentric distance both spectra evolve toward an asymptotic Kolmogorov spectrum. The turbulent dissipation is found to account for at least half of the heating required to sustain the background imposed solar wind and its shape is found to be determined by the reflection-determined turbulent heating below 1.5 solar radii.
Therefore reflection and reflection-driven turbulence are shown to play a key role in the acceleration of the fast solar wind and origin of the turbulent spectrum found at 0.3 AU in the heliosphere.

CORONAL RADIO SOUNDING EXPERIMENTS WITH MARS-EXPRESS: SCINTILLATION SPECTRA DURING LOW SOLAR ACTIVITY

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Coronal radio sounding experiments were carried out with the dual-frequency signals of the Mars Express spacecraft during the period from 25 August to 22 October 2004. Frequency and log-amplitude fluctuation observations were recorded during a period of low solar activity. The data are applicable to low heliographic latitudes, i.e. to slow solar wind. The RMS frequency fluctuation and power law index of the frequency fluctuation temporal spectra are determined as a function of heliocentric distance. The RMS frequency fluctuation can be described by a power-law function of the solar offset distance R given by $\sigma_f = A(R/R_s)^{-b}$, where R_s is the solar radius. The analysis yields A = 13.53 Hz, b = 1.77, for the ingress phase and A = 18.02 Hz, b = 1.92, for the egress phase. The average value of the power index for this period, $\langle b \rangle = 1.83$, and the RMS frequency fluctuation at 10 R_s, $\sigma_f(10R_s)$ =0.21 Hz (ingress) and 0.22 Hz (egress), are in good agreement with the results of a similar analysis obtained from Galileo coronal sounding experiments during low solar activity in 1994 and 1995. The radial dependence of the frequency fluctuation spectral index α reflects the previously documented flattening of the scintillation power spectra in the solar wind acceleration region. Values of $\alpha \approx$ 0.3–0.4 are observed over the range of solar offset distances 8 $R_s < R < 13R_s$. Temporal spectra of S-band and X-band normalized log-amplitude fluctuations were investigated over the range of fluctuation frequencies 0.01 Hz $< \nu <$ 0.5 Hz, where the spectral density is approximately constant. The radial variation of the spectral density can be represented by power-law functions of the form $G_0 = B_f(R/R_s)^{-b_f}$ for both sets of data. The coefficients of the least-squares power-law fit at S-band and X-band are determined to be $B_s = 1.41 \cdot 10^3$, $b_s = 4.0$, and $B_x = 6.92 \cdot 10^1$, $b_x = 4.0$, respectively. These values are consistent with those derived for the Ulysses solar conjunction of 1991 during high solar activity.

FIRST STEPS TOWARDS A TRANSPORT MODEL FOR SUB-ALFVÉNIC FLOWS IN THE CORONA

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Modeling the solar "wind" in the corona presents a different set of challenges than in parts further out in the heliosphere. Within the corona, the flows are sub-Alfvénic ($V_A \gg U$), with the gradients of the Alfvén speed leading to generation of inward and outward fluctuations. Further challenges come from the (likely) lack of a strong turbulent cascade and the high temperatures ($\sim$1 Million Kelvin) within the corona. The latter of which is sometimes handled through the use of ad-hoc heating functions.

We present work currently in progress to model sub-Alfvénic flows in the corona. We focus on the transport of fluctuation energies, their associated length scale, and temperatures. We derive the model for the flows using a procedure that has been successfully applied to modeling turbulence in the solar wind from 0.3 AU on out. We discuss each of the issues above and how they affect the model. The Alfvén speed profile is specified based on other simulations, the possible lack of a strong turbulent cascade leads to different models for the non-linear terms, and the temperature derives from the dissipation caused by the non-linear terms without resorting to an ad-hoc heating function. All these issues will be discussed and incorporated into the model. Overall, the model emphasizes relatively basic physics but provides promising beginning results.

SHOCK-DRIVEN TURBULENCE IN THE SOLAR CHROMOSPHERE

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We investigate the acoustic properties of the solar chromosphere in the high-frequency regime using time sequences of velocity measurements in the chromospheric Ca ii 854.2 nm line taken with the Interferometric Bidimensional Spectrometer (IBIS). Observations of quiet sun dynamics can be characterized in terms of the probability density functions (PDFs) of velocity increments. We confirm the presence of significant oscillatory fluctuation power above the cutoff frequency and find that it obeys a power-law distribution with frequency up to our 25 mHz Nyquist limit. The chromospheric PDFs are non-Gaussian and asymmetric, and they differ among the network, fibril, and internetwork regions. This suggests that the chromospheric high frequency power is not simply the result of short-period waves propagating upward from the photosphere but rather is the signature of turbulence generated within the chromosphere from shock oscillations near the cutoff frequency. The presence of this pervasive and broad spectrum of motions in the chromosphere is likely to have implications on the heating of chromosphere.

SEARCH FOR A SELF-CONSISTENT SOLAR WIND

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Our motivation is to adapt Suzuki and Inutsuka (2005) self-consistent polar wind model using a limited number of grid points, in order to further generalize the model to an axisymmetric wind. We discuss the necessary conditions for stability of the code. We report here the effect of radiative equilibrium terms, viscosity, ionization on pressure wave propagation and transition region oscillations. We also report preliminary results on an axisymmetric MHD 2.5 D version of the code.

ACCELERATION OF ENERGETIC PARTICLES THROUGH SELF-GENERATED WAVES IN A DECELERATING CORONAL SHOCK

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We have developed a simulation model of particle acceleration in coronal shock waves. The model is based on a Monte Carlo method, where particles are traced in prescribed large-scale electromagnetic fields utilizing the guiding center approximation. The particles are scattered in the turbulence according to quasilinear theory, with the scattering amplitude directly proportional to the intensity of Alfvén waves at gyro-resonant wavenumbers. The Alfvén waves are traced simultaneously with the particles, so that the wave field is propagated outwards from the Sun using WKB propagation supplemented with a phenomenological wavenumber diffusion term and a growth rate computed from the net flux of the accelerated particles. We consider initial wave amplitudes small enough to allow rapid escape of particles from the shock to the ambient medium. Thus, in our model the Alfvén waves responsible for the diffusive acceleration of particles are generated by the accelerated particles themselves. In this work, we study the effects of non-constant shock velocity and non-monotonic Alfvén velocity on particle acceleration scenarios. We report in particular how the deceleration of a shock affects particle intensity and turbulence power evolution in the vicinity of the shock.

AN ANISOTROPIC TURBULENT MODEL FOR SOLAR CORONAL HEATING

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We present a self-consistent model of solar coronal heating in which we include the dynamical effect of the background magnetic field along a coronal structure by using exact results from wave MHD turbulence. We evaluate the heating rate and the microturbulent velocity for comparison with observations in the quiet corona, active regions and also coronal holes. The coronal structures are assumed to be in a turbulent state maintained by the slow erratic motion of the magnetic footpoints. A description of the large-scale and the unresolved small-scale dynamics are given separately. From the latter, we compute exactly (or numerically for coronal holes) turbulent viscosites used in the former to self-consistently close the system and derive the heating flux expression. We show that the heating rate and the turbulent velocity compare favorably with coronal observations. Although the Alfvén wave turbulence regime is strongly anisotropic, and could reduce a priori the heating efficiency, it provides a unexpected satisfactory model of coronal heating for both magnetic loops and open magnetic field lines.

Bigot, Galtier and Politano H, A&A **490**, 325 (2008)

MODELING THE PREFERENTIAL ACCELERATION AND HEATING OF CORONAL HOLE O5+ AS MEASURED BY UVCS/SOHO

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We have recently presented a mechanism for preferential acceleration and heating of coronal hole minor ions [Isenberg and Vasquez, ApJ, in press]. The energization is due to the effect of multiple cyclotron resonances in the presence of sunward and anti-sunward dispersive ion cyclotron waves, providing a second-order Fermi interaction. The mechanism is preferential because coronal hole protons do not experience such multiple resonances. The detailed model results depend on many parameters, including poorly-known quantities such as the wave intensities, spectral shapes and radial profiles. For this reason, Isenberg and Vasquez explored the effects of a range of assumptions for the waves, to provide the broadest background for more specific models. In this paper, we show that reasonable choices for the poorly-known quantities can yield excellent agreement with the observations.

IS THE POLAR REGION DIFFERENT FROM THE QUIET REGON OF THE SUN?

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Solar Optical Telescope (SOT) aboard *Hinode* is the first large optical telescope flown in space to observe the Sun (Tsuneta et al., 2008a). It has an aperture of 50 cm and achieves an angular resolution of 0.25" (175 km on the Sun) covering a wavelength range from 380-650 nm. It is equipped with the Stokes spectro-polarimeter to allow accurate measurements of the magnetic field vector.

Tsuneta et al. (2008b) reported SOT observations of the magnetic landscape of the polar region of the Sun with an extremely high spatial resolution and high polarimetric precision. Many vertically oriented magnetic flux tubes with field strengths as strong as 1 kG were scattered in latitude between 70°and 90°. They all have the same polarity, consistent with the global polarity of the polar region. The field vectors have been observed to diverge from the centers of the flux elements, consistent with a view of magnetic fields that are expanding and fanning out with height (canopy-like structure). The polar region has also been found to have ubiquitous horizontal fields (Ishikawa, Tsuneta, 2009). The polar regions are the source of the fast solar wind, which is channeled along unipolar coronal magnetic fields whose photospheric source is evidently rooted in the strong-field, vertical patches of flux.

We observed the quiet Sun located on the extreme east limb to directly compare magnetic properties of the quiet Sun with those of the polar region. We notice that the properties of the kG patches in the quiet Sun are significantly different from those in the polar region: the size and number of the kG patches is much larger in the polar region than in the quiet Sun. The polarities of the magnetic patches are apparently of bipolar nature in the quiet Sun.

This is more clearly seen in the histogram of signed magnetic field strength (Probability Distribution Function, here after called PDF). The PDF for the quiet Sun is symmetric around zero, clearly showing balanced magnetic flux in both polarities, while the PDF for the polar region is highly asymmetric, showing dominance of single polarities (Ito, Tsuneta, Shiota, in preparation).

A high-resolution potential field extrapolation based on these *Hinode* data embedded in the MDI data is done (Shiota, Tsuneta, Ito, in preparation). The majority of magnetic fields lines from the kG patches in the polar region is open with canopy structure just above the photosphere, while in the quest Sun, majority of the field lines is closed. The bipolar nature of the quiet Sun and the uni-polar nature of the polar region (coronal hole) may explain some of the significant difference between the two regions. Numerous open field structure from kG-patches in the polar region may be related to acceleration of fast solar wind (Tsuneta et al., 2008b), plume structure, polar ject and micro-flares (Cirtain et al., 2008).

TURBULENT CASCADE OF FAST MAGNETOSONIC WAVES AND PERPENDICULAR PROTON HEATING IN THE SOLAR CORONA

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We present hybrid simulations of the turbulent cascade among fast waves in the vicinity of the proton inertial scale. The plasma beta is set to low values typical of the solar corona. The cascade proceeds radially in the wavenumber space with the highest rate in the direction across the mean magnetic field. The highly oblique fast waves can be efficiently dissipated on the protons by several mechanisms. The resulting proton heating is mostly perpendicular to the magnetic field. If the wave intensity is constrained by the observed density spectra in the corona, the heating is fast enough to generate the solar wind.

COMPARING MODELED EUV AND X-RAY EMISSION FROM THE GLOBAL CORONA WITH OBSERVATIONS

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Comparing emission in EUV and X-ray wavelengths from global coronal models provides a very sensitive constraint on coronal heating models. The ability of synthetic emission estimates to discriminate between different models increases considerably when observations are taken in many spectral lines. We will compare emission from our global 3D MHD model of the corona with EUV emission from EIT/SOHO and EUVI/SECCHI/STEREO, as well as soft X-rays from Yohkoh SXT and Hinode XRT. These constrains will help to improve our coronal heating model.

Research supported by NASA's Living With a Star Program, NASA's Heliospheric Theory Program, and NSF/CISM.

RESONANT INTERACTIONS BETWEEN PROTONS AND OBLIQUE ALFVEN/ION-CYCLOTRON WAVES

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University of New Hampshire

Resonant interactions between ions and Alfven/ion-cyclotron (A/IC) waves may play an important role in the heating and acceleration of the fast solar wind. Although such interactions have been studied extensively for "parallel" waves, whose wave vectors are aligned with the background magnetic field, much less is known about resonant cyclotron interactions between ions and oblique A/IC waves. This presentation describes some new analytical and numerical results on interactions between protons and oblique A/IC waves in collisionless low-beta plasmas such as the solar corona and inner solar wind. We find that if some mechanism generates oblique high-frequency A/IC waves, then these waves initially modify the proton distribution function in such a way that it becomes unstable to parallel waves. Parallel waves can then be amplified to the point that they dominate the wave energy at the large parallel wave numbers at which the waves resonate with the particles. If the parallel waves dominate at these large wave numbers, then wave pitch-angle scattering by these waves causes the plasma to evolve towards a state in which the proton distribution is constant along a particular set of nested surfaces ("kinetic shells") in velocity space, whose shapes have been calculated previously. As the distribution function approaches this state, the imaginary part of the frequency of parallel A/IC waves drops continuously towards zero, but oblique waves continue to undergo cyclotron damping (at a rate that we calculate analytically) while simultaneously causing protons to diffuse across these kinetic shells to higher energies. We conclude that oblique A/IC waves can be more effective at heating protons than parallel A/IC waves, because for oblique waves the plasma does not relax towards a state in which proton damping of oblique A/IC waves ceases.

TURBULENCE, ENERGY TRANSFERS AND RECONNECTION IN CORONAL HEATING FIELD LINE TANGLING MODELS

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In previous work, we studied the Parker field line tangling problem for coronal heating comprehensively via longtime high-resolution simulations of the dynamics of a coronal loop in cartesian geometry within the framework of reduced magnetohydrodynamics (RMHD). Although the efficient turbulent cascade prevents the magnetic field lines from becoming strongly entangled, current sheets are continuously formed and dissipated. Current sheets are the result of the nonlinear cascade that transfer energy from the scale of convective motions down to the dissipative scales, where it is finally converted to heat and/or particle acceleration. A picture is then realized, where both slightly entangled magnetic field lines and current sheets are present. Here we explore the system under different conditions, considering simpler forcing models, higher resolution simulations, and density stratification. We also investigate the spectral energy transfers between spatial scales that characterize the turbulence.

ALTERNATIVE GRAPHICAL DISPLAYS OF SOLAR WIND MODELS

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The distribution of the coronal and solar wind plasma density, bulk velocity, temperatures are commonly plotted versus r, the radial distance from the Sun, in units of the solar radius (RS).

1) Instead of r, the use of h, the altitude above the photosphere (units of km or RS) has some pragmatic advantages. Indeed, when plotted in a Logarithmic scale, this alternative variable (h) expands more advantageously the inner regions of the solar corona, where most of the heating and acceleration of the solar wind takes place. At large heliospheric distances, using h instead of r does not change significantly the slope/gradient of the density distribution nor of any other moment of the SW velocity distribution functions.

2) To facilitate inter-comparison of different hydrodynamic models of the solar wind, it is advantageous to utilize the plasma number density n (or of Log n, the Logarithm of the proton number density) as the independent variable, instead of r, (or instead of Log h). Indeed, plotting the bulk velocity,u, as a function of n or of Log n (from n = 0 to n = n0 : the number density at the base of the corona) is physically more indicative than plotting it versus the geometrical distances r or h. This procedure does not alter the standard topology of the subsonic, supersonic, and critical solutions (except for reversing the familiar trend of spatial variations which might be a ephemeral inconvenience for modelers and users). This more compact representation of SW distributions enables to easily recognize the usual classes of hydrodynamic solutions. From the slope of the curves giving Log (T) as a function of Log (n) in different SW models, the local value of the polytropic index can easily be inferred. To determine the position r or h corresponding to a given point in the (T, n) space, the inverse distribution of n = n(r) or of n = n(h) must be used. This new way of displaying SW models enables to overview synoptically how bulk velocity, as well as other moments of the VDF, are affected by increasing/decreasing the coronal temperatures, the polytropic index, the kappa index of non-maxwellian VDFs, the corona heating rates, etc. . . This more compact graphical representation of solar wind distributions facilitates also the inter-comparison between hydrodynamic models and kinetic models of the solar wind

Session 2:
Physical Processes in the Solar Wind
(Waves, Turbulence, Kinetics ...)

SOLAR WIND KINETICS AND VELOCITY DISTRIBUTIONS

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Observations of the solar wind from the inner corona to the outer heliosphere have shown that the plasma is rich with complex velocity distribution functions (VDFs) and electromagnetic fluctuations. Both ion and electron VDFs are observed to depart from simple Maxwellian distributions, with ion features including different temperatures, temperature anisotropies, and beams, and electrons possessing anisotropies, halos, and heat fluxes. These non-Maxwellian features are both an energy source for instabilities and signatures of solar wind heating and acceleration mechanisms. The microphysics of the solar wind is the non-linear coupling between particles and fields in a medium that at times acts as a fluid, a collisionless plasma, and a collection of individual particles. In this talk I will review recent work in both the experimental and theoretical study of the kinetic physics of wave coupling to non-Maxwellian ion and electron distribution functions. I will show how much progress has been made in topics such as heating, dissipation, and instabilities, what the major open questions are, and how upcoming missions such as Solar Orbiter and Solar Probe can address them.

ON THE ROLE OF WAVE-PARTICLE INTERACTIONS IN THE EVOLUTION OF SOLAR WIND ION DISTRIBUTION FUNCTIONS: OBSERVATIONS AND SIMULATIONS

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We investigate the role of kinetic effects in the solar wind expansion, using both simulations and in situ observations. The analysis with distance of proton distribution functions between 0.3 and 2.5 AU clearly shows a non-adiabatic evolution and suggests that several kinetic processes are at work during the solar wind expansion. From simulation studies wave-particle and wave-wave interactions, as plasma instabilities driven by temperature anisotropy, cyclotron heating and non-linear trapping due to parametric instabilities, are found to play an important role on constraining the proton temperature anisotropy and generating secondary velocity beams. We report results from hybrid comoving simulations that self-consistently retain and describe all these processes and we discuss our results comparing with direct solar wind observations from HELIOS and ULYSSES. We find that cyclotron interactions control the evolution of the proton temperature anisotropy with distance providing a perpendicular heating which contrasts the adiabatic cooling caused by the expansion. At the same time ion-acoustic modes driven by parametric effects produce a velocity beam in the proton distribution function. Finally at larger heliocentric distances the proton expansion results constrained by a fire hose instability, in agreement with observations at 1 AU and beyond.

GYROKINETIC TURBULENCE IN THE SOLAR WIND

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I will discuss (1) why gyrokinetic theory is useful and applicable for solar wind turbulence and what numerical results it produces (2) how energy cascade works in kinetic turbulence, where it is cascade in phase space (3) what that implies for dissipation range spectra, anisotropy and ion heating

SCATTERING OF SOLAR ENERGETIC ELECTRONS IN INTERPLANETARY SPACE

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Energetic electrons in the solar corona, that are produced by a flare, reveal their existence through the emission of X-ray and radio waves. But they can also be released into interplanetary space where they are directly observed by spacecraft, e.g. the STEREO satellites. Since electrons with higher energies move faster than those with lower energy, they reach a satellite at a solar distance of 1 AU earlier. This "velocity dispersion" yields information on the release time of the electrons in the solar corona, and on the distance traveled along the Parker spiral.

But many observations of energetic electrons in interplanetary space lead to release times that are between 10 and up to 30 minutes later as compared to the X-ray and radio emission of the corresponding flare. Both a delayed release at the Sun and scattering in interplanetary space are discussed as the underlying mechanism.

We present a kinetic model for the scattering of energetic electrons in interplanetary space through resonant interaction with whistler waves. The whistler wave spectrum is based on observed magnetic field fluctuation spectra in the solar wind. The model is based on a numerical solution of the Vlasov equation and includes Coulomb collisions and the inhomogeneous background of the solar corona and wind. It is applied on the propagation of solar-flare electrons that are injected into the corona and propagate into interplanetary space. The arrival times of the electrons at 1 AU is determined by the electron flux exceeding a given threshold value.

The resonant interaction of electrons with whistler waves is described within the framework of quasilinear theory. This leads to pitch-angle scattering of electrons in the reference frame of the waves. Since energetic electron speeds are much higher than whistler wave phase speeds in the solar wind, this is also mainly pitch-angle scattering in the plasma frame. Thus, a pure pitch-angle scattering model has been run along with one that considers the full diffusion equation.

The simulation results show a significant influence of the scattering on electron arrival times. Electrons with energies in the range of several tens of keV are delayed up to about one minute for a pure pitch-angle scattering model. It is demonstrated that this simplification is not applicable, and the full quasi-linear diffusion equation needs to be considered. This reduces the delays to values below 30 s. Thus, it follows from these numerical studies that scattering of electrons in interplanetary space cannot explain the observed delays of about 600 s, unless an unrealistic wave spectrum is assumed.

NONLINEAR DECAY OF ALFVéN-CYCLOTRON WAVES: PROTON AND ALPHA VELOCITY DISTRIBUTION FUNCTIONS

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The results of a systematic study of the nonlinear decay of circularly polarized Alfvén waves propagating along a background magnetic field in collisionless plasmas are presented. Kinetic theory and one-dimensional hybrid simulations are used to identify the instabilities and to follow the self-consistent reshaping of initially cold ion velocity distributions. The simultaneous generation of beam protons and the preferential heating and acceleration of alpha particles are shown to occur by the same mechanism: ion trapping and induced pitch-angle scattering by parametrically driven ion acoustic waves.

SOLAR WIND TURBULENCE: NEW QUESTIONS AND POSSIBLE SOLUTIONS

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The interplanetary medium provides a vast natural laboratory for studying many fundamental questions about astrophysical plasmas. In this talk I will make a short review on what we know about turbulent magnetic fluctuations which behave differently at low ($f < 1$ Hz) and high ($f > 1$ Hz) frequencies. The main question addressed is about the origin of a second inertial range at high frequencies characterized by steep power law spectra which cannot be associated with MHD turbulence. In that context I will present some recent results on Hall MHD turbulence; I will also discuss about the necessity to include anisotropy in the data analysis.

Bigot et al., Phys Rev E **78**, 066301 (2008)

Galtier, Phys Rev E **77**, 015302 (2008)

Galtier and Buchlin, ApJ **656**, 560 (2007)

Galtier, J. Plasma Physics **72**, 721 (2006)

NUMERICAL STUDIES OF KINETIC TURBULENCE IN THE SOLAR WIND

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A complete thermodynamic picture of the solar wind requires an understanding of the processes by which turbulent fluctuation energy is nonlinearly transferred from the large energy containing scales through an inertial range down to the small kinetic scales at which the turbulence is ultimately dissipated and its energy converted into heat. Although *in situ* satellite measurements of the solar wind turbulence at large scales have long been available, only current and planned satellite missions achieve the high data sampling rates necessary to measure fluctuations in the dissipation range of scales. Because the solar wind is a weakly collisional plasma, any attempt to study the dissipation mechanisms at these scales requires a kinetic treatment of the dynamics (fluid models of the solar wind, such as Hall MHD, are insufficient for this purpose). Numerical studies of kinetic turbulence in the solar wind dissipation range necessarily push the current limits of high-performance computing, yet such simulations will provide a critical framework for the interpretation of turbulence measurements from future satellite missions. We have recently reported [Howes *et al.* 2008, Phys. Rev. Lett. **100**, 065004] the first kinetic simulation of turbulence at the scale of the ion Larmor radius, showing that the spectra of anisotropic turbulence are qualitatively consistent with measurements in the solar wind. We will review recent progress in the understanding of kinetic turbulence using analytical models and high-performance kinetic simulations and outline key questions to be addressed in the study of the solar wind dissipation range.

Supported by the DOE Center for Multi-scale Plasma Dynamics, Fusion Science Center Cooperative Agreement ER54785.

SOLAR WIND TURBULENT SPECTRUM FROM MHD TO ELECTRON SCALES

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We study the solar wind turbulence in a very large range of scales, from MHD to electron scales, and for different plasma conditions. To measure the turbulent spectrum we use three Cluster instruments: FluxGate Magnetometer (FGM) at low frequencies ($f < 1$ Hz), Search Coil of the Spatio–Temporal Analysis of Field Fluctuations (STAFF-SC) at ion scales ($f > 0.5$ Hz) and Spectrum Analyser (STAFF-SA) at electron scales ($f > 8$ Hz). The highest frequency in our analysis is ~ 300 Hz. The total spectrum reveals a universal spectral shape independent on the plasma parameter β and the solar wind type, fast or slow. We analyze the importance of ion and electron scales for spectral shape features. Then, we discuss the role of the sound Mach number and compressibility in the solar wind turbulence as well as the topology of the turbulent fluctuations in the whole range of available scales.

USING CLUSTER II TO INVESTIGATE THE DISSIPATION/DISPERSION RANGE OF SOLAR WIND TURBULENCE

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In-situ observations of fluctuations in the solar wind typically show an 'inertial range' of MHD turbulence, and at higher frequencies, a cross-over to spatial temporal scales where kinetic effects become important. In-situ monitors such as WIND and ACE have provided observations over a decade of this dissipation/dispersion range which have motivated theoretical studies that in turn predict the nature of the scaling in this region.

We will present some results from very high-frequency magnetic and electric field data from the four Cluster II spacecraft in intervals where the spacecraft were in quasi-stationary ambient solar wind and where the instruments were operating in burst mode. The magnetic and electric field data are from the magnetometer, search coil and E-field probes from the Cluster FGM experiment ($\sim$67 Hz), and the STAFF and EFW experiments ($\sim$450 Hz). These data sets provide observations of this dissipation/dispersion range over approximately two orders of magnitude in scales, allowing a more precise determination of scaling exponents.

Theories centred around the dispersion of MHD waves and their associated damping and particle heating have been proposed to account for this scaling range. Since the spacecraft data shows a clean break from the scaling in the inertial range, followed by a different power-law spanning over approximately two decades, these theories centre around predictions of the spectral slope and the associated scaling exponents.

Motivated by the need to distinguish these theoretical predictions, we perform a robust statistical analysis focusing on power spectra, PDFs of field fluctuations and higher-order statistics to quantify the scaling of fluctuations; and use these results to infer the nature of the physical processes as we pass through the crossover from inertial range to near-dissipation range phenomenology; with special attention being made on quantification of sources of error from both instrument noise and finite sample size effects.

MHD MODELING OF THE SOLAR WIND WITH TURBULENCE TRANSPORT AND HEATING

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We have developed a magnetohydrodynamic model that describes the global axisymmetric steady-state structure of the solar wind near solar minimum with account for transport of small scale turbulence associated heating. The Reynolds-averaged mass, momentum, induction, and energy equations for the large-scale solar wind flow are solved simultaneously with the turbulence transport equations in the region from 0.3 to 100 AU. The large-scale equations include subgrid-scale terms due to turbulence and the turbulence (small-scale) equations describe the effects of transport and (phenomenologically) dissipation of the MHD turbulence based on a few statistical parameters (turbulence energy, normalized cross-helicity, and correlation scale). The coupled set of equations is integrated numerically for a source dipole field on the Sun by a time-relaxation method in the corotating frame of reference. We present results on the plasma, magnetic field, and turbulence distributions throughout the heliosphere and on the role of the turbulence in the large-scale structure and temperature distribution in the solar wind.

SHORT-WAVELENGTH SOLAR WIND TURBULENCE: THE ROLE OF WHISTLER FLUCTUATIONS

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The inertial range of solar wind turbulence corresponds to magnetic power spectra which scale as $f^{-\alpha}$ with $\alpha \simeq$ 5/3. Many observations show, however, that at observed frequencies $f \sim$ 0.2 Hz, there is a "breakpoint" such that power spectra at higher frequencies follow a steeper power-law dependence with $\alpha >$ 5/3. This short-wavelength regime at $f >$ 0.2 Hz is often called the "dissipation range", and the constitutent modes have been attributed to kinetic Alfvén modes which propagate at strongly oblique directions relative to the background magnetic field. But if kinetic Alfvén waves are present, they should indeed be dissipative, and should not contribute to a power-law spectrum.

Whistler fluctuations represent an alternative hypothesis to describe short-wavelength turbulence in the solar wind and, indeed, in any collisionless, magnetized, homogeneous plasma. If $\beta_p <$ 1, the right-hand polarized magnetosonic mode at quasi-parallel propagation is lightly damped; its cascade from the inertial range through the breakpoint is the driving source for the cascade of whistler turbulence. Recent particle-in-cell simulations have shown that the whistler cascade yields steep power-law power spectra consistent with observations [*Saito et al.*, 2008]. Our presentation will summarize the conclusions of the simulations, linear theory, and a simple turbulence model; using these predictions the whistler turbulence hypothesis can be tested via observations.

Saito, S., S. P. Gary, H. Li, and Y. Narita (2008), Whistler turbulence: Particle-in-cell simulations, *Phys. Plasmas*, *15*, 102305.

ON THE NATURE OF THE ELECTROMAGNETIC FLUCTUATIONS IN THE DISSIPATION/DISPERSION RANGE OF SOLAR WIND TURBULENCE

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Electromagnetic fluctuations in the inertial range of solar wind MHD turbulence and beyond (up to frequencies of 10Hz) have recently been studied for the first time using both magnetic field and electric field measurements on Cluster [*Bale et al.*, *PRL*, 2005]. It has been shown that at frequencies above the spectral breakpoint at 0.4Hz, in the so-called dissipation range, the wave modes become dispersive and are consistent with Kinetic Alfven Waves (KAW). This interpretation is based on the simple assumption that the measured frequency spectrum is actually a Doppler shifted wave number spectrum ($\omega \approx k\,V_{sw}$), commonly used in the solar wind and known as Taylor's hypothesis. While Taylor's hypothesis is valid in the inertial range of solar wind turbulence, it may break down in the dissipation range where temporal fluctuations can become important.

In this work, we analyze the effect of Doppler shift on KAW as well as compressional proton whistler waves, and revisit Cluster solar wind data using this approach. We focus our analysis on several low-beta ($\beta < 1$) ambient solar wind intervals. We first determine, both analytically and numerically, the dispersive properties of the KAW and the whistler wave modes and estimate the electric to magnetic field (E/B) ratio in the plasma and the spacecraft frame. Finally, we compare those estimates with the data directly in the spacecraft frame.

ELECTRON FIREHOSE INSTABILITY: LINEAR THEORY AND 2D PARTICLE-IN-CELL SIMULATIONS

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The kinetic Electron Firehose Instability (EFI) is thought to be a crucial mechanism for constraining the electron temperature anisotropy in the expanding solar wind, within the small observed values. The EFI arises in a bi-Maxwellian plasma when the parallel temperature is greater than the perpendicular one, it is naturally driven by the expansion process, and its effect is to reduce the anisotropy. We study this mechanism via kinetic linear theory and by new 2D Particle-in-Cell simulations. The results of PIC simulations show under which terms the EFI can indeed be regarded as a constraint for the electron distribution function. The detailed electron physics near marginal stability condition is analysed, with emphasis on the competition between growing and damping modes. The results indicate a possible observational signature of this process, namely the appearance of low-frequency, quasi-perpendicular whistler/electron cyclotron waves.

NEW OBSERVATIONS OF SPECTRAL ANISOTROPY AND POSSIBLE DAMPING OF KINETIC ALFVÉN WAVES IN THE DISSIPATION RANGE OF SOLAR WIND TURBULENCE

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A growing body of evidence suggests that solar wind turbulence, through the dissipation of a turbulent energy cascade, is responsible for heating solar wind protons as the solar wind flows outward from 0.3 to 1 AU and beyond. Measurements of the energy cascade rate in the last few years have shown that the observed cascade rate is in reasonable agreement with the required heating rate inferred from in-situ proton temperature measurements. Conversion of turbulent energy into plasma thermal energy occurs at kinetic scales near the proton gyro-radius and the proton inertial length where the turbulence is believed to make a transition from an Alfvén wave cascade to a kinetic Alfvén wave (KAW) cascade (Leamon et al. 1998, 1999, Bale et al. 2005). However, the physics of the energy dissipation process remains a mystery.

New insights into the nature of solar wind fluctuations in the dissipation range have recently been obtained using a novel wavelet analysis technique developed by Horbury et al. (2008). The technique allows the power spectrum of solar wind fluctuations to be measured along different directions relative to the local mean magnetic field using data from a single spacecraft. Podesta (2009) has applied this technique to study high-speed streams in the ecliptic plane using magnetic field data from NASA's two *Stereo* spacecraft. Stereo magnetometer data with a cadence of 8 vectors per second allows us to probe the first decade of the dissipation range, the range of frequencies just beyond the spectral break around 0.4 Hz in the spacecraft frame at 1 AU. This talk will discuss results of the first wavelet studies of the three-dimensional anisotropy of fluctuations in the dissipation range, results that are providing new information about kinetic dissipation process in *high-speed* solar wind.

Theory predicts a transition from an MHD-scale Alfvén wave cascade to a kinetic Alfvén wave (KAW) cascade near $k_\perp \rho_i \simeq 1$. For the high-speed streams analyzed in this study, this coincides with the spectral break which the data show occurs around $k_\perp \rho_i \simeq 1$. This is the start of the dissipation range. At slightly higher wavenumbers around $k_\perp \rho_i \simeq 2$ the ratio of the power spectra measured perpendicular and parallel to the local mean magnetic field exhibits a prominent peak with $P_\perp / P_\parallel \gg 1$. A similar peak is observed in all the intervals studied. This appears to indicate that the energy cascade in the KAW regime is directed perpendicular to $\mathbf{B}_0$, that is, the power resides mainly in wavevectors nearly perpendicular to $\mathbf{B}_0$. At slightly higher wavenumbers, around $k_\perp \rho_i \simeq 4$, the observed peak in the ratio $P_\perp / P_\parallel$ undergoes a rapid decay. The decay of the peak may be caused by the damping of KAWs. The hot plasma dispersion relation for an electron proton plasma at thermal equilibrium shows that the damping becomes strong, $\gamma T \simeq -1$ $(2\pi\gamma/\omega_r \simeq -1)$, near $k_\perp \rho_i \simeq 4$. This may be the dominant mechanism that converts the energy of solar wind fluctuations into particle thermal energy.

Wavelet techniques are providing new information and new clues about dissipation range processes that are just beginning to be explored. Future analysis of the variance anisotropy by decomposing the magnetic field into orthogonal vector components, analysis of low speed wind, and analysis of plasma velocity and density fluctuations will continue to shed further light on the details of this important plasma physical process.

MAGNETIC RECONNECTION IN THE SOLAR WIND: AN UPDATE

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Magnetic reconnection plays a central role in a wide variety of observed solar and space phenomena. In the solar wind magnetic reconnection commonly occurs in a quasi-stationary mode at extended X-lines. It produces Petschek-like exhausts of roughly Alfvenic jetting plasma bounded by back-to-back rotational discontinuities or slow mode waves that bifurcate a reconnecting current sheet. It occurs most frequently in low beta plasma and at thin current sheets associated with relatively small (less than 90 deg) magnetic field rotations. Reconnection exhausts are observed most frequently (40-80 events/month at 1 AU) in the low-speed wind and within interplanetary coronal mass ejections, and less frequently in the Alfvenic turbulence characteristic of the high-speed wind from coronal holes. Reconnection occurs relatively infrequently at the heliospheric current sheet (HCS), but observations of exhausts at the HCS are particularly revealing of the magnetic topology changes associated with the reconnection process. Reconnection in the solar wind is usually "fast", but not explosive - the magnetic energy release occurs over a long time interval following reconnection as the Alfvenic disturbances initiated by the process propagate into the surrounding solar wind plasma. Interestingly, there is as yet no hard evidence that would indicate that reconnection in the solar wind ever produces substantial particle acceleration. This paper provides a brief update/overview of magnetic reconnection in the solar wind as revealed by observations of reconnection exhausts.

PROGRESS IN THE STUDY OF INTERPLANETARY DISCONTINUITIES

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This talk reviews recent developments in the study of interplanetary discontinuities. Multi-spacecraft observations, especially by Cluster, have shown that the minimum variance method can usually not be relied on to determine the normal direction to a discontinuity surface. As a consequence the previous view that the majority of discontinuities are rotational discontinuities (RDs) with large components of the magnetic field across the surface is no longer tenable. Instead, most discontinuities have very small or no normal component of the field, consistent with tangential discontinuities (TDs), but have plasma properties (continuity of density, temperature, composition, and magnetic moment, together with parallel changes in the field and velocity vectors) expected of RDs. It has been suggested that these discontinuities are formed in interplanetary space by Alfvenic turbulence. A minority of interplanetary discontinuities are TDs with large rotations of the field and velocity vectors, which are thought to originate at the Sun. These include the interplanetary sector boundaries where the polarity of the magnetic field reverses. A controversial suggestion is that many of these large-angle discontinuities are the boundaries of solar flux tubes. Multi-spacecraft studies have also demonstrated that the radii of curvature of ripples on interplanetary discontinuities, including shocks, are of the order of the correlation length of the interplanetary field, and thus another effect of turbulence. It has also been shown that some of the closely spaced crossings of sector boundaries are caused by multiple crossings of a rippled boundary, whereas others are caused by single crossings of several independent boundaries.

STATISTICAL PROPERTIES OF SOLAR WIND DISCONTINUITIES AND INTERMITTENT TURBULENCE

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The statistical properties of the magnetic field have been studied comparing simulations of Magnetohydrodynamic (MHD) and Hall MHD turbulence with spacecraft data [1]. We combine analysis of intermittency with methods often employed to identify discontinuities in the solar wind. The hypothesis is that the statistics of intermittent events might be related to the statistics of classical MHD discontinuities. The comparison between ACE solar wind data and simulations of 2D and 3D MHD and Hall MHD turbulence shows a good agreement in the waiting-time analysis of magnetic field discontinuities, and in the related distribution of magnetic field increments. This result supports the idea that the magnetic structures in solar may emerge fast and locally from nonlinear dynamics that can be properly described in the framework of MHD theory. Moreover, probability distribution functions of increments in ACE data and in simulations reveal a robust structure consisting of small random currents, current cores, and intermittent current sheets. This classification provides a real-space picture of the nature of intermittency.

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Posters of session 2

KINETIC TEMPERATURES OF IRON IONS IN THE SOLAR WIND OBSERVED WITH STEREO/PLASTIC

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STEREO/PLASTIC provides detailed information on the three-dimensional velocity distributions of solar wind iron ions with a time resolution of 5 minutes. In general the distributions at 1 AU contain complicated structures showing persistence over several records, i.e. over time intervals of up to 30 minutes, but no clear correlation of the shapes of these distributions with the direction of the ambient magnetic field is evident. We have carried out a statistical analysis using approximately 5000 observations, as has been performed similarly for protons, helium ions and electrons in the solar wind. Iron ions follow the same trends as the other species: The ratio $T_{perpendicular}/T_{parallel}$ seems to be limited by the ion cyclotron instability, whereas $T_{parallel}/T_{perpendicular}$ is bounded by the streaming instability.

STEREO OBSERVATIONS OF LARGE AMPLITUDE, LOW FREQUENCY WAVES AND THEIR ASSOCIATION WITH COROTATING INTERACTION REGIONS

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We describe results of a survey of large amplitude, low frequency waves observed by the STEREO WAVES TDS instrument and the association with solar wind structures. The S/WAVES TDS is a new tool for understanding wave/particle interactions, providing 3d electric field waveforms, triggered on large amplitudes. This study focuses on waves in the intermediate range (between ∼10 Hz and several kHz, from above the ion cyclotron frequency to the electron cyclotron frequency and the ion plasma frequency. Theoretical and observational studies suggest that this frequency range is critical to understanding the evolution of the solar wind, specifically the pitch angle width of strahl, regulation of heat flux, and the halo and super-halo components. Initial observations have revealed waves in the 10s of Hz range (the band usually attributed to whistlers that could regulate heat flux and broaden strahl) that are 1 to 2 orders of magnitude larger than previously reported. This talk will focus on the class of waves in this frequency band that are very coherent. The waves often are right-hand polarized consistent with the whistler mode. Some are obliquely propagating and have both large longitudinal components and components parallel to the solar wind magnetic field (consistent with warm linear dispersion calculations for the observed parameters). Many of the large amplitude waves at frequencies <100 Hz were observed at co-rotating interaction regions (CIRs). Particle tracing code results indicate that, in a fraction of a second, the waves can scatter electrons by 10s of degrees and/or energize or de-energize electrons by ∼10-50%. The results suggest that coherent processes, such as trapping, rather than quasi-linear processes, may sometimes dominate scattering and energization by waves.

UNIVERSALITY IN THE GENERALIZED SIMILARITY OF EVOLVING SOLAR WIND TURBULENCE AS SEEN BY ULYSSES.

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We perform statistical analyses of the fluctuating magnetic field observed in- situ by the ULYSSES spacecraft, from the perspective of quantitative characterization of the evolving magnetohydrodynamic (MHD) turbulence. We focus on two successive polar passes around solar minimum which provide extended intervals of quiet, fast solar wind at a range of radial distances and latitudes: the south polar pass of 1994 and the north polar pass of 1995. Fully developed inertial range turbulence has a characteristic statistical similarity property of quantities that characterize the flow, such as the magnetic field components $B_k(t)$, so that the pth moment of fluctuations $\delta B_k(t,\tau) = (B_k(t+\tau) - B_k(t))$ have power law dependence on scale τ such that $<\mid \delta B_k(t,\tau) \mid^p>\sim \tau^{\zeta(p)}$ We instead find a generalized similarity $<\mid \delta B_k(t,\tau) \mid^p>\sim g(\tau/\tau_0)^{\zeta(p)}$ consistent with Extended Self Similarity; and in particular all of these ULYSSES observations, from both polar passes, share the same single function $g(\tau/\tau_0)$. If these observations are indeed characteristic of MHD turbulence evolving in- situ, then this quantifies for the first time a key aspect of the *universal* nature of evolving MHD turbulence in a system of finite size, with implications both for theoretical development, and for our understanding of the evolving solar wind. The timescales over which we have studied $g(\tau/\tau_0)$ are at approximately an order of magnitude longer than that of the dissipation scale of the turbulence, but include the outer scale where there is a crossover to $\sim 1/f$ fluctuations of coronal origin. The function $g(\tau/\tau_0)$ which we discuss here therefore gives information on the essential dynamics of the largest scales of the MHD turbulence, for example, their anisotropy, and interaction with the macroscopic heliospheric fields and flows.

This work to appear in Astrophysical Journal Letters, (2009).

SPATIO-TEMPORAL ANALYSIS OF MAGNETIC HELICITY IN THE SOLAR WIND

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The turbulent behaviour of the solar wind fluctuations can be described on statistical basis using the invariants for the ideal equations of motion. These are the total energy E, the cross-helicity H_C and the magnetic helicity H_m. The present study focuses mainly on magnetic helicity, which is a measure of the lack of mirror symmetry in the magnetic field fluctuations. In particular, a positive/negative Hm would indicate a left/right - hand sense of polarization.

Previous studies already showed that Fourier analysis of magnetic helicity does not provide enough information about the local topology of magnetic field lines. On the contrary, a remarkable help comes from the wavelet decomposition which shows interesting features of the magnetic field fluctuations probably related to the filamentary structure of turbulence. In particular, large scale helicity structures identified by this method seem to persist during the wind expansion. These filamentary structures might be responsible for SEP dropouts, as suggested in literature, and this kind of analysis might help to prove it.

THE PITCH-ANGLE DISTRIBUTION WIDTH BETWEEN 100 eV TO 100 keV DURING THE SOLAR ELECTRON BURST OF 2002 MARCH 22

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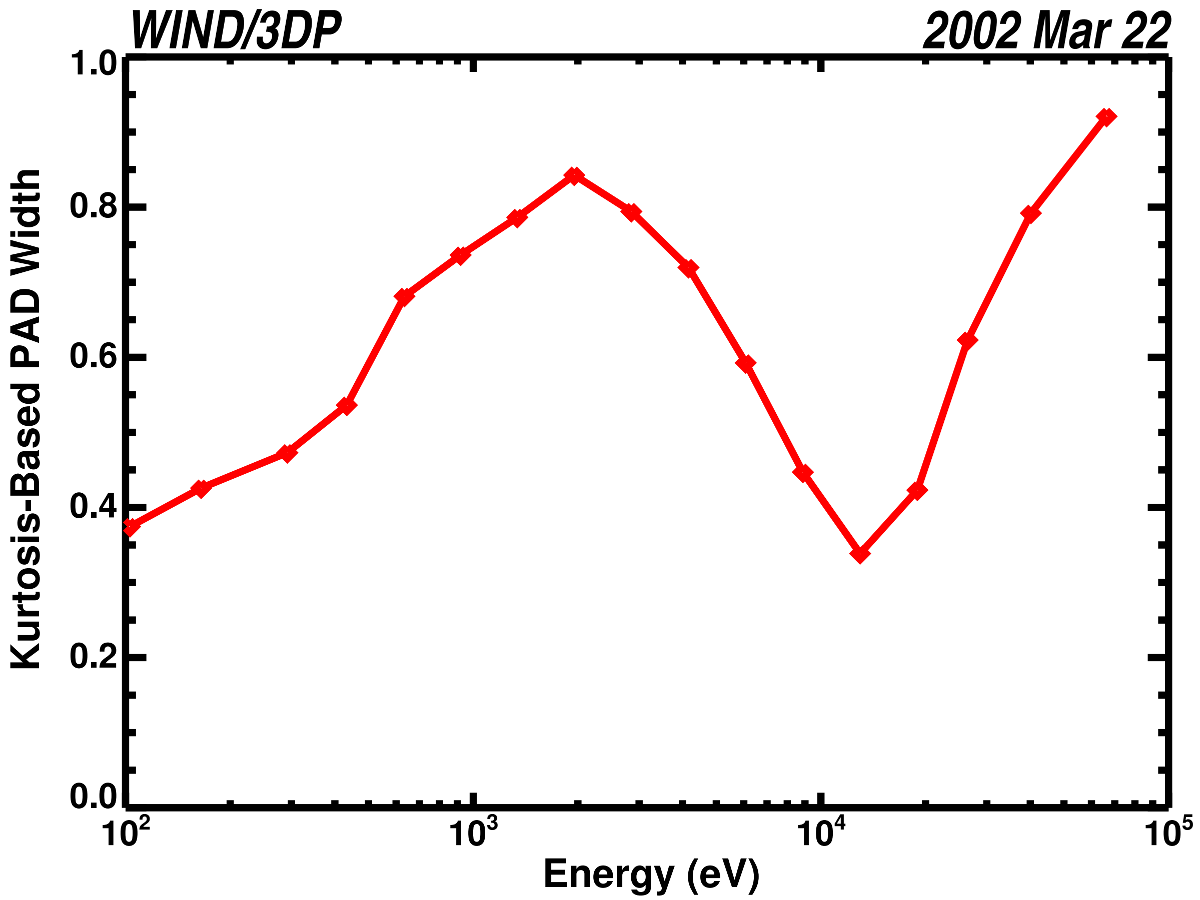
A compilation of various spacecraft measurements made over the last 30 years suggests that the pitch-angle distribution width of a solar electron burst may have a complex, non-monotonic energy signature. To date, only a few studies have considered the pitch-angle distribution width over a broad energy range during a single solar electron burst. Here we use WIND/3DP data to examine the energy dependence of the pitch-angle distribution width between 100 eV to 100 keV during the solar electron burst of 2002 March 22. We find that the pitch-angle distribution width during this event, shown in the attached figure, increased with energy from 0.1–2 keV, followed by a subsequent decrease in width from 2-10 keV, followed by another increase in width above 10 keV. In other words, the distribution width had a local maximum at $\sim$ 2 keV and a local minimum at $\sim$ 10 keV. These results imply that the details and effectiveness of the wave-particle scattering mechanism vary with energy. In particular, $>$ 20 keV electrons will cyclotron-resonate with large amplitude fluctuations, such as Alfvén waves in the turbulent inertial range, which will strongly scatter the burst electrons. Furthermore, the local maximum at $\sim$ 2 keV is a characteristic signature of the electrostatic electron/electron instability [Gary and Saito, GRL 34, 2007; Saito and Gary, JGR 113, 2008].



KINETIC SIMULATION OF TYPE II RADIO BURSTS IN CME

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The emission of solar radio bursts is closely related to coronal mass ejections. While the phenomenology of the bursts is rather well studied, the detailed mechanism of the emission is not yet fully understood [1]. Our approach to understand radio bursts - here the type II radio bursts - differs from previous approaches: Rather than trying to find the correct evolution of the CME using methods of fluid dynamics [2, 3] or combined fluid/kinetic methods, we are using a fully kinetic approach to model the movement of electrons and protons in a shock environment, therefore neglecting the large scale evolution of the shock, while correctly modelling the kinetic microphysics. The kinetic simulation itself is based on fully-relativistic Particle-in-Cell methods [4].

This technique allows for observation of plasma wave excitation in the shock region and gives a deep insight into the mechanisms of emission and transformation of different wave modes. We were using Fourier- and Laplace-transform based analysis to identify wave modes and electromagnetic emission, especially focused on their evolution in time.

In the setup of the simulation we were using a predefined shock environment in a computational box with periodic boundaries perpendicular to the shock direction and inflow boundaries along the shock direction. Our simulations were able to reproduce the phenomenological features of type II radio bursts and also additional information about fundamental processes taking place, with a focus on production of waves through three-wave interaction [5]. We will present results of these simulations and compare them to previous models of radio burst modeling.

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A ONE-SIDED ASPECT OF ALFVENIC FLUCTUATIONS IN THE SOLAR WIND

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Using ACE 64-s data at 1 AU we find that Alfvénic fluctuations propagating outward from the Sun along the magnetic field, **B**, in the solar wind often produce one-sided variations in one of the equatorial components of **B** and velocity, **V**. This is a natural consequence of the fact that the Alfvénic fluctuations are transverse fluctuations in which the magnitude of **B** remains nearly constant. Thus, fluctuations in the field component that defines the underlying background field direction are always relative to a base value rather than to an average value. This suggests that conclusions derived from statistical analyses of fluctuations in the solar wind that assume the fluctuations in all field components are relative to average values need to be re-examined. We also find that discrete, sunward-propagating Alfvénic fluctuations or rotational discontinuities are extremely rare in the pristine solar wind; thus far we have identified such discrete events in ACE data only in association with events identified as magnetic reconnection exhausts and/or in association with backstreaming ions from reverse shocks, including Earth's bow shock.

HARMONICS OF LANGMUIR WAVES IN THE SOLAR WIND

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Some care was taken with the design of the experiment SWaves on Stereo to ensure that the responses in the Langmuir wave frequency range were strictly linear. Hence accurate measurements of harmonics have become available. The amplitude of the harmonics relative to the fundamental is quite small, of the order of 1% maximum. This ratio varies widely, showing that it cannot be due to nonlinearities either in the circuit or in the antenna sheath, as these effects would be expected to produce amplitudes which are definite functions of the fundamental amplitude. Trapping of electrons in the Langmuir wave potentials seems to be what is happening. As there is no reason to expect that a propagating Langmuir wave would trap electrons, it appears that they are probably trapped as the Langmuir wave grows. The harmonics may give some indication of the age of the Langmuir wave therefore.

A NEW INTERMITTENT MODEL OF SPIN-DOWN

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One of the outstanding problem in solar physics is to understand the evolution of magnetic fields and rotation which play an indispensable role in the Sun and other stars. The evolution of these two is in fact inseparable since they are closely linked through spin down and dynamo processes. Specifically, magnetic fields accelerate the spin-down of stars via magnetized wind while global and differential rotation play an essential role in the generation of stellar magnetic fields (the so–called dynamo action).

In this contribution, we investigate a crucial effect of intermittency in solar (stellar) winds in rotational evolution. This is a particularly important problem since there has been accumulating evidence for intermittency in solar winds, varying over a broad range of time scales. Specifically, we show that that the intermittency in solar winds plays a key role in reproducing observational data on the distribution of rotational speed as a function of ages and spectral types of stars. Furthermore, this effect is shown to be similar to dynamo saturation mechanism, which has been a popular mechanism for explaining rotational history.

DUAL ROLE OF SHEAR FLOW IN TURBULENT TRANSPORT OF MAGNETIC FIELDS

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Fundamental processes governing the dynamics of coherent structures and their interplay with turbulence in magnetized fluids present some of the most outstanding problems in classical physics. In particular, various observations indicate that typical magnetic activities (e.g. solar magnetic cycles, solar flares, corona mass ejection) in astrophysical plasmas must involve the fast transport of magnetic fields on time scales much shorter than the Ohmic diffusion time scale. Turbulent transport of magnetic fields (turbulent reconnection) is one of the important mechanisms that are often invoked to explain this fast transport.

In this contribution, we report on the first comprehensive direct numerical simulations of 2D sheared MHD turbulence to elucidate fundamental physical processes which accelerate or moderate turbulent transport of magnetic fields [1]. This is achieved by an extensive exploration of the parameter space [1], which previous analytical works (e.g. [2]) have been unable to investigate. In particular, we show (i) that transport quenching by shear flows and resonant interactions are vitally important to understanding turbulence regulation in 2D MHD; (ii) that a shear flow plays a dual role of quenching transport by shearing and enhancing it by resonance and the overlap of resonant layers; (iii) that a strong suppression of transport by shear flow (magnetic fields) occurs when the shearing (Alfvénic) timescale is shortest among all the characteristic timescales in the system (with no resonance between coherent structures and turbulence/waves). Specifically, without resonance, turbulent magnetic diffusivity η_T is quenched as $\eta_T \propto B_0^{-4}$ for weak shear (Ω) and strong magnetic field (B_0) while $\eta_T \propto \Omega^{-2.7}$ for strong shear and weak magnetic fields. In comparison, η_T is less severely quenched with resonance with the scaling $\eta_T \propto B_0^{-2} \propto \Omega^{-2}$ for strong shear and magnetic fields. Important implications of these results for turbulent reconnection will be discussed.

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ON THE EFFECT OF PRE-EVENT BACKGROUND IN DETERMINING SOLAR PARTICLE EVENT ONSET

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The onset of a Solar Energetic Particle (SEP) event has been traditionally determined by using the velocity dispersion analysis (VDA), where the event onset at the Sun is determined by fitting the solar onset time and the particles' path length to match the observed event onset at 1 AU for several SEP energy channels. Recently, this approach has been studied by using energetic particle simulations, in order to understand the effect of the interplanetary scattering on the arrival time of the first particles to 1 AU. These studies have shown that scattering can explain the $\sim$2 AU path lengths obtained in some events when using the VDA method.

The simulation studies have so far defined the SEP event onset at 1 AU as the time when the intensities reach certain percentage of the maximum of the event. In many cases, when doing the onset analysis on real observations, this can not be done, as the event may be complex in its structure, and the pre-event background may mask the SEP onset to differing degrees in different energies. In order to estimate the usability of the VDA method, the simulation studies must thus be evaluated using the more realistic cases with varying pre-event background intensity.

In this work, we report the results of a parameter study of simulated SEP onset on a pre-existing particle background. The observed onset is defined as the time when the simulated event intensities exceed the pre-event background by a fixed percentage. We study the effect of the background on the particles' path length and the solar onset time, as obtained by the VDA method, by varying the pre-event background level, the difference of the pre-event background and the simulated event maximum spectral indices, the interplanetary mean free path and the injection profile. We find that the large path length variation can be explained as an artefact resulting from the use of the VDA method, as in the previous studies. More importantly, we find that the error in the obtained solar onset time depends strongly on the properties of the pre-event background. We discuss the implications of this study to the studies that require SEP event onset time determination.

QUASI-THERMAL NOISE IN SPACE PLASMA: "KAPPA" DISTRIBUTIONS

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The transport of the energy in space plasma, especially in the solar wind,is far from being understood. Measuring the temperature of the electrons and their non thermal properties must give important clues to understand the transport properties. Quasi-thermal noise spectroscopy is a reliable tool for measuring accurately the electron temperature since it is less sensitive to the spacecraft perturbations than particle detectors.

We model the Quasi-Thermal Noise (QTN) with a generalized Lorentzian ("Kappa") distribution function defined by three parameters : the electron density, temperature and kappa index. For collisionless and drifting plasma (like the solar wind), this noise is produced by the quasi-thermal fluctuations of the electrons and by the Doppler-shifted thermal fluctuations of the ions. A sum of two Maxwellian functions (one for the core and one for the supra-thermal halo) has previously been used for modelling the QTN of the electrons, but the observations have shown that the supra-thermal electrons are better fitted by "Kappa" distribution function. Pioneer work of Chateau and Meyer-Vernet (1991) only considered integer values of κ. We extend these calculations to real values of κ and give the analytic expressions and numerical calculations of the QTN with "kappa" distribution function. We also show some generic properties of the QTN.

We apply this method to Ulysses/URAP data, as this probe flew by pole-to-pole during more than a solar activity cycle. We compare these new results to those obtained from the same data set but assuming a classical core + halo distribution. These results will allow us to discuss the variations with heliocentric distance and latitude of the 3-fitted parameters : the electron density, temperature and kappa index of the distribution. Especially, the total temperature variation with distance during the solar minimum at high latitudes will be compare with the temperature profile predicted by a kinetic collisionless model of the solar wind.

KINETIC SIGNATURES OF TURBULENCE DISSIPATION IN SOLAR WIND PROTON VELOCITY DISTRIBUTIONS

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Beams, diffusion plateaus and temperature anisotropies usually occur in the proton velocity distributions of the solar wind. They are interpreted as direct evidence for ongoing wave-particle interactions, which are either nonresonant fluid-like or of kinetic nature, and thus involve cyclotron and Landau resonance with plasma waves. We discuss the salient kinetic features of the protons and observed spectral properties of the waves, and argue that ion kinetic instabilities and proton diffusion play a key role in the dissipation of the magnetohydrodynamic turbulence prevailing in the solar wind.

THE THIRD-ORDER LAW FOR MAGNETOHYDRODYNAMIC TURBULENCE WITH CONSTANT SHEAR

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The scaling laws of mixed third-order structure functions for isotropic, homogeneous and incompressible magnetohydrodynamic (MHD) turbulence have been derived [1] and recently used in solar wind [2, 3] analysis. Here we extend the theory by deriving the third-order laws for MHD turbulence with constant shear, where homogeneity is still assumed. A generalized similarity law is obtained. This scaling law has been confirmed using direct numerical MHD simulations including constant shear. Implications for solar wind turbulence are discussed.

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FINITE INSTRUMENTAL RESOLUTION SCALES IN SOLAR WIND MODELING

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The classical kinetic models of solar wind are developed under asssumption that coordinates of all particles are distinguishable what corresponds to infinitesimal resolution scales. The consideration of finite instrumental resolution scales is followed by description of fluctuations of solar plasma macroparameters on the base of multiparticle probability functions [1,2].

This approach provides essentially different results for plasma parameters than traditional models what is demonstrated by solving problems of acceleration of two- and multi-component solar plasma. The derived theoretical dependences consist with observational data.

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SOLAR WIND ACCELERATION AND DECELERATION THROUGHOUT THE HELIOSPHERE BY MULTI-SPACECRAFT ANALYSIS

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A multi-spacecraft study of the solar wind parameters throughout the heliosphere is performed: STEREO, SOHO, VEX and MEX. First we estimate the theoretical time lag between the spacecraft by assuming constant solar wind bulk velocity along its radial expansion. Over larger distances such predictions result in over-tilted bulk velocity time series, where faster streams overtake slower ones. In reality in these situations stream-stream interactions happen, so we must take into account the resulting particle acceleration and deceleration due to the pressure gradients.

HIGH RESOLUTION MEASUREMENTS OF MAGNETIC FIELD FLUCTUATIONS ASSOCIATED WITH TRANSITIONS IN SOLAR WIND PARAMETERS

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Fluctuations in the velocity, density and temperature of the solar wind and the heliospheric magnetic field have been studied extensively. In particular, the nature of fluctuations has been shown to depend on the origin of the solar wind. In high-speed solar wind from coronal holes there is a strong correlation/anticorrelation (depending on the dominant direction of the magnetic field) between the transverse components of the magnetic field and the solar wind velocity, indicating that the fluctuations are predominantly Alfvénic. In slow solar wind streams, the fluctuations in all components of the magnetic field seem to have closely equal power levels, although the power in the fluctuations of the magnetic field magnitude remains significantly less than that in the components. The transition between the two regimes, however, has not been investigated with high resolution. In this presentation we use high resolution magnetic field measurements on the Ulysses spacecraft to calculate the variances of the fluctuations in the magnetic field components and its magnitude over three timescales: 1 minute, 10 minutes, 1 hour, concentrating on intervals of rapid change in the solar wind parameters. Such changes lead to shears that may increase or decrease the levels of fluctuations and feed power into them. At the same time, the Alfvénicity of the waves undergoes a change. It is what happens at these transitions that may provide a continuing source of energy that maintains the level of fluctuations above what would be expected as a function of heliocentric distance. We also use cross helicity calculated using different time resolutions of the magnetic field and solar wind data to assess the Alfvénicity of the fluctuations and changes in it. The overall question is how and under what conditions local observations of changes in solar wind parameters, such as shears, can be related to the locally measured levels of fluctuations. For this study, we have concentrated on three different kinds of local solar wind transitions: the sharp boundaries observed at the times of transition from equatorial (slow, mixed) solar wind flows to the fast streams from the polar coronal holes; the changes associated with stream interactions; and smaller-scale gradients (microstreams) seen in the fast solar wind.

THREE-DIMENSIONAL WAVEVECTOR SPECTRUM OF SOLAR WIND TURBULENCE: INSIGHTS FROM WAVELET ANALYSIS OF SINGLE SPACECRAFT MEASUREMENTS

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The three-dimensional (3D) wavevector spectrum or 3D Fourier spectrum of solar wind turbulence is a fundamental physical property that is difficult to measure using data from a single spacecraft. The 3D distribution of energy in wavevector space has not been completely characterized and remains an important unsolved problem (Matthaeus et al. 1990, 1996, Carbone et al. 1995, Horbury et al. 1995, Bieber et al. 1996, Leamon et al. 1998, 1999, Dasso et al. 2005, Horbury et al. 2005, Osman & Horbury 2007, Chapman & Hnat 2007, Tessein et al. 2007, 2009, Narita et al. 2007, 2009).

A novel wavelet analysis technique developed by Horbury et al. (2008) using Ulysses data and further investigated by Podesta (2009) using data from NASA's Stereo spacecraft provides a wealth of new information that sheds light on the 3D wavevector spectrum of solar wind turbulence. The technique uses data from a single spacecraft to compute the power spectrum of the fluctuations (the reduced spectrum, trace power) as a function of the angle θ between the local mean magnetic field and the mean flow direction. Horbury et al. (2008) have shown that for high-speed wind the power-law exponent in the inertial range changes from approximately 5/3 to 2 as the angle θ changes from $\pi/2$ to 0. This result can be demonstrated more convincingly by plotting the ratio of the perpendicular power spectrum $P_\perp$ measured when $\theta = \pi/2$ to the parallel power spectrum $P_\parallel$ when $\theta = 0$. For the one interval of Ulysses data analyzed by Horbury et al. (2008) this shows a scaling of the form $P_\perp/P_\parallel \propto \nu^{1/3}$, where ν is the frequency in the spacecraft frame (Podesta 2009).

A possible interpretation given by Horbury et al. (2008) is that the 3D wavevector spectrum of solar wind turbulence has the form given in the anisotropic theory of incompressible MHD turbulence developed by Goldreich & Sridhar (1995). If true, then this represents a significant advance in our knowledge of the anisotropy of solar wind fluctuations. However, it should be kept in mind that this conclusion is based on the analysis of magnetic field fluctuations alone and the results may change significantly when the spectrum of velocity fluctuations are added to give the total energy. Therefore, such conclusions are preliminary and much work remains to be done. Unfortunately, high cadence plasma velocity and density measurements ($\sim$ 1 s) are rare in space physics. This significantly hinders progress in this field.

A wavelet technique similar to that of Horbury et al. (2008) is used by Podesta (2009) to study nine high-speed streams in the ecliptic plane using Stereo magnetic field data. As in the study by Horbury et al. (2008), it is found that in the inertial range the spectrum of magnetic field fluctuations is approximately azimuthally symmetric about the direction of the local mean magnetic field and the spectrum measured parallel to the local mean magnetic field has a power-law exponent of 2.0 ± 0.1 while the perpendicular spectrum has a power-law exponent of 1.6 ± 0.1. As might be expected, these results are similar to those reported by Horbury et al. at high ecliptic latitudes and appear to be a generic feature of *high-speed* wind.

In the study by Podesta (2009) experimental uncertainties in the measured spectra increase at low frequencies because of the short record lengths and possibly for other reasons. Therefore, it is difficult to determine whether the 5/3 scaling of the Goldreich & Sridhar theory or the 3/2 scaling of the Boldyrev theory provide better agreement with the data. More work is needed to investigate which, if any of these turbulence theories, can correctly explain not only the measured spectral anisotropy but also the energy cascade rate of the turbulence. The establishment of a practical theory is important for unifying our knowledge and understanding of the physics of solar wind turbulence.

This talk will highlight some of the new insights gained using the wavelet analysis technique of Horbury et al. (2008) and compare and contrast these results to those obtained in the comprehensive study by Tessein et al. (2009) based largely on ACE data.

ARE SOLAR-WIND-DUST INTERACTIONS RESPONSIBLE FOR WAVES AND TURBULENCE IN THE INTERPLANETARY MEDIUM?

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The solar system contains a population of orbiting charged dust particles with a mass density comparable to that of the solar wind. Thus, if dust interacts with the solar wind, it has the potential to significantly affect it, yet we seldom see treatments of the effect of the charged dust on the solar wind. On the other hand, treatments of the effect of the solar wind on the dust often begin with the Lorentz force, assuming that any momentum exchange has no discernible effect on the solar wind, which is a risky assumption. We have clear evidence that one such phenomenon in the interplanetary magnetic field, the Interplanetary Field Enhancement, is associated with dust pick-up, making a disturbance about 105 km across and traveling with the solar wind velocity. Other phenomena, too, may be dust associated. Discordant current sheets in ICMEs that have no obvious relation to the ICME structure are one such phenomenon, but possibly a large fraction of directional discontinuities are caused by the dust interaction. If so, the appearance of these signatures may be modulated by the Debye length, which changes the sphere of influence of each dust particle. We present examples of such phenomena in STEREO data.

SHOCK FORMATION IN THE SOLAR WIND

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Stream interactions are present in the solar wind throughout the solar cycle, even during the present deep solar minimum. These stream interactions create a pressure ridge in the center of the velocity gradient that marks the interaction of the fast and slow stream. When the velocity change across the interface becomes sufficiently large, exceeding the magnetosonic speed, shocks may form in the region of the velocity gradient. Steepening may occur in several places simultaneously, but eventually the different shocks merge to form a single strong shock. Examples are given, showing this coalescence from STEREO magnetic field measurements. Comparisons during solar conjunctions of Venus Express with STEREO indicate that shocks seldom form interior to 0.7 AU, but before they reach 1 AU, nearly half the stream interactions have formed shocks at solar minimum.

EVIDENCE OF CASCADE AND DISSIPATION OF SOLAR WIND TURBULENCE AT ELECTRON SCALES

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Most of observational work on solar wind (SW) turbulence has been devoted to large-scale/MHD scales where the Kolmogorov scaling $k^{-5/3}$ is frequently observed. Turbulence at frequencies above the proton gyrofrequency ($f_{cp} \sim 0.1$ Hz) has not been thoroughly investigated and remains far less well understood. Above f_{cp} the spectrum steepens to $\sim f^{-2.5}$ and a debate exists as to whether the turbulence has become dominated by dispersive kinetic Alfvén waves and is dissipative, or has evolved into a new dispersive turbulent cascade dominated by whistler waves. Here we report the first direct determination of the dissipation range of solar wind turbulence near the electron gyroscale (Sahraoui and Goldstein, submitted). Combining the high resolution magnetic and electric field data measured by the Cluster spacecraft, we compute the spectrum of turbulence over more than five decades, ranging from 10^{-3} Hz to 10^{2} Hz (in the spacecraft reference frame). Two distinct breakpoints are observed in the magnetic spectrum at the frequencies 0.4 Hz and 35 Hz, which correspond, respectively, to the Doppler-shifted proton and electron gyroscales, $f_{\rho p}$ and $f_{\rho e}$. Above $f_{\rho p}$ the spectrum follows a Kolmogorov scaling $f^{-1.62}$, typical of spectra observed near 1 AU. Below $f_{\rho p}$ a second inertial range is formed with a scaling $f^{-2.3}$ down to $f_{\rho e}$. Below $f_{\rho e}$ the spectrum has a steeper power law $f^{-4.1}$ down to the noise level of the instrument. We interpret this as the dissipation range. We show that these observations are remarkably consistent with theoretical predictions of a quasi-two-dimensional cascade into kinetic Alfvén waves (KAW).

SHORT-SCALE ELECTROSTATIC FLUCTUATIONS IN SOLAR WIND TURBULENCE

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The dynamics of the interplanetary medium is driven by plasma processes in a collision free regime. In the absence of collisional viscosity, fundamental questions about how energy is transfered from large to small scales and how it is eventually dissipated are still open and represent an outstanding problem in space physics. Since astrophysical plasmas are known to be highly turbulent, the understanding of the role of turbulence in such collisionless systems would be of key relevance for the interpretation of the physical processes of energy transport and plasma heating at short scales, where the system dynamics is presumably kinetic in nature.

We numerically investigated the role of kinetic effects on the evolution of the turbulent energy spectra in solar wind plasmas in the range of wavelengths around and beyond the ion inertial length, through a recently developed hybrid-Vlasov code [1], where ions are considered as kinetic particles, while electrons as a massless fluid. This zero-noise Vlasov algorithm is particularly efficient in the analysis of the short-scale termination of turbulence and especially allows for a detailed and complete description of the link between macroscopic and microscopic scales along the turbulent cascade.

In our simulations [2], nonlinear wave-wave coupling processes at large wavelengths trigger a turbulent cascade that transfers energy towards scales of the order of the ion skin depth. In this range of wavenumbers, proton cyclotron resonance with left-handed cyclotron waves self-consistently generates perpendicular temperature anisotropy in the ion distribution function. For hot electrons, a significant level of electrostatic activity is observed at short wavelengths. The careful analysis of the numerical $k - \omega$ spectra, showed that ion-acoustic waves, propagating parallel to the ambient magnetic field, are produced as the result of the nonlinear cascade of energy. Besides these ion-acoustic waves, in agreement with spacecraft observations in the solar wind [3], new short-wavelength fluctuations of the acoustic form, and with phase velocity close to the ion thermal speed, were recovered in the simulations. The analytical solution of the hybrid Vlasov-Maxwell equations [4] shows that these fluctuations are Berstein-Green-Kruskal structures, driven by particle trapping kinetic effects and associated with the generation of double-beam proton velocity distributions. The presence of fast beams in the proton velocity distributions is a feature frequently observed in solar wind plasmas [3], usually in presence of short-scale electrostatic activity.

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MULTIPLICATIVE AND ADDITIVE FORMATION PROCESSES OF SPACE-TIME STRUCTURES OBSERVED IN THE SOLAR WIND AND INTERPLANETARY MAGNETIC FIELD

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Multiplicative and additive physical processes are usually considered in some sense as equivalents to external versus internal driving forces, or non-local versus local phenomena correspondingly in open or closed systems. Solar wind and interplanetary magnetic field (IMF) parameters are formed as functions of space and time due to combination of linear and non-linear processes on the Sun and on the way in the heliosphere. Those processes are not completely separated and not well understood as yet. Additive processes are well represented by linear theories, which bring a solid framework for all interpretations of observed waves and convective structures in the solar wind. Roughly speaking, additive processes are simpler. They obey a superposition principle and encompass accumulation, summation, storage, exchange, interference etc. phenomena parent to laminar structures. Multiplicative processes are often described locally by parametric models with given (fixed or variable) amplification/attenuation factors (instabilities etc.). Otherwise, more complicated self-consistent, nonlinear and non-local dissipative MHD and kinetic formulations are used. They are practically not tractable in most non-local instances and often substituted by simplified or truncated approximations based on dimensionless scaling without known applicability limits, which are difficult to evaluate a priori. Multiplicative processes are common for complicated and non-separable turbulent situations. When chaotic numbers are added, one obtains Gaussian statistical distributions of corresponding parameters according to the central theorem of the probability theory. When the chaotic numbers are multiplied, the lognormal statistics appears. We demonstrate examples of Gaussian and lognormal fits using statistical analysis of the OMNI web and data bases. Both limiting and intermediate cases are met in the solar wind and in the IMF data interpretations. Lognormals generally indicate the situations when turbulent, non-local and non-linear processes are essential for the solar wind and IMF formation.

THE INTERACTION OF TURBULENCE WITH SHOCK WAVES, INCLUDING THE HELIOSPHERIC TERMINATION SHOCK

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The heliosheath was expected to be turbulent, the result of upstream turbulence and disturbances (shock waves, pressure and density enhancements, structures, etc.) being transmitted across and interacting with the heliospheric termination shock (HTS). A turbulent heliosheath has indeed been observed downstream of the HTS, but the character of the turbulence is significantly different from that of the solar wind. The 48-sec averages of the downstream magnetic field $\mathrm{B}(t)$ reveals that the turbulence is isotropic, and each component has a Gaussian distribution. The distribution of 1-hour averages of the magnetic field B was also Gaussian in the heliosheath, unlike the log-normal distributions of B found in the supersonic solar wind. The Gaussian distribution indicates a scale invariance in the form of the magnetic field distribution. The second intriguing observation was that the turbulence was substantially compressible since the width of the 48-sec averages of B is greater than that for the components. Here, we discuss the transmission of waves and turbulence across the HTS, both analytically and numerically, investigating both small amplitude and large-amplitude cases. We also consider the interaction of an upstream isotropic incompressible spectrum and discuss the transmission of this spectrum as a superposition of compressible and incompressible modes. Some discussion about the generation and amplification of downstream magnetic field will be presented and preliminary MHD results will be described.

MEASURED CONSTRAINTS ON THE ELECTRON TEMPERATURE ANISOTROPY IN THE SOLAR WIND

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We report on a statistical analysis of the measured electron temperature anisotropy in the solar wind using the 3DP instrument on the Wind spacecraft. Approximately one million independent measurements of the electron velocity distribution were integrated in two energy ranges corresponding to the solar wind 'core' and 'halo' components. The parallel and perpendicular (to the local magnetic field) temperatures were computed from the pressure integral and compared with the parallel electron beta parameter $\beta_{e,\parallel}$ and the electron 'collisional age' $A_{e,e}$. The low-energy core distribution remains relatively isotropic, due to its larger density and correspondingly large Coulomb collision frequency. However, the temperature anisotropy of the halo distribution ($E \geq\sim$80 eV) shows a striking signature which suggests that it is bounded by a whistler-mode instability from above ($T_\perp/T_\parallel > 1$) and the electron firehose instability from below ($T_\perp/T_\parallel < 1$). This confirms that solar wind electron expansion and compression are limited fundamentally by these instabilities.

3D VELOCITY DISTRIBUTION FUNCTIONS OF HEAVY IONS AT 1AU WITH ACE/SWICS

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The kinetic properties of the solar wind are a result of complex interactions in the solar corona and interplanetary space. Sofar, observations of velocity distribution functions (VDFs) of solar wind heavy ions have been solely 1D. They are known to exhibit non-thermal features , but because they are 1D projections of the 3D velocity phase space it is difficult to interpret them properly. Based on 3D observations of H^{1+} and He^{2+} from Helios, we have set up a model for heavy-ion VDFs. In it, the magnetic field vector plays a crucial role by defining the symmetry axis of the VDFs. A thermal anisotropy $T_{\|}/T_{\perp} \neq 1$ and a beam drifting along the magnetic field vector at a relative speed of approximately the Alfvèn speed are included. The modeled VDFs are analysed using a virtual detector and then compared with data from the Solar Wind Ion Composition Spectrometer (SWICS) on the Advanced Composition Explorer (ACE). Our observations give evidence for the existence of heavy-ion beams. The projection of these beams can explain observed differential streaming. We present in-situ measurements at 1 AU and implications for wave-paricle interactions between the Sun and Earth.

MIRROR MODE WAVES IN THE SOLAR WIND: STEREO OBSERVATIONS

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Mirror mode structures occur in the solar wind either as an isolated magnetic field depression or as trains of magnetic holes, named recently mirror mode storms (Russell, 2008). In this work we investigate mirror mode structures at distances $\leq$ 1 AU using STEREO A and B high resolution data. Magnetic field data were scanned to find magnetic holes using Zhang et al. criteria (2008) and examples of our results are presented here. In order to study mirror mode origin and evolution we characterize magnetic holes by analyzing their size, shape, duration as well as plasma and magnetic field conditions that occur in the region surrounding the mirror mode. We finally make a comparison between our results and the characteristics of mirror modes found at 1 AU or at greater distances reported in previous works.

STUDYING THE HEATING OF THE SOLAR WIND THROUGH ELECTRON AND PROTON EFFECTS

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Both the fast and slow wind possess temperature profiles that display non-adiabatic characteristics. This implies an extra heating source, with MHD turbulence dissipation being one possible and natural explanation. Numerous studies of MHD turbulence, however, typically only consider effects on proton temperatures. Yet electrons are very important, as turbulence dissipation must be apportioned in some way between the electrons and protons, while electron heat conduction provides another avenue for redistributing the electron temperatures. Additionally, the protons and electrons may interact through Coulomb collisions.

Here, we examine the effects of including both protons and electrons via two different approaches. In the first approach, we include the electron temperature in an MHD turbulence transport model for the solar wind. Heating of the wind come directly from the turbulence dissipation. The model computes the temperatures, which is then compared to the available Ulysses proton and electron temperatures. A reasonable accounting for the data is obtained when the energy exchange time is very long and the deposition of heat due to turbulence is divided with 60% going to proton heating and 40% into electron heating.

In the second approach, we adopt more empirically based methods. We analyze measured proton and electron temperatures in the high-speed solar wind in order to calculate the separate rates of heat deposition for protons and electrons. On the basis of the empirical results, we find that the protons initially receive about 60% of the total plasma heating in the inner heliosphere (up to about 1 AU). The fraction increases to approximately 80% by the orbit of Jupiter. Overall, we conclude that incorporating separate proton and electron temperatures and heat conduction effects provides an improved and more complete model of heating of the solar wind.

LANGMUIR WAVES INSIDE SOLAR WIND MAGNETIC HOLES: STEREO AND CLUSTER OBSERVATIONS

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Magnetic holes, solitary large amplitude depressions in the interplanetary magnetic field, are commonly observed in the solar wind. Some of these magnetic structures are accompanied by bursts of electrostatic waves close to the electron plasma frequency localized inside the magnetic holes. In this study we use data from the S/WAVES instrument on board of the STEREO spacecraft to demonstrate the first waveform observations of these waves and to analyze their polarization and modulation. The results are complemented by Cluster observations of these phenomena, which allow to resolve the electron distribution and obtain a better description of spatio-temporal variations in Langmuir wave activity. We present a detailed analysis of several individual cases and discuss the possible mechanism responsible for excitation of these waves.

ON THE RELATIONSHIP BETWEEN TRANSIENT GROWTH AND MARGINAL STABILITY: A NON-MODAL APPROACH

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Solar wind data bear two contradictions, when interpreted at the light of linear theory. It is thought that the temperature anisotropy of the plasma is constrained by kinetic linear instabilities, which are driven by the expansion. Therefore the plasma is supposed to live constantly in a marginally stable condition (i.e. at the border between stable and unstable conditions). However, most of the time the solar wind is observed to be almost isotropic and very stable, i.e very far from marginal stability. Moreover, a relatively high level of short wavelength magnetic fluctuations is constantly observed in the solar wind. This apparently contradicts the fact that, in a stable plasma, the linear theory predicts for any fluctuations to damp out exponentially in time. We study the non-modal linear stability of a collisionless bi-Maxwellian plasma in an homogeneous magnetic field, with a so-called Landau fluid (LF) model. LF includes linear Landau damping and finite Larmor radius corrections. We show that, even for a linearly stable plasma, small perturbations can undergo a transient growth, being amplified by large factors, before decaying. This is due to the non-normality of the linear operator, so that its eigenvectors are not mutually orthogonal. The non-normality of a collisionless plasma is intrinsically related to its kinetic nature, with the transient growth being more accentuated for smaller scales and higher plasma beta. We argue that a non-modal approach to linear stability might overcome the discrepancies between linear theory and observations.

REDUCED MAGNETIC HELICITY AND THE FORMATION OF DISPERSIVE/DISSIPATIVE RANGE IN SOLAR WIND TURBULENCE

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We investigate the scaling laws of reduced magnetic helicity obtained through measurements of the Cluster spacecrafts in the solar wind. We calculate a signed measure which quantify the handedness of the magnetic field, namely it can be related to the polarization of magnetic fluctuations (right-hand or left-hand) providing the propagation direction is known. We found that the measure so obtained is sign-singular. At variance to what happens for the energy spectrum, we don't observe any cross-scale effect at the ions-inertial scale. This means that cancellations between right-hand and left-hand polarizations continue well inside the dispersive/dissipative range. This indicates the presence of both polarizations at small scales in the solar wind turbulence.

UNDERSTANDING ESTIMATES OF THE VECTOR THIRD MOMENT OF SW FLUCTUATIONS, AND USING IT TO DETERMINE IN-SITU HEATING RATES

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Theories of the turbulent cascade in hydrodynamics(HD) and in magnetohydrodynamics (MHD) make exact predictions from the Navier-Stokes (in HD) and the MHD equations, that the scaling of the appropriate vector third moment of fluctuations is related to the energy dissipation rate (in HD) and the dissipation rates of the Z+ and Z- fluctuations in MHD. [Note: this is NOT the third moment used in intermittency studies of the slope of the structure function. Such work uses the absolute value of fluctuations, not the signed fluctuations.] In HD, this law is known as the KHM relation and in MHD we call it the Politano-Pouquet relations (after the first derivors). In vector form, these apply regardless of anisotropy; in the case of isotropic turbulence, the vector relations become simply the “Kolmogorov 4/5 law” and the Yaglom 4/3 law and their MHD analogs.

We have been pursuing the Politano-Pouquet relation using ACE magnetic field and plasma data, at first to see if it works in the solar wind, and then to compare the in-situ heating rate it implies, with values deduced from the non-adiabatic cooling of the solar wind at 1 AU. It was important that the relation should work if the turbulence and the cascade are anisotropic, since we know that solar wind turbulence is anisotropic. So far, we have found the third moment we measure scales linearly with lag, and is anisotropic, with most of the energy transfer perpendicular to the mean magnetic field; the value and scaling of the MHD vector third moment agrees reasonably well with in-situ heating rates estimated from the radial dependence of the solar wind temperature. Much more needs to be done with the third moment vectors to elucidate the structure of the turbulent cascade, and the various contributions to the cascade of energy and cross-helicity in the solar wind in different types of solar wind.

We were at first surprised that a month of ACE data at 64-second cadence was not usually enough to give a reliable third moment at any scale: the monthly values were too variable to be credible. Our first paper (at Solar Wind 11 in 2005) reported MHD third moments averaged over seven years of 2-day intervals. Later we showed that averaging estimates from a hundred or more 2-day intervals gives a reliable value whose accuracy can be evaluated from the variance of individual estimates. The number of actual data points in each average was over 100,000 to get a credible final result.

Recently we have discovered why so much data needs to be used to calculate a credible third moment in both HD wind tunnel data and in the solar wind. Basically, it’s because the variance of the third moment is the sixth moment. The (signed) third moment is small, and the sixth moment is large. We conclude that the accuracy of any estimate of the third moment of solar wind fluctuations can and must be calculated and considered in the reliability of any result on the dissipation rates in the solar wind (or any wind)! We also believe that intervals which do not give the expected scaling should not be ignored.

NONLINEAR ION-ACOUSTIC WAVES IN THE SOLAR WIND

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We consider a solar wind type of plasma, consisting of background proton, a proton beam, and an alpha particle beam. We assume that the alpha particle beam is moving backwards relative to the interplanetary magnetic field, while the proton beam moves in the direction of the external magnetic field. It is shown that in the presence of a finite amplitude Alfvén wave and for small negative drift velocity relative to the background plasma, there are several purely electrostatic instabilities of the ion-acoustic type. In a system like the one we consider here, there are several linear ion-acoustic waves when the finite amplitude wave is not present. These waves can be of several types. There are ion modes supported by the background plasma and move forward and backward relative to it in the direction of the interplanetary magnetic field. There are also ion-acoustic waves supported by the beams and moving forward and backward relative to each of the beams. These waves are stable in the absence of the finite amplitude wave. However, when there is a large amplitude Alfvén wave, the modes just describe give rise to a number of ion-acoustic nonlinear instabilities. These are triggered when either the phase velocity of a backward moving ion.acoustic mode becomes equal to the phase velocity a forward propagating ion-acoustic wave. These instabilities can occur between ion-acoustic waves supported by the same ion species or by different ion species. Some of these instabilities can reach large growth rates, such that can play an important role in the heating of the solar corona and solar wind. Previous results on this subject can be found in Gomberoff, JGR, 113, A10207, doi: 10.1029/2008JA013378; JGR , 114, doi: 10.1022008/2008JA013818.

ANISOTROPY AND SLOPES IN INCOMPRESSIBLE HOMOGENEOUS MHD TURBULENCE WITH MEAN FIELD

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We review arguments, both theoretical or based on numerical experiments, in favour of 3/2 or 5/3 slopes for energy spectra. We consider the spectral anisotropy problem, and show that the results depend strongly on the method used to measure the anisotropy. We compare finally resistive and ideal MHD simulations.

ION-ION COULOMB COLLISIONS IN THE SOLAR WIND

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Collisional transport in anisotropic plasmas is investigated comparing the theoretical predictions of the Fokker-Planck equation for bi-Maxwellian particle distribution functions and results of the corresponding Langevin equation.

VLASOV SIMULATIONS OF ELECTROSTATIC DECAY AND CONSEQUENCIES FOR SOLAR WIND OBSERVATIONS

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The electrostatic decay enables energy transfer from a finite amplitude Langmuir pump-wave (L) to a backscattered Langmuir wave (L') and ion acoustic density fluctuations (S):

$$L \rightarrow L' + S$$

This mechanism is frequently observed in laser plasma experiments. It is also thought to be a step for the generation of type III solar radio emissions at twice the plasma frequency. Henri et al. (2009) recently reported observations of electrostatic decay of beam-driven Langmuir waves during a type III solar event.

The electrostatic decay dynamics is here investigated through Vlasov-Poisson simulations for both a monochromatic pump-wave and a pump-wave packet.

Instability thresholds, growth rates and saturation are studied in both cases. Particular attention is given to the dynamics and the saturation level of ion acoustic-like density fluctuations generated by the electrostatic decay when electron and proton temperatures are identical, as it is the case in the solar wind plasma.

The results are discussed in the context of solar wind observations from the STEREO mission.

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GENERALISED ENTROPY DEFINITION APPLIED TO TURBULENT SPACE PLASMAS

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Entropy is a fundamental quantity describing the number of possible states of a system. According to the second law of thermodynamics, on a global scale entropy can only increase as the system evolves, and a number of processes such as turbulence contribute to its growth. There are several definitions for entropy of which Gibbs-Boltzmann (GB) is the most commonly used. However, a generalised entropy definition — Tsallis entropy — seems better suited for describing space plasmas: its theoretical formulation allows the system to have long range interactions and memory effects. Moreover, while GB entropy produces a Maxwellian distribution in velocities, the equilibrium distribution for Tsallis entropy is a kappa distribution similar to the ones observed, e.g., in the solar wind. We use this generalised definition to analyse proton and electron distribution data, as well as magnetic field data, from the Wind satellite in order to calculate the evolution of entropy in the solar wind plasma.

NEW MULTIFRACTAL ANALYSES OF THE SOLAR WIND TURBULENCE: RANK-ORDERED MULTIFRACTAL ANALYSIS AND GENERALIZED TWO-SCALE WEIGHTED CANTOR SET

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Since the work of Burlaga in 1991 based on Voyager 2 speed data, various multifractal analyses have been performed to better characterize the intermittency of the fluctuations in the turbulent solar wind. These analyses were based either on the classical structure functions or on the partition function. Recently, two new multifractal analyses have been proposed to go beyond and better characterize intermittent fluctuations: on one hand, Chang & Wu (2008) proposed a rank-ordered multifractal analysis which uses rank-ordered structure functions instead of the classical ones. On the other hand, to quantify scaling of the solar wind turbulence, Macek & Szczepaniak (2008) have developed a generalized two-scale weighted Cantor set using the partition function technique. We will present both methods and emphasize their advantages over the previous multifractal analyses. Links and differences between these two new approaches will also be discussed. As an illustration, these new multifractal analyses will be applied to a set of magnetic field data measured by Ulysses at about 3.8 AU in January 1994 while the spacecraft was moving in fast wind streams during a solar minimum.

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Macek W. & Szczepaniak A., Generalized two-scale weighted Cantor set model for solar wind turbulence, Geophys. Res. Lett. 35, L02108, 2008

TORSIONAL ALFVEN WAVES IN THE SOLAR WIND

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We have identified torsional Alfven waves in the solar wind by surveying the solar wind plasma and magnetic field data from the ACE spacecraft. Their wave fields are characterized by rotational varaiations in transverse components of magnetic fields and velocity fields, parallel or anti-parallel to each other, propagating along the bundles of magnetic field lines. The identification was performed through four steps: (1) selection of time intervals in which both velocity and magnetic field show smooth rotations, (2) confirmation of the Alfvenicity by examining the correlation between the two quantities, (3) determination of geometry of the regions of torsional Alfven waves, and (4) fitting to a magnetic flux rope model for comparison. The magnetic field rotations are very much similar to the rotations observed when the spacecraft crossed the magnetic flux rope structures. Therefore, it is not easy to differentiate between cases of torsional Alfven waves and cases of magnetic flux ropes, generally speaking. As a result of a careful analysis, however, we found more than 20 cases of torsional Alfven waves in one year of 1999, for which magnetic flux rope models cannot reproduce the observed magnetic fields. The durations of crossing the Alfven wave regions typically range from 1 to 3 hours, while several events with longer durations were also found. The propagations are directed from the Sun to the Earth, suggesting the generation in the solar corona. The magnetic reconnection of twisted fields in the active regions and open field lines provide a possible mechanism for the generation of the torsional Alfven waves, since such reconnection can give sudden twisting to open field lines.

A TWO-COMPONENT TRANSPORT MODEL FOR SOLAR WIND FLUCTUATIONS: WAVES PLUS QUASI-2D TURBULENCE

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Although spatial transport of MHD-scale fluctuations in the solar wind has been investigated for over 40 years it is yet to be completely understood. Even in the simplest case of radial transport there are numerous effects that may need to be represented to obtain accord with observations. These include wave and turbulence activity, forcing processes (e.g., stream shear, pickup ion driving), and the spatial and spectral anisotropy of the fluctuations [e.g., Ref. 1].

We will present a model for the transport of solar wind fluctuations, based on the assumption that they can be well-represented using two distinct components: a *quasi-2D turbulence* piece and a *wave-like* piece.[2] For each component, coupled transport equations for its energy, cross helicity, and characteristic lengthscale(s) are derived, along with an equation for the proton temperature. This energy-containing "two-component" model includes the effects of solar wind expansion and advection, stream shear driving, pickup ion forcing, and nonlinear cascades due to self and cross interactions of the quasi-2D and wave-like components. The nonlinear effects are modeled using a recently developed one-point phenomenology for such a two-component model of homogeneous MHD turbulence.[3] Heating due to these nonlinear effects is included in the temperature equation.

The development of the model will be outlined and numerical solutions appropriate for solar wind parameters presented. These solutions will be compared with observational data out to around 70 AU.

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INTERMITTENCY OF SOLAR WIND DENSITY AND MAGNETIC FIELD FLUCTUATIONS IN THE REGION OF SUDDEN CHANGES OF ION FLUX USING DATA OF HIGH FREQUENCIES (0.01–1 Hz).

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Intermittency is one of the main features of solar wind turbulence. We investigated the intermittency of ion flux and magnetic field fluctuations under large statistics of high time resolution measurements onboard Interball-1 spacecraft. A large degree of intermittency is observed in the solar wind, and it grows significantly (flatness increase more than 100 times) from large (more than 1000 sec) to small (1- 100 sec) scales. Special attention is given to a comparison of intermittency for solar wind observation intervals containing SCIF (Sudden Changes of Ion Flux) to ones for intervals without SCIF. Such a comparison allows one to reveal the fundamental turbulent properties of the solar wind regions in which SCIF is observed more frequently. Especially it is important that these investigation is carry out for the first time for the earlier unexplored (by plasma data) region of comparatively fast variations (frequency up to 1 Hz), so we significantly extend the range of intermittency observations for solar wind plasma.

COMPRESSIVE TURBULENT CASCADE IN THE SOLAR WIND

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Incompressible and isotropic magnetohydrodynamic turbulence in plasmas can be described by an exact relation for the energy flux through the scales. This Yaglom-like scaling law has been recently observed in some samples of data collected by the Ulysses spacecraft in the solar wind above solar poles, where turbulence is Alfvénic. An analogous scaling law, suitably modified to take into account compressible fluctuations, can be observed in a more extended fraction of the same dataset. Large scale density fluctuations, despite their low amplitude, play thus a crucial role in the basic scaling properties of turbulence. The compressive turbulent cascade, moreover, can supply the energy needed to account for the local heating of the non-adiabatic solar wind.

OBSERVED CHARACTERISTICS OF NON-THERMAL ELECTRONS AND THEIR RADIAL EVOLUTION IN THE LOW-LATITUDE SOLAR WIND

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Electrons play a significant role in the solar wind dynamics. They produce an ambipolar electric field through their thermal pressure gradient and above all carry a substantial amount of the solar wind heat flux. From the kinetic point of view the heat flux is determined by the skewness of the electron velocity distributions. The electron velocity distribution functions (eVDFs) observed in the solar wind are highly non-Maxwellian and exhibit strong non-thermal tails. The skewed part of observed eVDFs is represented by the so-called *strahl*, a beam-like population moving away from the Sun highly focused along the ambient magnetic field. In order to better understand the non-thermal features of observed eVDFs as well as the transport of the heat in the solar wind, we performed a statistical study of a substantial amount of eVDFs acquired in the low ecliptic latitudes covering the heliocentric distance from 0.3 up to 4 AU. For our study, a new model was proposed which, for the first time, describes all the eVDF components (including the strahl) analytically. The main characteristics, i.e., the density, temperature and heat flux, are examined as a function of the heliocentric distance. Furthermore, we study the effect of both, particle-particle and wave-particle interactions on the overall eVDF properties.

PROTON BEAM VELOCITY DISTRIBUTIONS IN AN ICME

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The plasma and magnetic-field instruments on the Helios 2 spacecraft, which was on 3 April 1979 located at 0.68 AU, detected an interplanetary coronal mass ejection (ICME) that revealed itself by the typical signature of magnetic field rotation, indicating a force-free magnetic flux tube. The solar wind flow speed ranged between 500 and 600 km/s. We present here, to our knowledge for the first time, the detailed proton velocity distributions measured within an ICME. These cold distributions are characterized by an isotropic core part with a low temperature, $T \leq 10^5$ K, and a broad and extended hot proton beam propagating along the local magnetic field direction with a speed of a sizable fraction of the local Alfvén speed. The beams lasted for almost an hour and appeared to be unusual as compared with the ambient ICME protons which were comparatively isotropic. Furthermore, we looked into the velocity and field fluctuations in this ICME and found signatures of Alfvén waves, which might be related to the occurrence of the hot protons beams.

1D MODEL FOR BEAM PLASMA INTERACTION IN THE PRESENCE OF EXTERNAL DENSITY FLUCTUATIONS

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Large amplitude spatially localized Langmuir waves are frequently observed in the solar wind, usually correlated with the presence of suprathermal electron beams. Recent in-situ observations by the TDS instrument equipping the STEREO spacecrafts showed that these localized waves could be interpreted as electrostatic modes trapped in density cavities present in the solar wind.

We present a new theoretical model based on the spectral resolution of the Zakharov's equations in which a term relative to beam particles has been added. This approach enables to reproduce the eigenmode structure of the observed waves fields, and to study the destabilization of the trapped waves by a beam of resonant particles.

A TOY-MODEL DEVOTED TO SCALE-DEPENDENT EFFECTS OF MAGNETIC TURBULENCE ANISOTROPY

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Existing literature shows that solar wind magnetic turbulence is strongly anisotropic. Understanding the properties of anisotropy is relevant to a better comprehension of turbulent phenomena. Recent results obtained within scales belonging to the so called dissipation range, showed that this anisotropy is well enhanced at smaller and smaller scales. In particular, it has been shown that a) the eigenvalues of the variance matrix have a strong intermittent behavior, with very high localized fluctuations below the ion cyclotron scale; b) the minimum variance direction is almost parallel to the background magnetic field at scales larger than the dissipative scales while it tends to become nearly perpendicular at scales within the 'dissipation' range.

We show that some of these features, observed in different regions of space plasmas, can be reproduced to a good degree by a toy-model in which the tip of the magnetic vector randomly fluctuates on the surface of a sphere with its directional fluctuations following a double-lognormal distribution. In addition, we show that in our model magnetic compressive fluctuations play a key role confirming a similar conclusion which has recently been proposed in literature.

RELATIVE DEGREE OF ORDER IN THE RADIAL EVOLUTION OF SOLAR WIND MAGNETIC FIELD

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In the last two decades complexity has become one of the central issue in space plasmas. Now, many space plasma systems are open systems in nonequilibrium states displaying turbulence and/or self-organized critical dynamics. This is particularly true for the solar wind, which represents a natural laboratory for the study of MHD turbulence, intermittency, self-organization, etc. In the last decade of the XX century, Y. Klimontovich [1996, 1997, 1998] approached the study of open systems by the information theory, introducing a criterion, known as S-theorem, for evaluating the relative degree of order of nonequilibrium states. Here, we make use of such a criterion to investigate the relative degree of order in the radial evolution of solar wind magnetic field. In detail, we compute the relative degree of order for the magnetic field intensity at different radial distances. The results clearly points toward an increase of order with the radial distance, suggesting the occurrence of structuring (formation of structures) in the course of the evolution.

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ANISOTROPIES OF MHD TURBULENCE IN THE INNER HELIOSPHERE

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Magnetohydrodynamic (MHD) waves are ubiquitous in the solar wind (SW). For over four decades, low frequency plasma and electromagnetic fluctuations have been observed in the SW, making it the most completely studied case of MHD turbulence in astrophysics, and the only one extensively and directly studied using *in situ* observations. Magnetohydrodynamic scale fluctuations in the interplanetary medium are usually anisotropic, and these fluctuations frequently present different properties in regions of quasi-stationary SW or in regions associated with the presence of transients (e.g., magnetic clouds). In this work, we present a study of the turbulent properties in the inner heliosphere (solar wind between 0.3 and 1 AU) based on modeling *in situ* plasma and magnetic observations collected by Helios 1 and Helios 2 spacecraft throughout one full eleven-year solar cycle. In particular we study the anisotropy properties in the inertial range. Results presented here will help us to refine models used to describe the propagation and diffusion of charged solar energetic particles in the inner heliosphere and to understand the MHD Alfvenic wave activity for this system.

DECORRELATION TIME SCALE FOR TURBULENT STRUCTURES IN THE SOLAR WIND

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The solar wind (SW) contains a very important level of fluctuations, which at 1 AU can be studied in the framework of the magnetohydrodynamic (MHD) turbulence for spatial scales in the range of $\sim 10^2 - 10^6$ km. These fluctuations in the SW are usually anisotropic, and frequently present different anisotropic properties in regions of the SW with different global magnetic connectivities (e.g., magnetic clouds) or different bulk plasma parameters. Previous studies analyzed turbulent properties of the SW, e.g. the magnetic selfcorrelation function, using two times – single point measurements, which assumes the analogues to the Taylor 'frozen-in-flow' hypothesis in hydrodynamics. However, the intrinsic mixing between spatial structures and their time evolution produced during the time of observation, can affect the interpretation of detailed observations (e.g., anisotropy). Thus, it makes feasible the question: 'How exact can be considered this hypothesis for SW turbulence studies ?'; The answer can be determined by examining data from multiple spacecrafts, taking simultaneous measurements separated in space. In the present study we compare the magnetic autocorrelation function for the inertial range in the SW obtained from two times – single point observations (single spacecraft) with the same quantity obtained from single time – two points measurements (two spacecraft). From this comparison we give estimations for the decorrelation time scale for turbulent structures in the solar wind at 1AU combining *in situ* observations from ACE and Wind spacecraft.

MULTI-SPACECRAFT STUDY OF INTERPLANETARY MAGNETIC FIELD DEPRESSIONS

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Magnetic depressions were observed and investigated in the interplanetary field by the four Cluster spacecraft at different times when the separation between the satellites was ranging from ∼500 km to ∼10000 km. In several cases the holes appeared in wave trains like quasi-sinusoidal oscillations suggesting that they are not the remnants of long time evolving magnetic dips. The motivation of the study was the reconstruction of the geometry of the magnetic structures, based on the correlation between the magnetic field profiles measured across the holes by the four spacecraft. It is shown that there are several holes where inside the depression the magnetic field was found to be close to zero. The relation between solar wind parameters and the characteristic features of the magnetic holes were investigated. In case when the depressions could be identified by all four spacecraft, the velocity of the structures was determined by triangulation. This study confirmed that the holes are likely to be frozen in the solar wind flow.

OBSERVATION OF LANGMUIR WAVES IN THE SOLAR WIND AND THE ROLE OF THE ANTENNA EFFECTIVE LENGTH

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Conversion of the open circuit voltage recorded on a receiving antenna terminals to the electric field amplitude of an incident wave requires the knowledge of the antenna effective length. Recently it was shown convincingly [1,2] that in resonant frequency bands, where the incident waves are quasi-electrostatic, i.e. the wave electric field is parallel to the wave vector, the effective length can exceed the antenna physical length by more than an order of magnitude.In observations of waves coming to the receiver from natural sources we cannot expect such a precision in the interpretation of wave amplitudes as in two point controlled experiments, but we can try at least to obtain a reasonable estimate and avoid exaggeration of wave amplitudes obtained with the antenna physical length. Here we discuss narrow band emmissions as seen in the wave data obtained with the University of Iowa wide band instrument on board the CLUSTER II spacecraft observed in the near vicinity of the local plasma frequency in the solar wind, well upstream of the Earth's bow shock [3,4]. This approach will be of use also for other space missions such as Stereo and Solar Orbiter. The fact that the effective length can exceed the antenna physical length might seem counterintuitive. Our explanation is related to the fact that in such cases the wave number surfaces (of Langmuir waves in a streaming plasma, or waves on the resonance cone in a magnetized plasma) show directions where either two waves coalesce, with the group velocity perpendicular to the phase velocity, or there exists a whole grouping of waves with a large spectrum of wave vectors but propagating in a narrow angle downstream with the solar wind at the plasma frequency. In the spectra obtained from wide band instrument an intense narrow line appears near the plasma frequency above the background of quasi-thermal noise, sporadically but not rarely. Its amplitude exceeds the noise by about an order of magnitude. According to our findings the waves going downstream from the source to the receiver are recorded with high amplitude, so that the overall appearance of the waveforms conforms well with a signature of a source of plasma waves situated upstream from the spacecraft and modulated due to the interplay of radiation patterns of the source and the receiving antenna. As these wave trains are often recorded by at least two spacecraft with a small time shift, a location and even the spatial extent of the source can be estimated. The amplitude modulation of such a signal contains also information on the radiation source, which may be e.g. a particle beam radiating through the Cherenkov effect. In such a case the radiation pattern is that of an electric field distribution on a Cherenkov cone emanating from the source and crossing the receiving point on either spacecraft. We conclude that this approach is able to help in understanding of spectral amplitudes of narrow band emissions in the solar wind .

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ULYSSES OBSERVATIONS OF THE PROPERTIES OF MULTIPLE ION BEAMS IN THE SOLAR WIND

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Observational properties of multiple ion beams in the solar wind beyond 1 AU will be presented. The proton dstributions are approximated by a two beam bi-Maxwellian model. The slower outward traveling beam typically comprises the majority of the solar wind density. Differential streaming between the primary and secondary proton beams decreases with distance from the Sun. The greatest difference between the beams in their evolution with distance from the Sun is that the parallel temperature component of the secondary beam decreases more rapidly (r^{-1}) than that of the primary beam ($r^{-0.45}$). The difference in behavior for the perpendicular components ($r^{-0.6}$ for the secondary beam and $r^{-0.9}$ for the primary beam) is real but less marked. The indication that relative perpendicular cooling is less for the secondary beam while relative parallel cooling is greater and differential beam speed decreases is generally consistent with expectations from the firehose instability. Recently, Kasper et al. (2008) have noted enhanced heating of alpha particles parallel to the magnetic field for cases when the drift speed is greater than the sound speed. The overall behavior of the secondary proton beam is cooling rather than heating, we shall investigate whether there is an sound speed related effect analogous to that seen by Kasper et al for alpha particles.

ON THE INTERPRETATION OF MAGNETIC HELICITY SIGNATURES IN THE DISSIPATION RANGE OF SOLAR WIND TURBULENCE

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Measurements of small-scale turbulent fluctuations in the solar wind find a non-zero right-handed magnetic helicity. This has been interpreted as evidence for the importance of ion cyclotron damping. However, theoretical and empirical evidence suggests that the majority of the energy in solar wind turbulence resides in low frequency anisotropic kinetic Alfvén wave fluctuations that are not subject to ion cyclotron damping. We demonstrate that a dissipation range comprised of kinetic Alfvén waves also produces a net right-handed fluctuating magnetic helicity signature consistent with observations. Thus, the observed magnetic helicity signature does not imply that ion cyclotron damping is energetically important in the solar wind.

Supported by the DOE Center for Multi-scale Plasma Dynamics, Fusion Science Center Cooperative Agreement ER54785.

ELECTRON DENSITY FLUCTUATION SPECTRUM FROM ULYSSES OBSERVATIONS: NATURE OF THE TURBULENCE

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The Ulysses spacecraft gave a unique opportunity to study the fast solar wind out of the ecliptic plane since it spent several months at high heliocentric latitudes during two successive minima of solar activity in 1994-95 and 2007. In-situ measurements have given a new picture on the large-scale properties of the fast solar wind as well as on the microscopic scales. Indeed, the identification of the most intermittent structures and their relation to dissipation represents a crucial problem in the framework of turbulence. On one hand, the electron macroscopic parameters have been measured during the whole solar cycle 23, from the radio and waves instrument (URAP) using the quasi-thermal noise spectroscopy method. This technique yields accurate measurements of the electron density and thermal temperature in various space media. From the large sample of data obtained during fast latitudinal scans, we will present on another hand the electron density fluctuation spectrum near both solar minima and compare to ongoing work on Wind spacecraft in the ecliptic plane. We will discuss recent results on scaling laws and intermittency based on the use of Wavelet transforms on Ulysses density and magnetic field data from the URAP and the FGM experiments respectively. More specifically, we will compute spectra, structure functions and probability distribution functions.

ADAPTED SINGULAR VALUE DECOMPOSITION OF A SPECTRAL MATRIX FOR AN EXTENDED SOURCE: APPLICATION TO TYPE III RADIO BURSTS OBSERVED BY STEREO

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The S/WAVES experiment (on-board the both STEREO spacecraft) provides us measurements of three components of the electric field in a wide frequency range from 10 kHz up to 16MHz. Two point observations of type III radio bursts with all components of the electric field allow us detailed investigation of goniopolarimetric properties including estimation of an angular size and shape of a source region. The singular value decomposition (SVD) method for multi-component propagation analysis of electromagnetic plasma waves was originally used on a special form of a spectral wave matrix by Santolik et al. (2003, Radio Sci.). SVD determines the wave vector direction, ellipticity and directions of axes of the polarization ellipse and estimators of the planarity of polarization for one-point source only. We present a special adaptation for an extended source considering the STEREO mission.

RADIAL EVOLUTION OF THE ELECTRON VELOCITY DISTRIBUTION FUNCTION IN THE HELIOSPHERE: ROLE OF COLLISIONS

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The electron velocity distribution function has often been described as the superposition of an isotropic core, a moderately energetic and slightly anisotropic halo and a high energy field aligned beam. The relative weight of these components depends on the characteristics of the solar wind streams (fast and slow) and on the heliocentric distance. In this work we study the effects of electron-electron and electron-proton collisions in shaping the electron velocity distribution function and in constraining the temperature anisotropy naturally developed by adiabatic expansion. To this end we use a fully kinetic code which has been shown to be able to produce a transsonic wind. Consequences on the radial temperature and heat flux profiles will be discussed.

NONRESONANT ELECTROMAGNETIC INSTABILITIES IN SPACE PLASMAS

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In coronal outflows and solar winds, the presence of the interplanetary magnetic field and heat fluxes combined with jets and shock waves give rise to important thermal anisotropies and energetic counterstreaming motion of plasma shells. Such anisotropic structures of plasma quickly lead to the onset of the kinetic electromagnetic instabilities which are dependent solely on bulk properties of the plasma and not on resonant interaction with charged particles. These instabilities constrain the increase of velocity anisotropy explaining thus the observations, and they also provide a plausible mechanism for the origin of magnetic field fluctuations observed in interplanetary medium. By considering the interplay of the nonresonant electromagnetic instabilities general criteria for their existence are derived, and some applications for particular cases in space plasmas are proposed.

SOLAR WIND TURBULENCE: CASCADE, DISSIPATION AND HEATING

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In this paper we show that a direct evidence for the presence of an inertial energy cascade, the most characteristic signature of hydromagnetic turbulence (MHD), is observed in the solar wind. A Yaglom-like scaling relation has been found in the high-latitude data samples measured by the Ulysses spacecraft. Moreover, an analogous scaling law, suitable modified to take into account compressible fluctuations, has been observed in a much more extended fraction of the same data set. Thus, it seems that large scale density fluctuations, despite their low amplitude, play a major role in the basic scaling properties of turbulence. The presence of a nonlinear turbulent magnetohydrodynamic energy cascade provides a direct estimation of the turbulent energy transfer rate, which can contribute to the in situ heating of the wind. In particular, The compressive turbulent cascade seems to be able to supply the energy needed to account for the local heating of the non-adiabatic solar wind.

DISPERSIVE EFFECTS OF HALL ELECTRIC FIELD IN TURBULENCE

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A familiar feature of turbulence in a low collisionality turbulence is an increase in the electric field spectrum, relative to the magnetic field spectrum, at wavenumbers near the reciprocal of the ion inertial scale. For example, it is observed in the solar wind [1]. Here we examine this feature numerically, using a variety of simulations, including compressible Hall MHD, incompressible Hall MHD, and one-, two-, and three- dimensional cases [2,3]. A feature of this type is even found in a statistical Hall MHD model with no dissipation. This leads to the conclusion that the only requirement for obtaining this dispersive effect is the Hall term in the generalized Ohm's law [3]. Therefore this observation does not distinguish between whistler and kinetic Alfven waves, nor even between fluid and kinetic plasma models [4,5,6].

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ACCELERATION AND RESONANCE DETUNING IN NON-UNIFORMLY MOVING PLASMA

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Motion of charged particles in the magnetized plasma of the solar wind is strongly influenced by the properties of the underlying plasma. A well-known example is the acceleration of charged particles by the abrupt variations of plasma velocity and magnetic field in a shock-wave. In this contribution we analyze the influences of smoothly varying velocity disturbances. It is shown that they also can cause significant acceleration or deceleration provided that the flow is compressible or the magnetic field is small (i.e. the cyclotron frequency is less than the velocity gradient) in the acceleration region. In addition even in an incompressible flow and/or strong magnetic field the effect of the velocity disturbances manifests itself by detuning the frequency of cyclotron resonance and wave-resonances.

REDUCED SOLAR WIND WAVE AND TURBULENCE LEVELS IN THE CURRENT UNUSUAL MINIMUM

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It has recently been shown (Smith and Balogh 2008) that power levels in the high speed solar wind are significantly lower in the current solar minimum that the previous one. We extend this analysis to show that there is a persistent North/South asymmetry in power levels in the polar solar wind in both the previous and current minima, consistent with the known asymmetric heliospheric current sheet configuration over this time. In addition, we show that the reduced power levels during this minimum are frequency-dependent, and reach around 40% at high frequencies. We discuss possible causes of this dramatic change and what it can tell us about solar conditions. We also discuss the implications for cosmic ray transport, and whether these effects are potentially observable.

ORSZAG TANG VORTEX - KINETIC STUDY OF A TURBULENT PLASMA

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The kinetic evolution of the Orszag-Tang vortex is studied using collisionless hybrid simulations. In magnetohydrodynamics (MHD) this configuration leads rapidly to broadband turbulence. At large length scales, the hybrid simulations evolve very similarly to MHD, with magnetic power spectra displaying scaling similar to a Kolmorogov scaling of -5/3. At small scales, differences from MHD arise, as energy dissipates into heat almost exclusively through the magnetic field. The magnetic energy spectrum of the hybrid simulation shows a break where linear theory predicts that the Hall term in Ohm's law becomes significant, leading to dispersive kinetic Alfvén waves. A key result is that protons are heated preferentially in the plane perpendicular to the mean magnetic field, creating a proton temperature anisotropy of the type observed in the corona and solar wind. To examine possible causes for this anisotropic heating, the $k - \omega$ spectra are examined. There are no clear resonances at frequencies associated with cyclotron damping, ruling out cyclotron damping as a candidate for the heating. Furthermore, there are no easily discerned resonances at other frequencies associated with the dominant energies in the system.

DIAGNOSIS OF MAGNETIC STRUCTURES AND INTERMITTENCY IN SPACE PLASMA TURBULENCE USING THE METHOD OF SURROGATE DATA

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Several observations in space plasmas have reported the presence of coherent structures at different plasma scales. Structure formation is believed to be a direct consequence of nonlinear interactions between the plasma modes, which depend strongly on phase synchronization of those modes. Despite this important role of the phases in turbulence, very limited work has been however devoted to study the phases as a potential tracers of nonlinearities in comparison with the wealth of literature on power spectra of turbulence where phases are totally missed. We present a method based on surrogate data to systematically detect coherent structures in turbulent signals. The new method has been applied successfully to magnetosheath turbulence (Sahraoui, PRE, 2008), where the relationship between the identified phase coherence and intermittency (classically identified as non Gaussian tails of the PDFs) as well as the energy cascade has been studied. Here we review the main results obtained in that study and show further applications to small scale solar wind turbulence. Implications of the results on theoretical modelling of space turbulence (applicability of weak/wave turbulence, its validity limits and its connection to intermittency) will be discussed.

LANGMUIR WAVES STATISTICS AND TYPE III BURSTS OBSERVED BY WIND SPACECRAFT

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A beam-plasma system, produced by CMEs and flares, is unstable to the generation of Langmuir waves at the local plasma frequency or its harmonic. Radio observations of Langmuir waves in range ≈ 4 kHz $- 40$ kHz from the WAVES experiment onboarded the WIND spacecraft have been statistically analyzed. A subset of 10 events has been selected for this study. The background consisting of the thermal noise and the type III signal has been removed and the histogram of the remaining flux density spectra has been fitted by model distributions. We discuss the results of this analysis, in particular the comparison of the mean values of the Langmuir waves histograms with the type III bursts radio power emitted in the same time.

MODELING THE STRAHL IN THE SOLAR WIND USING CLUSTER/PEACE ELECTRON VELOCITY DISTRIBUTION FUNCTIONS

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We present a study of kinetic properties of the strahl electron velocity distribution functions (VDF's) in the solar wind. These are used to investigate the pitch-angle scattering and stability of the population to interactions with electromagnetic (whistler) fluctuations. The study is based on high time resolution data from the Cluster/PEACE electron spectrometer. Our study focuses on the mechanisms that control and regulate the pitch-angle and stability of strahl electrons in the solar wind; mechanisms that are not yet well understood. Various parameters are investigated such as the strahl-electron density, temperature anisotropy, and electron heat-flux. The goal is to check whether the strahl electrons are constrained by some instability (e.g., the whistler instability), or are maintained by other types of processes. The electron heat-flux and temperature anisotropy are determined by modeling the 3D-VDF's to a spectral spherical harmonic model from which the moments are obtained directly from the spectral coefficients.

3D HALL MHD MODELING OF SOLAR WIND PLASMA SPECTRA

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The solar wind is an excellent insitu laboratory for turbulence studies in that it comprises a multitude of spatial and temporal length scales associated with an admixture of waves, fluctuations, structures and nonlinear processes. Dynamical evolution of the multiple scales leads to a complex picture that we do not fully understand. These include spectral break that occurs near the proton gyro frequencies occurs in the vicinity of the inertial and dissipation ranges. The spectral cascades near the spectral break observe characteristically disparate power spectra. The nonlinear interactions leading to the onset of the spectral break continue to be disputed including others such as compressibility and orientation of turbulent fluctuations. Because of the multi scale evolutionary nature of collisionless plasma fluctuations, existing MHD theory and modeling lacks a fully self-consistent description of many observed solar wind phenomena. In the present work, we present fully self consistent 3D simulations of compressible Hall MHD solar wind plasma that describes physical processes responsible for the onset of the spectral break in the solar wind plasma. We also discuss compressibility and other nonlinear processes that are relevant to the solar wind heating. Our work is important particularly in understanding the role of wave and nonlinear cascades in the evolution of the solar wind, structure formation at the largest scales , cosmic ray scattering and energization, and energy transfer across many scales and the heating of the solar wind.

MULTI-DIMENSIONAL MHD SIMPLE WAVES AND THE DIVERGENCE WAVE

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In this paper we investigate the nature of multi-dimensional simple waves in MHD using Boillat's formalism. For simple wave solutions, all physical variables (the gas density, pressure, fluid velocity, entropy, and magnetic field induction in the MHD case) depend on a single phase function, which in turn depends on the three space and time variables. The simple wave ansatz and the MHD equations then require that the wave normal and the normal speed of the wave front depend only on the phase function. This leads to an implicit equation for the phase function, and a generalisation of the concept of a plane wave. We obtain examples of Alfven and magnetoacoustic simple waves. We also consider the form of the MHD equations of Powell et al. (1999) and Jahnhunen (2000) used in numerical MHD, which use an eight wave Riemann solver, in which the eighth wave is the divergence wave. The divergence wave is advected with the fluid and is associated with a non-zero divergence of B (which in the numerical code is generated by the numerical approximation scheme). We obtain examples of simple waves for the divergence mode. We suggest that the divergence mode solutions will provide an important test for numerical MHD codes.

SELF-CONSISTENT SIMULATIONS OF PLASMA-NEUTRAL IN A PARTIALLY IONIZED ASTROPHYSICAL TURBULENT PLASMA

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A local turbulence model is developed to study energy cascades in the heliosheath and interstellar medium (ISM) based on self-consistent two-dimensional fluid simulations. The model describes a partially ionized magnetofluid ISM that couples a neutral hydrogen fluid with a plasma primarily through charge-exchange interactions. Charge-exchange interactions are ubiquitous in warm ISM plasma, and the strength of the interaction depends largely on the relative speed between the plasma and the neutral fluid. Unlike small-length scale linear collisional dissipation in a single fluid, charge-exchange processes introduce channels that can be effective on a variety of length scales that depend on the neutral and plasma densities, temperature, relative velocities, charge-exchange cross section, and the characteristic length scales. We find, from scaling arguments and nonlinear coupled fluid simulations, that charge-exchange interactions modify spectral transfer associated with large-scale energy-containing eddies. Consequently, the warm ISM turbulent cascade rate prolongs spectral transfer among inertial range turbulent modes. Turbulent spectra associated with the neutral and plasma ISM fluids are therefore steeper than those predicted by Kolmogorov's phenomenology. Our work is important in the context of the global heliospheric ISM interaction, the energization and transport of cosmic rays, gamma-ray bursts, ISM density spectra, etc. Furthermore, the plasma-neutral coupling is crucial in understanding the energy dissipation mechanism in molecular clouds and star formation processes.

SHOCK GEOMETRY AND SPECTRAL BREAKS IN LARGE SEP EVENTS

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Gradual Solar energetic particle (SEP) events are now widely accepted to be due to CME-driven shocks. As a CME shock propagates out, particles are accelerated at the shock front diffusively. In many of these large SEP events, particle spectra exhibit double power law or exponential roll-over features, with the break energy or roll-over energy ordered by $(Q/A)^{\alpha}$, with Q the ion charge in e and A the ion mass in unit of proton mass m_p. Such a Q/A dependence of the spectral break reflects certain constrains of the underlying acceleration mechanism and provides a good opportunity to learn the acceleration process. Here we examine how the Q/A dependence may depend on shock geometry. We show that the range of α can be from $1/5$ for a quasi-perpendicular shock using the Non-Linear Guiding Center (NLGC) theory to 2 at a quasi-parallel shock with enhanced upstream Alfvén waves. Our results provide a possible way to remotely examine the geometry of a CME-driven shock when it is close to the Sun and most of the acceleration of high energy particles occurs.

STRUCTURE OF AN OBLIQUE MHD SHOCK IN RESPONSE TO UPSTREAM TURBULENCE

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An analytic model developed by Ao et. al. 2008 describes the interaction of turbulence with a thin shock. Simulations based on the analytic model show the effect of turbulence on the shock structure for both parallel and perpendicular MHD shocks by solving a modified Burgers' equation. To generalize our understanding of the shock-turbulence interaction, we solve the modified Burgers' equation for an oblique MHD shock. Starting with the classical ideal MHD Rankine-Hugoniot condition, we introduce a perturbed upstream and demonstrate the evolution of the oblique MHD shock structure. The effect of obliquity is also discussed.

WHISTLER WAVE CASCADES IN SOLAR WIND PLASMA

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Whistler waves are present in solar wind plasma turbulence. These waves possess turbulent fluctuations that are characterized typically by the frequency and length scales that are respectively bigger than ion gyro frequency and smaller than ion gyro radius. The electron inertial length is an intrinsic length scale in whistler wave turbulence that distinguishably divides the high frequency solar wind turbulent spectra into scales smaller and bigger than the electron inertial length. We present nonlinear three dimensional, time dependent, fluid simulations of whistler wave turbulence to investigate their role in solar wind plasma. Our simulations find that the dispersive whistler modes evolve entirely differently in the two regimes. While the dispersive whistler wave effects are stronger in the large scale regime, they do not influence the spectral cascades which are describable by a Kolmogorov-like $k^{-7/3}$ spectrum. By contrast, the small scale turbulent fluctuations exhibit a Navier-Stokes like evolution where characteristic turbulent eddies exhibit a typical $k^{-5/3}$ hydrodynamic turbulent spectrum. By virtue of equipartition between the wave velocity and magnetic fields, we quantify the role of whistler waves in the solar wind plasma fluctuations.

WHY TEMPERATURE AND VELOCITY HAVE DIFFERENT RELATIONSHIP IN THE SOLAR WIND AND IN INTERPLANETARY CORONAL MASS EJECTIONS ?

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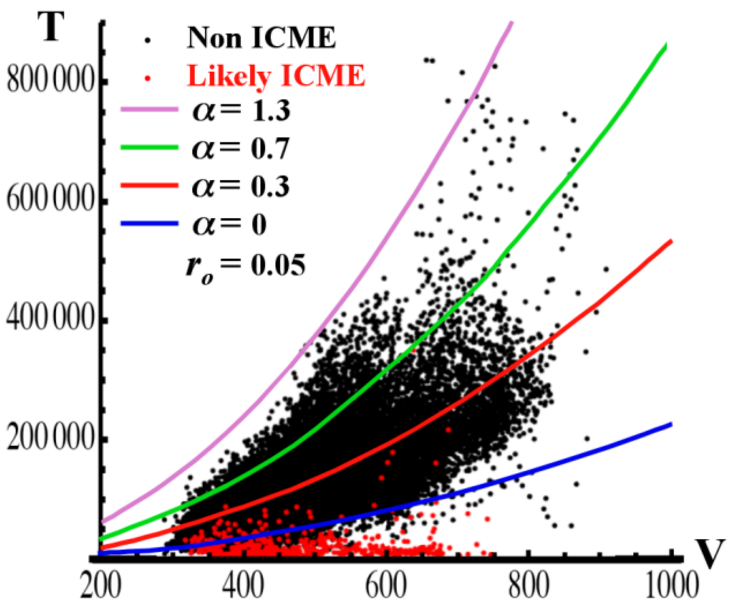
In situ observations of the solar wind (SW) show a temperature increasing with the wind speed, while such dependence is not observed in interplanetary coronal mass ejections (ICMEs). The aim of this paper is to understand the main origin of this correlation in the SW and its absence in ICMEs. For that purpose both the internal energy and momentum equations are solved analytically with various approximations. The internal energy equation does not provide a strong link between temperature and velocity, but the momentum equation does. Indeed, the observed correlation in the open magnetic field configuration of the SW is the result of its acceleration and heating close to the Sun. In contrast, the magnetic configuration of ICMEs is closed, and moreover the momentum equation is dominated by magnetic forces. It implies no significant correlation between temperature and velocity, as observed.

Figure caption: Comparison of the theoretical results with those of Matthaeus, Elliott, and McComas (2006). The data points are reproduced from their paper. T is the proton temperature and U is the velocity; both are measured by the spacecraft ACE. The red points are for data which satisfy three ICME criteria. A larger set of data points, called "possible ICMEs" are removed from the measurement series giving the non ICME data points which are from the SW. α is a dimensionless constant defining the magnitude of the thermal flux, and r_o is the distance from the Sun, in AU, where the polytropic law is supposed to begin.



Session 3:
Slow Wind Streams, CMEs & 3D Structure of the Corona and Heliosphere

THE DIVERGENT ORIGINS OF THE SLOW SOLAR WIND

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We suggest that the slow solar wind has three distinct sources: (1) rapidly diverging open field lines from small coronal holes with very strong footpoint fields; (2) rapidly diverging open field lines at the boundaries of large, weak-field coronal holes, in particular the polar holes; and (3) helmet streamers, which supply material to the heliospheric plasma sheet and its immediate vicinity by undergoing interchange reconnection with the surrounding open flux. We describe recent STEREO observations which indicate that many streamer "blobs" have the form of helical flux ropes. However, we also argue that the bulk of the slow wind comes not from streamers but from open field regions, and that it is the location and strength of the coronal heating that differentiates fast and slow wind. When the field diverges rapidly with height, most of the energy is deposited close to the coronal base and conducted down into the transition region, driving a large mass flux; the wind undergoes less net acceleration because the outer corona remains relatively cool. Numerical calculations demonstrate that very strong low-coronal heating, such as occurs in active region holes, gives rise to slow wind with high oxygen freeze-in temperatures, in agreement with in situ observations.

COMPARING THE OBSERVED AND MODELED GLOBAL HELIOSPHERIC MAGNETIC FLUX

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A number of papers have reported recently (e.g., Owens and Crooker [2006], Riley [2007], and Svalgaard and Cliver [2007]) that there are extended intervals over the solar cycle where significant discrepancies exist between the observed open flux and that determined from coronal models. One explanation for the source of these discrepancies (Owens and Crooker [2006]) is that it results from CMEs that have yet to disconnect from the Sun but whose closed fluxes, as measured by in situ spacecraft, are nonetheless included in the open flux estimates. This occurs because the open and closed field lines are not readily distinguishable in the data. In this paper, a comparison is made between the total global heliospheric magnetic flux derived from in situ interplanetary magnetic field observations from spacecraft located both in and out of the ecliptic plane. Specifically, the total (unsigned) flux obtained using ULYSSES spacecraft observations is compared to that determined from in situ measurements made near Earth (e.g., WIND and ACE) from 1990 to present. These results are then compared to the fluxes determined from the Potential Field Source Surface (PFSS) model using photospheric magnetic field Carrington maps from both the National Solar Observatory (NSO) at Kitt Peak and the Mount Wilson (MWO) Solar Observatory as its input. We find that (1) the open flux values obtained using MWO and NSO data in the PFSS model generally agree very well with each other, (2) there are indeed periods during which significant discrepancies exist between the open flux estimates derived from the model and from spacecraft measurements, which are consistent with findings reported by previous authors, and (3) significant discrepancies are found between the open flux estimates using observations from spacecraft located near Earth and ULYSSES.

COMPARING WHITE-LIGHT AND IN-SITU OBSERVATIONS OF SOLAR WIND TRANSIENTS

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White-light imagers provide detailed observations of coronal density variations from the Sun to Earth-like distances. At least two classes of transients are monitored by these imaging instruments; large-scale Coronal Mass Ejections (CMEs) and small-scale transients which are released intermittently in the slow solar wind. The constellation of spacecraft located between 0.3 and 1 AU can be used to compare directly in-situ observations of solar wind transients with their white-light signatures and allows a detailed analysis of the kinematic and dynamic evolution of solar wind transients. A review will be presented of studies which have combined imaging [SECCHI (STEREO), SMEI (Coriolis), SoHO coronagraphs] and in-situ measurements [STEREO, ACE, WIND, Venus Express, MESSENGER, Ulysses]. We present descriptions of the techniques employed to estimate the solar origin, acceleration, trajectory, radial speed and expansion rate of out-flowing CMEs using white-light images. The intermittent release of small-scale transients in the slow solar wind is also reviewed using the latest STEREO observations, these observations provide a diagnostic of the origin and topological evolution of these transients in the solar wind.

EXPANSION OF MAGNETIC CLOUDS FOR DIFFERENT SOLAR WIND CONDITIONS

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From over two decades, several properties of magnetic clouds (MCs) have been recognized and distinguished from those associated with the quasi-stationary parkerian solar wind or from other non-cloud transient structures. In particular, in contrast with the parkerian solar wind, MCs have a significant expansion along the radial direction from the Sun. Several previous studies suggest that the increase of their size is self-similar. Recently, Demoulin & Dasso [A&A, in press] have shown theoretical reasons in favor of a nearly isotropic expansion, mainly driven by (a) the global decrease of the surrounding solar wind pressure with the distance to the Sun and (b) the stretching of their main axes (e.g., caused because the feet of the flux rope can be anchored to the Sun during their propagation). These authors also quantified a normalized expansion rate for clouds for typical solar wind conditions. The main aim of this work is to analyze MCs with significantly different expansion rates, focussing on the reasons for finding these differences. In particular we discuss the characteristics of events that evolve in different environments, in a 'clean' solar wind or in a perturbed one (e.g., pushed by behind by another transient event), and quantify their expansion rates.

THE APPARENT LAYERED STRUCTURE OF THE HELIOSPHERIC CURRENT SHEET: MULTI-SPACECRAFT OBSERVATIONS

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Multiple current sheet crossings are ubiquitous features of the solar wind associated with high-beta plasma sheets, notably during the passage of the heliospheric current sheet (HCS). As the HCS is being convected past near Earth, we attempt to resolve spatial scales and temporal variations of the apparent layered structure of the HCS, including adjacent large scale field reversals. We use several spacecraft for good spatial and cross-scale coverage, spanning 550 RE across and 900 RE along the Sun-Earth line: STEREO, ACE and Cluster. The multi-spacecraft magnetic and plasma observations within the leading edge of the sector boundary are consistent with (i) a broad multi-layered structure; (ii) occasional non-planar structures and Alfvénic fluctuations; (iii) various stages of transient outflowing loops formed by interchange reconnection. By comparison of the observations at each spacecraft, we obtain a synthesis of the evolution between the patterns of loops, and hence of the transient outflow evolution along the sector boundary. In particular, we present circumstantial evidence that a heat flux dropout, traditionally signaling disconnection, can arise from interchange reconnection and scattering. Moreover, the inter-spacecraft comparison eliminates ambiguities between interpretations of electron counterstreaming. Overall, the sector boundary layer remains, locally, a steady structure as it is convected in the solar wind across a radial heliospheric distance of 560-580 RE. However, non-planar structures on the Cluster spatial scale indicate that on the broader scale we are not following the evolution of single loops but more likely a bunch of loops with variable properties.

UVCS SPECTROSCOPIC RESULTS, TEMPERATURE, VELOCITY AND 3D STRUCTURE OF CMES

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The UltraViolet Coronagraph Spectrometer (UVCS) onboard SoHO has detected for the first time spectra of Coronal Mass Ejections (CME) in the solar corona. Since 1996 almost 800 CME have been detected at several heliocentric distances. UV spectra provide diagnostic of many physical and dynamic properties such as density, temperature, ionization stage, bulk speed, line-of-sight speed etc etc. These diagnostics have been very important to understand the the nature of CMEs and in some case to disentangle the projection effects of white light images from the 3D structure. Thus, shocks during halo events or bulk expansion of the ejected material, current sheet formation after the CME, streamer blowout and many others aspects related to CME have been studied.

An overview of the results so far obtained from UV spectra of CMEs will be given along with requirements for future observations aimed to solve some of the open questions.

WHERE IS THE EXPECTED IMPRINT OF FLUX ROPE GEOMETRY ON SUPRATHERMAL ELECTRONS IN MAGNETIC CLOUDS?

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Magnetic clouds are a subset of interplanetary coronal mass ejections characterised by a smooth rotation in the magnetic field direction, interpreted and modelled as a signature of a magnetic flux rope. Suprathermal electron observations indicate that one or both ends of the flux rope remain connected to the Sun as the magnetic cloud moves out through the heliosphere. With distance from the flux rope axis out towards the flux rope edge, the magnetic field becomes more tightly wound about the axis, meaning electrons must traverse longer magnetic field lines to reach a heliospheric observer. The increased time of flight should result in more pitch-angle scattering, thus the suprathermal electron pitch-angle distributions should be systematically broader at the edges of the flux rope than at the axis. We model this effect with an analytical magnetic flux rope model and a numerical scheme for suprathermal electron pitch-angle scattering and find that the signature of a magnetic flux rope should be readily observable with the pitch-angle resolution of ACE's SWEPAM instrument. We are unable, however, to find this signature in any magnetic cloud observations and speculate on the reasons why.

THE THREE-DIMENSIONAL STRUCTURE OF THE INNER HELIOSPHERE

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The inner heliosphere, which can be defined as the region of space beyond the solar corona and out to perhaps 5 AU, is highly structured on all observable scales. In this talk, I will review our current knowledge of the three-dimensional structure of the quasi-steady, large-scale inner heliosphere. This knowledge is based on the interpretation of a wide array of remote and in situ measurements, in conjunction with sophisticated numerical models. Observations by the Ulysses spacecraft, for example, have provided an amazing and unique set of measurements more than 18 years, and observations by the STEREO spacecraft promise no less. Global MHD models of the solar corona and heliosphere are maturing to the point that a wide range of measurements can now be reproduced with reasonable fidelity. Corotating interaction regions (CIRs) dominate the large-scale, ambient structure of the inner heliosphere. They result from quasi-stationary conditions at the Sun, whereby solar rotation leads to parcels of plasma with different plasma and magnetic properties becoming radially aligned. This interaction is one of the principal global dynamic processes that shape the structure of the interplanetary medium. I will review the processes that lead to the formation and evolution of CIRs, describe past and present modeling work aimed at understanding their properties, and compare and contrast their characteristics at various epochs of the solar cycle. I will also highlight the properties of the current solar minimum, which is, thus far, quite distinct from any in recent history. I will close by posing some important and as yet unresolved questions related to heliospheric structure and attempt to anticipate the path that research may take in the future.

RELATING OBSERVED EMISSION FEATURES OF CMES TO MAGNETIC FIELD EVOLUTION

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The magnetohydrodynamic (MHD) equations are frequently used to investigate coronal mass ejections (CMEs), eruptive prominences, and solar flares. The proposed mechanisms responsible for these phenomena are under still under vigorous debate. Because most MHD models use relatively simple energy equations, the debate between theorists often centers on the interpretation and comparison of magnetic field evolution in the models with corresponding features observed in emission. On the other hand, observers often look at emission images and try to deduce what magnetic evolution is occurring.

We have developed MHD models that include energy transport (radiative losses, anisotropic thermal conduction, and coronal heating) in the transition region and solar corona. This more accurate representation of energy flow allows us to compute simulated EUV and X-ray emission and compare directly with observations. In this paper we will show examples of this modeling approach for specific CME events and describe the magnetic field evolution associated with commonly observed emission features such as dimming regions and postflare loops.

Work supported by NASA and the Center for Integrated Space Weather Modeling (an NSF Science and Technology Center).

SOLAR-TERRESTRIAL SIMULATIONS OF CORONAL MASS EJECTIONS WITH A REALISTIC INITIATION MECHANISM

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(2) Center for Space Environment Modeling - University of Michigan, USA
(3) Centrum voor Plasma Astrofysica - KU Leuven, Belgium

Most simulations of coronal mass ejections (CMEs) to date either focus on the interplanetary propagation of a giant plasma "blob" without paying too much attention to its solar origin and formation or focus on the complex evolution of the coronal magnetic field due to (sub-)photospheric motions which result in an eruption. Here, we present global simulations of CMEs where coronal motions are used to produce a realistic evolution of the coronal magnetic field and cause an eruption. We focus on active region 10069, which produced a number of eruptions in late August 2002, including the August 24, 2002 CME, a fast ($\sim$ 2000 km s^{-1}) eruption originating from W81, as well as a slower eruption on August 22, 2002, both of which were associated with large proton events. Using a three-dimensional magneto-hydrodynamic simulation of these ejections with the Space Weather Modeling Framework (SWMF), we show how a realistic initiation mechanism enables us to study the deflection of the CME in the corona and in the heliosphere. Reconnection of the erupting magnetic field with that of neighboring streamers and active regions modify the solar connectivity of the field lines connecting to Earth and change the expected solar energetic particle fluxes. We also compare LASCO images of the ejections with simulated line-of-sight images and discuss how the SECCHI suite onboard STEREO will help us to better constrain models of CME propagation and identify transient structures which may enhance or modify SEP flux at L1.

SOHO/UVCS DETECTION OF TURBULENCE AND INTERMITTENT EVENTS IN A CORONAL MASS EJECTION

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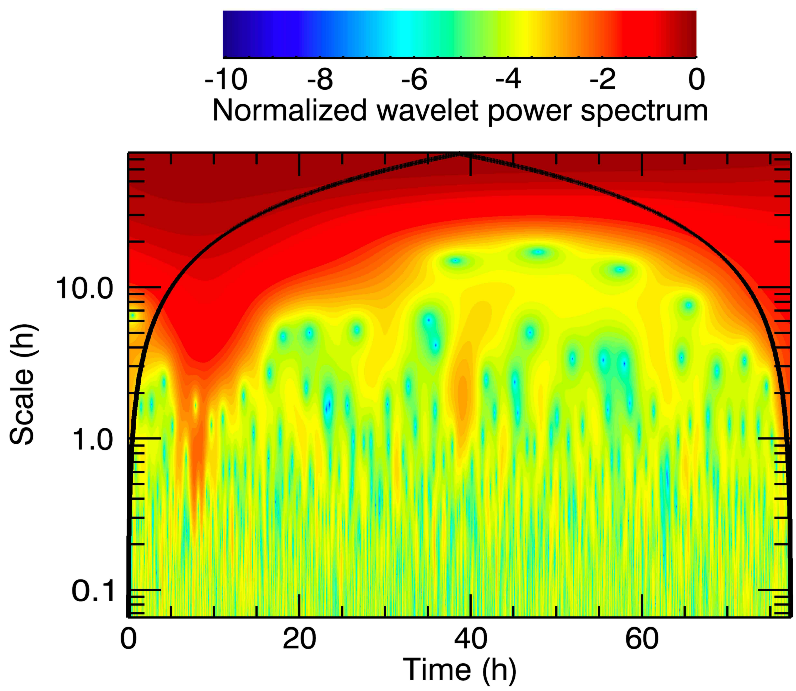
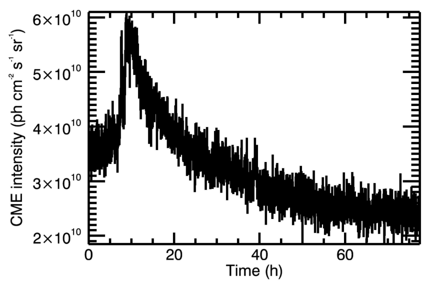
The wavelet analysis is applied for the first time to Coronal Mass Ejection (CME) data. In this work, we present the results obtained by investigating with the wavelet technique the time series of the Lyα 1215.67 Å intensity of the CME observed with the SOHO/UltraViolet Coronagraph Spectrometer (UVCS) in 2006 December 24, in the South polar coronal hole at an heliocentric distance of 1.8 solar radii. This temporal analysis reveals the existence of large-scale density fluctuations of periods from a few hours to a few days, during the whole observation time. However, during the CME, the power spectrum becomes less steep with a spectral slope about 1.7, typical of the turbulent regime, whilst prior to the CME and in the recovery phase the spectral slope is about 2, or more, as found in the coronal solar wind regions. This is evidence for the turbulent character of CME plasma. A new fractal technique, based on the phase coherence and wavelet analyses and developed in order to localize coherent events in a long time series, shows a high degree of phase synchronization of the coronal plasma of the mass ejection during the CME, at temporal scales of about the CME duration. Finally, we analyze the intermittent character of the CME with the Local Intermittent Measure (LIM), which allows us to identify intermittent phenomena at different scales. This last part of the analysis reveals the existence of strong intermittent events during the CME, which may be representative of recursive reconnection events occurring at different scales during/after the CME release. Hence, this study provides the first evidence not only for the development of turbulence in coronal mass ejections, but also for the intermittent and coherent character of the plasma density fluctuations localized in CMEs. These results are particularly important to advance in the understanding of physical solar phenomena, such as the CME generation, the SEP acceleration in CME shocks and the coronal plasma heating.





INTERACTION OF ICMES WITH THE SOLAR WIND

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Interplanetary Coronal Mass Ejections (ICMEs) are formed of plasma and magnetic field launched from the Sun typically at faster speed than the Solar Wind (SW). These coherent magnetic structures, frequently formed by a flux rope, interact strongly with the SW. Such interaction is reviewed by comparing the results obtained from in situ observations and numerical simulations. Like fast ships in the sea, fast ICMEs drive an extended shock in front. However, their interaction with the SW is much more complex than that of the ship analogy. For example, as they expand in all directions while traveling away from the Sun, a sheath of SW plasma and magnetic field accumulates in front, which partially reconnects with the ICME magnetic field. Furthermore, not only ICMEs have a profound impact on the heliosphere, but the type of SW encountered by an ICME has an important impact on its evolution (e.g. increase of mass, global deceleration, lost of magnetic flux, distortion of the configuration).

DETERMINATION OF CME 3D TRAJECTORIES FROM STEREOSCOPIC ANALYSIS OF STEREO/SECCHI CORONAGRAPH AND HELIOPSHERIC IMAGER DATA

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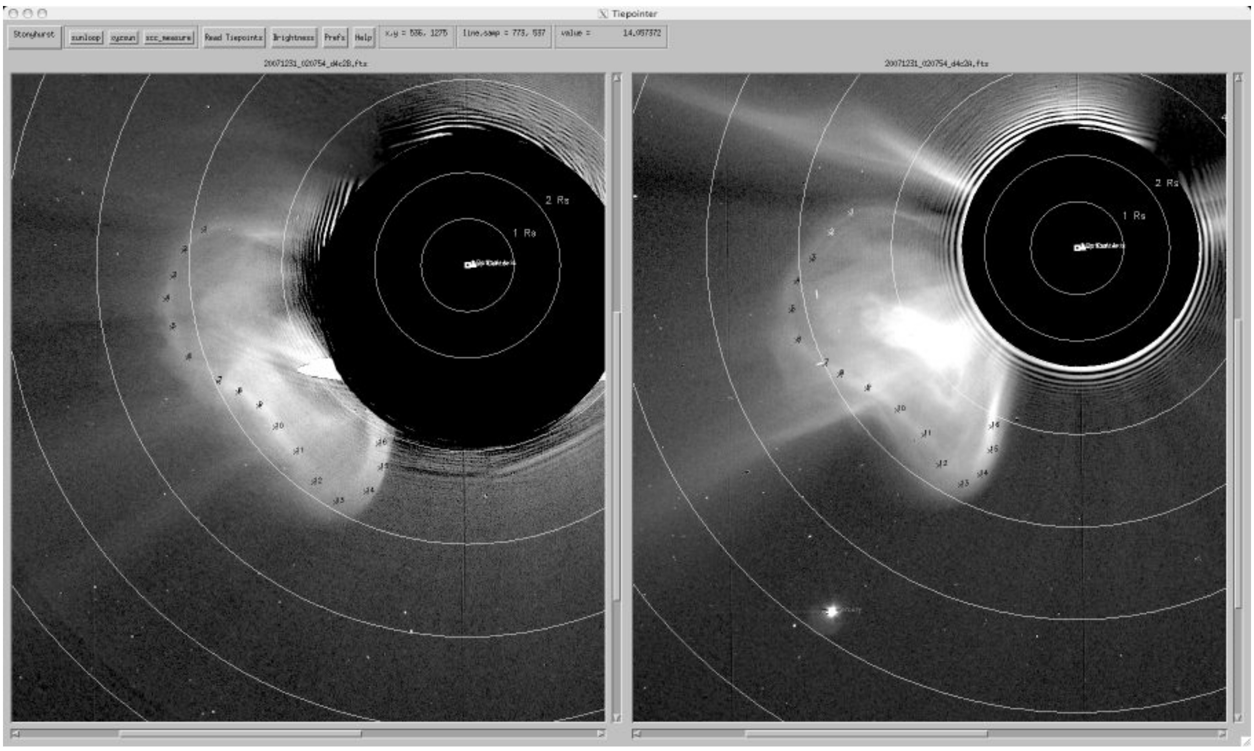
We present results demonstrating that the 3D (velocity and direction) trajectory of a CME can be determined from stereoscopic analysis of a series of simultaneous coronagraph image pairs from the STEREO A and B spacecraft. It has been demonstrated that stereoscopic analysis (aka triangulation) of bright coronal features such as loops can be used to determine their 3D location and geometry. In these cases, the emission from the feature comes from relatively localized volumes. This is not the case for bright features in white light images, which may capture scattered light from an extended volume. Even though line of sight (LOS) effects dominate the observed structure seen in white light coronagraph images of STEREO CMEs, we find that by "tiepointing" the bright leading edge of the CME in both images of a stereo pair, we are able to determine the 3D trajectory using stereoscopy. This technique has been validated previously using synthetic white light stereoscopic image pairs. Here, to validate our results, we compare our 3D trajectories with CME trajectories determined by a more sophisticated forward-modeling method developed by Thernisien et al (Ap. J. 2006). In addition, we compare 3D trajectory results from the coronagraph dte with trajectories determined from STEREO's heliospheric imagers using analysis techniques developed by Sheeley.



Posters of session 3

DYNAMICS OF CMES AND EVOLUTION OF CME MAGNETIC FIELDS IN INTERPLANETARY SPACE

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Coronal mass ejections (CMEs) constitute an important class of solar wind (SW) structures, having practical implications for geomagnetic conditions. With the new SECCHI/STEREO observations, it is now possible to observe CME trajectories in interplanetary space. This allows direct comparison of CME models with CME data over a much wider region in space than has been possible. Among the existing CME models, the erupting flux rope model (FRM) of Chen (1996) is the best tested model. It has been extensively shown to be able to replicate observed CME dynamics extending to the SECCHI HI1 field of view (100 Rs) (Kunkel and Chen 2009). Of the physical CME parameters, the strength and evolution of CME magnetic fields have not been accessible to direct measurement. In a theory-data comparison paper, however, Krall et al. (2006) showed that the FRM solution that best fit the observed halo CME data also yielded a flux rope whose magnetic field at 1 AU was in reasonable agreement with that of a magnetic cloud detected by the ACE spacecraft. This suggests that by fitting observed CME trajectories, the FRM is able to correctly predict magnetic cloud fields at 1 AU. In this talk, I will discuss a systematic study of this possibility. The talk will show in detail how the magnetic field of a CME evolves through interplanetary space, emphasizing the quantitative relationship between the CME trajectory and the evolution of the CME magnetic field. The theory will be applied to CME dynamics observed by SECCHI coronagraphs and the magnetic fields of associated magnetic clouds observed by instruments at 1 AU. The discussion will focus on a physical understanding that can be used to interpret observational data and numerical results of simulation models of CMEs.

Chen, J. 1996, JGR, 338, 453.
Krall, J., et al. 2006, ApJ, 642, 541.
Kunkel, V., and Chen, J. 2009, in preparation.

A CME-ICME STUDY USING DATA FROM SOHO AND ULYSSES

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We analyze the CME onset, its travel in space and the ICME characteristics, using data from SOHO, Ulysses and other satellites as well as ground based observations. The active region AR9845 gave a CME (N14W23) on 2 March 2002, 21:30 UT, originating from a flare started at 20:10 UT. The ejected mass from the Sun was 1.1e+15 g and the linear velocity was 465 km/s. The CME was orientated toward Ulysses position, which traveled above the solar pole at that time. Ulysses registered an ICME on 14 March 2002. AR9845 passed at the solar central meridian on 1 March 2002. On 2 March this region developed in a beta-gamma type, from a beta type that had in a previous day. More flares occurred in this day in AR9845, but only one gave a CME. Before this flare-CME onset, bright loops oscillating were reveled by EIT observations. We analyze the 3D coronal magnetic field extrapolations to understand the magnetic loops behavior during these explosive events.

A POSSIBLE DISSIPATION MECHANISM IN THE FRONT OF A SHOCK WAVE EXCITED AHEAD OF A CORONAL MASS EJECTION

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It was shown in [Eselevich, M. and V., GRL, 35, L22105, 2008] that shock wave formation is observed in front of a coronal mass ejection moving at a higher velocity than the local fast-mode MHD velocity, relative to the surrounding coronal plasma. Further studies, the results of which are presented in this work, show, that at $R < 15R_\odot$ from the Sun's center, the front width of such a shock wave is of the order of the free path relative to paired proton-proton collisions. This means that, at these distances, the energy dissipation mechanism in the shock front is collisional.

ON SHOCK WAVE FORMATION IN FRONT OF A CORONAL MASS EJECTION MOVING AT A HIGHER-THAN-CRITICAL VELOCITY

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The approach developed in [Eselevich, M. and V., GRL, 35, L22105, 2008] served as a context in which to examine the possibility of shock wave front registration based on LASCO-C2,C3/SOHO coronagraph data. Two methods were used to prove the fact of shock wave formation in front of a coronal mass ejection (CME): 1. Analysis of the formation phase of the disturbed region in front of a CME in the reference frame of the CME frontal structure; 2. Inspection of the disturbed region structure depending on CME speed. It was shown that there is a disturbed region extending along the CME propagation direction in front of a coronal mass ejection when the ejection's velocity u is lower than the critical velocity u_C relative to the surrounding coronal plasma. The time-difference brightness (plasma density) in the disturbed region smoothly decreases over large distances in front of the CME. A discontinuity forms in the radial distributions of the difference brightness in the frontal part of the disturbed region, at $u > u_C$. Since the u_C value is close to the local fast-mode MHD velocity the formation of such a discontinuity when u_C is exceeded may be identified with shock wave formation.

DETERMINATION OF TRUE GEOMETRIC AND KINEMATIC PARAMETERS OF CORONAL MASS EJECTIONS WITH THE USE OF STEREO SPACECRAFTS DATA

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It is well known that observation of coronal mass ejections (CME) in the coronagraph's field of view allows only their apparent characteristics to be determine, which may differ significantly from the true CME parameters, because of projection effects. A method for determining the true geometric and kinematical parameters of coronal mass ejections using simultaneous observations of CMEs by the STEREO A and B spacecraft has been proposed. These parameters include the CME direction, velocity and acceleration along its axis or any other direction, CME angular sizes, and position of the CME front. These parameters were determined at different time moments. The method rests on the assumption that the CME shape may be described by one of several varieties of the cone "ice-cream model". In each particular case, the specific type of the model hase been chosen on the basis of STEREO A and B image analysis. Relations between the apparent and the true CME parameters have been obtained for each of the three CME models, in the special plane determined for each spacecraft. These relations form a system of trigonometric equations; its solution enables the required CME characteristics to be found. The proposed method has been tested on several CMEs. Apparent CME parameters were determined by observation in the field of view of the COR1 coronagraphs. The accuracy of the method was estimated qualitatively by comparing the apparent vs. obtained CME velocities, acceleration, angular sizes, as well as by comparing the CME motion direction to the locations of the CME-related activity (flares, eruptive filaments (prominences)) on the visible solar disc.

THREE-DIMENSIONAL MAGNETOHYDRODYNAMIC (MHD) MODELING OF THE SOLAR WIND STRUCTURES ASSOCIATED WITH CORONAL MASS EJECTIONS

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(2) STEL, Nagoya University

A three-dimensional magnetohydrodynamic (MHD) simulation is performed to reconstruct the interplanetary propagation of a coronal mass ejection (CME) occurred on 13 December 2006. Spheromak-type magnetic field is superposed on a realistic ambient solar wind to reproduce the large-scale interplanetary magnetic field (IMF) associated with the CME. Here we show that westward and southward directed spheromak CME as observed by coronagraph reasonably reproduces the magnetic cloud, interplanetary shock, and sheath profiles as observed by in-situ spacecraft. We suggest that the dynamic solar wind model developed in this study is topologically complex enough to be consistent with in-situ observations. Also, we report some initial results of a dinamic MHD tomography using the MHD simulation and IPS observations.

ON THE MODEL OF THE GLOBAL HELIOSPHERIC CURRENT SHEET WITH THE FINITE THICKNESS AND ALL THREE COMPONENTS OF THE MAGNETIC FIELD

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The new model of the global heliospheric current sheet is suggested as the generalization of the well-known model of the infinitely thin tilted current sheet. In our model the current sheet has the finite normal dimension and all three components of the magnetic field. The normal to the current sheet magnetic field component is due to the nonstationarity of the radial magnetic field on the source surface of the heliospheric magnetic field. The parametrization of the model is based on the calculation of the radial magnetic field on the above surface in the potential approximation (Wilcox Solar Observatory model).

The model can be used in studying the small-scale structure of the magnetic field and solar wind characteristics near the current sheets and also in modeling the cosmic ray behavior in the heliosphere.

STEREO AND ACE OBSERVATIONS OF ENERGETIC PARTICLES FROM COROTATING INTERACTION REGIONS

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Since early 2007, significant particle enhancements due to corotating interaction regions (CIRs) have regularly appeared at 1 AU without any appreciable contamination from solar energetic particles. As of early 2009, the prevalence of CIRs seems to have diminished (as is typical at solar minimum) as the maximum speed of the high speed solar wind streams in the ecliptic decreased along with the tilt of the heliospheric current sheet. Observations of CIR time profiles from the two STEREO spacecraft, now more than 90 degrees apart in longitude, show delays between the Behind and Ahead spacecraft that are often roughly as expected from the corotation time lag. However, in many cases different features seen at Ahead and Behind may suggest that transient disturbances in the solar wind alter connection to or transport from the shock, or that temporal changes occur in the CIR shock itself.

Using data from the LET and the SIT instruments on STEREO along with measurements from ULEIS and SIS on ACE, we present observations of H and He spectra, anisotropies, and time profiles for CIR events of 2007-2009 at energies from about 0.5 to 10 MeV/nucleon. In particular, we examine the evolution of the time profiles with spacecraft separation in longitude, radius, and heliographic latitude, and investigate the dependence of the timing differences on the location of solar and heliospheric structures such as the heliospheric current sheet and coronal hole boundaries.

This work was supported by NASA grants NAS5-03131 and NNX08AI11G.

MULTIPOINT ANALYSIS OF THE THREE-DIMENSIONAL STRUCTURE OF INTERPLANETARY CORONAL MASS EJECTIONS

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(2)NOAA/SWPC
(3)UC Berkeley

Recent opportunity to analyze multipoint solar wind IMF, plasma, and composition measurements of large-scale transients has been provided by the STEREO mission. To date, most studies have used cylindrically symmetric, force-free flux rope models to invert single spacecraft magnetic cloud observations within interplanetary coronal mass ejections. Composition measurements within ICMEs have provided information about the solar source region, but single track observations have made interpretation difficult. We analyze two STEREO events May 22, 2007 and November 19, 2007 when the STEREO spacecraft were separated by 9°and 18°, respectively. Using a combination of non-force-free multispacecraft modeling together with a spatial mapping technique, we put plasma composition in context with the ICME structure. Simultaneous modeling of multipoint observations at the twin STEREO spacecraft along with ACE show that magnetic clouds are non-cylindrically symmetric flux ropes that bend along their axial field direction and that have a composition changes associated with the different magnetic field sub-structures interior to the ICME.

CMES AS A SHOCK STRUCTURE

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(1) Escuela Superior de Ingeniería Mecánica y Eléctrica, IPN
(2) Escuela Superior de Física y Matemáticas, IPN

Interplanetary shocks are associated to approximately one third of the CMEs detected in the interplanetary medium. Even though they have been associated to fast CMEs ($V > 1000$ km/s) it has been shown that some slow CMEs ($V \sim 300$ km/s) presented shocks at 1 AU. The structure of the features observed in coronagraph images can be hardly compared to the ones detected beyond the coronagraph field of view, where the shock is clearly identify. For a few cases, the shock in front of the CME has been distinguish in white light images, but, is there a real visual difference between the CME itself and the considered shock? In this work we compare the optical characteristics of CMEs and some hydrodynamic parameters of ICMEs to show that the feature observed in white light images can be considered as a working surface (a shock structure).

CONTRAST OF CORONAL HOLES AND PARAMETERS OF QUIET SOLAR WIND

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Pushkov Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation, Russian Academy of Sciences (IZMIRAN)

It is shown that the contrast of coronal holes, just as their size, determines the velocity of the solar wind streams. More than 400 SOHO measurements in the 284 A channel have been analyzed. The time interval under examination covers about 1500 days in the declining phase of cycle 23. All coronal holes recorded for this interval in the absence of coronal mass ejections have been studied. The comparison with some other parameters (e.g. density, temperature, magnetic field) was carried out without using any theoretical assumptions. The correlations are rather high (0.70-0.89), especially during the periods of moderate activity, and could be used for everyday forecast. Polar and equatorial CH were studied separately.

RELATING OBSERVATIONS OF SOLAR WIND PLASMA NEAR EARTH TO OBSERVATIONS OF SOLAR WIND PLASMA LEAVING THE SOLAR CORONA

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The topic of how and where the slow solar wind originates is becoming an area of lively debate (it being widely accepted that coronal hole outflows become the fast solar wind). Early Hinode results [e.g. Sakao et al., 2007] have shown areas of steady plasma flow away from the solar surface at the edge of a solar active region which have been interpreted as being on open field lines and hence able to escape and form part of the solar wind. This hypothesis remains controversial, and we will seek to test it by identifying situations where we can make a convincing one-to-one correspondence between similar solar outflows and solar wind flows seen in interplanetary space. We will outline and discuss a candidate event and consider what it tells us about the cause of these outflows and of acceleration to solar wind speeds.

CORONAL AND INTERPLANETARY STRUCTURES ASSOCIATED WITH INTERPLANETARY TYPE III BURSTS

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(2) Institut d'Astrophysique Spatiale Orsay, France
(3) Interferometris, Inc, Herndon, VA

This presentation pursues former studies of coronal structures that are associated with interplanetary type III bursts by taking advantage of the new performances of SECCHI/STEREO. Radio imaging observations show that electron beams, which are accelerated in the same active region and which produce type III emissions near the same time, can be injected along distinct diverging magnetic field structures. These structures remain well defined and collimated up to distances of at least 15 Rs. In the low corona, these thin streamers spread rapidly then reconverge and finally merge in the same plasma sheet which can be traced up to 0.25 AU. Inhomogeneities travel along these structures with velocities ranging between 180-350 km/s, typical of slow solar wind. These results are related to those obtained formerly by Buttighoffer (1998) who identified, at 1AU and beyond, plasma structures in which are excited the Langmuir waves associated with local type III bursts. The solar wind velocity measured inside these structures is small ranging, between 320 and 480km/s. Finally the observations are compared with open field lines derived from PFSS models. We discuss the implications of these results.

STEREO QUADRATURE OBSERVATION OF THE NOVEMBER 2-8, 2008 POLAR CROWN FILAMENT ERUPTION, CORONAL MASS EJECTION AND MAGNETIC CLOUD

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We make use of the ∼90 degree angular separation between the two STEREO spacecraft to analyze the filament eruption, coronal mass ejection (CME) and magnetic cloud chain of events of November 2-8, 2008.

A high-latitude prominence activation at the western limb was observed by STEREO-B (STB) EUVI 304 Å at approximately 16 UT on November 1, 2008, followed by a prominence eruption early 2 November. STEREO-A (STA) observed the prominence as a large polar crown filament.

At 01:05 UT, a slow CME (denoted CME1) was seen by the STB COR1 coronagraph, propagating initially clearly northward from the equator, consistent with the prominence eruption EUV observations. However, the CME was quickly deflected towards the equator while propagating further outward. At 23:01 UT, the front of a second, slightly faster, CME (denoted CME2) was observed by STB COR1. The eruption was possibly related to a B-class X-ray flare occurring at 20:17 UT in AR 11007. CME2 was also launched northward from the equator, but unlike CME1, it was not significantly deflected toward the equator.

The Heliospheric Imager HI-1 of STB observed CME2 to propagate above CME1. While the two CMEs did not seem to interact significantly, CME2 seemed to push CME1 further equatorward. STA/HI-1 observed only CME2, indicating that it was released and propagated eastward as compared to CME1.

At STA a period of clear magnetic field rotation and low magnetic field variance was observed between 7 November 2008, 02:00 UT and 8 November 2008, 01:20 UT. The magnetic field during this time was only slightly enhanced with respect to the ambient solar wind, but due to the prolonged magnetic field rotation the event was clearly identifiable from the ambient solar wind. The estimated arrival time of CME1 at STA matched very closely with the observed magnetic cloud signature. Thus, it seems very likely that the magnetic cloud at STA and CME1 were related.

The observations suggest that large, elongated eruptions are most likely deflected towards the equator since they cannot penetrate through the overlying coronal fields but are rather pushed down by the strong polar fields. Deflection of CMEs from the high-latitude regions of the new solar cycle 24 might also explain a sudden increase in the ICME rate in late 2008. Thus, the event under study clearly illustrates the usefulness of STEREO quadrature observations for establishing the relationship between the solar and in-situ signatures of CMEs.

ORIGIN AND EVOLUTION OF INTERPLANETARY CMES OBSERVED BY STEREO

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The twin STEREO spacecraft were launched during the minimum phase of the solar cycle, as a consequence not many ICMEs have been detected by the in situ instruments. Nevertheless, after more than two years of observations, there are some examples of ICMEs seen by more than one spacecraft (also including ACE) which provide important insights into different ICME characteristics. Furthermore, the increasing separation between STEREO-A and B allows a sampling of ICMEs with varying sizes and orientations. We will provide an overview of these events, together with the ones seen by a single spacecraft, from the beginning of the mission until present. In situ observations will be complemented with remote observations on the CMEs initiation process and their travel through the inner heliosphere. Properties of the ICME source region will be compared with the in situ data to infer the three-dimensional geometry of ICMEs, close to the Sun and at 1 AU. Both STEREO and ACE (also SOHO) provide a great opportunity for this kind of coordinated study of CMEs and their interplanetary counterparts.

COMPARISON OF STREAM INTERACTION OBSERVATIONS WITH ENLIL MODEL: CR 2016 – 2018

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During May to July 2004, a declining phase of solar cycle 23, Ulysses was close to the ecliptic plane at about 5.4 AU and was at nearly the same heliolatitude as ACE. Two stream interactions recurred for three successive Carrington rotations 2016 to 2018. There were no interplanetary CMEs encountered by ACE and Ulysses during these three rotations. We compare the solar wind observations at ACE and Ulysses with the numerical simulation results of the ENLIL model from CCMC. Some adjacent small stream interactions at 1 AU are found to merge into one big stream interaction at 5.3 AU. Through the comparison, we evaluate the current heliospheric modeling on reproducing the stream interaction and also evaluate the effect of different solar magnetographs and/or solar models (WSA and MAS models) on the ENLIL heliospheric model.

FLUX ROPE ERUPTION FROM THE SUN TO THE EARTH: WHAT DO REVERSALS IN THE AZIMUTHAL MAGNETIC FIELD GRADIENT TELL US ABOUT THE EVOLUTION OF THE MAGNETIC STRUCTURE?

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Using ACE in situ data we identify and describe an interplanetary magnetic cloud (MC) observed near Earth on 13 April 2006. We use multi-instrument and multi-wavelength observations from SOHO and TRACE and ground-based observatories to determine the solar source of this MC. Here we present the evidence that supports the link between an eruption in a small, spotless, northern hemisphere active region and this magnetic cloud, despite the presence of a number of larger active regions on the Sun which initially appeared to be more probable source regions of the MC. This event highlights the complexities associated with locating the solar source of an ICME observed near Earth, and serves to emphasise that it is the combination of a number of physical characteristics and signatures that is important for successfully tying together the Earth-end and the Sun-end of an event.

Further investigation of this MC has revealed some sub-structure towards its centre, observed as a small scale reversal of the azimuthal magnetic field of the MC, similar to that reported by Dasso et al., 2007. We explore several possible explanations for this signature, including the occurrence of multiple flux ropes and/or warping of the magnetic cloud. We also consider whether magnetic reconnection plays a role in creating the geometry that would explain these observations.

A THREE-DIMENSIONAL SOLAR WIND MODEL BASED ON SURFACE MEASUREMENTS OF THE MAGNETIC FIELD AND VELOCITY FIELD FROM GONG

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The solar wind, formed in the corona, is caused by high pressure near the Sun relative to the low pressure far from the Sun in the heliosphere. This pressure gradient exerts an outward force against gravity and accelerates the wind. One of the mechanisms to maintain this pressure gradient to accelerate the wind is the momentum and energy transport from the convective zone across the photosphere to the corona. To understand the physical mechanisms of momentum and energy transport from the convective zone to the corona and the formation of the wind, we have employed measurements of magnetic field and velocity field from GONG as inputs to a data-driven 3D radiative MHD model (Wang et al, 2008) to compute the amount of magnetic flux, momentum flux, and total energy across the photospheric boundary to the corona to maintain the pressure gradient and formation of the solar wind. Our results show that the slow and fast wind appears, respectively, at the boundary and center of a coronal hole. This result illustrates that without additional heating, the existence of slow and fast wind characteristics is due to the magnetic field topology.

STREAMERS STUDY AT SOLAR MINIMUM: COMBINATION OF UV OBSERVATIONS AND NUMERICAL MODELLING

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The study concerns the streamer belt observed during the minimum of solar activity (1996 and 2008) with the Ultraviolet Coronagraph Spectrometer (UVCS) onboard SOHO. On the basis of a spectroscopic analysis of the O VI doublet the solar wind plasma parameters are inferred in the extended corona. The data are combined with a 3D magneto-hydrodynamic model through the extrapolated coronal magnetic topology. In order to investigate the mechanism of the slow solar wind acceleration and the origin of its variability, we will also compare the data to the results of 2.5D three-fluid models of coronal streamer belt that includes O VI ions as one of the fluids. The results of the streamer core analysis allow the identification of the region where the current sheet forms.

THE AIR FORCE DATA ASSIMILATION FOR PHOTOSPHERIC FLUX TRANSPORT (ADAPT) MODEL

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Improved estimates of the global photospheric magnetic field distribution are important because they serve as primary input to all coronal and solar wind models. They are thus essential for accurate modeling of the corona and solar wind, which is vital for gaining the basic understanding necessary to improve forecasting models needed for Air Force operations. In this paper, we describe our efforts and progress toward developing the Air Force Data Assimilation for Photospheric flux Transport (ADAPT) model. ADAPT incorporates the ensemble Kalman filter data assimilation technique into the Worden and Harvey [2000] photospheric flux transport model using methods developed by Koller et al. [2007]. The Worden and Harvey [2000] model evolves the magnetic flux on the Sun using relatively well understood transport processes when observations are not available and then updates the modeled flux with new observations using the ensemble Kalman filter, which rigorously takes into account model and observational uncertainties, as well as accounting for regional correlations. Anticipated outcomes of the ADAPT model include improvement in the 1) description and predictions of the solar polar fields, 2) understanding of the nature and behavior of solar meridional flows over the solar cycle, and 3) modeling and prediction of the corona and solar wind.*

*[This work is supported by a grant from the Air Force Office of Scientific Research and by the AFRL Space Weather Forecasting Laboratory (SWFL).]

CALCULATING CME VELOCITY IN NEAR-REAL-TIME USING GEOMETRIC AND POLARIMETRIC TECHNIQUES

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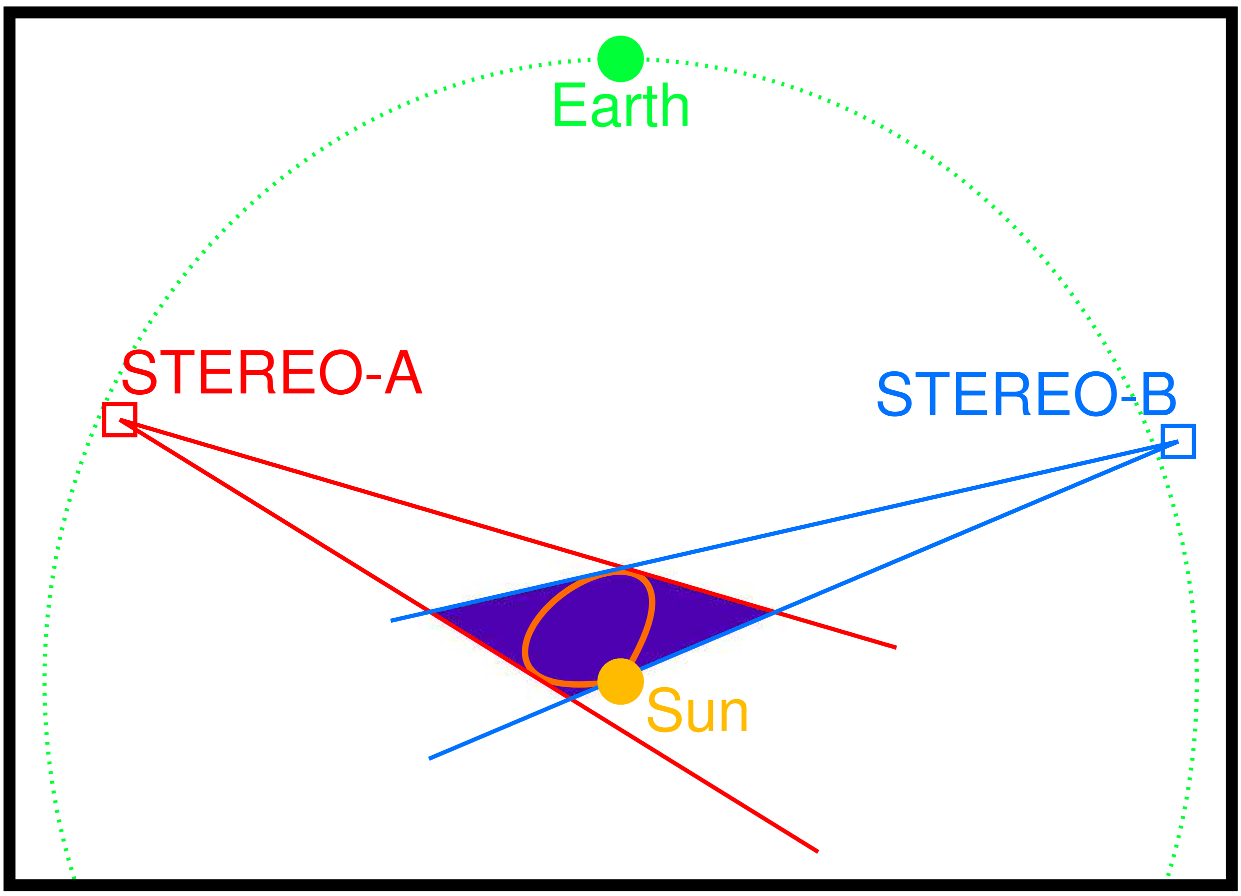
At the NOAA Space Weather Prediction Center, we have been investigating two different methods for determining the location, extent, and motion of coronal mass ejections (CMEs) in 3-space from STEREO coronagraph observations. Since this work is aimed at space weather applications, the emphasis is on use of beacon data, which are available in near-real-time. In addition, we primarily use observations from COR2, which has a field-of-view from 2.5–15$R_\odot$; this spatial coverage allows us to observe the early temporal development of a CME, and hence calculate its velocity, even for very fast CMEs. COR2 beacon data is transmitted every 15 min, alternating between total intensity only images and full polarization sets. These data are processed in two different ways to determine CME locations. One is a simple geometric localization, which is based upon triangulation concepts and utilizes a series of lines-of-sight from two space-based observatories to localize the CME position to within a small volume (see figure). The other technique involves using the polarization data to infer the mean distance from the plane of the sky, as seen from each spacecraft. Together, these analyses enable us to pin down the locus and motion of CMEs quite accurately. We will show results from some recent examples to illustrate the capabilities.



A SEARCH FOR COMPOSITIONAL DIFFERENCES IN SLOW SOLAR WIND AT LEADING AND TRAILING EDGES OF STREAM INTERFACES

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The elemental and ionic composition of the slow ($\sim$ 400 km/s) solar wind (SW) differs from that of the fast ($>$ 600 km/s) SW streams. In particular, the first ionization potential (FIP) effect and the O^7/O^6 ratios are higher in the slow SW than in the fast SW. While this fundamental difference between fast and slow SW has long been appreciated, there has been no reason to expect or effort to search for systematic variations within given fast or slow SW streams. If present, however, such systematic variations could be diagnostic of the solar processes at the sources of the SW. There are two reasons why we might expect such variations within slow SW streams. Observationally, the superposed epoch analysis of compositional variations from the Ulysses mission showed slightly enhanced O^7/O^6 and Mg/O ratios at the trailing edges of slow SW streams compared with those at their leading edges. Theoretically, in the Fisk model of solar open magnetic field transport an asymmetry in the interchange reconnection process exists between the eastern and western boundaries of quasi-rigidly rotating coronal holes that could produce compositional differences at the leading and trailing boundaries of slow SW streams. I looked for leading/trailing differences by first selecting long-lived fast SW streams from 2005 and 2006 and determining their slow-fast (SF) and fast-slow (FS) stream interfaces (SIs). ACE SWICS (version 3) compositional data were obtained for the 1-day periods of the preceding SF and following FS slow SW streams. The statistics were limited, but no compositional differences between the preceding and following slow SW regions were found. However, the He/O ratios were lower than expected, given that the observations precluded the heliospheric current sheet regions. Further, the obtained Ne/O ratios were nearly double the established long-term slow SW averages.

TRACKING NONRADIAL MOTIONS AND AZIMUTHAL EXPANSIONS OF INTERPLANETARY CMES WITH THE SOLAR MASS EJECTION IMAGER

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The trajectories of interplanetary CMEs (ICMEs) are modified by their interactions with solar wind streams. These interactions can result in nonradial deflections of ICME trajectories and changes to their rates of azimuthal expansions. These characteristics can be well observed by the heliospheric imagers on the STEREO spacecraft, but the Solar Mass Ejection Imager (SMEI), launched earlier in January 2003, has provided heliospheric images of several hundred ICMEs during the declining portion of solar cycle 23. SMEI images the full sky in white light every 102 minutes to obtain sequences of ICME images. We select the best observed SMEI ICMEs from 2003 through 2006, each traversing a range of observed solar elongation angles $> 24°$, and measure their leading-edge profiles. The fits to those profiles yield the propagation directions of the ICME centroids as well as their angular extents. When the ICMEs can be associated with CMEs observed with the Large-Angle Spectroscopic Coronagraph (LASCO), we can measure the changes in their propagation over 1 to 3-day periods.

FROM THE SUN TO THE SOLAR WIND: WHAT HAS HINODE TAUGHT US ABOUT SOLAR WIND SOURCES?

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Solar wind particles are accelerated and heated as they propagate from the solar corona to the earth. Using data from XRT and EIS on HINODE, ACE, and SOHO satellites, we follow the plasma characteristics such as density, flow speed, and composition from the solar corona to 1AU. XRT and EIS data are used to characterize the initial conditions of these solar wind particles. ACE is used to characterize the plasma at 1AU. The solar wind will be examined after a set of flares observed with HINODE to distinguish a propagation time. In addition, the coronal hole sources of the solar wind characterized and propagated to 1AU to be checked against ACE data.

THE PROPAGATION OF CMES USING SECCHI DATA

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The propagation of CMEs through the field of view of LASCO (2–30 Rs) has been extensively studied in the past 10 years. Based on theory-data comparison, it has been established that most, if not all, CMEs can be understood as erupting magnetic flux ropes and that the observed dynamics in this regime can be correctly described by the erupting flux rope model (Chen 1996). Until STEREO became available, CME dynamics were not observed and the EFR model has not been directly compared with data beyond 30 Rs. In this talk, I will discuss new SECCHI observations of CMEs and their dynamaics and extend the modeling of CME propagation to Hi 1 field of view (out to about 100 Rs projected). Four CMEs are discussed. It is shown that the erupting flux rope model is able to fit the observed height-time and velocity-time data throughout the EUVI-COR1-COR2-HI1 field of view. This suggests that the model correctly captures the main acceleration phase and the residual acceleration phase of CME dynamics, i.e., the forces acting on CMEs. It is found that significantly larger values of the drag coefficient in the model than previously used are required to fit both the COR1-COR2 data and HI1 data. The solar wind speed is a hyperbolic tangent function.

CAN SMALL-SCALE TRANSIENT FEATURES AT CORONAL HOLE BOUNDARIES PLAY ROLE IN THE SLOW SOLAR WIND GENERATION?

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We present first results of a study on the possible origin of the slow solar wind. The data used here were taken during the last 3 years with specially designed observing programs which involve SoHO/SUMER/CDS/MDI, TRACE, Hinode/XRT/EIS/SOT and Stereo/SECCHI/EUVI simultaneous observations (approximately 80 hrs of observing time; SUMER was used only during two observing periods). Our work is a continuation of the studies by Madjarska et al. (2004) who revealed the presence of events with strong blue- and red-shifted emission along coronal hole boundaries (SUMER) and Madjarska & Wiegelmann (2009, A&A, submitted) who showed that features seen in EIT Fe XII 195 Å and TRACE Fe IX/X 171 Å images along coronal hole boundaries play an important role in the evolution of coronal holes at small scales. These features represent small-scale loops (often named as coronal Bright Points) whose apperance and disappearance trigger contractions or expansions, respectively, of coronal holes. The authors suggested that these phenomena may also play a role in the generation of the slow solar wind. We present here a follow-up work using X-ray images from XRT/Hinode which demonstrates the existence of high concentrations of transient brightenings along coronal hole boundaries in respect to the quiet Sun. Spectroscopic observations from SUMER and EIS reveal that these phenomena often show proper motions of up to 700 km/s.

EUV OBSERVATIONS AND ANALYSIS OF MICRO-ERUPTIONS AND THEIR ASSOCIATED CORONAL WAVES

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The Solar Terrestrial Relations Observatory (STEREO) EUV telescopes have uncovered small-scale eruptive events, tentatively refer to as 'mini-CMEs' because they exhibit morphologies similar to large-scale coronal mass ejections (CMEs). Namely, they are accompanied by both coronal waves and dimmings. The high temporal and spatial resolution of the EUV data allows us to detect and analyze these eruptive events, resolve their fine structure and show that the observed 'mini-waves' have a strong similarity to the large scale "EIT" waves. Here, we analyze a set of microevents observed on October 17, 2007 by the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) EUV Imager (EUVI) in 171Å (Fe IX) with a 2.5 minute cadence. The mini-CMEs differ from their large-scale counterparts by having smaller geometrical sizes, a shorter lifetime, and reduced intensity of coronal waves and dimmings. The small-scale coronal waves seem to develop from microflaring sites and propagate up to a distance of 40,000 km in a wide angular sector of the quiet Sun over 20 min. The total intensity and area of the small-scale dimmings is 2 orders of a magnitude smaller than for large-scale events. The speed of small-scale coronal waves is 18.5km/s, which is at least 1 order of magnitude smaller than slow magnetosonic wave speed in the correspondent layers of solar corona.

THE RELATIONSHIP BETWEEN CORONAL DIMMINGS AND CORONAL MASS EJECTION PROPERTIES

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SWPC/NOAA

Coronal dimmings are thought to be the CME footpoints and, as such, offer information about CME origins and evolution. We investigate the relationship between CME and dimming properties. In particular, we compare CME quantities for events with and without associated dimmings. We find that dimming associated CMEs have much higher speeds than non-dimming associated events. In fact, CMEs without an associated dimming do not appear to travel faster than 800 km/s, i.e. the fast solar wind speed. Dimming associated events are also more likely to be associated with large flares. We conclude that when more energy is present in the event, the resultant CME will have a higher speed and will create a large flare and a dimming.

STUDY OF INTERPLANETARY SHOCKS USING MULTI-SPACECRAFT OBSERVATIONS

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We investigate the characteristics of interplanetary (IP) shock waves in the solar wind. IP shocks are produced by coronal mass ejections (CMEs) and stream interaction regions (SIRs). As IP shocks propagate, they encounter solar wind with different characteristics (density, speed) and different orientations of the ambient magnetic field. Hence, it is expected that shock profiles will vary strongly through the space. We use magnetic field and plasma data from STEREO, ACE and WIND spacecraft to study shock structure, strength and orientation. The use of multi-point observations will allow us to determine collisionless shock scales and gain insight about these interesting regions.

EVALUATION OF DYNAMICAL PARAMETERS OF LIMB CMES OBSERVED BY LASCO

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The dynamical parameters messured on limb CMEs can be considered as the real values due the low projection effects inherent to the possition. We present a compilation of limb CMEs detected by LASCO from 1996 to 2008. We considered as limb CME those related to an eruptive event observed within an interval of 15 degrees of solar longitud from the limb and evaluated the main dynamical parameters for each event.

STEREOSCOPIC RADIO OBSERVATION OF A TYPE II SOLAR BURST FROM THE CASSINI, ULYSSES AND WIND SPACECRAFT

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We present intensity and direction measurements of a type II radio burst observed on November 2, 2003 by the radio receivers of the Cassini, Ulysses and Wind spacecraft. We compare these different measurements made in different directions. We tentatively deduce properties on the radio source and propagation medium.

COMPARISON OF IN-SITU HELIOSPHERIC CURRENT SHEET STRUCTURE TO WHITE LIGHT SYNOPTIC MAPS OF THE STREAMER BELT

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The STEREO Heliospheric Imagers allow the construction of synoptic maps of the streamer belt by taking latitudinal cuts at a fixed height in the corona through sequences of images spread over a whole Carrington rotation. Information on the evolution of the streamer belt with distance from the Sun can be obtained by varying the height at which these cuts are made. In this work we explore the use of these synoptic maps for predicting the structure of the heliospheric current sheet at 1 AU by taking advantage of a unique combination of spacecraft trajectories in 2007. The two STEREO spacecraft were gradually separating in longitude and were located roughly 10° ahead and behind the Earth in mid 2007. Ulysses made a rapid scan in latitude crossing the equator in mid 2007 at a longitude close to that of the Earth. ACE and WIND provide additional reference points near the Earth. We use in-situ magnetic field data from this fleet of spacecraft to construct a latitude/longitude map of the heliospheric current sheet structure during this time period and investigate the relationship between this in-situ structure and that of the streamer belt observed in white light.

O^{+6} IONS IN SHOCKED SLOW SOLAR WIND IN FRONT OF A STREAM INTERFACE

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We present the bulk speed, temperature and density of protons and O+6 ions for Sep 16, 2008, when STEREO spacecraft A crossed a Corotating Interaction Region. Focusing on the time period when the spacecraft is between the forward shock and the stream interface, we find that the density of O+6 ions shows a different trend than that of the protons. The proton density slowly increases with the distance from forward shock before the spacecraft crosses the stream interface, then plummets at the stream interface. The density of O+6 ions maximizes just downstream of the shock and decreases to a minimum value near the stream interface. We discuss possible mechanisms to explain the O+6 density enhancement just downstream of the shock, including scenarios that involve these ions being trapped by the waves in this region, other wave-ion interactions, or ion composition variation relating to helioshperic current sheet and stream interface.

SOLAR SOURCES OF DRIVERLESS INTERPLANETARY SHOCKS

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Occasionally, interplanetary shocks driven by coronal mass ejections (CMEs) arrive at Earth without discernible ejecta behind them. Some authors have claimed that these driverless shocks are blast waves from the Sun. A detailed look at the solar sources of these "driverless" shocks indicates they fall into two groups: the disk center sources and limb sources. The limb sources are normal, because shock flanks arrive at Earth, while the driving CMEs do not. The shocks associated with disk-center sources are anomalous because the driving CMEs are expected to arrive at Earth, but they do not. The anomaly has been shown to be due to the presence of coronal holes near the eruption regions (Gopalswamy et al., 2009). In essence the coronal holes make the CMEs behave like limb CMEs. In this paper, we compare the CME, radio-burst, and flare properties of the two populations of driverless shocks and rule out the possibility that they are blast waves.

References:

Gopalswamy, N., Mäkelä, P., Xie, H., Akiyama, S., and Yashiro, S., *CME interactions with coronal holes and their interplanetary consequences, JGR, 114, A00A22, 2009*

EVOLUTION OF MAGNETIC CLOUDS IN THE INNER HELIOSPHERE

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Abstract:

Magnetic clouds (MCs) are objects in expansion during their travel through the heliosphere. *In situ* observations indicate that the MC front travels typically faster than its back, showing a clear empirical signature of expansion. With the aim of quantifying the expansion rate of MCs, we present here a statistical study of all the MCs observed in the inner heliosphere (from 0.3 to 1 AU) by the spacecraft Helios 1 and 2, during their complete period of operations. We first rotate the observed magnetic field into the MC frame (defined by the MC axis and the spacecraft trajectory). This allows a better localization of the MC boundaries for each event. We then split the sample in two subsets according to the characteristics of their velocity profiles, (a) those MCs with a significantly perturbed velocity profile due to the interaction with their surrounding solar wind (i.e. overtaken by streams) and (b) those that are not perturbed (not-overtaken). We analyze the expansion velocity (defined with respect to the cloud center), V_{exp} and its dependence with several MC properties, as its size, its helio-distance, its translation velocity, etc. The removal of the correlations found lead to the definition of a dimensionless local expansion rate (ζ) for MCs. This definition of ζ is fully consistent with previous works, which defined the same quantity from theoretical considerations. We find significantly different values of ζ for overtaken and not-overtaken events. Not-overtaken MCs expand at rates ζ consistent with the expected value from the global pressure decay in the surrounding solar wind (SW) for increasing helio-distances, while overtaken ones may present strong departures from that general rule. We interpret this departures of ζ for overtaken MCs as a consequence of their interaction with local SW streams on their expansion.

CORONAL LINEAR RAYS: ARE THEY FAST STREAMS FROM ACTIVE REGIONS?

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Eclipse observations of the W-L corona show linear rays above active regions at times of solar maximum. We show that these linear rays are also observed in the field-of-view of the C2-LASCO coronagraph, in perfect correspondence with the eclipse results. These observations strongly suggest high speed streams - because they apparently ignore the large scale coronal magnetic field - rooted rather low in the corona. A possible origin is the neutral magnetic points located above the active region. Several mechanisms exist to explain how the plasma could be accelerated in these regions to large quasi-relativistic velocities, possibly related to the occurrence of type III radio bursts. We point out a curious analogy with phenomena occurring inside coronal holes.

THE MODELS OF THE INFINITELY THIN GLOBAL HELIOSPHERIC CURRENT SHEET AND OF THE DISTRIBUTION OF THE MAGNETIC FIELD IN THE UNIPOLAR MAGNETIC "HEMISPHERES"

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The different models of the infinitely thin global heliospheric current sheet with small (≤ 5) number of parameters are considered which can be useful in the heliospheric studies. The time behavior in 1976-2009 of the model parameters fixed from the approximation of the form of the current sheet on the source surface (Wilcox Solar Observatory model) is discussed. Besides, we discuss the different model distributions of the radial component of the magnetic field over the latitude and longitude in each unipolar magnetic "hemisphere" separated by the heliospheric current sheet.

The models discussed can be used in studying the large-scale structure of the magnetic field and solar wind characteristics and also in modeling the cosmic ray behavior in the heliosphere.

EFFECTS OF THE WEAK POLAR FIELDS OF SOLAR CYCLE 23: INVESTIGATION USING OMNI FOR THE STEREO MISSION PERIOD

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The current solar cycle minimum seems to have unusual properties that appear to be related to weak solar polar magnetic fields. We investigate signatures of this unusual polar field in the ecliptic near–Earth interplanetary magnetic field (IMF) for the STEREO–period of observations, from Carrington Rotations 2053 to 2074. Using 1 AU OMNI data, we find that for the current solar cycle declining phase–to–minimum period the peak of the distribution for the values of the ecliptic IMF magnitude is lower compared to a similar phase of the previous solar cycle. We investigate the sources of these weak fields. Our results suggest that they are related to the solar wind stream structure, which is enhanced by the weak polar fields. The direct role of the solar field is therefore complicated by this effect, which redistributes the solar magnetic flux at 1 AU nonuniformly at low–to–mid heliolatitudes.

INFLUENCE OF EXPANSION EFFECTS ON THE MAGNETIC CLOUD FIT

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Magnetic clouds observed during the 1995–2003 years are fitted using force-free cylindrical flux rope models. The cloud parameters yielded by a static model are compared with those obtained from a modified model that includes magnetic cloud expansion. The deviations of these fits from measurements are quantified and compared with observations. The comparison reveals that the model with expansion provides better fits if the expanding speed is low (< 38 km/s), whereas the results are not conclusive for larger speeds. We conclude that expansion of magnetic clouds plays an important role in the MC formation and propagation but a further progress requires determination of cloud parameters from the model with expansion included self-consistently.

REVEALING CMES IN WHITE LIGHT CORONAGRAPH IMAGES

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A new method for isolating the signal of CMEs in white light coronagraph images is introduced. Whilst removing the background light of the F-corona (and other unwanted signals like instrumental stray light) is an established part of analysing coronal images, removing the background quiescent K-corona to enhance the signal of dynamic events is difficult. We show that above 3 solar radii (and below 30Rs), the structure in white light K corona images is almost completely radial. This fact can be exploited to remove the background quiescent corona in a simple and robust manner. Since CMEs are not radial structures, their signal is isolated effectively with this method.

A TEST OF MHD QUANTITIES CONSERVATION FROM THE SOLAR ERUPTION TO THE ASSOCIATED MAGNETIC CLOUD OBSERVED AT 1 AND 5 AU

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Once ejected from the Sun, the interplanetary counterparts of CMEs (ICMEs) evolve interacting with the surrounding solar wind. Magnetic clouds (MCs) form a particular subset of ICMEs. Detailed examinations of MHD quantities (e.g., magnetic fluxes and helicity) are a key to improve our knowledge of physical mechanisms during the solar eruptions and the interaction of MCs with their environment. In this work we present a multispacecraft study where we compare magnetic fluxes and helicity estimated at different stages of the evolution of a particular MC: at 1 AU (observed by ACE), at 5.4 AU (observed by Ulysses) and at the associated source solar region. We find that magnetic fluxes and helicity are well conserved during the travel of this MC. However, while the magnetic field profile observed at 1 AU is consistent with a classical and well behaved magnetic cloud, magnetic observations at 5.4 AU show a highly asymmetric and deformed magnetic profile, indicating a strong interaction with the surrounding solar wind. As aligned multispacecraft observations of MCs are rare, multipoint studies of these events represent a unique possibility to track the evolution of MCs from the Sun to large heliodistances.

SOHO/ACE OBSERVATIONS OF TWO CONSECUTIVE CMES FROM THE SAME SOURCE REGIONG

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On 2003 June 2 SOHO/LASCO coronagraphs observed two CMEs at the West limb of the Sun at, respectively, 00:30 and 08:54 UT, which appeared to originate from the same source region. Both CMEs show the typical three-part structure, corresponding to the, e.g., "flux-rope model" of Lin and Forbes (2000). These events have been also observed by SOHO UVCS allowing us to infer their physical parameters. We also looked for evidence of interplanetary signatures of the CMEs via ACE situ observations. Indeed, both CMEs are identifiable in ACE data. We discuss here coronal and interplanetary parameters of the two events.

MHD SIMULATION STUDY OF A POLAR CROWN FILAMENT ERUPTION

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Early 2 November 2008, the EUVI instrument onboard STEREO-A (STA) observed the eruption of a long polar crown filament in the 304 Ångström wavelength band. The eruption was simultaneously observed by STEREO-B (STB) as a prominence eruption at the western limb. Subsequently, the COR1 coronagraph on STB observed a slow coronal mass ejection (CME), initially propagating clearly northward from the equator, consistent with the direction of eruption of the filament deduced from EUVI images. However, the CME was quickly deflected towards the equator while propagating further away. The observations suggest that the CME could not penetrate through the overlying coronal structure, but was pushed towards the equator by the strong magnetic fields in the polar coronal holes.

In this work, we study this hypothesis by performing 2.5 dimensional magnetohydrodynamic (MHD) simulations in spherical coordinates. Our initial state consists of a solar minimum solar wind solution, to which we superpose a high-density flux rope structure near the solar surface at a high latitude to mimic a long polar crown filament. We study the dynamics of the eruption, and discuss under which conditions a CME can be deflected by the large-scale coronal structures.

IDENTIFYING THE ENDS OF HIGH-SPEED STREAMS WITH IN SITU DATA FROM STEREO/PLASTIC

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The transition from fast to slow solar wind has not been studied to the same extent as the transition from slow to fast streams, the stream interface. The fast-to-slow transition has been observed as a smaller-scale mirror image of a stream interface. It is characterized by changes in speed, density, temperature, and composition (Geiss et al. 1995; Zurbuchen et al. 1999; Burlaga, Mish, and Whang 1990; Siscoe and Intriligator 1993, Burton et al. 1999). In this study we use solar wind ion data from STEREO/PLASTIC to further investigate the fast-to-slow solar wind interface, with particular emphasis on possible correlations between changes in the proton entropy and the solar wind's flow direction.

MAGNETIC CLOUDS FITTED BY A CONSTANT-ALPHA FORCE-FREE TOROIDAL SOLUTION

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Magnetic clouds have been defined as special regions in the solar wind with higher magnetic field magnitude, lower proton temperature, and large rotation of the magnetic field vector. In some cases, the rotation exceeds 180 degrees and it is interpreted as a signature that a magnetic cloud/flux rope is curved. It corresponds to common understanding that magnetic clouds are large interplanetary flux ropes, which have loop-like shapes in the heliosphere. Recently we have found a constant-alpha force-free toroidal solution. The solution will be presented together with fits of several observations of magnetic clouds.

MODELING OF MAGNETIC FIELD DISTURBANCES IN SHEATH REGION OF INTERPLANETARY MAGNETIC CLOUDS OF ELLIPTICAL SHAPES

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It is widely accepted that magnetic disturbances around fast interplanetary magnetic clouds can play important role in their geo-effectiveness. On the other hand, magnetic and plasma structures in the sheath region, in front and behind the body, determines dynamics and evolution of the cloud. We propose in this paper an analytical solution for magnetic field in the sheath region of a cylindrical magnetic cloud with elliptical cross-section. The solution can be used for interpretation of in-situ observations.

AN ONLINE DATABASE OF PROCESSED CORONAL IMAGES

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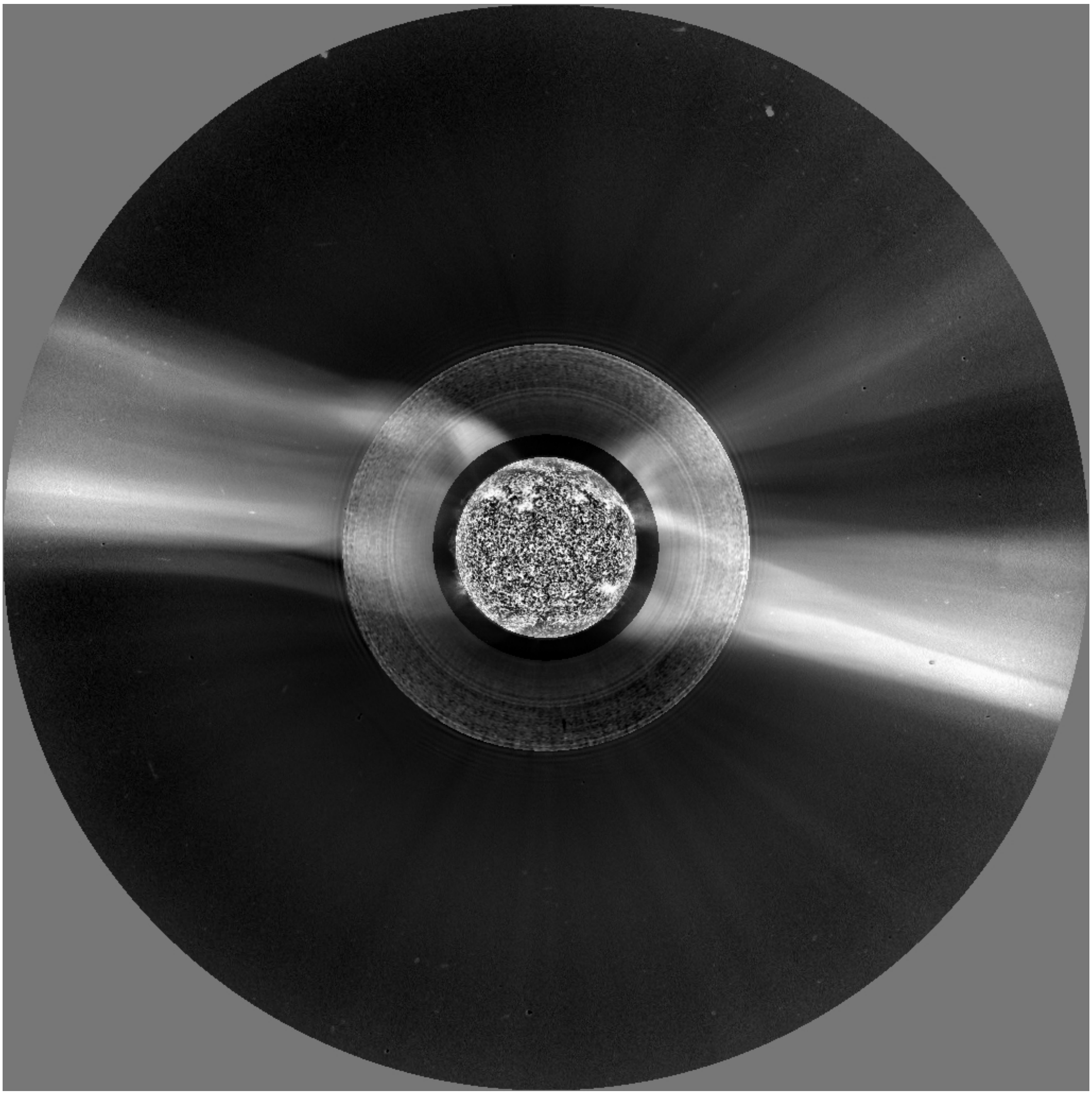
We present a new online database of coronal images, processed to reveal the detailed structure of the corona. Currently, the database is limited to SOHO data, and is in two sections. The daily section contains one set of images per day, providing composite images of the corona from the chromosphere to 30 solar radii. The LASCO section provides the whole LASCO C2 and C3 dataset, enabling detailed study of CME structure and propogation. The database will be extended to include STEREO data soon. The database can be accessed from the solar pages of the IfA, University of Hawaii (www.solar.ifa.hawaii.edu).



Session 4:
Solar Wind through its Interaction Processes with Solar System Objects and Dust

BOW SHOCKS IN THE SOLAR WIND: LESSONS TOWARDS UNDERSTANDING CORONAL AND INTERPLANETARY SHOCKS.

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Collisionless shock waves are an important component of the heliosphere and are ubiquituos in astrophysical environments. Across them the solar wind can be heated, deviated and compressed. In addition, collisionless shocks are able to accelerate a fraction of particles to very high energies. Shocks can be generated at the Sun's corona due to flare perturbations or driven by fast coronal mass ejections (CMEs). Some of them can continue as travelling shocks in the interplanetary medium. Additionally, shocks can be created in the solar wind by the interaction of fast streams with slow moving plasma or by solar wind interaction with planetary obstacles.

Bow shock waves are formed in front of every planet when the supermagnetosonic solar wind encounters the planets. In most cases the planets are shielded by a magnetic field and the bow shock acts as a mediator to decelerate the solar wind prior to its encounter with the magnetosphere. For Venus and Mars no global magnetic field is observed and the effective obstacle to the solar wind is the ionosphere. The physical processes at collisionless shocks depend on the Mach number (strength), plasma beta and the direction of the magnetic field relative to the shock normal. The curvature of bow shocks allows the formation of two type of shocks, namely the quasi-parallel and quasi-perpendicular shocks whose characteristics are very different. While the quasi-perpendicular shock has a well defined transition structure, its quasi-parallel counterpart is not well defined and the shock region is very extended. In addition the bow shock can have different Mach numbers across its surface. Thus, bow shocks allow the study of collisionless shocks under a variety of conditions.

A unique feature of collisionless shocks is the existence of a foreshock, a region upstream that is magnetically connected to the shock where backstreaming particles can generate a variety of waves, and plasma structures. The lack of collisions in solar wind shocks means that dissipation mechanisms require the participation of wave-particle phenomena. So studying kinetic effects at shock regions is very important to understand how thermalization and dissipation take place. For obvious reasons much of our current understanding of shock physics has been developed from earth's bow shock studies. However, there is still much to learn about coronal and interplanetary shocks. These shocks are important because they play a major role in the acceleration of solar wind particles (SEPs) and contribute to geomagnetic activity. At present the STEREO mission provides dual spacecraft observations at a high resolution to advance our understanding of interplanetary shocks.

In this talk we will discuss the earth's bow shock region and relate processes occuring at the shock and foreshock to phenomena associated to coronal shocks and shocks propagating in the solar wind. Our understanding of the bow shock microphysics can serve as a tool to understand corrotating and transient shocks structure, their evolution, and the kinetic phenomena that take place in regions associated with these shocks.

COMPOSITION OF THE INNER SOURCE MEASURED WITH THE SOLAR WIND ION COMPOSITION SPECTROMETER ON ULYSSES

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To explain their unexpected discovery of C+ in the heliosphere, Geiss et al. (JGR 100, 23373, 1995) proposed the existence of an inner source of pickup ions close to the Sun, and that the inner source material that created C+ pickup ions would contain carbon (and likely other) compounds evaporated or sputtered from grains and possibly larger objects orbiting the Sun. Thus, measurements of the velocity distributions and composition of inner source pickup ions provide important information about the spatial distribution and nature of interplanetary material near the Sun. The Solar Wind Composition Spectrometer on Ulysses has measured the velocity distributions and composition of singly ionized interstellar and inner source pickup ions for more than 15 years both in the ecliptic plane and at high latitudes. Here we report on some of our new results. For example, we find that, in addition to C+, mass/charge (m/q) 13, 14, 16, 17, 18, 19 and 20 ions are also present in the near ecliptic data, while in the high-latitude observations m/q 13 (CH+) and 17, 18 and 19 (water group molecules) are almost absent. Special attention will be focused on establishing the identity of m/q 20, 23-24 and 26-40 ions. We will end by speculating on the nature of the inner source and contributions from sun-grazing comets to this source.

DUST IN THE INTERPLANETARY MEDIUM

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This presentation summarizes current knowledge on dust in the interplanetary medium focusing on its interaction with the solar wind and on recent in situ observations. The mass density of interplanetary dust particles near Earth's orbit equals the mass density of the solar wind and the dust covers a broad range of nm to mm sizes. The large surface area of dust particles being exposed in the interplanetary medium possibly leads to various dusty plasma interactions in the solar wind.

Dusty plasma effects in general comprise (i) the alteration of the dust as a result of the ambient plasma, (ii) the generation of neutrals, electrons and ions from dust, (iii) the change in energy or charge state of plasma species by interaction with the dust, (iv) the dust motion or change of motion as a result of the ambient plasma, and (v) collective behavior caused by the presence of dust. Collective effects (v) are not likely to occur in the interplanetary medium on a large scale and the alteration of the dust component (i) will only shortly be discussed in this presentation. The presentation will focus on influences of the dust on the plasma (ii and iii) and on the dynamics of dust in the solar wind (iv) for the case of nano particles.

Recent relevant experimental in-situ results (for which the relevance of dust is differing and partly not quantified as yet) are the detection of nano particles in the interplanetary medium, the detection of pick-up ions in the solar wind, the detection of magnetic field enhancements in the solar wind crossing cometary dust trails, and the detection of energetic neutral atoms.

INTERPLANETARY FIELD ENHANCEMENTS: OBSERVATIONS FROM 0.3 AU TO 1.0 AU

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Interplanetary field enhancements are attributed to the pick-up of charged dust. They are seen from 0.3 AU to well over 1.0 AU. We have examined the records of Helios 1 and 2, Venus Express, and STEREO to characterize these disturbances. These structures are largest at Helios and decrease in strength with distance from the Sun. We present examples as a function of heliocentric distance and their occurrence frequency and other properties, as seen by the magnetometer on these three missions to gain further insight into the physical processes controlling their formation.

ON THE ORIGIN OF INNER-SOURCE PICKUP IONS II

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Inner-source pickup ions have been investigated by several workers who all assumed an initial velocity distribution function which is dominated by high velocities in the solar wind velocity frame. This is supposed to be due to the Lorentz force which acts on the freshly ionized particles. Because the location where inner-source pickup ions are ionized lies close to the Sun (probably between 5 and 25 $r_\odot$) and the magnetic field is near radial there, the Lorentz force acting on freshly created ions is small.

Here we show that particles expelled from interplanetary dust particles according to the *Gloeckler et al., (2000)* scenario only experience a very small mirror force in the inner heliosphere which only succeeds to accelerate a small fraction of them out of the solar vicinity after typically tens of hours. This results in a higher charge state than observed for heavy ions and further aggravates the problem of the high abundance of inner-source pickup ions.

X-RAY EMISSION FROM THE SOLAR SYSTEM BODIES: CONNECTION WITH SOLAR X-RAYS AND SOLAR WIND

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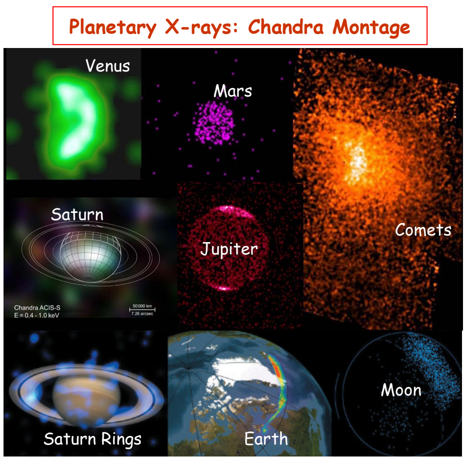
Today the field of planetary X-rays is very dynamic and in the forefront of new research. Apart from the Sun, the known X-ray emitters now include planets (Venus, Earth, Mars, Jupiter, and Saturn), planetary satellites (Moon, Io, Europa, and Ganymede), all active comets, the Io plasma torus (IPT), the rings of Saturn, the coronae (exospheres) of Earth, Mars and Venus, and the heliosphere. Scattering of solar X-rays mainly produces the non-auroral X-ray emissions from Jupiter, Saturn, and Earth, those from the disk of Mars, Venus, and Moon, and from the rings of Saturn. The X-ray emission from comets, the heliosphere, the geocorona, and the Martian and Venusian halos (exospheres) are all largely driven by charge exchange collision between highly ionized minor heavy ion in the solar wind and gaseous neutral species in the bodies' atmosphere – a process know as solar wind charge exchange (SWCX). In particular, the cometary X-ray spectrum can be used to derive abundances of high-charge state ions of O, C, Ne as well as the speed of solar wind. Thus cometary X-rays can provide a diagnostics of the solar wind properties even at far off distances from the Earth. This talk provides a brief overview on X-rays from the solar system bodies and their connection with solar X-rays and solar wind, and how planetary X-rays can be used to study the solar X-ray radiation and the solar wind properties.



THE HELIOSPHERIC CONTRIBUTION TO THE SOFT X-RAY BACKGROUND EMISSION

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The soft x-ray background observed from Earth contains contributions not only from outside the solar system such as the local bubble but contributions from within the solar system including from the interplanetary medium and from the terrestrial geocorona and magnetosheath. Great effort was spent on removing non-cosmic contamination from data collected during the ROSAT all-sky survey. Some of the contamination, however, was due to X-ray emission from solar wind charge exchange with interstellar and geocoronal neutrals. The time varying component of this contamination was removed, but the steady state component of this X-ray emission was not. We will discuss our method of calculation this steady state component of solar wind charge exchange and will present all-sky maps of the soft X-ray emission with the steady state component removed, which will allow a re-interpretation of the nature of the local interstellar bubble.

Posters of session 4

DETECTION OF FAST NANOPARTICLES IN THE SOLAR WIND

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Dust grains in the nanometer range bridge the gap between atoms and submicron grains made of bulk material. Their small size embodies them with special properties due in particular to their high relative surface area. Since their electric charge in the solar wind plasma is roughly proportional to their surface area, they have a high charge-to-mass ratio. As a result, the Lorentz force in the solar wind magnetic field exceeds the gravitational force and other forces by a large amount, and they are accelerated to a speed of the order of magnitude of the solar wind speed. When such fast nanoparticles impact a spacecraft, they produce craters whose matter vaporises and ionises, yielding wave bursts as high as do much larger grains of smaller speed. These properties are at the origin of their recent detection at 1 AU in the solar wind. We review the principles of detection of fast nanoparticles by wave instruments using different configurations and apply them to the recent detections on STEREO/WAVES and CASSINI/RPWS. We compare the results with dust models and discuss the implications. Finally we discuss the opportunities for nanoparticle detection by wave instruments on future missions and/or projects such as Bepi-Colombo and Solar Orbiter.

INTERACTION OF THE SOLAR WIND AND THE STREAM PARTICLES, RESULTS FROM CASSINI DUST DETECTOR

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The stream particles are nanometer-size dust particles ejected from the Jovian and the Saturnian systems with velocity greater than 100km/s. Due to the small scale of the nanometer size, stream particles are more sensitive to the electromagnetic force than to gravity. It has been shown that, in the interplanetary space, the dynamics of stream particles is dominated by the interplanetary magnetic field (IMF) [Grün et al, 1993, Hamilton and Burns, 1993, Zook et al., 1996]. Based on the measurements by the dust detector on-board Cassini spacecraft, we found that the detection patterns of stream particles are well correlated with the IMF structures. As the spacecraft crossing the compression regions of the Co-rotation Interaction Regions (CIRs), not only the directionality of the impacts changes with the field direction, the impact signal and the rate also vary with the increase of field strength. By understanding of the interaction of stream particles and solar wind, the data could provide important insight to the formation environments of the stream particles and gives us an unique opportunity to study the dust-moon-magnetosphere system of Jupiter and Saturn.

THREE-DIMENSIONAL INTERACTION BETWEEN INTERSTELLAR DUST GRAINS AND THE HELIOSPHERE

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The results of modeling the three-dimensional distribution of interstellar dust grains (ISDG) inside of the heliosphere are presented. As found by previous studies, the small dust grains with large charge-to-mass ratios are excluded from the heliosphere, while the largest grains are gravitationally focused. In addition, however, we find that the heliosphere asymmetry generated by the interstellar magnetic field also breaks the symmetry of the ISDG spatial distribution with respect to the axis of inflowing interstellar material, particularly for smaller grains. Grain trajectories inside of the heliosphere are shaped by Lorentz forces, gravity, and radiation pressure, with the relative importance of each force a function of the grain mass and composition. The spatial distributions of ISDGs are calculated for the 3-dimensional (3D) MHD heliosphere model of Pogorelov et al. (2007), which self-consistently includes neutral-plasma coupling, and is based on heliosphere interstellar boundary conditions of $n(p+) = 0.06$ /cc, $n(HI) = 0.16$ /cc, $T = 6527$ K, $Bk_IS = 3\mu$G, with the magnetic field directed into the southern ecliptic hemisphere at an angle of 30^o with respect to the ecliptic plane. The equilibrium electric charge and surface potential of ISDGs are calculated for astronomical silicates with radii between 0.01-0.30 microns, and out to distances of 500 AU from the Sun. Electron and ion impacts, secondary electron emission and photoelectric emission are evaluated using up-to-date values for the photoelectric yields and absorption coefficients. The radiation field includes the interstellar background radiation field and the Solar flux as determined by the TIMED/SEE mission. Grain charging in the heliosheath plasma is enhanced by secondary electron ejectron caused by solar wind electrons that are heated adiabatically in the termination shock, to temperatures in the range 5×10^5 K. The density of electrons could be in the range $5 \times 10^-4\,\mathrm{cm}^{-3}$.

THE IS He FOCUSING CONE SEEN THROUGH SOLAR WIND CHARGE EXCHANGE EMISSION

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We study the interstellar (IS) He focusing cone through a data to model comparison of Solar Wind Charge Exchange (SWCX) X-ray emission. The X-ray data are from three coupled observations of the South Ecliptic Pole (SEP, to observe the cone) and the Hubble Deep Field-North (HDFN, to monitor global variations of the SWCX emission due to variations in the solar wind) from the period 24 November to 15 December 2003. There is good qualitative agreement between the model predictions and the data, after the SEP data are corrected using the HDFN data, with the maximum SWCX flux observed at an ecliptic longitude of $\sim$ 72 deg, consistent with the central longitude of the He cone. However, the data results disagree with the model predictions on the total X-ray excess due to SWCX from the He cone. We discuss the model to data comparison and provide possible explanations for the discrepancies. We also qualitatively re-examine our SWCX model predictions in the 1/4 keV band with data from the ROSAT All-Sky Survey towards the North and South Ecliptic Poles, when the He cone was probably first detected in soft X-rays.

UNDERSTANDING THE INTERACTION OF STELLAR PLASMA FLOWS WITH PLANETS AND MOONS: GLOBAL 3-D KINETIC (HYBRID) SIMULATION RESULTS

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We study the phenomena caused by the interaction between stellar plasma flow and planets and moons, namely Mercury's magnetosphere, Moon, and Enceladus.

MULTIPLE SPACECRAFT OBSERVATIONS OF INTERPLANETARY FIELD ENHANCEMENTS

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Interplanetary Field Enhancements (IFEs) are cusp-shaped enhancements of the magnetic field strength lasting the order of an hour, accompanied by strong current sheets or magnetic discontinuities near the central peak. These structures are attributed to the pick-up of charged dust particles due to their frequent occurrence at near conjunctions with the asteroid 2201 Oljato. They occur at all ecliptic longitudes at 0.72 and 1.0 AU. With single spacecraft observations, ambiguity exists as to their direction of motion. Extreme possibilities are azimuthal around the Sun and radial outward from the Sun. Examining all known multiple spacecraft observations, we have found several 2-spacecraft and 1 each of 3-spacecraft and 4-spacecraft observations. All observations are consistent with outward radial motion. The observations also show that the disturbance of the orientation of the field extends over a larger region than does the magnetic field increase, but the field strength does decrease below the ambient field at larger distances from the central field increase. These structures are indicative of important interactions in the solar wind, but are poorly characterized. More multiple spacecraft observations are needed at scale lengths of the order of 10^5 km.

SOLAR WIND IMPACTS ON PLASMA ENVIRONMENT AT MARS

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The observations carried out on Mars Express show that the Martian environment is influenced by perturbations in solar wind. In contrast to Earth, whose atmosphere and ionosphere are shielded by a large magnetic screen, the Martian ionosphere lacking such a screen is directly exposed to the incoming solar wind. Therefore space weather effects related to impacts on Mars of solar wind streams with high density and pressure strongly affect the planetary ionosphere. Large blobs of solar wind plasma penetrate to the ionosphere and sweep out a dense ionospheric plasma. As a result, the lossses of volatile material at Mars essentially increase.

STUDYING THE SOLAR WIND-LUNAR INTERACTION WITH THE SARA EXPERIMENT ABOARD THE INDIAN LUNAR MISSION CHANDRAYAAN-1

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The first Indian lunar mission Chandrayaan-1 is launched in October 2008. The Sub-keV Atom Reflecting Analyzer (SARA) instrument on board Chandrayaan-1 consists of a low energy neutral atom (LENA) imaging mass spectrometer called CENA (Chandrayaan-1 Energetic Neutral Analyzer), and an ion mass spectrometer called SWIM (Solar Wind Monitor). The CENA is performing the first ever experiment to study the solar wind–planetary surface interaction via detection of sputtered neutral atoms and neutralized back-scattered solar wind hydrogen in the energy range 10 eV to 3.3 keV with its 160 x 15 degree field of view. The production of LENA in the 0.01-3.0 keV range on the Moon results largely due to the impact of solar wind plasma, as well as the Earth's magnetotail plasma when moon is inside magnetosphere. The SWIM is measuring solar wind ions, magnetotail ions, as well as ions scattered from lunar surface, in the 10 eV-15 keV energy range with its 180 x 9 degree field of view. The neutral atom sensor uses conversion of the incoming neutrals to positive ions, which are then analyzed via surface interaction technique. The ion mass spectrometer is based on the same principle. The scientific objectives of SARA include studying the solar wind interaction with lunar surface and deriving Moon's surface composition and investigating the magnetic anomalies on the lunar surface, including the presence of mini-magnetospheres and related physics. This paper will present the SARA instrument and discuss the first results obtained by the SWIM and CENA instruments.

THE ALTERED SOLAR WIND - MAGNETOSPHERE INTERACTION AT LOW MACH NUMBERS: CORONAL MASS EJECTIONS

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Fundamental alterations of the solar wind – magnetosphere interaction occur during low Mach number solar wind. We show that such low Mach number solar wind conditions are often characteristic of coronal mass ejections (CME), and magnetic clouds in particular. We illustrate the pivotal role of the magnetosheath. This comes from the fact that low Mach number solar wind leads to the formation of a low thermal Beta magnetosheath downstream of the bow shock. This property influences magnetic forces and currents, in particular, and in turn alters magnetosheath – magnetosphere coupling. The implications of this unusual regime of interaction have generally been overlooked. Potentially affected phenomena include: (1) asymmetric magnetosheath flows (with substantial enhancements); (2) asymmetric magnetopause and magnetotail shapes; (3) changes in the development of the Kelvin-Helmholtz instability and giant spiral auroral features; (4) variations in the controlling factors of dayside magnetic reconnection; (5) cross polar cap potential saturation and Alfvén wings; and (6) global sawtooth oscillations. In this presentation we will briefly describe these phenomena, primarily by use of global magneto-hydrodynamic simulations, and discuss the mechanisms that rule such an altered interaction. We emphasize the fact that all these effects tend to occur simultaneously so as to render the solar wind – magnetosphere interaction drastically different from the more typical high Mach number case. In addition to the more extensively studied inner magnetosphere and magnetotail processes, these effects may have important implications during CME-driven storms at Earth, as well as at other astronomical bodies such as Mercury.

THE LLBL THICKNESS UNDER CHANGES OF THE IMF ORIENTATION

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Interaction of the solar wind with the Earth's magnetosphere is mediated by magnetopause boundary layers. Among them, a low-latitude boundary layer (LLBL) filled by a mixture of magnetosheath and magnetospheric plasmas is still under debate that is now associated with the Themis mission. For formation of the LLBL, magnetic reconnection between the magnetospheric and magnetosheath magnetic fields, impulsive penetration of magnetosheath plasma, and viscous/diffusive mixing of plasma populations at the magnetopause have been considered. Observed fluctuations of plasma parameters inside the LLBL are attributed either to transient nature of the phenomena forming the layer or to sweeping of deformations of the magnetopause or an inner edge of the LLBL along the spacecraft. There is an evidence that the LLBL is at times on the closed field lines and at times on open field lines, i. e., magnetospheric field lines which have one foot in the ionosphere and extend into the magnetosheath.

We use measurements of five THEMIS spacecraft that cross the dayside LLBL and allow us to determine the LLBL thickness under different upstream conditions. In this respect, the direction of the interplanetary magnetic field (IMF) is a main factor controlling changes of the LLBL thickness. Under a northward IMF orientation, the LLBL thickness increases and it vanishes during the southward orientation as our study shows. We also discuss the speed of the response of plasma parameters inside the LLBL to abrupt changes of the IMF direction.

FORESHOCK COMPRESSIVE BOUNDARY OBSERVED BY CLUSTER

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Recent global hybrid simulations (kinetic ions, fluid electrons) of the solar wind interaction with Earth's magnetosphere (Omidi, et.al. 2009) revealed the existence of a new structure at the edges of the foreshock, named foreshock compressional boundary (FCB). This structure represents a transition region that separates solar wind plasma from the foreshock and is associated with compression of magnetic field and density strength. Beside the enhancements in field and density, the FCB also shows a region where these two parameters decrease below the ambient solar wind values. Simulations have showed that the formation and strength of FCB depends on the generation and nonlinear evolution of foreshock ULF waves which in turn have been produced by the interaction of backstreaming ions with the solar wind. In this work we use Cluster magnetic field and plasma data to study the characteristics (size, duration, amplitude, orientation) of FCBs for different interplanetary field geometries and solar wind speeds. We find that FCBs are highly nonlinear structures with $\delta B/B_o$ and $\delta n/n_o$ large amplitudes and extensions of hundreds inertial lenghts. Cluster data reveal that solar wind flow can be decelerated and strongly deviated when crossing the FCB. The boundary can form for different IMF geometries.

ANALYSIS OF PLASMA WAVES SURROUNDING FORESHOCK CAVITONS

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On its way through the Solar System, the solar wind encounters various obstacles, such as the magnetospheres of the planets. This interaction generates a bow shock in front of the planets where the solar wind is slowed down and deflected from its original direction of propagation. In the bow shock part of the incoming solar wind particles are reflected backwards. These particles interact with the incoming solar wind creating a foreshock region, where many interesting phenomena occur.

One of the most recently discovered phenomena in the Earth's foreshock region are cavitons. Their existence was first suggested by global hybrid simulations results. Cluster data have confirmed the existence of cavitons during numerous passages through the Earth's foreshock. The cavitons are observed as simultaneous depressions of the magnitude of the magnetic field and plasma density, surrounded by a rim of enhanced values of B and n. They are always immersed in a sea of low frequency plasma waves. The numerical simulations suggest that the cavitons are produced by the interaction of foreshock sinusoidal plasma waves with perpendicularly propagating compressive fast mode waves. In our previous work we studied statistical properties of foreshock cavitons. In this work we focus on the properties of the surrounding plasma waves, such as their spectra, polarization and compressibility and study the role in the formation of cavitons. We compare our results with the data obtained from numerical experiments.

ANALYSIS OF PROPAGATION OF AN INTERPLANETARY SHOCK ACROSS MAGNETOSPHERIC BOUNDARIES

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(3) Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore, USA

An important problem of the Space Weather Program is the interaction of interplanetary (IP) shocks with the Earth's magnetosphere because their interaction often (but not always) leads to major geomagnetic storms. Since the huge interaction region can be covered by simultaneous spacecraft observations only sporadically, global MHD modeling can help in our understanding of the interaction process. We have developed a procedure that clearly distinguished magnetospheric boundaries in an output of the global MHD model and compare its results to spacecraft observations.

Using one IP shock observed by Geotail, we compare its passage through the magnetosphere with a model prediction of the global BATS-R-US MHD code. We demonstrate the complexity of the IP shock interaction with the bow shock, magnetopause, and oscillations of the whole system with a period of 10-12 minutes. Moreover, based on the changes of the magnetopause and bow shock locations in the nightside region, we suggest that the information about the IP shock hitting the subsolar magnetopause reaches the nightside magnetopause earlier than the IP shock can arrive. This information is, in our view, mediated by fast magnetosonic waves in the inner magnetosphere. Although we have found generally a good agreement, we discuss possible sources of deviations of modeled and observed locations of the boundaries.

CORRELATION LENGTH OF THE MAGNETOSHEATH FLUCTUATIONS AND UPSTREAM PARAMETERS

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The magnetosheath is characterized by a variety of low–frequency fluctuations but their features and sources are different. Taking advantage of multi-point magnetic field measurements of the Cluster spacecraft, we present a statistical study to reveal properties of waves. We discuss these properties from point of view of their short correlation lengths. In the frequency interval of 0.001–0.125 Hz, we found that the correlation length of fluctuations increases (1) through intervals of high solar wind speeds, (2) with increasing IMF strength, (3) if the cross-correlation between the IMF and magnetosheath magnetic field is higher, and (4) if the amplitude of fluctuations is larger.

SHEATH TRANSPORT OBSERVER FOR THE REDISTRIBUTION OF MASS (STORM): THE PROMISE OF GLOBAL FORESHOCK, BOW SHOCK, AND MAGNETOSHEATH OBSERVATIONS

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Through studying properties of the Earth's foreshock, bow shock, and magnetosheath, we can determine much about other less accessible shocks that occur throughout the plasma universe. Pioneering single and multi-point measurements provide transient, localized glimpses of the complex layered structures of the bow shock, foreshock and magnetosheath, their response to the variable solar wind conditions and the fascinating transient kinetic phenomena that lie superimposed upon them. However, only simultaneous global observations of the foreshock, bow shock and magnetosheath can resolve and define the characteristics of the various phenomena, distinguish between proposed causes, and validate model predictions.

Motivated by observations of solar wind charge exchange soft X-ray emission, simulations have demonstrated the feasibility of globally imaging both the shocked solar wind within the magnetosheath and kinetic structures in the foreshock region. We will present a concept for an X-ray camera employing a new wide angle optic technology, different from previous designs intended for astrophysical applications, one that is capable of simultaneously imaging the entire dayside magnetsheath and the upstream foreshock.

EVOLUTION OF KELVIN-HELMHOLTZ ACTIVITY ON THE DUSK FLANK MAGNETOPAUSE

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Our purpose is to characterize the evolution of the magnetopause Kelvin-Helmholtz (KH) wave activity with changes in thickness of the adjacent boundary layer, geomagnetic latitude and interplanetary magnetic field (IMF) orientation. As the IMF turns northward, wave activity may be generated at the dayside before propagating down the tail, where the boundary layer is expected to support longer wavelengths. We use two-point observations on the dusk magnetopause at low latitudes, from Geotail on the dayside and Cluster tailward of the dusk terminator. We quantify the wavelength, power, wavefront steepness and propagation direction at Cluster. An estimate of the thickness of the low-latitude boundary layer (LLBL) is obtained by correlating normal distances to the magnetopause, derived from two empirical solar-wind-driven models, with a systematic relationship (the "transition parameter") found between the electron number density and temperature; the correlation factor is used to infer the temporal evolution of the thickness of the locally sampled layer. We find that wavelengths are controlled by the IMF clock angle, as expected when generated by the KH mechanism at the dayside, although amplitudes, wavefront steepness and propagation directions are more closely correlated with the layer thickness. A survey of parameter space provides evidence of the contribution of the KH mechanism to the widening of the electron LLBL.

PHYSICAL STUDY OF SOLAR WIND AND ITS COMPATIBILITY WITH GEOMAGNETIC INDICES (AP,KP)

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Abstract

Nowadays,solar wind variation and its effects on earth play an important role for study of space weather. Geomagnetic activity was affected significantly by solar wind. In this work, we have studied these effects as geomagnetic indices (ap , kp) by using Parker model. We solve isothermal motion equation of solar wind theoretically and compare the results with Observational data. We hypothesize that ap data would show a similar periodicity because of both plasma speed and the magnetic field of geomagnetic activity. So,we present here an empirical study of the long-term relationship between solar wind speed and ap index. In addition, we show that there is a very good correlation between Sigma kp(a daily index by summing the eight values of kp) and the velocity of the solar wind for geomagnetic disturbances.

LARGE MAGNETOPAUSE PERTURBATIONS DURING QUIET SOLAR WIND AND RADIAL IMF: CLUSTER OBSERVATIONS

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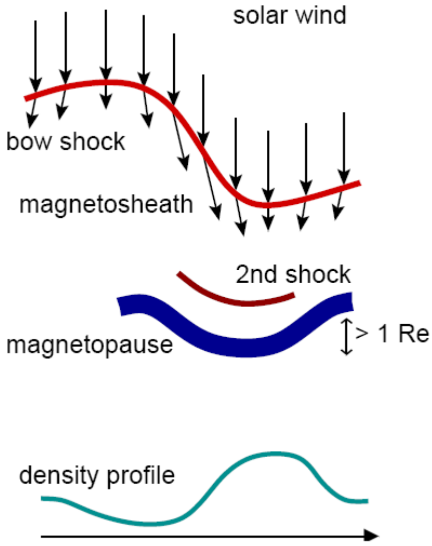
We present observations of how ripples inherent to quasi-parallel shocks may cause large magnetopause perturbations during quiet solar wind and radial interplanetary magnetic field (IMF). Radial IMF is not the most common but quite frequent a configuration in the near-Earth space.

The four Cluster spacecraft were close to the nose of the magnetosphere on the evening of March 17 2007. According to ACE and Wind, the solar wind at the time was quite fast ($\sim$530 km/s), very steady, and approximately radial. During a 3 hour period from 17:00 to 20:00 UT Cluster observed several high velocity streams in the magnetosheath. We will concentrate on the stream between 18:12-18:18 UT.

At the beginning of this interval, all four spacecraft were in the magnetosphere. First the magnetopause moved inwards passing over Cluster at 250 km/s. Then the spacecraft observed a weak shock moving in the same direction at 140 km/s. After the shock Cluster entered a cold, high velocity ($\sim$500 km/s) stream. Spacecraft 2 then moved back through the shock and the magnetopause into the magnetosphere, while spacecraft 1, 3, and 4 stayed in the stream for a few minutes moving gradually back into normal sheath-type plasma. While in the stream, they observed a gradual increase in both plasma density and magnetic field together with a turning of the plasma velocity.

According to our interpretation, this stream was created by a change in the local curvature the bow shock, a ripple. The geometry of a ripple can be such that locally the angle between the bow shock normal and the upstream plasma flow direction is large, close to 90 degrees. In such locations the shock mainly turns the flow direction while the plasma speed stays close to the upstream value. If the velocity of the stream is still super(magneto)sonic in the magnetopause reference frame, it has to shock for a second time in the magnetosheath. The ripple also creates a density gradient in the sheath since, depending on the ripple geometry, there can be convergence and divergence of the flow in neighbouring regions.

Furthermore, the high dynamic pressure of the stream can cause a large perturbation in the magnetopause shape; based on the spacecraft separation we estimate the scale size of the perturbation to be larger than 1 R_e.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Session 5:
Energetic Particles and Frontiers of the Heliosphere

LARGE SCALE HELIOSPHERIC STRUCTURE AND THE VERY LOCAL INTERSTELLAR MEDIUM

Edward C. Stone
Caltech

Now 89 and 110 AU from the Sun, the two Voyager spacecraft are in the heliosheath where the subsonic wind is deflected as it interacts with the local interstellar medium. There are significant differences between Voyager 1 at 34 degrees north latitude and Voyager 2 at 28 degrees south. On approaching the shock, Voyager 2 observed ions streaming inward along the spiral interplanetary magnetic field, opposite to the direction previously observed by Voyager 1. In August 2007, Voyager 2 crossed the termination shock at 84 AU, indicating that the shock had been at $\sim$87 AU in the southern hemisphere in December 2004 when Voyager 1 crossed it at 94 AU in the north. In addition, the radial flow speed in the heliosheath at Voyager 1 is only half that at Voyager 2, signifying a much stronger non-radial deflection in the north. Heliospheric asymmetries could result from a local interstellar magnetic field pressing inward on the southern hemisphere, and these and other large scale aspects of the outer heliosphere will be discussed in the context of current models of the complex interaction of the solar wind with the surrounding interstellar medium.

FIRST RESULTS FROM THE INTERSTELLAR BOUNDARY EXPLORER (IBEX)

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**On behalf of the IBEX Science and Mission Teams*

IBEX was launched October 19th from a Pegasus rocket flown out of Kwajalein in the Marshall Islands. After being dropped off in low Earth orbit, we ignited our own solid rocket, which carried the IBEX spacecraft into an orbit with perigee of $\sim$200 km altitude and apogee of $\sim$34 Re (geocentric). Finally, using a series of hydrazine burns, we raised the orbit to be $\sim$18,000 km x 48 Re. Since then, the IBEX team completed commissioning of the spacecraft and payload and IBEX is currently observing ENAs in space over the energy range from $\sim$10 eV to 6 keV, from a variety of sources. IBEX's heliospheric observations compliment the *in situ* measurements being made by Voyager 1 and 2 in the inner heliosheath. Because IBEX provides all-sky maps of ENAs produced in all directions in space, it is the first mission to provide truly global information about the outer heliosphere and its interaction with local interstellar medium. In addition, because the IBEX sensors make energy resolved measurements in 14 energy bins (including three ones measured independently by the two sensors), these observations provide the energy spectral information needed to understand the details of this global interaction. While the bulk of the all-sky observations can not be released until later this summer when the initial round of all sky maps are published, this talk will provide some first results and observations as well as an overview of the IBEX mission.

POSSIBLE EFFECTS OF MAGNETIC FIELDS ON STRONG DISCONTINUITIES AND WAVES IN THE HELIOSPHERIC INTERFACE

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It is known that the cyclotron frequency of charged particles (electrons and protons)is much larger than the frequency of their collisions in the heliospheric plasma ($\omega_\alpha \tau_\alpha \gg 1$). In this case transport coefficients are anisotropic relative to the magnetic field direction. Moreover, the inequality $\omega_\alpha \tau_\alpha \geq 1$ gives rise to a wave dispersion (Hall dispersion). Possible effects of the trasport property anisotropy and the Hall dispersion on the heliospheric interface shocks and heliopause are considered in this presentation. The problem of the heliospheric bow shock splitting are also discussed.

LOW-ENERGY CHARGED PARTICLES FROM THE TERMINATION SHOCK AND HELIOSHEATH

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Intensities of low-energy charged particles measured at Voyagers 1 (V1) and 2 (V2) have been dominated by particles from the termination shock (TS) and inner heliosheath (HSH) since the spacecraft entered the TS foreshock region in mid-2002 and early 2005, respectively. After spending $\approx$2.5 years in the foreshock, V1 crossed the TS on 2004/351 at 94.0 AU and V2 on 2007/242-245 at 83.7 AU, and both have since been in the HSH. We compare energetic ion (0.03-20 MeV) and electron (0.03-1.5 MeV) intensities, energy spectra, and anisotropies, and the variability of these quantities, measured by the Low Energy Charged Particle (LECP) instruments on V1 (now at 109 AU, N34 deg) and V2 (now at 88 AU, S28 deg). Low-energy HSH ions from a few tens of keV to a few MeV constitute the high-energy tail of solar wind pickup ions that undergo further acceleration at the TS and in the turbulent HSH, or both. On the long-term, data averaged over the latter half of 2008 show that HSH ion intensities and energy spectra $\approx$0.03 - few MeV are comparable at V1 and V2, with the energy spectral index $\gamma \approx$-1.5 to -1.6, indicating a remarkable uniformity of average ion intensities in the HSH over the $\sim$120 AU separating the two spacecraft. On the short-term, 0.03-3.0 MeV HSH ion intensities at V2 continue to show intensity and energy spectrum variations on time scales $\approx$20-30 days, probably resulting from V2's relative proximity to a region of TS that is being perturbed by quasi-recurrent solar wind variations. By contrast, HSH intensities of ions 0.04-4.0 MeV at V1, which is relatively far from the TS, remain flat and featureless, and show a nearly constant spectral slope. The HSH plasma flow velocity in the R-T plane at V1, as estimated from analysis of low-energy ion angular distributions, has shown decreases in both the R- and T-components since late 2007. This indicates the increasing dominance of N-component of plasma flow, the component to which the LECP is insensitive, as V1 moves further into the HSH toward the heliopause. We will discuss these results and implications thereof for particle acceleration processes at the TS and in the HSH and for variations of the plasma flow patterns in the HSH.

MODELING NEUTRAL HYDROGEN IN THE HELIOSPHERIC INTERFACE

Jacob Heerikhuisen and Nikolai Pogorelov
Department of Physics and Center for Space Plasma and Aeronomic Research, University of Alabama in Huntsville

Observational data of neutral atoms provides us with a 1 AU picture of the neutral atom flux in the heliosphere. The large mean free paths of neutrals allow us to infer properties of their distant source, as well as the properties of the intermediary medium. Energetic neutral hydrogen, for example, travels on almost straight trajectories, so that the particles observed coming from a particular direction were created from energetic protons along that line of sight. Similarly, low energy interstellar atoms are attenuated and deflected as they enter the heliosphere, and this deflection tells us something about the structure of the heliospheric interface. Of course, to infer quantitative features of the global heliosphere from neutral atom observations at 1 AU, we need accurate models that capture the 3D structure of the heliosphere. We will present an advanced MHD-neutral model of the heliosphere which is 3D, employs kinetic neutral Hydrogen, and incorporates a suprathermal tail on the solar wind proton distribution to approximate pick-up ions. We will demonstrate that with the help of such a model, we can test various hypotheses regarding the heliospheric boundary via forward modeling and comparison with data.

THE STRUCTURE OF THE SOLAR-WIND TERMINATION SHOCK AND THE NATURE OF CHARGED-PARTICLE DISTRIBUTIONS IN ITS VICINITY

Joe Giacalone
University of Arizona

The shock-wave associated with the termination of the solar wind, which has now been crossed by both Voyager spacecraft, is unlike those that we have seen elsewhere in the solar system. For example, recent Voyager 2 observations have revealed that downstream of the shock, the solar wind is supersonic, rather than subsonic, as expected. This is perhaps not surprising since the solar-wind instrument on Voyager 2 cannot measure interstellar pickup ions, which contribute as much as 20-30% of the number density of ions in the outer heliosphere, and far dominate the plasma pressure. In addition, both Voyagers observed a large increase in the intensity of low-energy anomalous cosmic rays as each crossed the termination shock. The diversity in the charged particle populations, including cold solar wind ions, numerous interstellar pickup ions, and high-energy particles with significant contribution to total plasma pressure, and large-scale interplanetary magnetic-field turbulence, leads to particularly unique environment in which the shock exists. In this talk, I will discuss the physics of the termination shock focusing on its microstructure and the nature of the particle distributions in its vicinity. This problem is possibly best solved by numerical simulation, particularly the well-known hybrid simulation which treats the ions kinetically and the electrons as a massless fluid. Among other things, I will present results from new simulations that show that the termination shock is a rapid and efficient accelerator of suprathermal pickup ions and the simulations results agree well with the low-energy part of the ACR spectrum (up to about 100 keV).

THE STRUCTURE OF THE FLOW NEAR THE HELIOPAUSE STAGNATION POINT

Nikolai A. Belov and Michael S. Ruderman
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The plasma flow in the vicinity of the heliopause stagnation point in the presence of the H atom flow is studied. The back reaction of the plasma flow on the H atom flow is neglected, and the density, temperature and velocity of the H atom flow are taken to be constant. The solution describing the plasma flow is obtained in the form of power series expansions with respect to the radial distance from the symmetry axis. The main conclusion made on the basis of the obtained solution is that the heliopause is not the surface of discontinuity anymore. Rather it is the surface separating the flows of the solar wind and interstellar medium with all plasma parameters continuous at this surface.

MAGNETIC FIELDS AND COSMIC-RAY TRANSPORT AT FLUID VELOCITY SHEAR

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The interaction of a turbulent magnetic field with fluid shear can play a significant role in energetic-particle transport in the heliosphere and other astrophysical fluids. We will discuss some of the expected effects that have been published and go on to discuss some recent, new ideas which may be important. We find that shear layers can provide significant barriers to charged-particle transport. Shear increases field-line mixing and increases the magnetic field magnitude. Both effects reduce the transport of energetic particles across the shear layer.

For example, we find that the heliopause may be a significant barrier to galactic cosmic rays entering the heliosphere. The shear flow near the heliopause should reduce transport across the heliiopause. The same effect may act to confine anomalous cosmic rays to the heliosphere. These factors may be closely related to the "magnetic wall" in the outer heliosheat which has been discussed by earlier authors in connection with numerical simulations. Shear also occurs in the inner heliosphere across the boundaries between fast and slow streams. The effects at these boundaries depends on the relation between the radial flow and magnetic field near the Sun.

VOYAGER UVS MEASUREMENTS IN THE OUTER HELIOPSHERE: OBSERVATIONS AND MODELS

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We present new results of models of the interplanetary background in the outer heliosphere. They are compared with scans performed by the Voyager 1/2 UVS instruments between 1993 and 2003. This study shows that the excess intensity initially reported by Quémerais et al. (1996) can be explained by models of the hydrogen atoms including effects of the heliospheric interface. The models used for this computation have been developed from the initial scheme of Baranov et al. (1993). We find that the upwind intensity excess initially reported by Quémerais et al. (1995) can be explained when a full radiative transfer computation is performed. This computation must include a description of the different hydrogen populations which enter the heliosphere after crossing the interface. The excess upwind intensity observed by V1 and V2 can be explained as an emission of the decelerated hydrogen population near the stagnation point of the heliopause. Because those atoms are shifted away from the bulk velocity of the hydrogen flow, photons scattered by these hydrogen atoms suffer less absorption and are visible at a much larger distance. The shape and extent of the excess emission gives information of the decelerated population near the heliopause stagnation point.

ENERGETIC NEUTRAL HYDROGEN ATOMS FROM A SOLAR FLARE: OBSERVATIONS AND INTERPRETATION

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We report observations of energetic neutral atoms (ENAs) from a solar flare/coronal mass ejection event. The observations were made by the Low Energy Telescopes (LETs) on the STEREO A and B spacecraft during the December 5, 2006 X9 solar flare, located at E79. Within 1-2 hours of the flare onset, both LETs observed a sudden burst of 1.6 to 15 MeV protons arriving from a longitude within +-10 degrees of the Sun, arriving hours before the onset of the main solar energetic particle (SEP) event at Earth. The derived emission profile at the Sun had a profile very similar to the GOES soft X-ray profile and lasted for more than an hour. The observed arrival directions and energy spectrum argue strongly that the particle events <5 MeV were due to ENAs that were stripped of their electrons upon entering the LET sensor. Possible origins for the production of ENAs in solar events are discussed, including charge-transfer reactions involving both flare and shock-accelerated protons. Assuming isotropic emission, we find that $\sim 2 \times 10^{28}$ ENAs escaped from the Sun in the upper hemisphere. RHESSI measurements of the 2.2 MeV gamma-ray line confirm that there was extensive acceleration of high-energy protons in this flare and lead to an estimate of $>1.2 \times 10^{31}$ interacting protons with >30 MeV, assuming a spectral index of -3.5. Using this proton fluence along with measured and theoretical cross sections, we estimate that $>3 \times 10^{31}$ ENAs with 1.8–5 MeV were produced by protons accelerated in the flare if all >10 MeV protons slow and stop in the solar atmosphere. CME-driven shock acceleration is also a possible ENA source, but unfortunately there were no CME observations available from this event. Taking into account ENA losses, we conclude that the observed ENAs were most likely produced in the high corona at heliocentric distances more than 1.6 solar radii.

VOYAGER PLASMA OBSERVATIONS IN THE HELIOSHEATH

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Voyagers 1 and 2 continue to explore the heliosheath. The first 21 months of Voyager 2 plasma observations in the heliosheath will be presented.The speeds observed by V1 and V2 are very different, with V2 observing radial speeds about twice those observed at V1. This difference is in the opposite direction of that predicted by models. Densities slowly decreased across the sheath, possibly due to a decrease in solar wind flux throughout the heliosphere. Temperatures also decrease across the heliosheath. Non-radial flows observed at the heliosheath are much larger parallel to the solar equatorial plane than perpendicular plane, suggesting that termination shock is more extended in the equatorial plane and smaller at the poles.

THE INTERSTELLAR HYDROGEN FLOW: UPDATED ANALYSIS OF SWAN DATA

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LATMOS/IPSL

The direction of the interstellar neutral hydrogen flow is determined based on SOHO/SWAN hydrogen cell data at solar maximum (2001). It is compared with the flow direction derived from solar minimum data. The similarity of the results suggests that the deflection of the hydrogen flow w.r.t. the circum-heliospheric motion is only marginally due to the solar wind asymmetries. We update the hydrogen deflection plane.

TRANSIENT PHENOMENA IN THE DISTANT SOLAR WIND AND IN THE HELIOSHEATH

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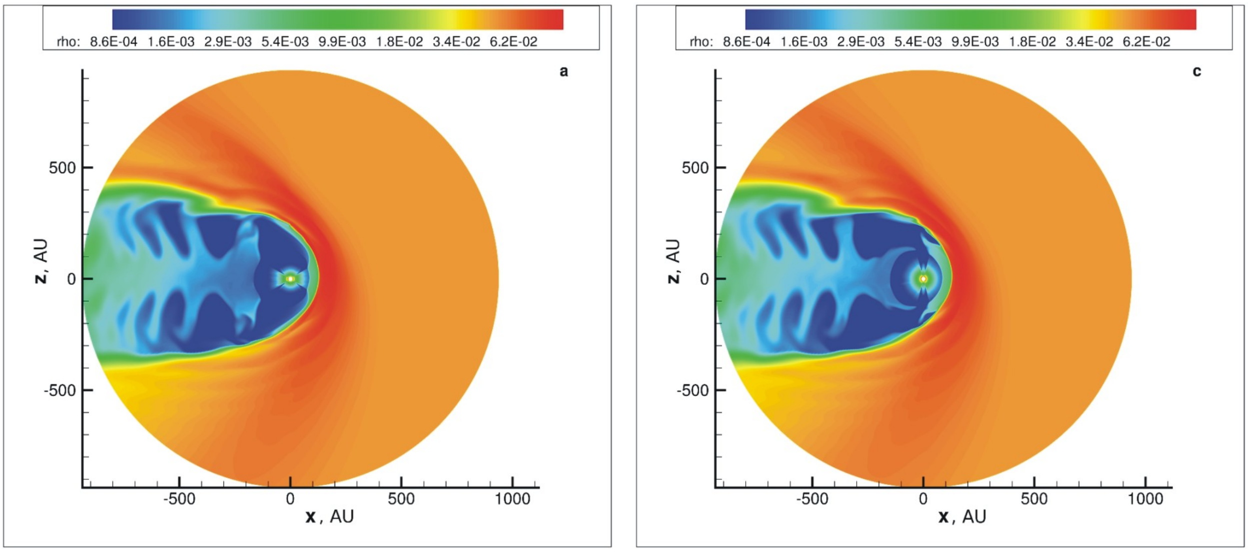
The difference in the heliocentric distances at which Voyager 1 (V1) and Voyager 2 (V2) spacecraft crossed the termination shock (TS) is very likely to be determined by the combination of the heliospheric asymmetry caused by the interstellar magnetic field (ISMF) and time-dependent boundary conditions at the Sun (Pogorelov et al. 2007). We analyze both effects numerically in an attempt to compare the results with Voyager observations. It is shown that the increase of the ISMF strength above 4 microgauss can alone explain a 10 AU difference in the TS positions when it was crossed by V1 and V2. We confirm that the solution obtained does not contradict directly to the SOHO data on the defection of the neutral hydrogen flow in the inner heliosphere from its original direction in the unperturbed circum-heliospheric interstellar medium (CHISM) and the physics of 2-3 kHz radio emission. However, the ISMF increase results in an increasingly large discrepancy between the calculated and observed distributions of the solar wind (SW) velocity in the inner heliosheath. We also estimate that the decrease of the SW dynamic pressure, observed by Ulysses over the past three years, may lead to essentially similar difference in the TS stand-off distances in the V1 and V2 directions. This emphasizes the importance of the solar cycle and transient phenomena occurring at the Sun. We analyze possible effects of the solar cycle on the SW properties in the inner heliosheath with the model that takes into account the variations in the latitudinal extent of the slow and fast SW regions and in the angle between the Sun's rotation and magnetic axes (the figure shows the proton density distribution near a solar minimum and a maximum). For example, the possibility is explored of the SW velocity to have a rather small gradient as V2 penetrates deeper into the heliosheath. Comparison is made of the calculated and observed interplanetary magnetic field (IMF) gradients. The implications are discussed of the solar cycle and transient phenomena effects for the energetic neutral atom propagation into the inner heliosphere.

In order to further analyze the effect of the solar cycle we also perform calculations of the SW–CHISM interaction with inner boundary conditions specified by Ulysses, which is a unique source of three-dimensional, time-dependent SW data. We also analyze the effect of propagation of a CME-related velocity pulse into the inner heliosheath and further beyond the heliopause, where it modifies the ISMF resulting in the radio emission generation. The evolution of the radio emission criterion is analyzed both during the solar cycle and due to the passage of transients, which allows us to speculate about the space distribution of radio emission sources. **... see next page**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Posters of session 5

ON THE INTERACTION OF SOLAR NEAR-RELATIVISTIC ELECTRONS WITH BACK-SCATTER REGIONS BEYOND 1 AU

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Several solar near-relativistic (NR) electron events observed by spacecraft at 1 AU have been previously explained by assuming that the propagation of NR electrons in the inner heliosphere (r < 1 AU) is essentially "scatter-free" along the interplanetary magnetic field and that beyond 1 AU, particles are "back-scattered" by magnetic field compressions and irregularities.

We use Monte Carlo simulations to explore this approach. We assume that the interplanetary magnetic field is an Archimedean spiral and that the interplanetary transport of NR electrons is characterized by 1) a large radial mean free path and anisotropic scattering in the inner heliosphere, and 2) a small radial mean free path and isotropic scattering in the back-scatter region.

We apply the model to study the 2000 February 18 electron event observed by the ACE spacecraft. We fit observational sectored intensities to assure that all the directional information contained in the data is used in full. We discuss the deconvolved injection histories of NR electrons. Possible diagnostics of this kind of interplanetary magnetic field structures are discussed as well.

NEUTRAL INTERSTELLAR OXYGEN AND HELIUM AT EARTH ORBIT IN ANTICIPATION OF IBEX OBSERVATIONS

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With the launch of IBEX in October 2008, the heliospheric community obtained a tool for direct studies of various neutral atom species that stem from a variety of sources. IBEX is a Sun-pointing spinner with single-pixel, relatively wide-field cameras pointing perpendicular to the spin axis. They are capable of detecting neutral atoms in 15 energy bands from 0.01 to 6 keV and are immune to electromagnetic due to the consequent use of triple-coincidence techniques. In particular, IBEX can observe the populations of neutral He and O atoms, both incoming directly from the Local Interstellar Cloud and coming up in the outer heliosheath due to charge exchange between the local plasma and the interstellar gas. Simultaneous observations of the O and He atoms provide information on the processes going on in the outer heliosheath. Oxygen is affected strongly by charge exchange with protons in the ambient plasma and hence is modified in the outer heliosheath, while helium goes through almost unaffected, thus providing a reference population, which resembles pristine interstellar gas. Simultaneously, unlike H, O and He are insensitive to solar radiation pressure and propagate in the heliosphere under the sole influence of solar gravity, which facilitates interpretation of the observations. We calculate the populations of these species at the Earth orbit using a kinetic model of neutral interstellar gas and ionization rates taken from observations. With these on hand, we study the expected distributions of these populations along the Earth orbit, as well as their inflow directions and spatial structure of the beams, taking into account the observation conditions for IBEX. We point out the modifications of the atom beams as a messenger of the deformation of the heliosphere by the interstellar magnetic field. We discuss the use of IBEX observations to propagate the distribution functions of these atoms to the termination shock.

SIMULTANEOUS OBSERVATIONS OF SUPRATHERMAL ELECTRONS AND ENERGETIC IONS: EVIDENCE FOR DISCONNECTION AND RECONNECTION

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Suprathermal electron heat flux dropouts (HFD) serve as a sensitive test of the magnetic topology of the inner heliosphere. Since the heat flux electron strahl always flows away from the Sun, a heat flux dropout must indicate some interference with particle transport on the field line between the observing spacecraft and the injection of the heat flux, either magnetic disconnection at the source or a region where the heat flux electrons are scattered. In the latter scenario, the closed field lines from one leg of an interplanetary coronal mass ejection at several AU undergo interchange reconnection with open field lines close to the Sun. If the heat flux is substantially scattered along the lengthy path of the still-connected leg, from the Sun to the ICME apex, the electrons will not reach the spacecraft at 1 AU, and the spacecraft will see a heat flux dropout. We will present new observations of suprathermal electron heat flux dropout events observed by the ACE spacecraft which occur simultaneously with impulsive energetic ion events. Since suprathermal electrons encompass the same velocity range as ions with energies of a few MeV/nucleon, the similarities and differences between them as observed at 1 AU probes the sources and transport of these two species. The interpretation of these events in the context of the reconnection and disconnection models will be discussed.

FIRST MEASUREMENTS OF RADIAL AND LATITUDINAL GRADIENTS OF ANOMALOUS COSMIC RAY OXYGEN IN THE INNER HELIOSPHERE DURING AN A<0 PERIOD

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We use data from the Ulysses, STEREO, and ACE missions to investigate the radial and latitudinal gradients of anomalous cosmic ray (ACR) oxygen with energies $\sim$4 to 21 MeV/nuc during the period from 2007 to the present. This time interval includes a period when the Ulysses spacecraft executed a fast-latitude scan from south to north covering $\pm$ 80°in heliographic latitude. This is the first time such a measurement has been made in the inner heliosphere in an A<0 solar magnetic cycle period. Assuming the radial and latitudinal gradients are fixed, we find for ACR O with 7.3-15.6 MeV/nuc that the radial gradient is 48 $\pm$ 14 %/AU and the latitudinal gradient is consistent with zero for the time interval 2007/003 to 2008/150. We will compare and contrast our results with observations made during the last A>0 period and relate them to models of particle transport in the heliosphere.

This work was supported by NASA at Caltech and JPL under contracts NAS5-03131 and NNX08AI11G.

ROLE OF LATITUDE OF SOURCE REGION IN SOLAR ENERGETIC PARTICLE EVENTS

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Solar Energetic Particle (SEP) measurements from the Ulysses spacecraft have shown that the latitudinal separation between the parent solar flare and the nominal footpoint of the detecting spacecraft is an important parameter in ordering characteristics of the observed time-intensity profiles, such as the time to maximum intensity and onset delay. In this study we consider data from a variety of near-Earth missions over 2 solar cycles, to address the question of whether the same trend can be observed from in-ecliptic SEP measurements at 1 AU. Because of the inclination of the ecliptic plane with respect to the heliographic equatorial plane, the latitudinal separation between the location of the parent flare associated to an SEP event and the footpoint of a near-Earth detecting spacecraft can vary in latitude between 0 and about 40 degrees. We discuss whether a large latitudinal separation means a lower likelihood of an SEP event being detected, and analyse how the characteristics of SEP time-intensity profiles depend on the latitudinal separation.

FORMATION OF COSMIC RAY ANISOTROPY IN THE HELIOSPHERE AS RESULT OF GALACTIC CR INTERACTION WITH SOLAR WIND

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The convection-diffusion model of cosmic ray (CR) anisotropy in the interplanetary space was supposed in the first time by Krymsky (1964) and Parker (1964). The main sense of this model is as following: the moving from the Sun solar wind with interplanetary shock waves and other disturbances formats the convection CR flux directed from the Sun; as a result the CR density decreased with decreasing of the distance from the Sun and the radial CR gradient directed out of the Sun formatted. As result, the diffusion flux in direction to the Sun, but mainly along the spiral interplanetary magnetic field appears. In equilibrium state the radial component of the diffusion flux will be compensated by the CR convection flux, but the azimuthal component doesn't compensate and will be observed as 18h local solar time anisotropy. In the period of solar activity decreasing (CR intensity increasing) the time maximum will be move to later time, and in opposite case - to earlier time than 18h local time.

Later this model was developed in the frame of the anisotropic convection-diffusion theory of CR propagation in the interplanetary space with taking into account the adiabatic energy change of CR particles as well as drift effects (Parker, 1965; Dorman, 1965, 1975; Axford, 1966; Jokipii and Parker, 1969; Jokipii, 1971; Forman et al., 1974; Forman and Gleeson, 1975; Dorman and Kats, 1977; Kota and Jokipii, 1983; Ahluwalia and Riker, 1987; Riker and Ahluwalia, 1987a,b; Belov, 1987; Belov et al., 1988, 1990, 1991, 1993; Bieber and Chen, 1991; Chen and Bieber, 1993; Dorman, 2006). The comparison with experimental data and testing of this theory were made by many authors. The problem is that usually in observation data we have mixed information on the sum of convection-diffusion and drift anisotropies which properties (dependence from particle rigidity, from solar activity, from solar magnetic polarity and others) are completely different. One method to solve this problem is to use statistical investigations of mixed data and compare obtained results with predicted from the theory (Belov, 1987; Belov et al., 1987a,b, 1988,1991, 1993; Belov and Oleneva, 1995; Dorman, 2000, 2006). The other method is in the first to separate the convection-diffusion and drift anisotropies and then to investigate their properties separately (Ahluwalia and Dorman, 1994, 1995, 1997; Dorman and Ahluwalia, 1995a,b; Dorman, 2000, 2006).

Here we will concentrate on two key problems: 1) connection between observed CR anisotropy with parameters of CR transportation and CR density gradients in the interplanetary space (main results of statistical research) and 2) separation on convection-diffusion and drift modulations and estimation of their relative role in formation CR anisotropy in dependence of particle energy.

THE MULTIFLUID CHARACTER OF THE SOLAR WIND TERMINATION SHOCK

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At the more recent Voyager-2 crossings (Sept.2007)of the solar wind termination shock MHD jump phenomena were recognized that cannot be understood in the frame of classical monofluid MHD shock relations. Especially the fact that downstream thermal protons still appear with a supersonic signature due to inefficient shock-heating, while suprathermal ions seem to absorb most of the upstream kinetic solar wind energy, can only be understood in the frame of a multifluid approach to the plasma passing over the shock. In this presentation we present a two-fluid approach of the solar wind plasma consisting of a thermal and a suprathermal ion fluid in hydrodynamical and thermodynamical coupling to eachother. Within a consistent set of conservation equations we can derive univocal solutions for the properties of the downstream two-fluid plasma, if the conservation of effective magnetic particle moments is respected in the jump conditions. As we can show, depending on the upstream plasma conditions, we find a downstream thermal ion plasma with inefficient heating and supersonic signature and a downstream suprathermal plasma as the main entropy carrier and with subsonic signature.

STOCHASTIC ACCELERATION IN THE HELIOSPHERE AND THE IMPLICATIONS FOR ACCELERATION IN THE INTERSTELLAR MEDIUM

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There are a number of important observations of acceleration of suprathermal and more energetic particles in the heliosphere that require explanation: (1) The suprathermal tails in a variety of different quiet-time conditions, e.g. in the quiet solar wind, downstream from shocks, and in the heliosheath, have a common spectral shape, a power law in particle velocity with a spectral index of -5 when expressed as a distribution function. (2) The Anomalous Cosmic Rays (ACRs) appear to be accelerated in the heliosheath. A new theory for stochastic acceleration has been developed that can account for the observations. The theory invokes the constraint that the total energy of the accelerated particles is constant. This constraint is particularly appropriate in the heliosheath where the pressure of the pickup ions, suprathermal tails, and thus the ACRs must be constant. The theory may also apply to the acceleration of Galactic Cosmic Rays in the interstellar medium. The theory will be reviewed, and applied in a number of different settings in the heliosphere and to the interstellar medium.

CIR-ASSOCIATED ENERGETIC PARTICLES DURING 2008: MULTI-POINT OBSERVATIONS BY STEREO AND ACE

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During 2008 the angular separation between the twin STEREO spacecraft grew from 44 to 88 degrees. During this period solar activity remained very low, providing an excellent opportunity for multi-point studies of CIRs, using combined observations from STEREO and near-Earth spacecraft. In-situ energetic particle and plasma data from the SEPT, LET and PLASTIC instruments onboard STEREO along with observations from ACE SWEPAM and EPAM have been mapped back to the Sun. The use of this technique, allowed us to directly compare the in-situ data from different spacecraft and correlate them with the parent coronal holes. We found telltale discrepancies in the structures observed by the three spacecraft. Heliographic latitudinal separation between the spacecraft cannot always account for the observed discrepancies. The observations suggest that temporal evolution of the parent coronal holes as well as the interaction between CIRs and transient solar wind structures in the interplanetary medium can also play an important role.

INTERSTELLAR OXYGEN IN 3D HELIOSPHERE

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This paper presents results of new model calculations of interstellar oxygen flow in the region of the solar wind interaction with the local interstellar medium and inside the heliosphere. Oxygen atoms are of particular interest, because they are strongly coupled with the protons through charge exchange reactions, and because they are now observed under the form of pick-up ions and anomalous cosmic rays, and will be observed directly on board of Interstellar Boundary Explorer (IBEX). The measurements provide observational tests of the processes at work at the boundary of the heliosphere. Our calculations are based on Izmodenov et al. (2005) model of the solar wind/interstellar medium interaction that takes into account 3D effects of the interstellar magnetic field. Distributions of the interstellar oxygen atoms and ions are computed through the H and H^+ interface. The model accounts for direct charge-exchange (O atoms with protons), reverse charge-exchange (O ions with neutral H), photoionization and solar gravitation. Source distributions of O^+ pick-up ions resulting from oxygen atom ionization are also produced, as well as density distributions of the oxygen ions in the heliosphere, assuming that newly created oxygen ions are instantaneously assimilated to the plasma. Inside the TS interstellar oxygen is modeling according to advanced hot-type model (Katushkina & Izmodenov, 2009). Fluxes of interstellar oxygen at 1 AU that can be directly compared with IBEX measurements will be presented.

INTERSTELLAR PICKUP PROTONS AS SOURCE OF THE HELIOSPHERIC ENAS: RESULTS OF GLOBAL MODELING

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We present results of our recent developments of multi-component model of the solar wind interaction with the partially ionized local interstellar medium developed by Malama et al (2006). This model includes a multi-component treatment of charged particles in the heliosphere. All charged particles are divided into several co-moving types. The coldest type, with parameters typical of original solar wind protons, is considered in the framework of fluid approximation. The hot pickup proton components created from interstellar H atoms and heliospheric ENAs by charge exchange, electron impact ionization and photoionization are treated kinetically. In addition to the heliospheric pickup protons, the model includes now kinetic description for interstellar pickup protons which are created outside the heliopause. The pickup proton population is a result of charge exchange of interstellar hydrogen atoms and heliospheric ENAs that enter the region outside the heliopause from the inner heliosheath between the termination shock and the heliopause. It will be shown that the ENAs created outside of the heliopause from the interstellar pickup protons provide essential contribution into the spectra of heliospheric ENAs at 1 AU and, therefore, these ENAs are important for analyses of IBEX observations.

TEMPORAL VARIATION AND ANISOTROPY OF SUPRATHERMAL PARTICLE FLUXES IN THE SUPERSONIC AND SUBSONIC SOLAR WIND DOMAINS

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The behavior of recent suprathermal and energetic particle fluxes and directional distributions along the trajectories of the two Voyagers differ in several respects. One important point of difference concerns the structure of omnidirectional flux variations, both in their short-term and long-term properties. The energy dependence of temporal variations also displays discordant features. Below the energy of about 200 keV, pre-shock activity is much less pronounced at Voyager-2 than at Voyager-1. After a transition period following termination shock transit, particle fluxes at Voyager-2 behave considerably less smoothly than those at Voyager-1. First harmonic anisotropy amplitudes and phases also behave in a different manner for the two spacecraft, both before and after shock transit. A comparison will be made between the characteristics of the shock transits and of subsequent records, updated to the most recent data sets available. Implications of those findings will be discussed, also taking into account the plasma measurements at Voyager-2 and the magnetic field measurements at both distant heliospheric space probes.

INVESTIGATION OF ACCELERATION SOURCES OF THE MAJOR SEP EVENTS

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Solar energetic particles (SEPs) are one manifestation of violent releases of magnetic energy on the Sun. All geo-effective or major SEP events are associated with coronal mass ejections (CMEs) and/or flares. The main controversy focuses on which process is dominant during particle injection. We first present studies of SEP dynamics, flare magnetic reconnection rate, and the coronal magnetic configuration during the 2006 December 13 event. Our analysis suggests that flare acceleration dominates as the cause of the initial SEP injection and produces a highly anisotropic particle distribution with a hard energy spectrum. Subsequently, the acceleration source appears to switch to a wide-spread interplanetary CME-driven shock, which produces a nearly isotropic particle distribution with a softer energy spectrum. We then present a statistical survey of the major SEP events occurred from February 2002 to December 2006. Systematic correlations are found between the characteristics of in-situ SEPs (time history, spectrum, and anisotropy) and the associated flare active regions (location, multi-wavelength emission, and photon spectrum).

MULTIFRACTAL TURBULENCE AT THE TERMINATION SHOCK

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We analyze time series of the solar wind magnetic field measured in situ by Voyager 1 and 2 spacecraft in the outer heliosphere. The aim of this study is to examine the question of scaling properties of intermittent solar wind turbulence at the termination shock at 84 and 94 AU from the Sun. To quantify scaling of solar wind turbulence, we consider a generalized two-scale weighted Cantor set with possibly two different scales [1, 2]. We investigate the resulting spectrum of generalized dimensions and the corresponding multifractal singularity spectrum depending on one probability measure parameter and two rescaling parameters. We observe the evolution of multifractal scaling of the solar wind in the outer heliosphere [3]. In particular, we demonstrate that this scaling is asymmetric before shock crossing, in contrast to the symmetric spectrum observed in the heliosheath. Moreover, we show that the degree of multifractality for magnetic filed fluctuations of the solar wind before shock crossing is greater than that for the heliosheath; the solar wind in the outer heliosphere may exhibit strong asymmetric scaling. It is worth noting that for the multifractal two-scale phenomenological model a good agreement with the data is obtained. Hence we propose this model as a useful tool for analysis of intermittent turbulence also at the heliospheric boundaries.

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SHORT-PERIOD VARIABILITY OF ENERGETIC PARTICLES ASSOCIATED WITH INTERPLANETARY CORONAL MASS EJECTIONS

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We examine several cases of short-period variability in the SEP and GCR flux in the solar wind and in the magnetosphere using background channels in several spacecraft including Polar, ACE, and INTEGRAL and find correlations between the fine-scale particle flux structure and the local solar wind magnetic field topology. Often these periods occur in and around the time of a Forbush decrease caused by the passage of an interplanetary coronal mass ejection (ICME) and its sub-structures. The fine structures in the energetic particle intensities along with the Forbush decrease are propagated outward with very little change from L1 to the Earth indicating that parcels of solar wind are transporting the energetic particle populations outward in the heliosphere. We find the particle fine structure is bracketed by solar wind magnetic field discontinuities within the ICME. Similar to the dispersionless modulation of the electron heat flux, which is an indicator of changes in magnetic field topology, fine structures in the particle observations show that the intensity levels in the GCR flux may undergo a similar partitioning associated with local changes observed in the interplanetary magnetic field. Undoubtedly, the high-resolution measurements made available by the background channels from the INTEGRAL, Polar, and ACE spacecraft give us an unprecedented view into the microphysical processes of energetic particle transport in the interplanetary medium.

ON THE THICKNESS OF THE HELIOSHEATH: IMPLICATIONS FROM UPPER LIMITS ON ENA INTENSITIES FROM CASSINI/INCA FROM THE DIRECTIONS OF VOYAGERS 1 AND 2.

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Preliminary estimates of upper limits on ENA intensities measured by the Magnetospheric IMaging Instrument (MIMI) onboard the Cassini Saturn orbiter were recently reported by Krimigis et al. ["Voyagers in the Heliosheath", Kaua'i, HI, 9-14 January 2009]. These, when combined with $insitu$ ion intensities measured by Voyager, imply upper limits on the thickness of the heliosheath. MIMI is a suite of energetic particle sensors that includes the Ion and Neutral Camera (INCA) that images hydrogen ∼3 to >200 keV in energy bands ∼10 keV wide with a pixel resolution ∼4 deg over a field of view 90 deg by 120 deg. For many months prior to Saturn orbit insertion 01 July 2004, INCA scanned different regions of the sky. Later, while in orbit, there are periods during which INCA looks out into the sky away from Saturnian sources of ENAs (magnetosphere, magnetosheath, and upstream foreshock). Both pre- and post-insertion observations may contain ENAs produced within the solar wind (inside the termination shock). We have evidence that the INCA coincidence channels respond almost solely to ions and ENAs, with no sensible response to photons (UV, EUV, or Xrays). Regardless of any non-ENA contamination, the lowest intensities measured by INCA in any direction of the sky must constitute upper limits on the actual ENA intensities from the heliosheath. Of particular interest are the directions towards the Voyager 1 and 2 spacecraft that passed through the termination shock into the heliosheath on 16 December 2004 and 30 August 2007, respectively. The Low Energy Charged Particle (LECP) instruments on both Voyagers measure ion intensities 30 keV to well above 1 MeV, thus covering the range of the INCA ENA measurements. The actual ENA intensity (j_{ENA}) divided by the (energy-dependent) charge-exchange cross-section (σ) with interstellar H-atoms (density n_H) is equal to an equivalent heliosheath thickness (L) multiplied by the interstellar-H-density-weighted mean ion intensity $< n_H j_{ION} >$ averaged outward through the heliosheath along the INCA line-of-sight (LOS) through the heliosheath: $j_{ENA} = \sigma$L$< n_H j_{ION} >$. Thus if one normalizes any model of the energetic ion intensities (j_{ION}) by the measured LECP intensities in the inner heliosheath and chooses a model for the radial dependence of the interstellar H-atom density along the INCA LOS, the INCA ENA intensity upper limits ($j_{ENA}* > j_{ENA}$) will provide independent upper limits (L*>L) for the heliosheath thickness (L) along the LOS corresponding to Voyagers 1 and 2. Very rough initial estimates yield L*<100AU.

RELATIVISTIC SOLAR ELECTRONS – WHERE AND HOW ARE THEY FORMED?

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Relativistic Solar Electrons are observed in conjunction with flares or coronal mass ejections (CMEs), however their formation mechanisms seem elusive. The existence of non-thermal electrons in the solar atmosphere and along the heliospheric field lines is deduced through emission of electromagnetic waves and via direct in situ satellite measurements at 1 AU. Their spectral shapes and the relative timing with respect to imaging and spectrographic observations may identify potential acceleration sites and processes controlling the formation of the (delayed with respect to a timing of a flare or initiation of CME) relativistic electrons. It is conjectured that the delayed acceleration occurs along the stretched, closed coronal field lines, when an anisotropic seed population of low-energy electrons is injected in conjunction with the high frequency coronal radio bursts behind the large CME, as recorded by radioheliographs. The energization proceeds as a bootstrap process due to resonant interaction with oblique whistler waves, which are excited by the nonisotropic seed electrons. The flare serves mainly as a time reference for the electromagnetic emissions, while the CME subsequently opens an access for the relativistic electrons to the interplanetary medium.

ENERGETIC PARTICLES AND UPSTREAM WAVES AT CO-ROTATING SHOCKS

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Acceleration by shocks involves multiple crossings of the shock by the particles as they are scattered back and forth by upstream and downstream magnetic field fluctuations. Self-consistent theory includes the generation of waves by the accelerated particles as they travel upstream and their effect on the particles. The theory has so far been tested successfully at the planetary bow shock and at traveling shocks associated with Coronal Mass Ejections under a limited set of conditions. Over its 18 -year lifetime, the Ulysses mission has returned magnetic field, plasma and energetic particle measurements at numerous shocks bounding Co-rotating Interaction Regions. This valuable data set is available to study the particle acceleration and wave generation processes in great detail. Our preliminary analysis of the Forward Shocks has shown that the intensities of the higher energy particles are correlated with the power in the ever-present magnetic variations in the solar wind. Spectra of the magnetic fluctuations show the power increasing as the shock is approached presumably because of the addition of the self-generated upstream waves. The present study involves many more examples under a wide variety of conditions and including Reverse Shocks that are prolific sources of energetic particles. A major objective is to determine how the particle intensities are governed by the properties of the solar wind and the shocks. The identification and properties of the waves upstream and downstream of the shocks are also investigated in detail by spectral analysis and by carefully examining the waveforms to distinguish waves generated by the solar wind fluctuations, the energetic particles and the shock itself.

IONIC CHARGE STATES INFERRED BASED ON ELEMENTAL AND ISOTOPIC FRACTIONATION IN ^{3}He-RICH SOLAR ENERGETIC PARTICLE EVENTS

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Data from the ACE Solar Isotope Spectrometer (SIS) have been used to study heavy ion elemental and isotopic abundances at energies above 10 MeV/nuc in a number of ^{3}He-rich solar energetic particle (SEP) events. The isotopic composition observations have revealed a fractionation pattern in which heavy isotopes are enhanced relative to lighter isotopes of the same element as a power law in the ratio of the masses. Assuming that this mass fractionation represents a special case of a fractionation law that depends on both ionic charge, Q, and mass, M, we have used the SIS data to infer charge states in the material being fractionated. Two physically reasonable assumptions about the Q-dependence of the fractionation law have been considered. For fractionation as a power-law in Q/M, as might arise due to the rigidity dependence of the interaction with accelerating electromagnetic fields, we find high Fe charge states (Q_{Fe}) that could represent an extension of the increasing trend of Q_{Fe} with increasing energy previously observed in data from the ACE/SEPICA instrument below 1 MeV/nuc. This would indicate that the fractionation occurs late in the acceleration process. On the other hand, if the fractionation is a power law in Q^2/M, as might occur if Coulomb collisions were the dominant energy-loss process limiting the acceleration, the inferred charge states are found to be consistent with values in the solar wind and presumably similar to values in the coronal source material from which the accelerated particles are derived. This would suggest that fractionation occurs in the earliest stages of particle heating and acceleration. We will discuss these two alternative interpretations of the data and their implications for the origin of ^{3}He-rich SEP events.

This work was supported by NASA at the California Institute of Technology (under grant NNX08AI11G), the Jet Propulsion Laboratory, and the Goddard Space Flight Center.

THE INTERACTION OF PICKUP IONS AT THE TERMINATION SHOCK AND IMPLICATIONS FOR NEUTRAL ATOMS

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Observations by the Voyager 2 spacecraft of the structure of the heliospheric termination shock revealed a quasi-perpendicular structure that possessed many of the characteristics that are familiar to us from perpendicular shocks observed in the inner heliosphere. However, a surprise was the relative lack of heating experienced by thermal solar wind ions (and electrons), leading to the suggestion that the pickup ions were primarily heated at the heliospheric termination shock. Because the Voyager plasma instrument cannot measure the interstellar pickup ions directly, their behavior at the termination shock could not be gauged directly. Nonetheless, it had already been predicted by Zank et al. 1996 that the primary dissipation mechanism for the quasi-perpendicular termination shock would be the reflection of pickup ions rather than solar wind ions; this because of the shell-like structure of the pickup ion distribution function. We discuss the effect of pickup ions including their trajectories within the structure of the shock observed by Voyager 2. A model for the shock structure is constructed on the basis of preferentially reflected pickup ions, solutions are discussed, and we estimate the degree of heating for the various components.

SUPERDIFFUSIVE TRANSPORT UPSTREAM OF THE SOLAR WIND TERMINATION SHOCK

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The acceleration of energetic particles at shock fronts in the heliosphere depends on the transport properties of ions in the presence of magnetic turbulence. Recent numerical simulations have shown that superdiffusive transport is possible along the magnetic field. Superdiffusion implies a mean square deviation growing like $\langle \Delta x^2 \rangle \propto t^\alpha$, with $\alpha > 1$, and is related to a non Gaussian statistics for the random walker displacements. We have developed a technique, which allows to unravel the transport properties from the analysis of the energetic particle time profiles [1,2]: it is shown that while normal diffusion leads to an exponential decay for the intensity of energetic particles upstream of the shock, superdiffusion leads to a power-law decay with an exponent $2 < \gamma < 3$.

We investigate the propagation of 0.54–3.5 MeV ions accelerated at the termination shock of the solar wind. Data are from Voyager 2 LECP instrument and refer to a time interval about one year long, just before the Voyager 2 termination shock crossing at the end of August 2007, at roughly 83.7 AU. The ion time profiles exhibit a power-law decay from a few days to 200 days before the shock front, so that transport is found to be superdiffusive, with $\langle \Delta x^2 \rangle \propto t^\alpha$, with $\alpha \sim 1.3$ [3]. This means that ion propagation in the heliosphere can be intermediate between normal diffusion and ballistic motion. The implication of ion superdiffusion on particle acceleration mechanisms at the termination shock is discussed, as well as some observational evidences, coming from both Voyager 1 and Voyager 2, which question diffusive shock acceleration. Indeed, the finding of superdiffusion matches well with the strong anisotropy of energetic particles upstream of the termination shock, and with the unusual spectral index of energetic particles beyong the termination shock.

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REENTRANT HELIOSPHERIC PARTICLES IN CASE OF SHOCKS AMPLIFIED MAGNETIC FIELDS

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We investigate the contribution of shocks amplified magnetic field in turbulent fluids [1] to reentrant particle effect [2]. More specifically we focused our attention on the reentrant particles influence to the solar modulation of energetic particles, in the heliosphere, in particular with amplified fields close to the termination shock. A simple 1D model of heliosphere is used for a first approximation of modulation in such a case. Sketch of situation in more complex and realistic 2D model of heliosphere is also presented.

The parameters of simulations are mean free paths of particles in heliosphere and in interstellar magnetic field. Mean free paths are scaled to multiplication of particle gyroradius. In Heliosphere we use Paker's field amplified close to the termination shock and in interstellar space we test a set of possible values of magnetic field.

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PION-DECAY GAMMA RAYS FROM INTERACTIONS OF HIGH ENERGY SOLAR COSMIC RAYS WITH THE MATTER OF UPPER CORONA AND SOLAR WIND

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For great solar flare events we calculate expected gamma-ray fluxes in periods of flare energetic particle (FEP) generation and propagation. We calculate the expected space-time-energy distribution of these particles in the Heliosphere in the periods of FEP events. On the basis of investigations of cosmic ray non-linear interaction with solar wind we determine also the expected space-time distribution of solar wind matter. Then we calculate the expected generation of gamma rays by decay of neutral pions generated in nuclear interactions of FEP with solar wind matter and determine the expected space-time distribution of gamma ray emissivity. Then we calculate the expected time variation of the angle distribution and spectra of gamma ray fluxes. For some simple diffusion models of solar FEP propagation and simple model of non-linear interaction of cosmic rays with solar wind we found expected time evolution of gamma ray flux angle distribution as well as time evolution of gamma ray spectrum. We show that by observations of gamma rays generated by solar FEP interactions with solar wind matter can be obtained important information on FEP time generation and spectrum in the source, on mode of FEP propagation in the interplanetary space, on the character of the non-linear interaction of cosmic rays with solar wind, and on matter distribution in the Heliosphere.

SOLAR WIND AND ENERGETIC PROTONS AT MeV ENERGIES

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The possible role of solar wind speed in the characteristics of cosmic ray particles at MeV energies is considered. Assuming the prevalence of convection and adiabatic deceleration in particle propagation at a few MeV energies the decay after SEP events is defined by the escape rate from the observation region. Hence characteristic time of exponential-form decays should be inversely proportional to solar wind speed. Observations at various locations (SOHO, Ulysses) are discussed. The 11-year modulation of GCR and MeV protons during quiet time periods correlates with solar activity, in particular, with solar wind speed. The comparison of particle fluxes and solar wind speed during the solar activity minima of 1976-77 and 1986-87 indicates that whereas fluxes of both quiet time low energy protons and GCR were lower in 1986-87, the corresponding solar wind speeds were higher. The two recent minima, 1996-97, and 2006-07 are also compared using SOHO data. Such dependences suggest the possible role of the solar wind in establishing the global characteristics of energetic particles in the inner heliosphere.

ORGANIZATION OF ENERGETIC PARTICLES BY THE SOLAR WIND STRUCTURE

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During quiet solar periods, it is known that corotating-interaction-region (CIR) particles have variable intensities, but it is unclear whether the variations are related to the characteristics of the solar wind stream interaction regions. Sanderson et al. [1998] investigated the association of energetic particles with CIRs for the end of Solar Cycle 22 to the beginning of Solar Cycle 23, and their results suggested that CIR proton events are organized by the structure of the solar wind streams. We extend their investigation by using OMNI L1 data obtained during the declining-to-minimum phase of Solar Cycle 23. Although we expect this period to be dominated by CIR particles, we found that there were a number of solar events that generated a population of solar energetic particles (SEPs). The analysis will provide some insight to the coexistence of the population of energetic particles of this declining-to-minimum phase of Solar Cycle 23. Our results may bear on the question of whether CIR particles produce the seed population for CME shock events, which perhaps make the event more intense than they otherwise might be.

THE INTERPLANETARY CONDITIONS ASSOCIATED WITH QUASI-PERPENDICULAR SHOCKS

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The angle between the normal to an interplanetary shock front and the upstream magnetic field direction (θ_{Bn}) is often thought of as a property "of the shock", especially in discussions of particle acceleration at shocks. However, θ_{Bn} is also determined by the configuration of the magnetic field within the solar wind structure through which the shock is propagating at the time of observation. We investigate the interplanetary circumstances that gave rise to ~90 near-Earth quasi-perpendicular shocks during 1996–2005. These shocks are defined by either $\theta_{Bn} \geq 80^o$ in the Berdichevsky, Kasper or ACE shock lists, or by evidence of features suggestive of shock-drift acceleration in ~1 MeV ion anisotropy and/or intensity observations from IMP 8 and other spacecraft. We find that a variety of types of upstream solar wind structures are involved, including interplanetary coronal mass ejections, the heliospheric plasma sheet, slow solar wind and high-speed streams. The relative association rates depend on the fraction of the solar wind occupied by these structures, which varies during the solar cycle. We also consider the relationship between the composition of the ions accelerated in the vicinity of these shocks, in particular the Fe/O ratio, and the composition of the solar wind observed by ACE/SWICS at shock passage. In general, at energies of $<\sim 1$ MeV/n, the Fe/O ratio is similar to that in the local solar wind (~0.1) but in a few cases, the ratio for both the energetic particles and solar wind is significantly elevated. The Fe/O ratios are also most variable for shocks propagating through interplanetary coronal mass ejections. The observations suggest that the source population for acceleration at quasi-perpendicular shocks includes a significant contribution from the local solar wind plasma. Although Tylka and Lee (2006) have discussed how the energetic particle Fe/O ratio may be enhanced at quasi-perpendicular shocks by the acceleration of a Fe-rich suprathermal particle source, at 1 AU there is little evidence of such an enhancement at most quasi-perpendicular shocks.

DIFFUSIVE SHOCK ACCELERATION NEAR ACTIVE REGIONS IN THE SOLAR CORONA

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In some of the largest solar energetic particle (SEP) events ions are accelerated into sufficiently high energies so that the secondary particles produced by these ions, when colliding with the particles in the Earth's atmosphere, are detectectable at the surface. These ground level events are much rarer than gradual SEP events in gerenal, roughly one event per year vs. 20 events per year during solar maximum on average. This suggests that there are some special requirements for ions to be accelerated into GeV per nucleon energies and above, or that these ions are produced in so small regions in the solar corona that they are only rarely magnetically connected with the Earth.

We study diffusive shock acceleration in the vicinity of an active region in the solar corona, as modeled by a bipolar magnetic structure just below the surface (so-called delta spot), using test particle simulations. We find that the exact geometry of the magnetic field can have a significant impact on the efficiency of diffusive shock acceleration, and that there are regions where, all other simulation parameters kept constant, the coronal protons can be accelerated significantly higher energies (1-10 GeV) than elsewhere.

THE INTERSTELLAR HELIOPAUSE PROBE / HELIOSPHERIC EXPLORER: IHP/HEX

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The Sun, driving a supersonic solar wind, cuts out of the local interstellar medium a giant plasma bubble, the heliosphere. Dedicated deep-space missions have greatly enhanced our understanding of our immediate neighborhood. Ulysses is the only spacecraft exploring the third, out-of-ecliptic dimension, while SOHO has allowed us to better understand the influence of the Sun and to image the glow of interstellar matter in the heliosphere. Both Voyager spacecraft have recently encountered the innermost boundary of this plasma bubble, the termination shock, and are returning exciting yet puzzling data of this remote region.

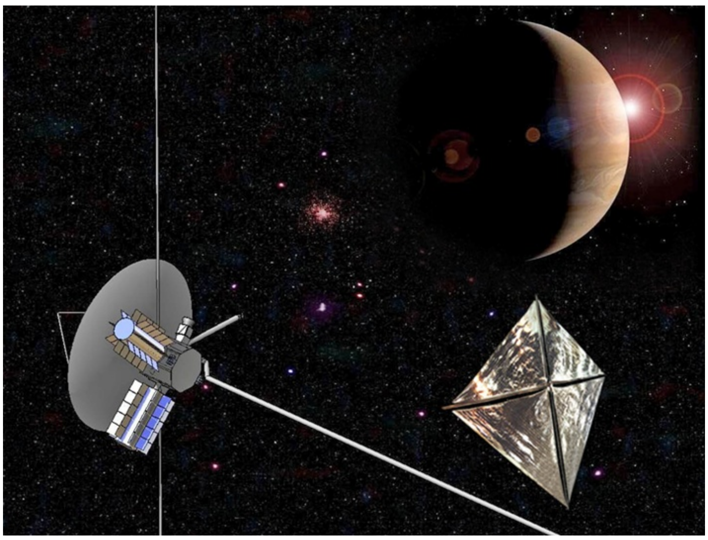
The next logical step is to leave the heliosphere and to thereby map out in unprecedented detail the structure of the outer heliosphere and its boundaries, the termination shock, the heliosheath, the heliopause, and, after leaving the heliosphere, to discover the true nature of the hydrogen wall, the bow shock, and the local interstellar medium beyond. This will greatly advance our understanding of the heliosphere that is the best-known example for astrospheres as found around other stars. Thus, IHP/HEX will allow us to discover, explore, and understand fundamental astrophysical processes in the largest accessible plasma laboratory, the heliosphere.

IHP addresses three core Science goals:

H: How do solar wind and interstellar medium interact to form the heliosphere and how does this relate to the universal phenomenon of the formation of astrospheres?

A: What are the properties of the very local interstellar medium and how do they relate to the typical ISM?

F: How do plasma, neutral gas, dust, waves, particles, fields, and radiation interact in extremely rarefied and incompletely ionized plasmas?



ION HEATING AT THE HELIOSPHERIC TERMINATION SHOCK

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The one-dimensional Los Alamos hybrid code has been used to carry out simulations of the perpendicular termination shock in the presence of both solar wind and pickup ions. The simulations show that specular reflection is an important mechanism for heating the cool solar wind ions for all plausible values of the relative density of the pickup ions, n_{PU}/n_{total}. However at $n_{PU}/n_{total} >$ 0.10, pickup ions gain the larger fraction of the energy dissipated at the shock, consistent with termination shock observations of Voyager 2. Pickup ion heating is not due to specular reflection, but rather arises due to the work done by the motional electric field on a limited number of particles that encounter the shock with the correct gyrophase to be accelerated. Details of this energization process will be presented.

EXPLORATION OF THE HELIOSPHERIC INTERFACE IMPRINTS IN DISTRIBUTION OF INTERSTELLAR HYDROGEN INSIDE THE HELIOSPHERE

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The goal of this study is to clearly explore imprints of the heliospheric interface in the distribution of interstellar H atoms inside the heliosphere. To do this we compare results of two kinetic models for the interstellar hydrogen atoms in the heliosphere. The first model is the classical hot model that assumes Maxwellian distribution of H atoms far from the Sun. The second is the advanced model developed by us. This model takes into account effects of latitudinal variations of the solar wind and photoionization and solar cycle variations as well as the effects of heliospheric interface. Outer boundary condition of the advanced model is taken at a sphere of large radius that is close to the heliospheric termination shock distance in the upwind direction. The velocity distribution at this boundary takes into account disturbances of the heliospheric interface as they obtained in the frame of self-consistent model of the the solar wind interaction with the local interstellar medium. We study and discuss several technical methods that allow to take into account the heliospheric effects at the outer boundary properly in a simplified but efficient manner. We explore possibilities to apply the developed models for analyses of backscattered solar Lyman-alpha radiation.

This work is supported by ISSI in Bern, RFBR grant 07-02-01101-a, 06-02-72557, and "Dynastia" Foundation.

HELIOSPHERIC ENERGETIC PARTICLE RESERVOIRS: ULYSSES AND ACE 53-315 KEV ELECTRON OBSERVATIONS

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Particle intensities measured in the decay phase of large solar energetic particle (SEP) events by widely separated spacecraft (in longitude, latitude and radial distance) often present equal intensities (within a factor of 2-3) that evolve similarly in time. These periods of small radial, longitudinal and latitudinal particle intensity gradients were first noted by McKibben (1972, JGR 77, 3957) and were named reservoirs by Roelof et al. (1992; GRL 19, 1243). The Ulysses orbit over the poles of the Sun provides us with the opportunity to analyze the observation of heliospheric energetic particle reservoirs at both high and low latitudes. We correlate near-relativistic electron observations from ACE and Ulysses throughout solar cycle 23 to determine the conditions under which these reservoirs were observed. Particle reservoirs were more prominently observed during the intense active periods of November 2000 and November 2001 when Ulysses was at high (>70 deg) latitudes. However, significant cases were also observed at low latitudes and during relatively less intense periods. Possible mechanisms for the formation and observation of energetic particle reservoirs in the inner heliosphere are discussed.

CHARGE EXCHANGE AT LOCAL CLOUD/LOCAL BUBBLE BOUNDARY: POSSIBLE EFFECTS ON THE INTERSTELLAR GAS STATE IN THE VICINITY OF THE SUN

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We present results of the cold (or warm) neutral cloud interaction with surrounding hot fully ionized plasma. The model is non-stationary and has two components. Neutral and plasma components interact via charge exchange that plays an important role in formation of the interaction region. At this stage of the modeling a cloud is assumed to be spherically symmetric and consists of atomic hydrogen. Plasma is assumed to be quasi-neutral and magnetic field is ignored. The role of the electron heat conduction and radiative transfer in cloud-plasma interaction is investigated. Using conditions appropriate to the Local Cloud embedded in the Local Bubble we estimate how parameters of the interstellar gas are changed within the cloud with time and space. We also give an estimate on life-time of the cloud. Some implications regarded the X-ray emission from the Local Cloud/Local Bubble interaction zone are discussed as well.

THE LOCAL INTERSTELLAR MAGNETIC FIELD PREDICTIONS FROM THE MHD MODEL AND VOYAGERS DATA

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The termination shock (TS) crossings by Voyager 1 (V1) and Voyager 2 (V2) revealed the asymmetry of the heliosphere. Crossings happened at distances 94 AU and 84 AU, respectively, in two different times, on December 16, 2004 - V1, and on August 30, 2007 - V2, however both on declining phase of the previous 11-year solar cycle. The asymmetry can result from the solar wind dynamic pressure asymmetry, from the shock motion or from the local interstellar magnetic field (LIMF) asymmetric pressure. The question arises: if the interstellar magnetic field were the only factor responsible for the measured asymmetries, is it possible to find such a shape of the TS, which would reflect the real positions of V1 and V2 when they crossed the shock? Using our 3D MHD time dependent code we simulate the heliosphere/interstellar medium interactions for several different combinations of physical parameters to answer this question. The obtained result places substantial constraint on the orientation and magnitude of the interstellar magnetic field.

OBSERVATIONS OF ^{3}He-RICH SOLAR ENERGETIC PARTICLE EVENTS OVER A BROAD RANGE OF HELIOGRAPHIC LONGITUDES: RESULTS FROM STEREO AND ACE

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In the prevailing model of ^{3}He-rich solar energetic particle (SEP) events, acceleration of ions and electrons is powered by magnetic reconnection at the site of a solar flare. When the reconnection involves some open magnetic field lines, energetic particles can escape into the heliosphere. It is expected that the longitudinal distribution of these escaping particles should be relatively narrow due to the localized nature of the source region. This expectation is supported by studies comparing single-point observations of ^{3}He-rich SEP events at 1 AU with locations of the associated flare sites at the Sun, as well as by several studies using data from Helios-1 & -2 and near-Earth spacecraft. One of the goals of the NASA STEREO mission is to make multipoint in situ measurements of SEP events while imaging their source regions in order to better understand acceleration and transport processes in these events. Several solar flares occurred in an active region at $\sim$W40 (as seen from Earth) on 3–4 November 2008, leading to SEP emission with the enhancements of ^{3}He/^{4}He and Fe/O that are characteristic of ^{3}He-rich events. These ions were detected by ACE at its location near Earth and by STEREO-BEHIND, which was trailing Earth by 40 degrees in heliographic longitude at that time. The ion event was not detected at STEREO-AHEAD, which was leading Earth by 40 degrees and thus approximately radially aligned with the flare site. The ion event was accompanied by energetic electron events that were detected at all three locations. In addition to these in situ observations, data on the solar context of the event were obtained from radio burst and imaging instruments at the same three locations. We will present the in situ and remote sensing observations, discuss their implications for heliospheric transport of energetic particles in this event, and compare with previous results.

This work was supported by NASA at Caltech and JPL under sub-contract SA2715-26309 from the University of California, Berkeley under NASA contract NAS5-03131.

MAGNETIC STRUCTURES IN THE HELIOSHEATH

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We extend the three fluid model of Avinash and Zank [2007] for magnetic structures in the heliosheath to a four fluid model consisting of electrons, pick-up ions (PUI), solar wind ions (SWI), and neutral hydrogen. The PUI are generated by neutrals via charge exchange with SWI. Since the kinetic pressure of PUI is nearly three to four times the pressure of SWI, these are more suited to mediate small scale structures in the heliosheath such as magnetic holes/humps etc. The constant energy exchange between these two fluids drives them non-adiabatic. The PUI are isothermal ($\gamma = 1$) while SWI are non adiabatic with an index $\gamma = 1.25$. The four fluid model captures these effects via a modified equation of state for PUI and SWI. The phase space of time independent solutions in terms of the Mach numbers of PUI and SWI is constructed to delineate the parameter space which allows structure formation in the heliosheath. We discuss the stability of the time independent solutions computed in the first part by evolving them via a full system of Hall–MHD equations. The simulation results show that these solutions are not quite stable. As the structure propagates it develops growing oscillations in the wings. Concomitantly, there are changes in the amplitude and width of the structure. This modulational instability could be due to the local changes in the velocity of the structure and reflects an exchange between the kinetic and the magnetic parts of the total energy. Our results about the presence of growing oscillations in the wings of solitary wave solutions are consistent with the recent analysis of magnetic holes in the heliosheth by Burlaga et al [2007].

AN ENERGETIC-PARTICLE MEDIATED TERMINATION SHOCK OBSERVED BY VOYAGER 2

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Voyager 2 crossing of the solar wind termination shock during August 30 - September 1 of 2007 was remarkably different from Voyager 1 shock encounter 2.5 year earlier. Observations made with the plasma instrument revealed the presence of a broad shock precursor extending some 0.7 AU upstream of the TS, where the solar wind decelerated from 400 km/s to 300 km/s, in three steps. Here we show that the third decrease that started some 40 days before the shock crossing event, could be plausibly produced by the pressure gradient of energetic ions with energies of a few MeV acting on the upstream plasma flow. We argue that Voyager 2 encountered a cosmic-ray mediated termination shock, in agreement with theoretical predictions made years ago.

MODELING A GRADUAL SEP EVENT WITH THE PATH CODE

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We model a gradual solar energetic particle (SEP) event that occurred on 2001 September 29, and was possibly caused by a coronal mass ejection related shock. A computer code PATH (Particle Acceleration and Transport in the Heliosphere) was tuned to simulate this event. The model includes local particle injection at an evolving quasiparallel shock, first-order Fermi acceleration at the shock, and self-consistent excitation of MHD waves to enhance particle scattering, particle trapping, and escape from the shock complex, and transport in the inner heliosphere up to several AU. The shock and solar wind boundary conditions are derived from ACE observations at 1 AU, which are then extrapolated to 0.1 AU. Modeled spectra for energetic protons, iron, and oxygen ions are compared with ULEIS and SIS measurements onboard ACE, and with GOES-8 data. There is very good fit between observations at 1AU and our modeling.

MODELING THE MIXED SEP EVENT OF DECEMBER 13, 2006: PROTON AND HEAVY ION SPECTRA AT 1AU

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We apply the Particle Acceleration and Transport in the Heliosphere (PATH) one-dimensional numerical code to model the SEP event of December 13, 2006. The code is initiated by modeling a quiet-time solar wind and a propagating CME-driven oblique shock. We assume two energetic particle populations in the modeling, one originating from solar flare particles and the other from solar wind particles accelerated at the traveling shock. Observed shock parameters at 1 AU and flare characteristics are used as input into the code. We assume a diffusive shock acceleration mechanism at the shock and model subsequent transport of particles escaping from the shock through the interplanetary medium to 1 AU. We focus on modeling spectra of protons, oxygen and iron ions and their composition ratios. Our results are compared with in situ measurements by ACE, STEREO, GOES and SAMPEX for this event.

HELIOSHEATH ACCELERATION

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Fermi I electron acceleration by magnetic reconnection exhausts on closely stacked current sheets near the heliopause

Recent observations (up to 32 AU) of solar wind reconnection exhausts suggest fairly frequent occurrence of such events on current sheets associated with the ICME fronts and on the heliospheric current sheet (HCS). Comparison of relevant plasma-beta values and magnetic field strengths with conditions in the heliosheath indicates that reconnection may also take place in the heliosheath, especially towards the heliopause where the folds of HCS are expected to be pressed together by the slowing of solar plasma flow. We propose a Fermi I type acceleration mechanism in which particles gain energy by random collisions with reconnection exhausts expanding typically with local Alfven speed. The most probable place for this process is a (several AU wide) region of tightly folded HCS near the nose of heliopause. The process may accelerate the 100eV heliosheath electrons up to MeV energies and in particular provide the mechanism of ‘priming’ the electron population needed for generation of 2-3 kHz heliospheric emissions.

Session 6:
Open session

RESULTS FROM THE GENESIS SOLAR WIND SAMPLE MISSION

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The GENESIS mission collected samples of solar wind from November, 2001 to April, 2004 at the Earth-Sun L1 point. Solar-wind collection substrates included Si, Ge, Au, Al, SiC, diamond, sapphire, and metallic glass. In addition to collecting bulk solar wind, the mission collected separate long-term averaged samples of coronal hole (CH), interstream (IS), and coronal mass ejection (CME) material. An electrostatic Concentrator provided higher-fluence (average of $\sim$20x) samples of elements lighter than $\sim$30 amu. GENESIS was the first spacecraft to return from beyond the Moon, arriving in September, 2004. Despite a hard landing, many of the samples were recovered, enabling achievement all of the major science objectives of the mission.

The goal of the mission was to complement *in-situ* spacecraft solar-wind composition measurements, particularly for isotopes, providing an unprecedented understanding of the average solar-system composition. To date, accurate measurements have been made for the isotopes of all noble gases. As an example, the solar-wind $^{36}Ar/^{38}Ar$ ratio was measured from GENESIS samples as 5.501 ± 0.005 (2σ uncertainty; Meshik *et al.*, 2007), improving the accuracy by nearly two orders of magnitude. Bulk solar-wind xenon isotope measurements are now available from GENESIS and it should be feasible to also obtain accurate Xe isotopic ratios from the different solar-wind regime samples. Preliminary $^{16}O/^{17}O/^{18}O$ measurements have been made (McKeegan *et al.*, 2009) which show for the first time that the Sun is enriched by 6% in ^{16}O relative to the Earth, Moon, Mars, and differentiated meteorites. Preliminary $^{15}N/^{14}N$ suggests the possibility of a strong solar enrichment in ^{14}N relative to the Earth and Mars, similar to the Jovian atmosphere (Marty *et al.*, 2009; cf. Pepin *et al.*, 2009).

The GENESIS mission also provides new data for understanding solar-wind acceleration. Elemental compositions obtained from GENESIS samples (Reisenfeld, this meeting) provide additional constraints on the supposed first ionization potential / time (FIP/FIT) fractionation of heavy ions in the solar wind. For example, GENESIS regime data clearly show that the three regimes lie along a trend line for He, Ne, and Ar, with IS intermediate between CH and CME (Heber *et al.*, 2008), contrary to what might be expected for FIP/FIT fractionation. Isotopic ratios show mass-dependent fractionation between IS and CH of $6.3 \pm 0.4\%$ for He, $0.4 \pm 0.1\%$/amu for Ne, and $0.26 \pm 0.10\%$/amu for Ar. Together these data suggest the solar-wind He/H fractionation is due partially but certainly not totally to Coulomb drag.

In turn, the GENESIS results beg for a more accurate quantification of solar-wind fractionation, both elementally and isotopically, so that solar-wind measurements can be accurately translated into solar abundances for comparison with geochemical data from the Earth, Moon, Mars, Jupiter, and meteorites.

INTERACTING STRUCTURES IN THE SOLAR WIND: IPS AND STEREO HI OBSERVATIONS

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We report results from simultaneous long-baseline interplanetary scintillation (IPS) and Solar TErrestrial RElations Observatory (STEREO) Heliospheric Imager (HI) observations of interacting structures in the solar wind. The combination of high-resolution observations of small-scale structure from IPS and the global overview of HI allows the IPS observations to be interpreted in the light of their position in the large-scale structure, something which has not been possible with this degree of accuracy before.

The results presented include coronal mass ejection (CME) cannibalisation and a small-scale solar wind transient entrained within the compression region of a co-rotating interaction region, as well as showing solar wind structures which impacted on the Venus ionosphere. We also present evidence of rapid variability in the solar wind in the aftermath of a CME and suggest these as a driver for continued comet-tail activity.

STATUS OF GALACTIC COSMIC RAY RECOVERY FROM SOLAR CYCLE 23 MODULATION

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The sunspot activity cycle 23 turned out to be a long cycle, like cycle 20 before it. Solar polar field measurements made at the Wilcox Solar Observatory at Stanford, CA, indicate that polar field strength for cycle 23 is about 50 % lower (than for previous three cycles); the flux of the open field lines at earth orbit is at its lowest level since measurements began in 1963. Also, the structure of the heliosphere is significantly different (from that observed for cycles 21 and 22) during recovery phase of cycle 23. So, it is interesting to enquire whether GCR recovery from solar modulation at earth is different also. For this investigation, we use hourly, pressure corrected data obtained with the global network of NMs. These detectors respond to a wide range of GCR rigidity spectrum. We find that GCR intensity recovery is quite different from those for previous cycles. The physical significance of our results is discussed.

SOLAR CYCLE VARIATIONS OF QUIET-TIME SUPRATHERMAL AND CME-SHOCK ACCELERATED IONS

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CME-driven coronal and interplanetary shocks are believed to be the most prolific producers of solar energetic particles (SEPs) and energetic storm particles (ESPs) that pose radiation hazards for us, our environment, and our assets on Earth and in space. Despite the recent observational and theoretical advances, many important questions regarding SEPs remain unanswered. This is because the SEP observations near Earth orbit are smeared by a confluence of various poorly understood physical effects all of whose contributions can vary with time and location. In order to identify the main sources of material accelerated in CME shocks near 1 AU, we compare the compositional and spectral variability of the accelerated heavy ion populations with that measured upstream of the shocks and during quiet-times in the interplanetary medium. We discuss our results in terms of our current understanding of the origin of energetic particles during CME-related solar particle events. Finally, we highlight the new opportunities provided by missions such as STEREO in cycle 24 that will enable us to quantitatively model and predict key properties such as intensity and spectra of the accelerated ions.

SOLAR CYCLE 23: AN UNUSUAL SOLAR MINIMUM?

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We are currently observing the minimum phase of Solar Cycle 23. When compared to Cycles 21 and 22, this has been a weaker and longer magnetic cycle characterized by a lower rate of sunspot emergence and a lack of large spot groups. Solar magnetic activity during the years 2006-2009 has been very weak with sunspot numbers reaching the lowest values in over 75 years. This long and extended minimum is marked by weak polar magnetic fields and a more complex corona morphology than observed during the previous two minima. The polar coronal holes are smaller and low-latitude coronal holes of significant size –usually seen during the declining phase– persisted into the minimum phase and continued to be important sources of the solar wind observed at the Earth. This clearly illustrate that not all solar minima are alike and different magnetic configurations are possible during very quiet times. We will compare coronal and solar wind observations during the last two minima to illustrate these differences and will discuss their implication for the geospace environment.

LATITUDINAL OFFSET OF THE HELIOSPHERIC CURRENT SHEET: ULYSSES MAGNETIC OBSERVATIONS THROUGH TWO SOLAR CYCLES

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The possible latitudinal offset of the location of the heliospheric current sheet (HCS) is an important question, since it has impact on the understanding of various phenomena including the solar dynamo and the modulation of cosmic rays. In the declining phase of the previous, 22nd solar cycle, in 1993, a southward displacement of the HCS by 10 degrees was proposed to explain the north-south asymmetry of energetic charged particle fluxes measured by Ulysses. Other observations supported the north-south asymmetry as well, and it is now widely accepted by the scientific community that in 1993 the HCS was displaced by 10 degrees southward. However, in reality, Ulysses magnetic field measurements did not give direct evidence for such a large displacement of the HCS. Here we revisit the question and extend our previous study for the declining phase solar cycle 23 as well. Careful analysis of the HCS crossings observed by Ulysses during the fast latitude scans shows that a southward displacement of the HCS by 2-3 degrees is possible and consistent with the data for both cycles 22 and 23.

SOLAR WIND SOURCE MAPPING THROUGH THREE SOLAR MINIMA

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It has been pointed out that the recent solar minimum solar wind has a number of different features compared to the previous solar minimum. These differences include a reduced mass flux and reduced interplanetary field observed on Ulysses by McComas et al. (2008) and Smith et al. (2008), as well as low ecliptic fields (Lee et al., 2009) seen on ACE and STEREO. One way to investigate the cause(s) at the photospheric level is through use of Potential Field Source Surface models, which have been shown to provide good approximations to the coronal hole/ open field regions and coronal streamer belt geometry when solar activity is at a low level. The ways in which the photospheric magnetic fields control both the high speed and slow wind for the three solar minima at the ends of cycles 21, 22 and 23 is suggested by the PFSS model source mapping. The results suggest how the solar dynamo operation modifies even the 'quietest' space weather at Earth.

Posters of session 6

THE UNDERLYING MAGNETIC FIELD DIRECTION IN THE PRESENCE OF LARGE-AMPLITUDE ALFVENIC FLUCTUATIONS IN THE SOLAR WIND

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The solar wind, particularly the high-speed wind from coronal holes, is often filled with large-amplitude Alfvenic fluctuations that propagate predominantly away from the Sun along the magnetic field, **B**. How does one accurately determine the direction of the underlying **B** in the presence of such fluctuations? Most prior studies have simply assumed that the fluctuations are about suitably obtained average values of **B**, and that those average values determine the direction of the underlying **B** at each moment of time. However, because the Alfvenic fluctuations are transverse fluctuations in which the magnitude of **B** remains nearly constant, the fluctuations in the field component that defines the underlying background field are one-sided relative to a base value rather than being distributed about an average value. Further, for field rotations less than 90 degrees from the underlying field direction, the fluctuations in the underlying field direction component are smaller than the fluctuations in the total transverse field component. We use these characteristics of the Alfvenic fluctuations to develop a technique that incorporates minimum variance analysis of **B** (MVAB) and that requires several sequential coordinate rotations to determine the direction of the underlying magnetic field direction. In each step we restrict the points used in the MVAB to field rotations less than 90 degrees away from the assumed underlying field direction. As a check on the accuracy of our final result we ascertain that the fluctuations in the field component corresponding to the underlying field direction are all one-sided and that the base value for those fluctuations agrees well with the total field magnitude. In the present study we have analyzed a 10-day interval of ACE 64-s magnetic field data using 4-hr segments and determining the MVAB in those segments using sliding15-minute windows in steps of 7.5 minutes. The good agreement obtained when making the above-noted check implies that we have obtained reliable directions for the underlying field and that the directions of the individual Alfvenic fluctuations are randomly distributed relative to the underlying field direction. The underlying field directions obtained from our analysis often differ by 5 degrees or more (sometimes much more) from the average field direction calculated for these same intervals. Our analysis suggests that the results of numerous previous analyses to determine the underlying magnetic field direction that used average values of field direction during intervals of substantial Alfvenic fluctuations need to be re-evaluated.

THE SOLAR MASS EJECTION IMAGER (SMEI) 3D-RECONSTRUCTION OF DENSITY ENHANCEMENTS BEHIND INTERPLANETARY SHOCKS

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The Solar Mass Ejection Imager (SMEI) observes the increased brightness from the density enhancements behind interplanetary shocks that are observed in situ near the Earth. We use the UCSD time-dependent 3D-reconstruction technique to map the extents of these density enhancements in 3D. As examples, we examine the shock density enhancements associated with several well-known coronal mass ejections (CMEs) including those on 28 October 2003 (Halloween storm), and on 20 January 2005. We compare these with reconstructed velocity measurements from STELab interplanetary scintillation (IPS) observations when these are available. The SMEI analyses are used to certify that the brightness enhancements observed are in direct response to the plasma density enhancements that are also measured *in situ*.

STATISTICAL THEORY OF SELF-ORGANIZATION

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Understanding multi-scale interactions is an outstanding problem in astrophysical plasmas. Despite complex nonlinear dynamics, coherent structures such as shear flows often form from small-scale turbulence, which then feed back on small-scales. A remarkable consequence of this mutual interaction is self-organization, which provides a powerful paradigm for understanding complexity in many systems (e.g. solar wind/flares, population, forest fires, reaction-diffusion). In particular, self-organization has emerged as one of the key physical processes governing transport and mixing in solar and space plasmas, with a growing body of observational evidences. A non-perturbative statistical theory [probability distribution functions (PDFs)] is absolutely necessary for a proper modelling of self-organisation due to inherent intermittency, instead of traditional mean-field theory based on Gaussian distribution. In this contribution, we present a novel statistical theory of self-organisation of shear flows, modeled by a nonlinear diffusion equation driven by a stochastic forcing. A non-perturbative method based on a coherent structure is utilized for the prediction of the PDFs, showing strong intermittency with exponential tails. We confirm these results by numerical simulations. The predicted power spectra are also in a good agreement with simulation results. Furthermore, the results reveal a significant probability of supercritical states due to stochastic perturbation, which could have crucial implications in a variety of systems. To elucidate a crucial role of relative time scales of relaxation and disturbance in the determination of the PDFs, we present numerical simulation results obtained in a threshold model where the diffusion is given by discontinuous values.

Our results highlight the importance of the statistical description of gradients, rather than their average value as has conventionally been done. We discuss some of the important implications of these results for the dynamics and the role of shear flows (e.g. zonal flows) in solar, space and geophysical plasmas, which is vital not only in momentum transport, but also in transporting chemical species and controlling mixing of other quantities (e.g. air pollution, weather control). Furthermore, we explore the implications of the outcome for solar flares.

PRECISION ELEMENTAL ABUNDANCES OF THE SOLAR WIND DERIVED FROM THE GENESIS SAMPLES

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The NASA Genesis mission collected solar wind on ultrapure materials between November 30, 2001 and April 1, 2004. Here we report elemental abundance values of the light noble gases (He, Ne, and Ar) and the abundant metals, Mg and Fe, from laboratory analysis of Genesis collector materials. In addition to samples exposed continuously throughout the Genesis collection period, samples were collected on arrays exposed for specific solar wind regimes (coronal hole (CH), interstream (IS) and CME), as determined by an onboard algorithm. In the case of the noble gases, owing to the accuracy of ground-based noble gas analysis techniques as well as the long exposure times on orbit, we can determine elemental abundances with a much higher degree of accuracy than by previous *in situ* methods. We have processed regime-specific samples for the He, Ne and Ar abundances, and can now report solar wind abundances with unprecedented precision ($\pm 1 - 3\%$, absolute fluences; $\pm 0.25 - 1.5\%$, relative) as compared to on-orbit measurements (typically $\sim \pm 15 - 20$ %).

We find abundance variations of up to 20% between regimes, with a high degree of confidence. A systematic trend appears in which the lighter masses (He, Ne) are enriched over Ar in the IS vs. CH material, and are even further enriched in CME material. Remarkably, the three regimes lie along a mixing line for He, Ne and Ar having a tight linear correlation ($r^2 = 0.993$). Thus, these results should put strong constraints on theories of solar wind fractionation. In contrast to recent GENESIS isotopic fractionation results (see Wiens et al., this meeting), the observed elemental fractionation do not correlate at all with composition variations expected due to Coulomb drag. Nor do they follow a discernable FIP or FIT fractionation trend (which may be expected, since these are all high-FIP/FIT elements). On the other hand, fractionation arising from gravitational settling or wave-particle acceleration may be supported.

We also compare the Genesis abundance values to elemental composition data collected during the same time period from the ACE/SWICS spectrometer, finding agreement to within measurement uncertainty (with the possible exception of Ne). We apply the Genesis and ACE data to an analysis of the first ionization potential (FIP) fractionation of the solar wind, and compare this to the FIP analysis of Ulysses data from the previous solar cycle. We find agreement between all data sets (again, with the possible exception of Ne), indicating that the fractionation state of the solar wind is relatively stable.

ON THE BIFURCATION IN THE BONDI MODEL AND THE SOLAR WIND ORIGIN PROBLEM

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The spherically symmetric model of the quasi-steady flow in the stellar atmospheres (Bondi, 1952) is very simple and physically transparent for analytical considerations. Three admissible types of solutions of the governing Bernoulli equation are available in this model: 1) static $v=0$, 2) expanding wind type flow $v>0$, 3) contracting accretion type flow $v<0$. The selection between them depends on the imposed internal and external boundary conditions. This means that the solar wind origin problem can be not properly addressed nor completely explained in the framework of the model alone without additional assumptions. More appropriate and complicated non-steady state and inhomogeneous models are not well developed. Nevertheless, the Bondi model is useful for the demonstration of the necessity of the time dependent approach for obtaining a physically correct answer to the long standing question: "Why the solar wind blows?" It is not only because of the instantaneous hot corona and rarefied interstellar medium around the Sun, as often correctly assumed, but also because of the evolutionary stage of the given star. Solar-like stars of the same type as our Sun can exist with hot corona and situated in a rarefied interstellar medium, but without any wind or even in the accretion state. The existence of such stars ("acceptors") is not prohibited by physical laws and could be searched in UV line Doppler measurements as well as other solar-type stars similar to the Sun in this respect ("donors"). Donors and acceptors can be isolated or grouped in binary or more complicated associations of stars.

LARGE-SCALE SOLAR WIND STRUCTURES: OCCURRENCE RATE AND GEOEFFECTIVENESS

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Large-scale phenomena in the solar wind are important elements of heliospheric physics and space weather. On the basis of the OMNI database of interplanetary measurements we identified large-scale structures of solar wind (SW types) for all time intervals during 1976–2000. Our classification includes $quasi-steady$ types: (1) Heliospheric current sheet (HCS), (2) Slow and (3) Fast SW streams, respectively, from closed and open magnetic field structures in the solar corona, and $disturbed$ types: (4) Corotating interaction regions (CIR – compressed regions between slow and fast SW streams), (5) Sheath (compressed regions ahead of MC/Ejecta) and (6) Magnetic cloud (MC) and (7) Ejecta as well as (8) direct and (9) reverse interplanetary shocks (see catalogue on site $ftp://ftp.iki.rssi.ru/pub/omni/$ and paper by Yermolaev et al., Cosmic Res., N2, 2009). We discuss several preliminary results obtained with our catalogue (see more details in $http://www.iki.rssi.ru./people/yyermol\_inf.html$) including effects on the Space Weather. Yearly numbers of different structures are 124 ± 81 for HCS, 8 ± 6 for MC, 99 ± 38 for Ejecta, 46 ± 19 for Sheath before Ejecta, 6 ± 5 for Sheath before MC, and 63 ± 15 for CIR. Taking into account that average durations of phenomena are 5 ± 2 h for HCS, 24 ± 11 h for MC, 29 ± 5 h for Ejecta, 16 ± 3 h for Sheath before Ejecta, 9 ± 5 h for Sheath before MC, and 20 ± 4 h for CIR, solar wind observations consist of $6 \pm 4\%$ of total time of observations for HCS, $2 \pm 1\%$ for MC, $20 \pm 6\%$ for Ejecta, $8 \pm 4\%$ for Sheath before Ejecta, $0.8 \pm 0.7\%$ Sheath before MC, $10 \pm 3\%$ for CIR. Geoeffectiveness (number of selected SW type resulted in magnetic storms with Dst < - 50 nT divided by total number of this SW type) of MC with Sheath is the largest (61%), geoeffectivenesses for CIR and Ejecta with Sheath are medium (20-21%) and types of Sheath and Ejecta without Sheath have the lowest geoeffectiveness (15 and 8%, respectively). We discuss solar cycle variations of these parameters during 1976-2000. Paper is supported in part by Physical Department of Russian Academy of Sciences, Program N 15, Presidium of Russian Academy of Sciences, Program N 16, and by RFBR, grant 07-02-00042.

ENERGETIC ELECTRONS IN ^{3}He ENHANCED SOLAR ENERGETIC PARTICLE EVENTS

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^{3}He-enhanced solar energetic particle (SEP) ion events were found to be accompanied by non-relativistic electrons in the 10-100 keV energy range. However, there is no clear relationship between the electrons and ions beside their occurrence. We therefore examined the electron associations in the general class of impulsive ^{4}He ion SEP events over the same time period: 43 out of 97 impulsive ^{4}He ion events were associated with impulsive electron events. The weak correlations between maximum electron intensities and maximum helium intensities (either ^{3}He or ^{4}He) are statistically indistinguishable between the general class of impulsive He events and the special class that was ^{3}He enriched. Consequently, we have found no evidence (at the energies we studied) that the energetic electron population that escapes into interplanetary space is causally involved in the preferential enrichment of ^{3}He. However, this does not rule out the possibility that a separate (non-escaping) population of electrons in the corona participates in the preferential acceleration of ^{3}He. Additional support for the interpretation that the escaping electron population is unrelated to the ^{3}He populations is found in our previous result that there seems to be an upper limit on the ^{3}He fluences (Ho et al., 2005). No corresponding upper limit is apparent in the electron peak intensities.

ON THE TEMPORAL VARIABILITY OF THE 'STRAHL': STEREO SWEA OBSERVATIONS.

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The 'strahl' is a specific population of the solar wind, constituted by electrons moving away from the Sun, with energies of a few 100 eV and small pitch angles. Using the Solar Wind Electron Analyzer (SWEA) onboard STEREO, we investigate the short scale fluctuations of this population. It is shown that its phase space density (PSD) at times presents fluctuations larger than 50 % with scales of minutes and less. The fluctuations are particularly strong for periods of a few 10 hours following the crossing of the interfaces of high speed streams, when the strahl is also the most collimated in pitch angle. After the passing of the high speed streams, the amplitude of the fluctuations tends to decrease in conjunction with a broadening in pitch angle. Generally, the strongly fluctuating strahl is observed when the magnetic field is also highly perturbed. The fast variability of the strahl appears to be an intrinsic characteristic of the streams.

SELF-REFORMATION OF THE QUASI-PERPENDICULAR SHOCK: CLUSTER OBSERVAT

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Among several mechanisms issued from simulation and theoretical studies proposed to account for the nonstationarity of quasi-perpendicular supercritical shocks, one process - the so-called self-reformation - driven by the accumulation of reflected ions at a foot distance from the ramp has been intensively analyzed with simulations. Present results based on experimental CLUSTER mission clearly evidence signatures of this self-reformation process for the terrestrial bow shock. The study based on magnetic field measurements includes two parts: (i) a detailed analysis of two typical shock crossings for almost perpendicular shock directions where the risk of pollution by other nonstationarity mechanisms is minimal. A special attention is drawn on appropriate treatment of data to avoid wrong interpretation. One key result is that the ramp width can reach a very narrow value covering a few electron inertial lengths only; (ii) a statistical analysis based evidences the signatures of this nonstationarity versus different plasma conditions and shock regimes. Present results are compared with previous theoretical and simulation works.

THE ELECTRODYNAMICS AND DISSIPATION INTERPLANETARY EXPLORER (EDDIE) MISSION CONCEPT

S. D Bale for the EDDIE Team

The solar wind is an ideal laboratory to study the microphysics of turbulent dissipation in collisionless plasmas. The standard theory of collisionless plasma turbulence predicts a energy cascade in perpendicular wavenumber; energy associated with these fluctuations must eventually heat the plasma ions and electrons. However, the details of the dissipation and heating mechanisms are not known. Several candidate mechanicms have been proposed, including ion cyclotron and kinetic Alfven wave damping, as well as current sheet instabilities and magnetic reconnection. Remote sensing measurements of perpendicular ion heating in the inner heliosphere imply significant wave power in k-parallal, which is not observed at 1 AU. Furthermore, it is well known that the solar wind is is a state of nonequilibrium, with several populations of ions and electrons driving local instabilities. Examples include electron and ion anisotropy, streaming, and heatflux instabilities. The EDDIE concept is for a small, fully instrumented spacecraft, sun-pointed spacecraft dedicated to making solar wind microphysics measurements. Here we describe the EDDIE science goals, instrument complement, and mission scenario, as well as the possibility of providing a real-time (RT) link for space weather applications.

SOLAR WIND FORECAST BY USING INTERPLANETARY SCINTILLATION OBSERVATION

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Radio waves from a compact radio source such as a quasar are scattered by irregularities of electron density in the interplanetary medium. The scattered waves interfere with each other as they propagate toward the Earth producing amplitude scintillations which are then seen as diffraction patterns at Earth. This phenomenon is called interplanetary scintillation (IPS). The IPS pattern contains the information of solar wind velocities and density fluctuations passing across a line of sight (LOS) from an observer to a radio source. We determine solar wind velocity and density structures by employing computer assisted tomography (CAT) to reduce the LOS integration effect which degrades the accuracy determination of these structures. This technique can be applied to forecast the solar wind for a few days prior to its reaching Earth. This is because our IPS observations from the Solar-Terrestrial Environment Laboratory (STELab) radio arrays at an observing frequency of 327 MHz are sensitive to a region of from 0.2-1 AU distance from the Sun. However, the CAT algorithm assumes that a solar wind structure does not change and requires a redundancy of LOS numbers. Therefore, the accuracy of the solar wind forecast depends on solar activity as well as the number of IPS data for the period of interest . In this study, we simulated real-time analyses of a forecast procedure using IPS data obtained during years 1999 to 2008 inclusive. In this procedure, a few tens of IPS observations are included in the CAT algorithm to update the solar wind structure inside of Earth's orbit each day. Then, forecast plots, that is, time profiles of the solar wind velocity at the Earth position for several future days, are drawn. These results are compared with in situ measurements to evaluate the accuracy of the solar wind forecast by using STELab IPS observations. We will present the forecast procedure and discuss dependencies of the accuracy on several factors such as solar activity and observing conditions.

EUV SPECTROSCOPY OF SOLAR ACTIVITY ON DISK AND ABOVE THE LIMB

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EUV Spectroscopy, both on the Solar disk and above the limb, is the only method of remotely determining key plasma properties necessary to understand the linkage between in-situ measurements of solar wind streams and their source regions near the Sun. Understanding these linkages is one of the primary scientific objectives of both the ESA Solar orbiter mission and the NASA Solar Probe mission.

Specifically, EUV spectroscopic measurements, together with in-situ measurements from both Solar Orbiter and Solar Probe promise to:

- Discriminate models of solar wind origin by matching composition signatures in solar wind streams to surface feature composition.
- Discriminate physical processes that inject material from closed structures into solar wind streams.
- Confirm or falsify ion-cyclotron wind acceleration models & determine acceleration profiles in the low corona.
- Image remotely the supra-thermal ions thought to be seed populations of SEP events as they are accelerated & depleted.
- Test partial disconnection models of magnetic clouds & characterize flux ropes in pre-eruptive & erupting CMEs.
- Determine conditions under which CMEs produce shocks by imaging the turbulent broadening associated with their formation.

We will discuss, in this talk, the methods and specific observations necessary to address these topics in the context of these two exciting missions.

SERVICES AND PROJECTS FOR HELIOPHYSICS AT CDPP.

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The CDPP is the French national centre for space physics data. The CDPP provides data from its own databases but also from external databases through interoperable links. It eases the access to a wide collection of measurement obtained onboard spacecraft in the heliosphere, in the Earth's magnetosphere and in the planetary ionized environments as well. The datasets can be exploited using the web-based service AMDA for integrated analysis. This tool allows the user to perform on line classical manipulations such as data visualization, parameter computation or data extraction. AMDA also offers innovative functionalities such as event search on the content of the data in either visual or automated way. These functionalities extendable for automated recognition of specific signatures can be used to perform classification of events and to generate time-tables and catalogues. Other projects are underway at CDPP, including specialized services on radio and wave form data or propagation tool. As a participant of the HELIO project (7th Frame Plan of European Union), the CDPP will provide these services in the future european virtual observatory of heliophysics.

THE SOLAR WIND ANALYZER ION (SWA-I) FOR THE SOLAR ORBITER (SO) MISSION

Stefano Livi (1), Frederci Allegrini (1), Michael Collier (2), Mihir Desai (1), Toni Galvin (3), Justin Kasper (4), Lenn Kistler (3), Kathy Korreck (4), Susan Lepri (5), Dave McComas (1), Nathan Schwadron (1), and Thomas Zurbuchen (5)

(1) Southwest Research Institute, (2) Goddard Space Flight Center, (3) University of New Hampshire, (4) Smithsonian Astrophysical Observatory, (5) University of Michigan

The Solar Orbiter (SO) mission, the first flight element of the joint ESA-NASA HELiophysical Explorers (HELEX) program, provides the unique opportunity to discover fundamental connections between the magnetically structured solar atmosphere and the dynamic solar wind that permeates our solar system and ultimately drives all space weather. The keys to understanding the multiple connections between activity on the Sun's surface and the heliosphere, which lie at the heart of the SO mission, are in situ measurements of the solar wind. In fact, Table 3.2 of the HELEX-Joint Science and Technology Definition Team (JSTDT) report clearly states that direct solar wind plasma ion measurements, along with the DC magnetic field and the near-Sun coronagraph observations, are the only three observations that are required on SO to answer all eight science questions. To decipher the dynamics of the solar wind and establish its origins, the plasma measurements must be fully integrated and coordinated with theory, modeling, and cross-sensor data analysis. The comprehensive plasma observations needed by SO are provided completely by our international SWA consortium. The SWA instrument suite addresses all of the HELEX/SO science objectives by fully characterizing the bulk solar wind plasma properties inside 1 AU, including its chemical composition and the threedimensional (3D) velocity distribution functions (VDF) of ions and electrons. In its unique role, SWA will establish unambiguously the origins of the solar wind and its disturbances, characterize their properties and dynamics, and determine how they influence the inner heliosphere. These coordinated multi-sensor measurements are critical for discovering the fundamental links between the heliosphere and the Sun's atmosphere. the proposed SWA-I sensor investigation, will provide the fastest ever measurements of bulk solar wind parameters and 3D ion VDFs, as well as the first ever composition measurements of the solar wind and suprathermal ions between 0.23–0.9 AU.

Special solar cycle (posters)

HEURISTIC FORECAST FOR SOLAR SUNSPOT CYCLE 24 ACTIVITY PARAMETERS

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Our prediction for the development of solar sunspot cycle 23 activity parameters came true; one of the very few to have attained this status. We make use of a 3-cycle quasi-periodicity observed in the planetary index Ap. We have improved our method of prediction by including aa index data for 150 years. We draw inferences as to what to expect for the development phase of cycle 24. Our prediction for the smoothed sunspot number at cycle 24 peak is 107. Therefore, cycle 24 will be less active than cycle 23. The possibility that the next three cycles may be progressively less active cannot be ruled out; the trend may even continue for the rest of the twenty-first century. We are in the process of computing the rise time for cycle 24. Our results will be presented and discussed.

QUANTIFYING THE ANISOTROPY AND SOLAR CYCLE DEPENDENCE OF SOLAR WIND FLUCTUATIONS OF CORONAL ORIGIN

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(2) UKAEA Culham Division, Culham Science Centre, UK

In-situ observations of the solar wind from satellites such as WIND and ACE provide measurements of bulk plasma parameters in the solar wind on timescales spanning seconds to years, enabling exploration of the full solar cycle. At frequencies lower than the inertial range of turbulence, solar wind power spectra of magnetic field components typically show a region of "$1/f$" inverse power law dependence. These "$1/f$" range fluctuations in the solar wind may directly embody aspects of the complex magnetic field structure of the solar corona, and of footpoint stirring in the solar photosphere. Analysis of these fluctuations may thus shed light on intriguing physical questions, such as the extent to which the possibly fractal nature of the coronal magnetic carpet is projected into the solar wind.

Here we present statistical analyses that quantify the scaling properties of solar wind fluctuations in the "$1/f$" energy range, focusing on dependence on solar cycle, fast/slow wind, and on anisotropy with respect to the background magnetic field. In particular, we present structure function analysis of magnetic and velocity field fluctuations, in the directions parallel and perpendicular to the mean background magnetic field. It is necessary to go beyond power spectral analysis, which does not uniquely quantify the statistical scaling of the fluctuations, in order to address the question of fractal and multifractal scaling. Whilst the magnetic field fluctuations show behaviour close to "$1/f$", the velocity fluctuations, show distinct scaling. Parallel and perpendicular fluctuations differ from each other in their scaling, which also varies with the solar wind speed and solar cycle. These results point to distinct physical processes in the corona, and to their mapping out into the solar wind. The scaling exponents obtained constrain the models for these processes.

Turing to scalar quantities, such as magnetic energy density, we also find a solar cycle dependence. At solar maximum in the ecliptic, the magnetic energy density as seen by WIND and ACE shows a fractal signature, whereas at minimum it is multifractal. This is corroborated by ULLYSES polar observations at solar minimum in quiet, fast solar wind where again, multifractal scaling is found. High magnetic complexity in the corona then corresponds to fractal, rather than multifractal scaling in magnetic energy density seen at 1AU; remarkably, this fractal signature dominates the full dynamic range of observations, extending across timescales typically identified with both the "$1/f$" and 'inertial range'.

TIME VARIATIONS OF 3-D HELIOSPHERE OVER A SOLAR CYCLE

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We discuss the global structure of the heliosphere that follows from our 3D MHD time dependent code for several sets of boundary conditions. We simulate time variations of the solar wind caused by the 11-year solar cycle and analyze how they affect the termination shock and heliopause. The results from different models, assuming spherical or anisotropic solar wind, with or without the interplanetary magnetic field, are compared with each other. The interaction with neutral hydrogen via charge exchange is included. A role of the interstellar magnetic field is discussed.

SOLAR ENERGETIC PARTICLES DURING THE CYCLE 23 MINIMUM, AND THE CYCLE 24 ASCENDING PHASE

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Solar energetic particle during its entire period (launch on Aug. 2005 to re-entry on Dec. 2008) were given. The data were obtained from Solar Geophysical data reports by the US Department of Commerce. Descriptive studies have been done, and the Power spectrum analyses method were used for the data treatments too, to find the intermediate-term periodicities. Long term periodicities periodicity 311 days appeared, and confirmed with the other results.

SOHO/SWAN SOLAR WIND MASS FLUX OVER THE ENTIRE CYCLE

Rosine Lallement(1), Eric Quémerais(1), Jean-Loup Bertaux(1), Stéphane Ferron(1), and Walter Schmidt(2)
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(2) FMI, Helsinki, Finland

The analysis of the SOHO/SWAN Lyman-alpha data is updated to cover the entire 1996-2008 period, i.e. including the full solar activity declining phase. We will present the evolution of the large scale 3D solar wind distribution as it results from this analysis, and discuss some consequences on solar wind flux and acceleration area as a function of heliolatitude.

ANALYSIS OF THE SOLAR WIND QUASI–INVARIANT THROUGH SOLAR CYCLE 23

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(2) Space Science Center and Dep. of Physics, Univ. of New Hampshire, Durham, NH, USA,
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(4) NASA Goddard Space Flight Center, Greenbelt, MD, USA

The solar wind quasi–invariant (QI) is defined as the ratio of the solar wind magnetic energy density to the plasma kinetic energy density, i.e., the inverse square of the Alfvén Mach number. Previous work has found this quantity to be a good proxy for solar activity, correlating very well with the solar sunspot number at various heliospheric distances. It has the advantage of being locally determined from in situ measurements and can thus function as a heliospheric index of solar activity.

(1) We find that the QI-distributions are reasonably well represented by a log–normal distribution. Improvements are obtained by fitting the log-kappa distribution with advantage that the additional parameter kappa gives information about the structuredness of the datasample.

(2) We analyse the change of QI from solar minimum to solar maximum, with a focus if the minimum in 2007 is indeed a weaker minumum than previous ones. For this we use data from Wind, Stereo and Helios. Further we show the difference in the QI distribution behavior between the fast and the slow solar wind.

OBSERVATIONS OF THE 3D CORONAL STRUCTURE OVER A SOLAR ACTIVITY CYCLE

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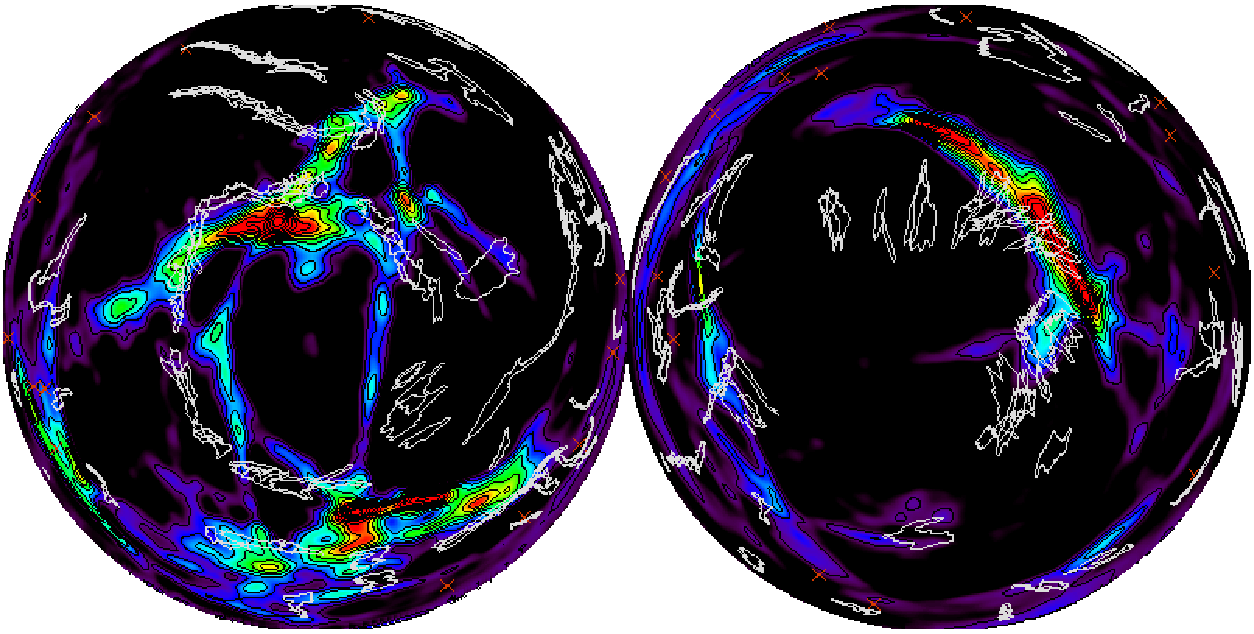
Solar rotational tomography is applied to almost eleven years of LASCO C2/SOHO data (September 1996 to July 2007), revealing the large-scale coronal density structure over almost a full solar activity cycle. Plotting the latitude of high-density streamers over the cycle reveals a butterfly diagram for the corona which is reasonably symmetric in latitude, with a minimum latitudinal deviation from the equator at Carrington rotation 1921 (April 1997). The shape of the butterfly diagram is compared to that of active regions over the same period. Whilst active regions generally reach maximum latitudes of only around 30°, the streamers reach the poles for a short period during March 2000 (North pole) and July 2000 (South pole). Therefore, whilst the same underlying mechanism may control the latitude of active regions and coronal streamers, long-lasting and large-scale streamers cannot be associated with active regions exclusively (streamers are in general not centered above active regions). In contrast, the maximum latitudinal extent of filaments observed against the solar disk has a strong correlation with the maximum latitudinal extent of streamers over the solar cycle. The figure below shows the distribution of filaments (white contours) plotted on polar density maps of the corona for CR1953 (August-September 1999). The longitudinal correlation between coronal streamers and disk filaments is less clear, and it seems that the coronal differential rotation may complicate matters, particularly above the poles.



LONG TERM VARIATION OF CORRELATION LENGTH IN THE SOLAR WIND

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Measuring the correlation length, λ, of solar wind parameters allows the investigation of the turbulent and large scale properties of the solar wind using shorter data periods or data with more data gaps than is possible using Fourier methods. λ is important in our understanding of cosmic ray scattering in the heliosphere, the turbulent behaviour of the solar wind and the interaction of the solar wind with other space plasmas, such as planetary magnetospheres and the termination shock.

We present the results of a long term study of the λ of $|B|$, **B**, $|V|$ and **V** in the solar wind. Observations from the IMP 8 spacecraft and the OMNI dataset are used to estimate λ quarterly between 1974 and the present day; this covers the last three solar cycles. There is clear evidence for a solar cycle effect on λ in the magnetic field magnitude, with solar minimum having a shorter λ by a factor of 2 than solar maximum. The correlation length of the solar wind speed also varies; with longer λ seen in 1974 after the most recent weak cycle, and since 2005 in the recent unusual conditions. The components of **B** and **V** do not show a strong modulation of λ with solar cycle and have very similar values for λ of around 1.5×10^6 km.

The lack of variation in λ for the components of **B** and **V** is explained by the presence of continuous and developed Alfvénic turbulence which is not strongly modulated by the activity of the Sun. The increase in λ of magnetic field magnitude at solar maximum is found to be due to increased magnetic field structure caused by structures of solar origin such as CMEs and stream interactions, which in turn are increased by solar activity.

These results provide useful input parameters for models of cosmic ray scattering, the radial evolution of the solar wind, and the termination shock as well as increasing our understanding of solar wind turbulence. They also indicate that the recent unusual solar minimum is not necessarily unusual since solar wind parameters are indicating a return to behaviour previously seen at the end of solar cycle 20.

LARGE-SCALE HELIOSPHERIC STRUCTURE DURING SOLAR-MINIMUM CONDITIONS USING A 3D TIME-DEPENDENT RECONSTRUCTION SOLAR-WIND MODEL AND STELAB IPS OBSERVATIONS

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Interplanetary scintillation (IPS) observations provide information about a large portion of the inner heliosphere. We have used STELab IPS velocity and *g*-level observations with our 3D-reconstruction model to determine velocities and densities of the inner heliosphere in three dimensions. We present these observations using synoptic maps from our time-dependent model that can measure changes with durations of less than one day. These synopses show large-scale stable solar-wind structure during solar-minimum conditions in relation to transients that are present during this period. These are also available as differences relative to the background. Here, we concentrate primarily on data covering the 2007-2009 International Heliophysical Year (IHY) which includes the Whole Heliosphere Interval (CR2068).

SOLAR CYCLE CHANGES IN THE SOLAR CORONA

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The corona is a magnetically dominated system that is organized by the Sun's magnetic field into 'closed' and 'open' regions. Basic properties of the corona, such as its global appearance, brightness, and temperature vary with the 11-year magnetic activity cycle. These changes are ultimately driven by the solar dynamo and determine the large scale structure of the solar wind. Understanding how the basic properties of the solar corona vary with the 11-year solar cycle provides insights into the physical processes that drive the solar dynamo, heat the corona and structure the solar wind. We report on observations of coronal brightness variations over 3 solar cycles recorded by the Mauna Loa Solar Observatory K-coronameters spanning the period from 1980 to 2009. These data provide the longest running continuous set of white light coronal observations. Results indicate the brightness, and hence mass of the corona is correlated with the 11-year sunspot cycle. We compare these changes with observations from other coronal data sets and models of the global structure of the solar magnetic field and discuss how these effect the structure of the solar wind.

THE SUN'S MAGNETIC FIELD DURING SOLAR MINIMUM

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The past three years have been characterized by a very weak sunspot and CME activity making this a long and deep solar minimum. In spite of the lack of magnetic activity at the Sun, white light and EUV images have shown that a dimmer but relatively complex corona -with multiple streamers and low latitude coronal holes- persisted during most of this extended minimum. Solar wind observations indicated that the heliopsheric current sheet was more warped during the declining and minimum phase of this cycle and there was an increase of about 13% in solar wind velocity near the Earth. Interestingly, the polar magnetic fields observed at the photosphere during the present minimum are 30-40% weaker than during the previous minimum. Can the weaker polar fields (and associated weaker dipole moment) explain the differences observed in the corona and heliosphere? To answer this question, we will use PFSS model computations. We will run the Wang-Sheeley-Arge model from 1996 to the present to determine the relative importance of the dipole moment vs. higher moments during the two minimum periods. We will then artificially modify the polar magnetic field strength during the two minima to investigate how increasing/decreasing the strength of the polar fields during the present/past minimum changes the derived coronal holes and coronal field.

SOLAR WIND MINOR ION SIGNATURES AT LARGE-SCALE STRUCTURE INTERFACES DURING SOLAR MINIMUM

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Several large scale solar wind structures have been observed in situ by the STEREO spacecraft since their launch in October 2006. Given the prevailing solar minimum conditions, these structures have been predominantly fast and slow solar wind interfaces, with the occasional transient event. The interfaces for these structures observed by STEREO have been identified using IMPACT magnetic field and PLASTIC solar wind proton data
(e.g., http://www-ssc.igpp.ucla.edu/forms/stereo/stereo_level_3.html). In this presentation, we extend earlier solar wind interface composition studies (e.g., Burton et al., 1999; Wimmer et al., 1996, 1997; Balogh et al., 1999) into the current solar minimum. We investigate minor ion (Fe, O) kinetic and composition parameters at selected events.

ENERGETIC SOLAR PARTICLES DURING LAST 3 CYCLES

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Energetic Solar particles and energetic during its entire period (launch on Aug. 1966 to re-entry on Dec. 2006) were given. The data were obtained from Solar Geophysical data reports by the US Department of Commerce, hard X-ray burst spectrometer (HXRBS) during the solar cycle21,22 and 23. The bursts emitted from solar coronal atmosphere, and extended to the outer layers of the sun, were also studied. Power spectrum analyses method were used for the data treatments, to find the intermediate-term periodicities, 14, 28, 35 are significant. Long-term periodicities periodicity 311 days appeared, and confirmed with the other results.

STATISTICS OF COUNTER-STREAMING SOLAR WIND SUPRATHERMAL ELECTRONS AT SOLAR MINIMUM: STEREO OBSERVATIONS

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Previous works have shown that solar wind suprathermal electrons can display a number of features in terms of their anisotropy. Of importance is the occurrence of counter-streaming electrons, i.e., with "beams" both parallel and anti-parallel to the local magnetic field, which is believed to shed lights on the heliospheric magnetic field topology. In the present study, we use STEREO multi-spacecraft data to obtain the statistical properties of counter-streaming suprathermal electrons. We investigate (1) the dependence of their occurrence rate on the criteria used to define their counter-streaming nature, (2) the relation between their occurrence rate and the local magnetic field strength and solar wind bulk speed, and (3) their location relative to corotating interaction regions (CIRs) during the period of interest here (February – August 2007). Because this period corresponds to a minimum of solar activity, the results are unrelated to the sampling of coronal mass ejections, which can lead to counter-streaming electrons owing to their closed topology. The results are interpreted in terms of the occurrence of both shock acceleration/back-scattering and electron halo depletions at 90 degree pitch angle, as previously reported. Our statistical results confirm that both depletion- and shock-related counter-streaming suprathermal electrons are preferentially observed both just before and after the passage of CIRs, owing to the properties and magnetic topology of such structures.

EVOLUTION OF SOLAR WIND STREAMS IN THE SOLAR ACTIVITY CYCLE

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The study is based on the experiments on systematic sounding of circumsolar plasma at radial distances R=4.0-70RS carried out at the Pushchino Radioastronomical Observatory. The intensity $|B_R|$ and structure of coronal magnetic fields calculated from WSO magnetic measurements have been used. The experimental data allowed us to localize the inner boundary of the solar wind transonic transition region and the solar wind sources (magnetic field components in the solar corona) at $R = 10 - 20R_S$. The solar wind diagnostics was performed using the correlation diagrams $R_{in} = F(|B_R|)$. The experiments carried out in the period 1997-2007 have revealed streams of ten different types in the solar wind. It is shown that dramatic changes occur in the solar wind over an activity cycle: some types of the stream disappear giving way to the others.

THE STUDY OF SOLAR WIND PLASMA AND INTERPLANETARY MAGNETIC FIELD PARAMETERS DURING 2001

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In-situ data measured by Ulysses - SWOOPS, SWICS and VHM instruments- are used for the study of solar wind plasma parameters and interplanetary magnetic field parameters during the year 2001. The ICMEs events that exist in this interval of time are analyzed considering classical identification conditions (high abundance of alpha particle, low kinetic temperature, low proton plasma beta, increased magnetic field strength), plasma dynamics signatures (thermal index, depressed proton temperature than expected, Te/Tp ratio threshold), and plasma composition signatures (enhanced alpha/proton ratio, high Fe charge state, elevated oxygen charge state ratio, anomalies of heavy ion species abundance, low ion temperatures and speeds).

THE PROPERTIES OF CYCLE 23 SOLAR ENERGETIC PROTON EVENTS

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Around 320 solar energetic proton events were detected by near-Earth spacecraft during solar cycle 23 at energies above 25 MeV. We summarize the properties of these events, focusing in particular on the 281 events with intensities in the 20-30 MeV range above 2×10^{-4} particles/(cm^2 ster s MeV) that were also not compromised by data gaps and other events. We consider the event intensity distribution, composition, and the properties of the related solar phenomena, including the speed and size of the associated CMEs, flare properties, accompanying radio bursts and the properties of the shocks observed at 1 AU.

INTERPLANETARY CORONAL MASS EJECTIONS DURING SOLAR CYCLE 23

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We have identified ~ 300 interplanetary coronal mass ejections (ICMEs) near the Earth during 1996-present, encompassing the complete solar cycle 23 (http://www.ssg.sr.unh.edu/mag/ace/ACElists/ICMEtable.html). We summarize the properties of these ICMEs including their occurrence rate, fraction that are magnetic clouds, average parameters (e.g., speed, field intensity, density, radial size and expansion speed) and their variation through the solar cycle and relationship with the properties of the associated solar events. We also discuss briefly signatures in the recently revised (2008) ACE/SWICS composition/charge state data set that are associated with ICMEs.

SOLAR WIND INFLUENCE ON MAGNETOSPHERIC FLUCTUATIONS: WAITING TIMES AND CRITICAL SCALING

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We have examined the burst lifetime distribution functions of solar wind VBs and epsilon for 1995–2005 and compared them with the same for contemporaneous SYM-H. The analysis yields clear power-law exponents of the lifetime probability distributions. When we analyzed three years around solar minimum we found similar scaling behavior for all the variables, including SYM-H. However, for the three years around solar maximum the difference between solar wind and SYM-H scaling was very clear. The fact that power laws were consistently observed for different activity thresholds show that these features are robust and repeatable, although scaling can vary depending on solar cycle. During solar maximum it appears that the scaling properties of the low-latitude magnetosphere, whose output is recorded by SYM-H, are not purely a direct response to the scale-free properties of the solar wind but are due to inherent properties of the magnetosphere. Since SYM-H scaling is remarkably robust, irrespective of solar cycle, it could be that the solar wind never acts as a direct driver for the SYM-H scaling. Critical scaling results further support this hypothesis.

POLAR CORONAL JETS IN THE CURRENT SOLAR MINIMUM

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The SOHO polar coronal jets were first observed by SOHO instruments (EIT, LASCO, UVCS) during the previous solar minimum in 1996. They were small, fast coronal eruptions originating from the flaring UV bright points within large polar coronal holes. Data analysis and modeling provided estimates of the jet plasma conditions, dynamics, evolution of the electron temperature and heating rate. In the current minimum of solar activity large polar holes are again dominating structures in the solar corona. We analyzed recent UVCS/SOHO observations of the polar regions in search of the jet counterparts. We present the observations and discuss the results.

RADIAL HELIOSPHERIC MAGNETIC FIELDS IN SOLAR WIND RAREFACTION REGIONS: ULYSSES MISSION-LONG STUDY

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We examine the distribution of directions of the heliospheric magnetic field (HMF) measured by the Ulysses spacecraft during its two and a half high-latitude orbits over the poles of the Sun (from 1992 to the end of 2007). We are looking in particular for the nearly radial field orientations that were first reported by Jones et al. [1998] and analyzed in greater detail by several subsequent authors. As they all noted, such radial fields are commonly observed in the mid-latitude region ($\sim$10°-40°), when the observed solar wind velocity shears from the high-latitude fast solar wind toward the low-latitude slow solar wind (i.e. in rarefaction regions where the solar wind velocity decreases monotonically over several days). In contrast to ICMEs where the HMF tends to be enhanced, the rarefaction regions with radial magnetic fields tend to have extremely low values of the HMF. Within these rarefaction regions, there are "dwells" in the coronal source longitude of the measured solar wind [Nolte and Roelof, 1973] in which the time dependence of the solar wind velocity is given to very good approximation by $V(t)$=$r/(t-t_0)$, where r is the radius of the spacecraft. We have therefore compiled distributions within the dwells of the parameter $|B_r/B|$ which is the cosine of the cone angle of the field from the radial direction. We study the mid-latitude transits that occurred during different phases of solar activity: 1992 (decline), 1996 (rise), 2002 (maximum), and 2005 (minimum). During three out of these four periods, the distributions of the HMF tended to be rather uniform in all HMF directions (0<$|B_r/B|$<1), but during 2002, when the dwells were more frequent and of shorter duration, the distributions tended more strongly toward $|B_r/B|$$\sim$1. Such distributions were observed up to very high latitudes (65°N). We discuss these observations in terms of the large-scale topology of the HMF as described by an analytic function that includes as special cases both a temporal variation in the coronal solar wind velocity [Gosling and Skoug, 2002] and a longitudinal velocity gradient at the eastern edge of a solar wind source region [Schwadron and McComas, 2005].

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