21st Annual International Astrophysics Conference

Turin, Italy; March 25 – 29, 2024

AGENDA

Sunday, March 24th

5:00 PM – 8:00 PM	Registration – Sala Banchetti Foyer
6:00 PM – 9:00 PM	Welcome Reception – Sala Banchetti Foyer

Monday, March 25th

8:00 AM – 4:00 PM	Registration Check-In – Sala Banchetti Foyer
8:00 AM – 5:10 PM	General Session – Sala Banchetti

CHAIR: Zank, G		
8:00 AM – 8:25 AM	Zank, Gary	Welcome
8:25 AM – 8:50 AM	Carella, Francesco	Clustering of the Solar Wind at 1 AU: Reconnection and the Ambient Solar Wind
8:50 AM – 9:15 AM	Kontar, Eduard	Radial variation of anisotropic density turbulence from the low corona to 1 au
9:10 AM – 9:40 AM	Puzzoni, Eleonora	Role of magnetic arcades in explaining the puzzle of the gamma-ray emission from the solar disk
9:40 AM – 10:05 AM	Sako, Takashi	Modeling of the sidereal anisotropy of TeV galactic cosmic rays with the Tibet ASgamma experiment
10:05 AM – 10:30 AM	BREAK	
CHAIR: Strauss, Du Toit		
10:30 AM – 10:55 AM	Dayeh, Maher	PSP Observations of the Suprathermal Spectrum in the inner Heliosphere
10:55 AM – 11:20 AM	La Vacca, Giuseppe	Towards a Semi-Analytical Model of the Long-Term Variations of the Heliospheric Structures
11:20 AM – 11:45 AM	Giacalone, Joe	On the time intensity behavior of energetic particles associated with shocks close to the Sun
11:45 AM – 12:10 PM	Pezzini, Luca	Fully kinetic simulations of solar wind protons observed by Parker Solar Probe (PSP)
12:10 PM – 12:35 PM	Cohen, Christina	Multi-spacecraft Observations of SEP Events Using Parker Solar Probe Measurements
12:35 PM – 1:30 PM	LUNCH	
CHAIR: Zhang, Ming		
1:30 PM – 1:55 PM	Opher, Merav	The Sun's Trajectory in the Last 10 Million years and possible terrestrial implications on Climate Evolution
1:55 PM – 2:20 PM	Dialynas, Konstantinos	On the anisotropies of 40-139 keV ions from LECP: has Voyager 1 entered a new regime in the VLISM?
2:20 PM – 2:45 PM	Slavin, Jonathan	Interstellar Dust Inflow and the Heliospheric current Sheet Near the Heliopause

2:45 PM – 3:10 PM	Czechowski, Andrej	Dust dynamics in the solar wind: semi analytical models
3:10 PM – 3:35 PM	Fisk, Len	The Interaction of the Heliosheath with the Magnetic Field of the Very Local Interstellar Medium (VLISM)
3:35 PM – 3:55 PM	BREAK	
CHAIR: Richardson, John		
~~3:55 PM – 4:20 PM~~	~~Zhao, Lulu~~	~~Modeling Solar Energetic Particles Using Solar Wind with Field Lines and Energetic Particle (SOFIE) Model~~
4:20 PM – 4:45 PM	Florinski, Vladimir	Scattering of Energetic Charged Particles in Focusing Magnetic Fields
SESSION ADJOURNS		

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Tuesday, March 26th		
8:00 AM – 4:00 PM	Registration Check-In – Sala Banchetti Foyer	
8:00 AM – 5:10 PM	General Session – Sala Banchetti	
CHAIR: Asgari-Targhi, Mahboubeh		
8:00 AM – 8:25 AM	Sterling, Alphonse	How Small-scale Solar Coronal-jet-like Events from Miniature Flux Rope Eruptions Might Produce the Solar Wind and Magnetic Switchbacks
8:25 AM – 8:50 AM	Bastian, Tim	The Role of Solar Spicules in the Mass Budget of the Low Solar Atmosphere
8:50 AM – 9:15 AM	Yalim, Mehmet Sarp	Investigating Joule Heating as a Solar Active Region Atmosphere Heating Mechanism
9:10 AM – 9:40 AM	Chhiber, Rohit	On the properties of the Alfven transition zone separating the solar corona and the solar wind
9:40 AM – 10:05 AM	Zank, Gary	Characterization of Turbulent Fluctuations in the Sub-Alfvenic Solar Wind
10:05 AM – 10:30 AM	BREAK	
CHAIR: Servidio, Sergio		
10:30 AM – 10:55 AM	Zhao, Lulu	Modeling Solar Energetic Particles Using Solar Wind with Field Lines and Energetic Particle (SOFIE) Model
10:55 AM – 11:20 AM	Adhikari, Laxman	Turbulence, and Proton and Electron Heating Rates in the Solar Corona: Analytical Approach
11:20 AM – 11:45 AM	Boldyrev, Stanislav	Alfven turbulence at kinetic scales: spectra, intermittency, and particle acceleration
11:45 AM – 12:10 PM	Passot, Thierry	On the transition range in imbalanced Alfvén wave turbulence: the role of co- and counter-propagating waves
12:10 PM – 12:35 PM	D'Amicis, Raffaella	On the Alfvénic content of solar wind streams and their origin: a focus on Solar Orbiter observations
12:35 PM – 1:30 PM	LUNCH	
CHAIR: Fisk, Len		
1:30 PM – 1:55 PM	Winebarger, Amy	Identifying source regions of the solar wind with the Multi-slit Solar Explorer
1:55 PM – 2:20 PM	Landi, Enrico	Solar cycle evolution of solar wind heavy ion properties
2:20 PM – 2:45 PM	Antiochos, Spiro	The Nature of the Sun-Heliosphere Magnetic Connection
2:45 PM – 3:10 PM	Raymond, John	The Temperature in the Acceleration Region of Impulsive SEPs

3:10 PM – 3:35 PM	Tenerani, Anna	Evolution of Alfvén wave packets in fluid and kinetic models: a comparative study
3:35 PM – 3:55 PM	BREAK	
CHAIR: Winebarger, Amy		
3:55 PM – 4:20 PM	Consolini, Giuseppe	On the stochastic character of space plasma turbulent fluctuations at sub-ion scales: a brief review
4:20 PM – 4:45 PM	Zieger, Bertalan	Inverse Energy Cascade of Ion Bernstein Turbulence in the Inner Heliosheath
4:45 PM – 5:10 PM	Cairns, Iver	Ion Acoustic Waves Driven by a Reactive Ion Beam Instability
SESSION ADJOURNS		

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Wednesday, March 27th		
8:00 AM – 4:00 PM	Registration Check-In – Sala Banchetti Foyer	
8:00 AM – 5:10 PM	General Session – Sala Banchetti	
CHAIR: Cohen, Christina		
8:00 AM – 8:25 AM	Wijsen, Nicolas	Recent advances in modeling solar energetic particle events using PARADISE
8:25 AM – 8:50 AM	Leske, Rick	Comparison of Heavy Ion Behavior at Parker Solar Probe and Solar Orbiter During the 5 September 2022 Solar Energetic Particle Event
8:50 AM – 9:15 AM	Servidio, Sergio	Coherent Structures in Solar Wind Turbulence: Models, Measurements, and Future Space Missions
9:10 AM – 9:40 AM	Ho, George	Multi-spacecraft Observations of Energetic Particle Events Inside of 1 au: Measurements by Solar Orbiter, ACE and STEREO
9:40 AM – 10:05 AM	Bellan, Paul	Energetic electron tail production from binary encounters of discrete electrons and ions in a sub-Dreicer electric field
10:05 AM – 10:30 AM	BREAK	
CHAIR: Raymond, John		
10:30 AM – 10:55 AM	Pierrard, Viviane	Origin of the Solar Wind: Acceleration by Ambipolar Electric Field
10:55 AM – 11:20 AM	Micera, Alfredo	Heat flux regulation by collisionless processes in the solar wind
11:20 AM – 11:45 AM	Baratashvili, Tinatin	A novel full MHD forecasting model chain from Sun to Earth: COCONUT+ Icarus
11:45 AM – 12:10 PM	Wang, Linghua	Energy Spectrum of Solar Energetic Electron Events
12:10 PM – 12:35 PM	Strauss, Du Toit	On the parallel mean-free-path of solar energetic particle protons and electrons
12:35 PM – 1:30 PM	LUNCH	
CHAIR: Wilson, Lynn		
1:30 PM – 1:55 PM	Pitna, Alexander	Turbulent Heating Downstream of Collisionless Shock Waves
1:55 PM – 2:20 PM	Isenberg, Philip	Kinetic model of solar wind generation by imbalanced turbulence with helicity barrier effects
2:20 PM – 2:45 PM	Mazelle, Christian	Bow shocks and foreshocks around induced magnetospheres in the solar wind: recent advances
2:45 PM – 3:10 PM	le Roux, Jakobus	Tempered Superdiffusive Shock Acceleration at a Perpendicular Shock
3:10 PM – 3:35 PM	Medvedev, Mikhail	Quasi-nonlinear approach to the Weibel instability in the upstream medium of a collisionless shock

3:35 PM – 3:55 PM	BREAK	
CHAIR:		
3:55 PM – 4:20 PM	Raouafi, Nour E.	Role of Small-Scale Solar Activity in the dynamics of the Coronal and Solar Wind Plasma
4:20 PM – 4:45 PM	Trueba, Nicolas	Understanding Energetic Electrons in Coronal Shocks via EUV and Radio Diagnostics
4:45 PM – 5:10 PM	Song, Paul	Formation of the Transition Region for the Quiet Sun
SESSION ADJOURNS		
6:00 PM – 9:00 PM	GROUP DINNER	

AGENDA

Thursday, March 28th		
8:00 AM – 4:00 PM	Registration Check-In – Sala Banchetti Foyer	
8:00 AM – 5:10 PM	General Session – Sala Banchetti	
CHAIR: Tenerani, Anna		
8:00 AM – 8:25 AM	Guzman, Juan	Galactic Cosmic Ray Modulation in the Heliosheath: The Effect of Magnetic Sectors and Unipolar Regions
8:25 AM – 8:50 AM	Arrò, Giuseppe	Energy transfer and space-time properties of plasma turbulence from magnetohydrodynamics to kinetic scales
8:50 AM – 9:15 AM	Hegde, Dinesha	MHD Modeling of the Ambient Solar Wind with Quantified Uncertainties: Multi-Spacecraft Validation in the Inner Heliosphere
9:10 AM – 9:40 AM	Zhao, Siqi	First Observational Evidence of the Weak-to-strong Transition in Alfvénic Turbulence
9:40 AM – 10:05 AM	Li, Hui	Compressible Turbulence in near-Sun Solar Wind: Lessons from 3D MHD Simulations
10:05 AM – 10:30 AM	BREAK	
CHAIR: Pierrard, Viviane		
10:30 AM – 10:55 AM	Wilson, Lynn	Electron velocity distribution functions in the solar wind
10:55 AM – 11:20 AM	Che, Haihong	Electromagnetic electron Kelvin–Helmholtz instability
11:20 AM – 11:45 AM	Salem, Chadi	New Insights on Solar Wind Electrons at 1 AU: Collisionality, Heat Flux, and Thermal Force
11:45 AM – 12:10 PM	Richardson, John	Voyager observations of the interstellar medium
12:10 PM – 12:35 PM	McComas, David	Energetic Neutral Atom Observations from IBEX to IMAP
12:35 PM – 1:30 PM	LUNCH	
CHAIR: Bellan, Paul		
1:30 PM – 1:55 PM	Pogorelov, Nikolai	Topology and Structure of the Solar Wind Interaction with the Local Interstellar medium
1:55 PM – 2:20 PM	Van der Holst, Bart	Multi-fluid Outer Heliosphere Model with Pickup Ions and Turbulence Transport
2:20 PM – 2:45 PM	Zhang, Ming	Exploring the magnetic field structure of the heliosphere and surrounding local interstellar medium with TeV cosmic ray anisotropy
2:45 PM – 3:10 PM	Nakanotani, Masaru	Application of a kinetic PUI-multifluid model to the Heliospheric termination shock
3:10 PM – 3:35 PM	Matsukiyo, Shuichi	Generation of nonthermal pickup ions in an oblique Heliospheric termination shock
3:35 PM – 3:55 PM	BREAK	
CHAIR: Salem, Chadi		

3:55 PM – 4:20 PM	Fraternale, Federico	Time dependence of compressible turbulence observed by Voyager in the inner and outer Heliosheaths
4:20 PM – 4:45 PM	Elliott, Heather	Solar Wind in the Outer Heliosphere
4:45 PM – 5:10 PM	Hill, Matthew	Future New Horizons Encounter with the Solar Wind Termination Shock
SESSION ADJOURNS		

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AGENDA

Friday, March 29th

8:00 AM – 4:00 PM Registration Check-In – Sala Banchetti Foyer
8:00 AM – 5:10 PM General Session – Sala Banchetti

CHAIR: Wang, Linghua		
8:00 AM – 8:25 AM	Guo, Xiaocheng	Numerical Simulation of Galactic Cosmic-Rays during the Heliopause Crossing for Voyager 2
8:25 AM – 8:50 AM	Scott, Roger	The Dynamic Evolution of Solar Wind Streams Following Interchange Reconnection
8:50 AM – 9:15 AM	Heidrich-Meisner, Verena	Pickup-ion measurements with STEREO-A/PLASTIC and Solar Orbiter/EPD/STEP
9:10 AM – 9:40 AM	Livadiotis, George	Entropy defect in thermodynamics: Theory and applications in space plasmas
9:40 AM – 10:05 AM	Davidson, Katherine	Dependence of High-Latitude Neutral Wind Responses on Geomagnetic Conditions
10:05 AM – 10:30 AM	BREAK	
CHAIR: Zank, G		
10:30 AM – 10:55 AM	Huang, Zhenguang	The Energy Deposition Rate in the Open Field Region from MHD Simulations
10:55 AM – 11:20 AM	Harvey, Rebecca	Observational analysis of small-scale structures across the Earth's bow shock
11:20 AM – 11:45 AM	Gautam, Sujan Prasad	Turbulence properties in upstream and downstream regions of interplanetary shocks
11:45 AM – 12:10 PM	Asgari-Targhi, Mahboubeh	Study of Non-thermal Velocities and Their Comparisons with Alfven Wave Turbulence Model in Solar Active Regions
END OF CONFERENCE		

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TALKS BY PARTICIPANT

Adhikari, Laxman	Tue. Mar 26	10:55 AM – 11:20 AM	Turbulence, and Proton and Electron Heating Rates in the Solar Corona: Analytical Approach
Antiochos, Spiro	Tue. Mar 26	2:20 PM – 2:45 PM	The Nature of the Sun-Heliosphere Magnetic Connection
Arrò, Giuseppe	Thu. Mar 28	8:25 AM – 8:50 AM	Energy transfer and space-time properties of plasma turbulence from magnetohydrodynamics to kinetic scales
Asgari-Targhi, Mahboubeh	Fri. Mar 29	11:45 AM – 12:10 PM	Study of Non-thermal Velocities and Their Comparisons with Alfven Wave Turbulence Model in Solar Active Regions
Baratashvili, Tinatin	Wed. Mar 27	11:20 AM – 11:45 AM	A novel full MHD forecasting model chain from Sun to Earth: COCONUT+ Icarus
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Boldyrev, Stanislav	Tue. Mar 26	11:20 AM – 11:45 AM	Alfven turbulence at kinetic scales: spectra, intermittency, and particle acceleration
Cairns, Iver	Tue. Mar 26	4:45 PM – 5:10 PM	Ion Acoustic Waves Driven by a Reactive Ion Beam Instability
Carella, Francesco	Mon. Mar 25	8:00 AM – 8:25 AM	Clustering of the Solar Wind at 1 AU: Reconnection and the Ambient Solar Wind
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Cohen, Christina	Mon. Mar 25	12:10 PM – 12:35 PM	Multi-spacecraft Observations of SEP Events Using Parker Solar Probe Measurements
Consolini, Giuseppe	Tue. Mar 26	3:55 PM – 4:20 PM	On the stochastic character of space plasma turbulent fluctuations at sub-ion scales: a brief review

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Puzzoni, Eleonora	Mon. Mar 25	9:15 AM – 9:40 AM	Role of magnetic arcades in explaining the puzzle of the gamma-ray emission from the solar disk

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Raouafi, Nour E.	Wed. Mar 27	3:55 PM – 4:20 PM	Role of Small-Scale Solar Activity in the dynamics of the Coronal and Solar Wind Plasma
Raymond, John	Tue. Mar 26	2:45 PM – 3:10 PM	The Temperature in the Acceleration Region of Impulsive SEPs
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Zieger, Bertalan	Tue. Mar 26	4:20 PM – 4:45 PM	Inverse Energy Cascade of Ion Bernstein Turbulence in the Inner Heliosheath

POSTERS BY PARTICIPANT

Baruwal, Prashant	Evolution of turbulence fluctuations during Parker Solar Probe and Solar Orbiter radial alignment
Baruwal, Prashrit	Identification of turbulent modes in the magnetosheath
Giordano, Silvio	Solar Wind Speed Maps thought a Full Solar Cycle from UVCS/SoHO and Recent Metis/Solar Orbiter Results
Tasnim, Mst Ismita	Mode Decomposition in Hydrodynamics

SCHEDULE OF TALKS

Monday, March 25: 8:25 AM – 8:50 AM
Presenter: Carella, Francesco

Clustering of the Solar Wind at 1 AU: Reconnection and the Ambient Solar Wind

Francesco Carella, KU Leuven, Belgium
Giovanni Lapenta, KU Leuven, Belgium
Alessandro Bemporad, INAF-Turin Astrophysical Observatory, Italy
Maria Elena Innocenti, Institut für Theoretische Physik, Ruhr-Universität Bochum, Germany
Stefan Eriksson, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, USA
Sophia Köhne, Institut für Theoretische Physik, Ruhr-Universität Bochum, Germany

Investigating the solar wind is critical for our understanding of the dynamics of plasma in the solar system environment. At 1 AU, where the solar wind interacts with the Earth's magnetosphere, we can identify different transient processes, such as Interplanetary Coronal Mass Ejections (ICMEs), Corotating Interaction Regions (CIRs), which may result in the occurrence of magnetic reconnection. In this work we use Self Organizing Maps (SOMs), an unsupervised learning method which combines dimensionality reduction and neural networks, to transform time series from WIND observations (proton density, proton temperature, solar wind speed and magnetic field strength) into visual maps. We use clustering techniques applied to the SOM we train to obtain a classification of the solar wind. Then, by using a reconnection exhausts catalogue from Eriksson et al. the occurrence of magnetic reconnection in the different clusters is examined.

Monday, March 25: 8:50 AM – 9:15 AM
Presenter: Kontar, Eduard

Radial variation of anisotropic density turbulence from the low corona to 1 au

Eduard Kontar, University of Glasgow, UK
Francesco Azzollini, University of Glasgow, UK
Daniel L. Clarkson, University of Glasgow, UK
A. Gordon Emslie, Western Kentucky University, USA
Nicolina Chrysaphi, Sorbonne University, France
Natasha L.S. Jeffrey, Northumbria University, UK
Mykola Gordovskyy, University of Hertfordshire, UK

Radio signals propagating via solar corona and solar wind are significantly affected by density fluctuations, impacting solar radio burst properties as well as the observations of sources viewed through the turbulent atmosphere. Using large-scale simulations of radio-wave transport, the radial profile of anisotropic density turbulence from the low corona to 1 au is explored.
For the first time, a profile of Heliospheric density fluctuations is deduced that accounts for the properties of extra-solar radio sources, solar radio bursts, and in-situ density fluctuation measurements in the solar wind at 1 au. Combining the anisotropic turbulence model with the space-craft frequency broadening measurements radial and perpendicular to radial velocities are deduced. The deduced properties of turbulence could be used to estimate the energy deposition rates due to Landau damping ion-sound waves and specific energy rate Alfven wave turbulent cascade at large scales.

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SCHEDULE OF TALKS

Monday, March 25: 9:15 AM – 9:40 AM
Presenter: Puzzoni, Eleonora

Role of magnetic arcades in explaining the puzzle of the gamma-ray emission from the solar disk

Federico Fraschetti, University of Arizona and Center for Astrophysics Harvard & Smithsonian, USA
Jozsef Kota, University of Arizona, USA
Joe Giacalone, University of Arizona, USA

In 1991, Seckel, Stanev, and Gaisser (SSG91) proposed a theoretical model aimed at predicting the gamma-ray emission originating from the solar disk from the interaction of Galactic Cosmic Rays (GCRs) with the solar atmosphere. However, the GeV-TeV gamma-ray emission remains an enigmatic and unresolved puzzle to date. Notably, observations by Fermi-LAT and HAWC present a gamma-ray emission with a brighter, harder spectrum extending to significantly higher energies than predicted by SSG91. The solution to this puzzle presumably lies in our understanding of how GCRs interact with solar magnetic fields in the corona and lower atmosphere and are thereby useful probes of this structure. Consequently, there is a pressing need for a new theoretical framework to comprehensively elucidate the mechanisms governing gamma-ray emission from the solar disk. This study focuses on exploring the impact of a closed magnetic field geometry on the observed gamma-ray flux. Numerical simulations, employing the PLUTO code, involve test-particle protons and depict the evolution of GCRs within a static magnetic arcade associated with an active region. Test-particle protons are injected at varying altitudes, accounting for the plausible migration of GCRs from adjacent flux tubes to closed arcade structures. A magnetic turbulent component is introduced into the arcade magnetic field, and multiple simulations explore increasing turbulence strengths. Our exploration focuses on understanding the influence of both the large-scale magnetic field within the arcade and its turbulent fluctuations on the trapping of particles. Our findings highlight a predominant gamma-ray emission pattern in the solar disk limb at higher energies and a more isotropic emission at lower energies, aligning with observations from Fermi-LAT. The resulting gamma-ray flux displays a discernible slope contingent upon the strength of turbulence. A comparative analysis with observations from Fermi-LAT and HAWC establishes a favorable agreement, bolstering the validity of our proposed model and affirming the consistency of our results with observations.

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SCHEDULE OF TALKS

Monday, March 25: 9:40 AM – 10:05 AM
Presenter: Sako, Takashi

Modeling of the sidereal anisotropy of TeV galactic cosmic rays with the Tibet ASgamma experiment

T. K. Sako for the Tibet ASgamma collaboration

Galactic cosmic rays are high-energy nuclei, mostly protons, accelerated in our galaxy and continuously arriving at the earth after traveling through the interstellar medium and the heliosphere. Anisotropies in the arrival directions of those cosmic rays reflect the structure of the local interstellar magnetic field surrounding the solar system. In the sidereal time frame, there is no model accepted as the common understanding of the origin of the anisotropy observed at TeV energies with an amplitude of ~0.1% by various past observations including ground-based air-shower arrays as well as underground muon telescopes. In addition, recent high-statistics experiments have revealed that the amplitude and phase of the anisotropy dramatically change above ~100 TeV from those below ~100 TeV. In this presentation we report our recent studies on how the cosmic-ray anisotropy at the

Heliospheric outer boundary can be modeled at TeV energies, by applying the idea of Liouville mapping to the experimental data of the Tibet ASgamma experiment.

Monday, March 25: 10:30 AM – 10:55 AM
Presenter: Dayeh, Maher

PSP Observations of the Suprathermal Spectrum in the inner Heliosphere

Maher A. Dayeh, Southwest Research Institute, USA - Michael Starkey, Southwest Research Institute, USA
Radoslav Bučik, Southwest Research Institute, USA - Mihir I. Desai, Southwest Research Institute, USA - Don G. Mitchell, Johns Hopkins University Applied Physics Laboratory, USA - Matt E. Hill, Johns Hopkins University Applied Physics Laboratory, USA
Gang Li, University of Alabama at Huntsville, USA - Nathan A. Schwadron, University of New Hampshire, USA
Ben Alterman, Southwest Research Institute, USA - Robert C. Allen, Johns Hopkins University Applied Physics Laboratory, USA
Christina Cohen, California Institute of Technology, USA - Rachael Filwett, Montana State University, USA
Joe Giacalone, University of Arizona, USA - Leila Mays, Goddard Space Flight Center, USA - David J. McComas, Princeton University, USA - Nour Raouafi, Johns Hopkins University Applied Physics Laboratory, USA - Jamey R. Szalay, Princeton University, USA

The Suprathermal (ST) particle population with energies just above the thermal solar wind (SW) energy is of significant interest in Heliospheric physics. This population is permanently present in interplanetary space during all phases of solar activity and is unambiguously thought to form the seed population from which solar energetic particle events draw their material. The latter is a key driver for space weather. Two prevailing theories currently describe the ST population origin and acceleration. One theory suggests that they originate from the SW and are accelerated by localized processes such as compressions, while the other suggests that they are partially remnants of previous solar transient events.

In this study, we utilize data from the EPI-Lo instrument aboard the Parker Solar Probe (PSP) spacecraft, collected between June 2021 and January 2023. The data pertains to He with energies ranging from ~40 to ~400 keV, and PSP's radial distance spanning from 0.06 to 0.79 au. We infer the Compton-Getting corrected, cumulative ST spectra during times from “quiet” to “ultra-quiet” times in the inner heliosphere. We find that (i) Defining "quiet" times in the IP space requires more than a simple cutoff threshold or a combination of conditions to eliminate particle enhancements, the level of quietness varies, and instrument considerations need to be accounted for. (ii) EPI-Lo analysis of quiet-time periods reveals an averaged spectral index between ~1.85 ± 0.05 (quiet; 1-count level stretches maintained for 10 minutes) and decreases to 1.59 ± 0.06 (ultra-quiet; 1-count level stretches for 21 hours). We recommend modelers adopt the latter value. The convergence of the spectral index near ~1.5 during ultra-quiet times aligns with the idea of continuous compressive acceleration of ST particles in the solar wind, supporting a specific school of thought in the field.

Monday, March 25: 10:55 AM – 11:20 AM
Presenter: La Vacca, Giuseppe

Towards a Semi-Analytical Model of the Long-Term Variations of the Heliospheric Structures

Giuseppe La Vacca, University of Milano-Bicocca, Italy
Stefano Della Torre, INFN Milano-Bicocca unit, Italy
Massimo Gervasi, University of Milano-Bicocca, Italy

When developing a model to accurately predict the solar modulation of galactic cosmic rays, it is crucial to consider the global characteristics of the heliosphere. The dynamics and variability of the boundaries of the heliosphere have a significant impact on the long-term variation of cosmic rays, even at Earth's location. Therefore, it is highly desirable to have a global, time-dependent, and user-friendly Heliospheric structure modelization. With this aim, we developed a semi-analytical, data-driven model that uses a simplified approach for solving the solar wind dynamics through the heliosphere, including the effect of the pick-up ions on the

termination shock. The model also uses measurements of the energetic neutral atoms' spectra at 1AU to determine the distance of the heliopause. The model's predictions have been compared with the observations of the Voyager probes.

Monday, March 25: 11:20 AM – 11:45 AM
Presenter: Giacalone, Joe

On the time intensity behavior of energetic particles associated with shocks close to the Sun

Joe Giacalone, Lunar and Planetary Laboratory, University of Arizona, USA

This talk will focus on the acceleration of particles by a shocks for which an observer is close to where the particles are first injected into the acceleration process. Recently, it has been noted that in some shock-associated solar-energetic particle (SEP) events, there were two types of velocity dispersion observed in the time period before the shock arrival: normal dispersion when higher energy particles arrive before lower-energy ones, and then, later, an inverse dispersion when subsequently higher energy particles arrive later. This leads to a “nose-like” feature in energy vs. time spectrograms of the particle flux. A particularly good example was the 5 Sep 2022 CME-related event observed by the ISOIS/EPI-Lo instrument on Parker Solar Probe. In this event, the high-energy particles had not yet been accelerated, but were in the process of doing so. It has since been noted that this feature is more common in SEP events that previously recognized. These observations are generally consistent with expectations from time-dependent shock acceleration theory, as will be discussed. We will also present the results from numerical modeling of the 5 Sep 2022 SEP event, which are consistent with the observations, as well as new results from hybrid simulations of interplanetary shocks close to the Sun, which also reveal this feature.

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Monday, March 25: 11:45 AM – 12:10 PM
Presenter: Pezzini, Luca

Fully kinetic simulations of solar wind protons observed by Parker Solar Probe (PSP)

Luca Pezzini, KU Leuven & Royal Observatory of Belgium, Belgium.
Andrei Zhukov, Royal Observatory of Belgium, Belgium.
Fabio Bacchini, KU Leuven & Royal Belgian Institute for Space Aeronomy, Belgium.
G. Arrò, Los Alamos National Laboratory, USA.
Rodrigo Lopez, Universidad de Santiago de Chile, Chile.
Alfredo Micera, Ruhr-Universitat Bochum, Germany.
Maria Elena Innocenti, Ruhr-Universitat Bochum, Germany.
Giovanni Lapenta, KU Leuven.

The expanding solar wind plasma ubiquitously exhibits anisotropic non-thermal particle velocity distributions. Typically the proton Velocity Distribution Functions often show the presence of a core and a field-aligned beam. However, novel observations made by the Parker Solar Probe have revealed never-before-seen features in the proton VDFs. These complex shapes in the proton VDFs occur when the tip of the beam experiences important perpendicular diffusion. This phenomenon gives rise to VDF level contours that resemble a “hammerhead”. In this study, we use a 2.5D fully kinetic simulation to investigate the stability of anisotropic proton VDFs observed PSP in the innermost heliosphere. Our setup consists of a core and a beam population that drift with respect to each other. This configuration triggers a firehose-like instability from which parallel fast magnetosonic modes develop. Our results demonstrate that before this instability reaches saturation, the waves resonantly interact with the beam protons, causing significant perpendicular heating at the expense of the parallel temperature. Furthermore, the proton perpendicular heating induces a hammerhead-like shape in the resulting VDF, consistent with recent observations made by PSP and the linear theory.

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Monday, March 25: 12:10 PM – 12:35 PM
Presenter: Cohen, Christina

Multi-spacecraft Observations of SEP Events Using Parker Solar Probe Measurements

C.M.S. Cohen, California Institute of Technology, USA
G.D. Muro, California Institute of Technology, USA
Z.G. Xu, California Institute of Technology, USA
E.R. Christian, Goddard Space Flight Center, USA
A.C. Cummings, California Institute of Technology, USA
G.A. de Nolfo, Goddard Space Flight Center, USA
M.I. Desai, Southwest Research Institute & University of Texas at San Antonio, USA
J. Giacalone, University of Arizona, USA
M.E. Hill, Johns Hopkins University Applied Physics Laboratory, USA
A.W. Labrador, California Institute of Technology, USA
R.A. Leske, California Institute of Technology, USA
D.J. McComas, Department of Astrophysical Sciences, Princeton University, USA
R.L. McNutt Jr., Johns Hopkins University Applied Physics Laboratory, USA
D.G. Mitchell, Johns Hopkins University Applied Physics Laboratory, USA
J.G. Mitchell, Goddard Space Flight Center, Greenbelt, J.S. Rankin, Department of Astrophysical Sciences, Princeton University, USA
N.A. Schwadron Department of Astrophysical Sciences, Princeton University & University of New Hampshire, USA
T. Sharma, Department of Astrophysical Sciences, Princeton University, USA
M.M. Shen, Department of Astrophysical Sciences, Princeton University, USA
J.R. Szalay, Department of Astrophysical Sciences, Princeton University, USA
M.E. Wiedenbeck, Jet Propulsion Laboratory, California Institute of Technology, USA
G.M. Mason, Johns Hopkins University Applied Physics Laboratory, USA
G.C. Ho, Southwest Research Institute, USA
R.F. Wimmer-Schweingruber, Institute of Experimental and Applied Physics, Kiel University, Germany
J. Rodríguez-Pacheco, Universidad de Alcalá, Space Research Group, Spain

The addition of the Parker Solar Probe (Parker) and Solar Orbiter (SolO) to the fleet of spacecraft making solar energetic particle (SEP) measurements in the inner heliosphere has enabled SEP events to be observed by more spacecraft than ever before. These observations often not only span large ranges in longitude but also provide measurements for varying distances from the Sun. Through a variety of configurations, events can be studied with spacecraft at similar distances but different longitudes, similar longitudes but spaced in radial distance, distributed along a similar Parker spiral magnetic connection, or highly distributed throughout the region inside of 1 AU. Here we describe a number of multi-spacecraft events, with an emphasis on those observed by Parker, and discuss the insights revealed and questions raised by these detailed observations.

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SCHEDULE OF TALKS

Monday, March 25: 1:30 PM – 1:55 PM
Presenter: Opher, Merav

The Sun's Trajectory in the Last 10 Million years and possible terrestrial implications on Climate Evolution

MERAV OPHER, Boston University, USA

Until recently the primary focus with respect to astronomical impacts on Earth's climate and biota have centered around those arising from changes in the tilt of the Earth axis, spin, and rotation, which not only drive seasonal change but are also implicated in shifts between arid and wet climatic regimes over periods ≥ 10,000 years, due to changes in solar insolation. The Sun moves large distances (~19pc/Myr) through the quite variable Interstellar Medium. There is geological evidence from 60Fe and 244Pu isotopes that Earth received interstellar material about 2-3 Myr ago and 7 Myr ago. These isotopes were interpreted as evidence for a nearby supernova, however that has been cast into doubt. In this talk I will discuss our new research indicating the encounter of Earth with massive cold clouds in Local Ribbon of Cold Clouds, 3 Myr ago and with the edge of the Local Bubble 7 Myr ago. Both encounters shrunk the Sun's protective bubble—the heliosphere—to within Earth's orbit exposing Earth to a cold dense interstellar medium. Such scenario should be discussed in context with other ones proposed to explain the cooling seen by Oxygen isotopes measured in deep sea Foraminifera.. Previous studies that examined climate effects of encounters with massive clouds argued for an induced ice age due to the formation of global noctilucent clouds (NLCs). I will describe our current work, revisiting such studies with a modern 2D atmospheric chemistry model using parameters of global Heliospheric magnetohydrodynamic models as input. We show that NLCs remain confined to polar latitudes and short seasonal lifetimes during these dense cloud crossings lasting ~ 105 years. Polar mesospheric ozone becomes significantly depleted, but the total ozone column broadly increases. I will comment how this work should be extended as well as including an expected increase in radiation. Increased radiation alone could have effects on climate as well as organismal mutation rates, aging, and extinction rates, and thus broad patterns of diversification.

Monday, March 25: 1:55 PM – 2:20 PM
Presenter: Dialynas, Konstantinos

On the anisotropies of 40-139 keV ions from LECP: has Voyager 1 entered a new regime in the VLISM?

Konstantinos Dialynas, Academy of Athens, Center for Space Research & Technology, Greece.
Stamatios M. Krimigis, Academy of Athens, Center for Space Research & Technology, Greece.
Robert B. Decker, Applied Physics Laboratory, The Johns Hopkins University, USA.
Matthew E. Hill, Applied Physics Laboratory, The Johns Hopkins University, USA.
Romina Nikoukar, Applied Physics Laboratory, The Johns Hopkins University, USA.

The crossing by Voyager 1 (V1) of the heliopause (HP) showed that the interaction between the Heliosheath and the Very Local Interstellar Medium (VLISM) is more complex than previously thought. We present a new analysis on the 40-139 keV ion measurements obtained by the Low Energy Charged Particle (LECP) on V1 from the year 2000 up to the end of 2023, to determine the energetic ion anisotropies in the Heliosheath and upstream of the HP, out to about 41 AU past the boundary. Our results are consistent with the previous analysis published by Dialynas et al. (2021), supporting the possibility of a flux tube interchange instability at the HP (or some other mechanism that can support an inflow of energetic ions into the Heliosheath) and a Suprathermal ion population that leaks from the Heliosheath into the VLISM. We identify: (a) a region of about 9-10 AU before the HP where the radial (perpendicular to the magnetic field) anisotropy of 40-139 keV ions is negative; (b) a region of about 30 AU past the HP where the radial anisotropy of 40-139 keV ions is positive, with the azimuthal ion anisotropy (parallel to the magnetic field) being persistently nearly zero and (c) a region of about 10 AU, i.e. from the year 2021 up to (at least) November of 2023, where the 40-139 keV radial anistotropy drops to nearly zero, whereas the azimuthal anisotropy continues to be zero. Has V1 entered a new regime in the VLISM since (at least) the year 2021, progressively developing characteristics akin to the pristine interstellar medium, as also suggested by measurements from the Plasma Wave (PWS) instrument on Voyager 1 (Kurth, 2024)?

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SCHEDULE OF TALKS

Monday, March 25: 2:20 PM – 2:45 PM
Presenter: Slavin, Jonathan

Interstellar Dust Inflow and the Heliospheric current Sheet Near the Heliopause

Jonathan Slavin, Center for Astrophysics | Harvard & Smithsonian, USA

The end point of the solar wind in the upstream direction is the heliopause where shocked solar wind is diverted by inflowing interstellar medium plasma. This region near the nose of the heliosphere is complex with the solar wind, interstellar neutrals and various high energy particles including pick-up ions and anomalous cosmic rays playing significant roles in the dynamics and energetics. One particularly complex aspect of the region is the role of the Heliospheric current sheet, which is expected to be highly rippled and compressed. The morphology of the solar wind magnetic field in this "sector region" could have a significant impact on the inflow of charged interstellar dust grains into the heliosphere. The rippled morphology of the magnetic field could allow small grains that otherwise would be excluded penetrate the heliosphere. We discuss our results from modeling this region and what the dust can tell us about this farthest upstream region of the solar wind.

Monday, March 25: 2:45 PM – 3:10 PM
Presenter: Czechowski, Andrej

Dust dynamics in the solar wind: semianalytical models

Andrzej Czechowski, Space Research Center, Poland

The dynamics of charged dust grains in the solar wind and the heliosphere is discussed using semi-analytical models of solar plasma flow and the heliosphere. The models include the effects of variability of the solar cycle over the period of about 40 years. The dust of solar origin and the interstellar dust are both considered. results concerning dust acceleration and the effects of dust passage in the vicinity of the Sun are also presented. Particular attention is given to the role of the Heliospheric magnetic field and the Heliospheric current sheet.

Monday, March 25: 3:10 PM – 3:35 PM
Presenter: Fisk, Len

The Interaction of the Heliosheath with the Magnetic Field of the Very Local Interstellar Medium (VLISM)

Len A. Fisk, University of Michigan, USA

Using reanalyzed Voyager 1 (V1) LECP observations, Dialynas et al. observed the radial anisotropy of low-energy energetic particles that result from and are a measure of the radial flow of the solar wind and its embedded magnetic field. At heliocentric radial distances beyond 121.6 AU, the location of the heliopause (HP) declared by the V1 PIs, the radial flow is outward for ~30 AU. Models in which the HP is at 121.6 AU and the VLISM beyond cannot account for the observed radial outflow. The model of the Heliosheath of Fisk and Gloeckler, published in 2014, can account for and in fact predicted the radial outflow. The success of the F&G model validates the premise on which the F&G model is based: the Heliosheath consists of two independent plasmas: (1) The pickup ions and particles accelerated from the pickup ions, the ACRs, which have the dominant pressure; and (2) the thermal solar wind, which has the mass. Dialynas et al. observed that the radial outflow stops at ~152 AU, beyond which the Heliosheath magnetic field is expected to merge with the VLISM magnetic field that is draped around the Heliosheath, as predicted in the F&G model. From the direction of the draped interstellar magnetic field observed by V1, and the draped magnetic field observed by V2, a model for the interaction of the Heliosheath with the VLISM can be constructed, from which the orientation of the VLISM magnetic field can be determined.

SCHEDULE OF TALKS

Monday, March 25: 3:55 PM – 4:20 PM
Presenter: Zhao, Lulu

Modeling Solar Energetic Particles Using Solar Wind with Field Lines and Energetic Particle (SOFIE) Model

Lulu Zhao, University of Michigan, USA
Igor Sokolov, University of Michigan, USA
Tamas Gombosi, University of Michigan, USA
Zhenguang Huang, University of Michigan, USA
Gabor Toth, University of Michigan, USA
Ward Manchester, University of Michigan, USA
Nishtha Sachdeva, University of Michigan, USA
Bart van der Holst, University of Michigan, USA

In this presentation, I will describe the solar energetic particle model, Solar-wind with Field-lines and Energetic-particles (SOFIE) and its application to model the solar energetic particle events. SOFIE is built on the Space Weather Modeling Framework (SWMF) developed at the University of Michigan. There are three modules in the SOFIE model, the background solar wind module, the CME initiation and propagation module, and the particle acceleration and transport module. The background solar wind plasma in SOFIE is modeled by the Alfven Wave Solar-atmosphere Model(-Realtime) (AWSoM-R) driven by the near-real-time hourly updated GONG magnetogram. In the background solar wind, the coronal mass ejections (CMEs) are launched by placing an unbalanced magnetic flux rope on top of the active region, using the Eruptive Event Generator using Gibson-Low configuration (EEGGL). The acceleration and transport processes are then modeled by the multiple magnetic field line tracker (M-FLAMPA). The temporal flux profiles of energetic particles at any locations in the inner heliosphere is solved in SOFIE, therefore, by comparing the SOFIE results with observations made by spacecraft located at different longitudinal and radial locations, our understanding of the acceleration and transport processes of SEPs will be improved. Using SOFIE, we modeled nine historical solar energetic particle events selected as the challenge events by the SHINE community. The performance of the model and its capability in studying the temporal and spatial properties of SEP events will be discussed. In addition, we will describe the new development of the CME initiation module and particle acceleration and transport module in SOFIE.

Monday, March 25: 4:20 PM – 4:45 PM
Presenter: Florinski, Vladimir

Scattering of Energetic Charged Particles in Focusing Magnetic Fields

Vladimir A Florinski, University of Alabama in Huntsville, USA

Focusing and mirroring by magnetic fields can have a profound effect on charged particle transport in the presence of magnetic turbulent fluctuations. We present a simple quasi-linear model of scattering in inhomogeneous plasmas where the particle's unperturbed helical trajectory features a variable pitch angle and a mirroring event. It is shown that because of coherent interaction between the particle and field near the mirroring point, the pitch-angle diffusion coefficient becomes oscillatory if the focusing lengthscale is comparable to the correlation length of the turbulence and the particle's Larmor radius. The applicability of the theoretical results is demonstrated on a simple model of particle escape from a magnetic trap. We also suggest that the scattering coefficient could become locally negative leading to increased concentration at certain values of pitch angle.

SCHEDULE OF TALKS

Tuesday, March 26: 8:00 AM – 8:25 AM
Presenter: Sterling, Alphonse

How Small-scale Solar Coronal-jet-like Events from Miniature Flux Rope Eruptions Might Produce the Solar Wind and Magnetic Switchbacks

Alphonse C. Sterling, NASA/MSFC, USA
Ronald L. Moore, UAH/CSPAR, and NASA/MSFC, USA
Navdeep K. Panesar, BAERI, LMSAL, USA

Small-scale jet-like events are extremely common on the Sun, occurring in all solar regions and throughout the solar cycle. It has recently been argued that some of these features might be the source for the continuously outflowing solar wind, and also for the magnetic switchbacks that flood the solar wind and that are detected in copious quantities during Parker Solar Probe (PSP) perihelia. We show how a proposed mechanism that produces “coronal jets” --- and their smaller cousins called “jetlets,” and perhaps with even-smaller-scale jet-like events --- plausibly feeds and heats the solar wind, and also plausibly produces the switchbacks. According to this mechanism: magnetic flux cancelation produces small-scale flux ropes, with the flux ropes frequently holding a cool-material "minifilament." Continued and/or additional cancelation triggers the minifilament/flux rope to erupt, after which it reconnects with adjacent open coronal field, resulting in heated plasma flowing out along the open field forming the jet spire. Twist originally contained in the flux rope is transferred to the open field via the reconnection, and then travels outward as an Alfvénic twist-wave pulse, evolving to become a magnetic switchback in the inner solar wind. We further suggest that the evolving twist wave plausibly heats the coronal and solar-wind plasma through which is propagates, contributes material to that wind, and, in the outer corona and inner solar wind, accelerates that plasma to make a solar-wind micro stream accompanying the switchback.

Tuesday, March 26: 8:25 AM – 8:50 AM
Presenter: Bastian, Tim

The Role of Solar Spicules in the Mass Budget of the Low Solar Atmosphere

T. S. Bastian, NRAO, USA
C. A. Alissandrakis, Univ Ioannina, Greece
A. Nindos, Univ Ioannina, Greece

Solar spicules are a ubiquitous phenomenon in which multitudes of dynamic, filamentary jets with temperatures of order 10000 K extend thousands of kilometers from the chromospheric network up into the low solar corona. With the advent of modern observations of spicules in optical and UV spectral lines with instruments like Hinode/SOT, IRIS, and the GST there has been renewed interest in the role of spicules in the mass and energy budget of the solar atmosphere. Complementary to O/UV observations are those at millimeter wavelengths, for which the temperature of spicular plasma is simply related to the observed flux density. We discuss observations of solar spicules in a polar coronal hole made at 1.25 and 3 mm by the Atacama Large Millimeter/Submillimeter Array (ALMA) with high angular and temporal resolution. These allow strong constraints to be placed on the emission measure of spicular plasma and, hence, limits on their contribution to mass in the low solar atmosphere.

SCHEDULE OF TALKS

Tuesday, March 26: 8:50 AM – 9:15 AM
Presenter: Yalim, Mehmet Sarp

Investigating Joule Heating as a Solar Active Region Atmosphere Heating Mechanism

Mehmet Sarp Yalim, UAH, USA
Debi Prasad Choudhary, CSUN, USA
Sanjiv Tiwari, BAERI, USA
Christian Beck, NSO, USA
Sushree Nayak, UAH, USA
Qiang Hu, UAH, USA
Gary Zank, UAH, USA

The physics of the solar chromosphere is complex from both theoretical and modeling perspectives. The plasma temperature from the photosphere to corona increases from 5,000 K to ~1 million K over a distance of only 10,000 km in the chromosphere and transition region. Understanding the mechanisms underlying the heating of the solar atmosphere is a fundamental problem in solar physics. We investigate Joule heating as a solar active region atmosphere heating mechanism, in particular in the lower chromosphere where Cowling resistivity is dominant, resulting from the anisotropic dissipation of electric currents due to the weakly-ionized plasma environment. We focus on target structures where strong gradients in the magnetic field strength and field orientation are prevalent resulting in currents such as light bridges inside the umbra of sunspots, magnetic flux emergence into a field-free or magnetic environment, polarity inversion lines or magnetic reconnection sites like Ellerman bombs. To calculate the Cowling resistivity and the resulting Joule heating rate, we developed a state-of-the-art data-constrained analysis based on observational data from space-based and ground-based solar observational instruments as well as tabulated data from theoretical or semi-empirical solar atmosphere models. In this study, we present an overview of our analysis focusing on our first type of target region, namely light bridges, by incorporating magnetic field data from SDO/HMI vector magnetograms, and temperature data from DST/IBIS and IRIS obtained from inversions of spectroscopic data into our analysis. This investigation is supported by an NSF SHINE award (AGS-2230633).

Tuesday, March 26: 9:15 AM – 9:40 AM
Presenter: Chhiber, Rohit

On the properties of the Alfven transition zone separating the solar corona and the solar wind

Rohit Chhiber, NASA GSFC and University of Delaware, USA
Francesco Pecora, University of Delaware, USA
Steven Cranmer, University of Colorado, USA
Arcadi Usmanov, NASA GSFC and University of Delaware, USA
Sohom Roy, University of Delaware, USA
Riddhi Bandyopadhyay, Princeton University, USA
William Matthaeus, University of Delaware, USA
Melvyn Goldstein, Space Science Institute, USA

The Alfven surface marks the critical transition between sub-Alfvenic and super-Alfvenic flow in the solar atmosphere, and so forms a natural boundary separating the solar corona from the young solar wind. This talk presents an investigation of some properties of this region, using a global magnetohydrodynamic model of the solar wind that includes turbulence transport, and recent Parker Solar Probe (PSP) observations. Ubiquitous turbulent fluctuations in this region lend support to the view that that the transition occurs in fragmented subvolumes within a general "Alfven zone" that extends over several solar radii. Model estimates of the probability of Alfvenic transitions as a function of heliocentric distance 'r' are compared with PSP observations, finding remarkable agreement. Maps are made of characteristic sizes and durations of subAlfvenic blobs/intervals as a function of 'r' and heliolatitude. The flow of Alfvenic signals in this zone is investigated, indicating the possibility of a prolonged period of stochastic motion wherein signals are trapped between subAlfvenic and superAlfvenic states before eventually flowing towards or away from the Sun. The modeling results presented here are relevant to PSP, which is expected to sample subAlfvenic intervals with increasing frequency during its primary mission phase, and also to NASA's planned PUNCH mission, which aims to map the Alfven zone using remote sensing.

Tuesday, March 26: 9:40 AM – 10:05 AM
Presenter: Zank, Gary

Characterization of Turbulent Fluctuations in the Sub-Alfvenic Solar Wind

Gary P Zank, University of Alabama in Huntsville, USA
Lingling Zhao, University of Alabama in Huntsville, USA
Laxman Adhikari, University of Alabama in Huntsville, USA
Daniele Telloni, Astrophysical Observatory of Torino, Italy
Prashant Baruwal, University of Alabama in Huntsville, USA
Prashrit Baruwal, University of Alabama in Huntsville, USA
Xingyu Zhu, University of Alabama in Huntsville, USA
Masaru Nakanotani, University of Alabama in Huntsville, USA
Alexander Pitna, Charles University, Czechia

Parker Solar Probe (PSP) observed sub-Alfvenic solar wind intervals during encounters 8 - 14, and low-frequency magnetohydrodynamic turbulence in these regions may differ from that in super-Alfvenic wind. We apply a new mode-decomposition analysis [Zank_etal_2023] to the sub-Alfvenic flow observed by PSP on 2021 April 28, identifying and characterizing entropy, magnetic islands, forward and backward Alfven waves, including weakly/non-propagating Alfven vortices, forward and backward fast and slow magnetosonic modes. Density fluctuations are primarily and almost equally entropy and backward propagating slow magnetosonic modes. The mode-decomposition provides phase information (frequency and wavenumber k) for each mode. Entropy-density fluctuations have a wavenumber anisotropy k_|| >> k_perp whereas slow mode density fluctuations have k_perp > k_||. Magnetic field fluctuations are primarily magnetic island modes (delta B^i) with an O(1) smaller contribution from uni-directionally propagating Alfven waves (delta B^A+) giving a variance anisotropy of <delta {B^i}^2> / <delta {B^A}^2> = 4.1. Incompressible magnetic fluctuations dominate compressible contributions from fast and slow magnetosonic modes. The magnetic island spectrum is Kolmogorov-like k_perp^{-1.6} in perpendicular wavenumber and the uni-directional Alfven wave spectra are k_||^{-1.6} and k_perp^{-1.5}. Fast magnetosonic modes propagate at essentially the Alfven speed with anti-correlated transverse velocity and magnetic field fluctuations and are almost exclusively magnetic due to the plasma beta >> 1. Transverse velocity fluctuations are the dominant velocity component in fast magnetosonic modes and longitudinal fluctuations dominate in slow modes. Mode-decomposition is an effective tool in identifying the basic building blocks of MHD turbulence and provides detailed phase information about each of the modes.

Tuesday, March 26: 10:30 AM – 10:55 AM
Presenter: Zhao, Lulu

Modeling Solar Energetic Particles Using Solar Wind with Field Lines and Energetic Particle (SOFIE) Model

In this presentation, I will describe the solar energetic particle model, Solar-wind with Field-lines and Energetic-particles (SOFIE) and its application to model the solar energetic particle events. SOFIE is built on the Space Weather Modeling Framework (SWMF) developed at the University of Michigan. There are three modules in the SOFIE model, the background solar wind module, the CME initiation and propagation module, and the particle acceleration and transport module. The background solar wind plasma in SOFIE is modeled by the Alfven Wave Solar-atmosphere Model(-Realtime) (AWSoM-R) driven by the near-real-time hourly updated GONG magnetogram. In the background solar wind, the coronal mass ejections (CMEs) are launched by placing an unbalanced magnetic flux rope on top of the active region, using the Eruptive Event Generator using Gibson-Low configuration (EEGGL). The acceleration and transport processes are then modeled by the multiple magnetic field line tracker (M-FLAMPA). The temporal flux profiles of energetic particles at any locations in the inner heliosphere is solved in SOFIE, therefore, by comparing the SOFIE results with observations made by spacecraft located at different longitudinal and radial locations, our understanding of the acceleration and transport processes of SEPs will be improved. Using SOFIE, we modeled nine historical solar energetic particle events selected as the challenge events by the SHINE community. The performance of the model and its capability in studying the temporal and spatial properties of SEP events will be discussed. In addition, we will describe the new development of the CME initiation module and particle acceleration and transport module in SOFIE.

Tuesday, March 26: 10:55 AM – 11:20 AM
Presenter: Adhikari, Laxman

Turbulence, and Proton and Electron Heating Rates in the Solar Corona: Analytical Approach

Laxman Adhikari, University of Alabama in Huntsville, USA
Gary P. Zank, University of Alabama in Huntsville, USA
Daniele Telloni, National Institute for Astrophysics - Astrophysical Observatory of Torino, Italy
Lingling Zhao, University of Alabama in Huntsville, USA
Bingbing Wang, University of Alabama in Huntsville, USA
Gary Webb, University of Alabama in Huntsville, USA
Bofeng Tang, Center for Space Plasma and Aeronomic Research, USA; State Key Laboratory of Space Weather, China
Katariina Nykri, Embry-Riddle Aeronautical University, USA

Analytical solutions for 2D and slab turbulence energies in the solar corona are presented, including a derivation of the corresponding correlation lengths, with implications for the proton and electron temperatures in the solar corona. These solutions are derived by solving the transport equations for 2D and slab turbulence energies and their correlation lengths, and proton and electron pressures. The solutions assume background profiles for the solar wind speed, solar wind mass density, and Alfvén velocity. Using our analytical solutions, we compute the radial evolution of solar wind parameters, 2D and slab turbulence energies and their correlation lengths, and the proton and electron temperatures and their heating rates. Our analytical solutions can be related to those obtained from joint Parker Solar Probe (PSP) and the Solar Orbiter Metis coronagraph observations, as reported in Telloni et al. (2023). We find that the solution for 2D turbulence energy in the absence of nonlinear dissipation decreases more slowly compared to the dissipative solution. The solution for slab turbulence energy with no dissipation exhibits a more rapid increase compared to the dissipative solution. The proton heating rate is found to be about 82% of the total plasma heating at 6.3 Rsun, which gradually decreases with increasing distance, eventually becoming ~ 80% of the total plasma heating at ~ 13 Rsun, consistent with that found by Bandyopadhyay et al. (2023). These analytical solutions provide valuable insight in our understanding of turbulence, and its effect on proton and electron heating rates, in the solar corona.

Tuesday, March 26: 11:20 AM – 11:45 AM
Presenter: Boldyrev, Stanislav

Alfven turbulence at kinetic scales: spectra, intermittency, and particle acceleration

Stanislav Boldyrev, University of Wisconsin-Madison, USA

In a magnetized collisionless plasma, the Alfvenic turbulent energy cascade can extend to scales smaller than the particle microscales. Such turbulence may be responsible for the heating and acceleration of plasma particles and may play a role in space and astrophysical phenomena such as solar flares, radiation coming from pulsar wind nebulae, non-thermal Galactic radio filaments, and others. This presentation will discuss turbulence at sub-inertial scales, drawing parallels between non-relativistic and relativistic regimes. Based on [1,2] it will address possible relations between intermittent structures formed by turbulence and non-thermal particle distribution functions.

Tuesday, March 26: 11:45 AM – 12:10 PM

Presenter: Passot, Thierry

On the transition range in imbalanced Alfvén wave turbulence: the role of co- and counter-propagating waves

T. Passot, Observatoire de la Côte d’Azur, France
S.S. Cerri, Observatoire de la Côte d’Azur, France
D. Laveder, Observatoire de la Côte d’Azur, France
P.L. Sulem, Observatoire de la Côte d’Azur, France

Solar wind Alfvén wave (AW) turbulence, especially close to the Sun, is often in an imbalanced state where the energy of outgoing waves exceeds that of incoming waves. It has recently been demonstrated by Bowen et al. (Nat. Astron. 2024), that such a high level of cross-helicity in the inertial range is associated with a steep ion transition range in the magnetic energy spectrum and with the generation of ion-cyclotron waves (ICWs). This result was theoretically predicted by Squire et al. (Nat. Astron. 2022) based on the so-called “helicity barrier” effect whereby in the presence of a large cross-helicity, the energy flux towards small perpendicular scales is quenched at the ion scale, leading to a transfer towards small parallel scales and to the generation of ICWs.
In this talk, we revisit the properties of imbalanced AW turbulence in a regime where the ion beta parameter is of order one or larger, and where the turbulence nonlinearity parameter is moderate. For this purpose, we use simulations of a two-field Hamiltonian gyrofluid model retaining ion finite Larmor radius corrections, parallel magnetic field fluctuations and electron inertia [1,2], which describes the quasi-perpendicular dynamics of both Alfvén and kinetic Alfvén waves (KAWs). Turbulence is driven in such a way that the energy of both co- and counter propagating waves is maintained at a specific level, avoiding a large accumulation of energy above the ion scale. We then show that a helicity barrier emerges between the MHD and the kinetic scales, visible only at the level of the cross-helicity flux, which causes the development of a transition range in the magnetic-field spectrum across the ion scales [3]. We also develop theoretical arguments to support the idea that the steep transition range is here associated with co-propagating KAW interactions that, in strongly imbalanced turbulence, are dominant at these weakly-dispersive scales. This scenario is comforted by recent simulations of colliding plane KAWs that develop turbulence and display a steeper transition range in the case where the initial conditions take the form of two co-propagating waves [4].

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SCHEDULE OF TALKS

Tuesday, March 26: 12:10 PM – 12:35 PM
Presenter: D’Amicis, Raffaella

On the Alfvénic content of solar wind streams and their origin: a focus on Solar Orbiter observations

Raffaella D'Amicis, INAF - IAPS, Rome, Italy
Marco Velli, UCLA, Los Angeles, USA
Denise Perrone, ASI, Rome, Italy
Olga Panasenco, Advanced Heliophysics, Pasadena, USA
Rossana De Marco, INAF - IAPS, Rome, Italy
Luca Sorriso-Valvo, ISTP - CNR, Bari, Italy
Jim Raines, University of Michigan, Ann Arbor, USA
Daniele Telloni, INAF - OATo, Torino, Italy
Ben Alterman, Southwest Research Institute, San Antonio, USA
Roberto Bruno, INAF - IAPS, Rome, Italy

Alfvénic fluctuations are ubiquitous in the solar wind and are thought to play a fundamental role in Heliophysics in different processes such as solar wind heating and acceleration, energetic particle acceleration, and cosmic-ray propagation. They can be observed not only in the main portion of the high-speed solar wind streams, but, in some cases, in the slow wind. The so called Alfvénic slow wind resembles the fast wind in many respects, including a similar solar source, identified as a region of strongly diverging open magnetic field. Indeed, this would result in a super-radial expansion that may slow down the slow wind, setting the conditions for the origin of the Alfvénic slow wind.
In this study, we take advantage of the unique opportunity offered by the ESA/NASA Solar Orbiter mission to study the origin and radial evolution of this solar wind regime, thus contributing to a better understanding of the general problem of solar wind acceleration. In particular, we will present some results on the characterization of the Alfvénic content of velocity and magnetic field fluctuations for fast and Alfvénic slow wind. Our aim is to gain a better understanding of the evolution of the Alfvénicity in solar wind fluctuations, which is found to be very high close to the Sun also in slow streams, while it is rapidly lost at 1 AU in some cases (likely related to the streamer slow wind), surviving instead in the Alfvénic slow wind.

SCHEDULE OF TALKS

Tuesday, March 26: 1:30 PM – 1:55 PM
Presenter: Winebarger, Amy

Identifying source regions of the solar wind with the Multi-slit Solar Explorer

Amy Winebarger, NASA Marshall Space Flight Center, USA
Bart De Pontieu, Lockheed Martin Solar and Astrophysics Lab, USA
Mark Cheung, Commonwealth Scientific and Industrial Research Organisation, Austrailia
Juan Martinez-Sykora, Bay Area Environmental Research Institute, USA
Paola Testa, Smithsonian Astrophysical Observatory, USA

The solar wind is composed of a distribution of plasma moving at different velocities ranging from 100 km/s to 800 km/s and can include interesting magnetic topologies, such as the switchbacks observed by in-situ measurements. The so-called fast solar wind originates from coronal holes, while the sources of the slower solar wind streams have been debated. Recently, several studies of data from the EUV Imaging Spectrometer (EIS) on Hinode have suggested the outflows from periphery of active regions can contribute to the slow solar wind. Furthermore, properties of the plasma detected on the Sun can persist and be detected in situ, confirming the active regions can be source regions. Additionally, high resolution observations made with the High-resolution Coronal Imager (Hi-C) rocket have been used to identify the drivers of active region outflows. A limitation of this previous analysis has been slow temporal scan provided by slit spectrographs, like EIS, and the lack of availability of high-resolution spectra and images. Similarly, magnetic switchbacks are thought to originate between interchange reconnection in the low solar atmosphere around the network. A limitation of identifying the source of the switchbacks is the lower resolution and lower cadence data currently available. The Multi-slit Solar Explorer (MUSE) offers the capability of making both rapid velocity maps and images at high resolution. Combining MUSE with other high-resolution spectrographs, such as the EUV High Throughput Spectroscopic Telescope (EUVST), which is sensitive to additional markers in the solar wind, like the abundances, can provide clear evidence of the link between the solar surface and in situ measurements. In this talk, I will introduce the MUSE mission and discuss the potential of this mission alone, and the potential synergies between this mission and other planned missions, to explore source regions of the solar wind.

Tuesday, March 26: 1:55 PM – 2:20 PM
Presenter: Landi, Enrico

Solar cycle evolution of solar wind heavy ion properties

Enrico Landi

Properties of the solar wind have been routinely measured for decades, including bulk (proton speed and density, magnetic field) and compositional properties (elemental abundances, charge state composition, individual ion densities and temperatures). Such a long-term database has allowed studies of the variation of solar wind properties over the solar cycle, showing that the magnetic, dynamical and compositional properties do depend on the phase of the solar cycle. In this talk I will review in detail the response to the solar cycle of the abundance, ionization and kinetic properties of heavy ions traveling at different speeds, using the whole 1998-2011 ACE observations. I will place particular emphasis on elemental abundance variations and their significance for both the FIP effect and solar wind origin and acceleration.

SCHEDULE OF TALKS

Tuesday, March 26: 2:20 PM – 2:45 PM
Presenter: Antiochos, Spiro

The Nature of the Sun-Heliosphere Magnetic Connection

Spiro K Antiochos, U Mich, USA
C. Nick Arge, NASA/GSFC, USA
Andrew Leisner, GMU, USA
Samantha Wallace, NASA/GSFC, USA
Carl J Henney, AFRL, USA

A primary goal of Space Science and a major focus of the NASA/ESA flagship missions, the Parker Probe and Solar Orbiter, is to determine the origins of the Heliospheric magnetic flux back at the Sun. It is generally believed that this flux originates in so-called coronal holes, regions in the corona that are dark in EUV & X-rays. The long-standing, major problem with this picture is that the total unsigned magnetic flux measured in coronal holes is consistently smaller, by as much as 50%, than the flux measured in situ by Heliospheric missions. Furthermore, the magnitude of this disagreement has varied substantially over the past few decades, so it cannot be explained as due to some simple scaling mismatch. The observed coronal hole flux, on the other hand, is in excellent agreement with steady-state models, both source-surface and MHD, but apparently not with the actual field in the heliosphere. We review this outstanding puzzle and the ideas that have been proposed to resolve it. We argue that the correct explanation for this infamous “missing open-flux problem” is that there is a dynamic boundary layer surrounding every coronal hole in which magnetic flux is dynamically opening and closing, primarily via interchange reconnection. We present observational and theoretical analysis using the WSA model demonstrating that a layer of roughly a supergranular width can account for the missing flux and its temporal variations. Our results have major implications for understanding the coronal sources of the slow solar wind, in particular, they strongly support the dynamic S-Web model. They also have critical implications for understanding Heliospheric structures such as switchback and micro-streams, which have been proposed by many to originate via interchange reconnection. We argue that a dynamic boundary layer between open and closed flux in the corona is essential for understanding the physics of the solar wind’s initiation.

Tuesday, March 26: 2:45 PM – 3:10 PM
Presenter: Raymond, John

The Temperature in the Acceleration Region of Impulsive SEPs

John Raymond
Jin-Yi Lee
Yuan-Kuen Ko

Don Reames has published a number of studies of the ionization states of SEPs, using the observed values, and an assumption that acceleration efficiency goes as a power law of charge-to-mass ratio to derive the electron temperature in the region where the SEPs were accelerated. This is especially interesting for impulsive SEPs, because one would expect the gas in a flare current sheet to be strongly heated and to have a strongly non-Maxwellian velocity distribution. We examine the effects of kappa-distributions on the derived temperatures, and we consider the resulting constraints on electron temperature and acceleration time.

SCHEDULE OF TALKS

Tuesday, March 26: 3:10 PM – 3:35 PM
Presenter: Tenerani, Anna

Evolution of Alfvén wave packets in fluid and kinetic models: a comparative study

Anna Tenerani, The University of Texas at Austin

Alfvén waves play a central role in energy storage and transport in magnetized plasmas, and they are though to play an important role in solar wind acceleration and plasma heating. Switchbacks are a particular type of Alfvénic fluctuations commonly observed in the solar wind leading to a local kink of the magnetic field. Observations suggest that switchbacks have a scale-dependent evolution as they propagate outwards from the sun, and that different mechanisms might be at play causing their decay or disruption. Here we discuss two processes that can affect the radial evolution of switchbacks, and of large amplitude Alfvén wave packets in general, depending on their spatial scale: parametric decay instability and dispersive effects. We conclude by discussing how our results can help interpret switchbacks observations as well as the possible energetic contribution of switchbacks decay/disruption to solar wind internal energy.

Tuesday, March 26: 3:55 PM – 4:20 PM
Presenter: Consolini, Giuseppe

On the stochastic character of space plasma turbulent fluctuations at sub-ion scales: a brief review

Giuseppe Consolini, INAF-Istituto di Astrofisica e Planetologia Spaziali, Italy
Simone Benella, INAF-Istituto di Astrofisica e Planetologia Spaziali, Italy
Mirko Stumpo, INAF-Istituto di Astrofisica e Planetologia Spaziali, Italy
Tommaso Alberti, Istituto Nazionale di Geofisica e Vulcanologia, Italy

The dynamical state of space plasmas in the Heliosphere is usually turbulent. Magnetic field fluctuations exhibit a power-law spectrum at large scales, i.e., at frequencies lower than 0.1–1 Hz, with spectral exponents that are close to those predicted by theories of fluid-like turbulence. On the other hand, ions' inertia separates from electrons' one below the ion-inertial length, or ion/sub-ion scales, and the magnetic field fluctuations' spectrum exhibits a distinct dynamical regime that is currently poorly understood. In this talk, we discuss the scale-to-scale coupling in this domain in terms of a stochastic Langevin-like dynamics and discuss recent findings on the Markovian aspects of the fluctuations at these scales.

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Tuesday, March 26: 4:20 PM – 4:45 PM
Presenter: Zieger, Bertalan

Inverse Energy Cascade of Ion Bernstein Turbulence in the Inner Heliosheath

Bertalan Zieger, Boston University, USA

The solar wind in the inner Heliosheath beyond the termination shock (TS) is a non-equilibrium collisionless plasma consisting of thermal solar wind ions, Suprathermal pickup ions, and electrons. The kinetic dispersion relation of such plasma predicts multiple harmonics of ion Bernstein waves. Ion Bernstein waves are electrostatic ion cyclotron waves propagating quasi-perpendicular to the magnetic field and because of this they are not damped by electron Landau damping. We demonstrate that the three-fluid description of the solar wind, where thermal solar wind ions, pickup ions, and electrons are treated as separate fluids, closely reproduces the fundamental ion Bernstein wave mode on fluid and ion scales. We present high-resolution (1/6 ion inertial length) three-fluid simulations of the TS and the inner Heliosheath up to 2.2 AU downstream of the TS. We show that downstream propagating nonlinear fast magnetosonic and ion Bernstein waves grow until they steepen into shocklets, overturn, and start to propagate backward in the frame of the downstream propagating wave. The counter-propagating nonlinear waves result in 2-D turbulence, which is driven by the ion-ion hybrid resonance instability. Kinetic energy is transferred from small scales to large scales (inverse cascade) and enstrophy is transferred from large scales to small scales (direct cascade). The inverse cascade of ion Bernstein turbulence results in a train of fluid-scale magnetic holes slowly propagating upstream in the plasma frame of the solar wind at the speed of the group velocity of nonlinear ion Bernstein wave packets (~ 16 km/s). We validated our three-fluid simulations with high-resolution Voyager 2 observations of magnetic holes in the inner Heliosheath. Based on these results, we suggest a new generation mechanism of magnetic holes in the inner Heliosheath: Magnetic holes are likely produced by nonlinear ion Bernstein wave packets propagating upstream in the non-equilibrium solar wind plasma. Our simulations also reproduce the observed magnetic turbulence spectrum with a spectral slope of -5/3 in frequency domain. However, the fluid-scale turbulence spectrum is not a Kolmogorov spectrum in wave number domain because Taylor's hypothesis breaks down in the inner Heliosheath. The magnetic structure functions of the simulated and observed turbulence follow the Kolmogorov-Kraichnan scaling, which implies self-similarity.

Tuesday, March 26: 4:45 PM – 5:10 PM
Presenter: Cairns, Iver

Ion Acoustic Waves Driven by a Reactive Ion Beam Instability

Iver H. Cairns (School of Physics, University of Sydney, Sydney, NSW 2006, Australia)

David M. Malaspina (Astrophysical and Planetary Sciences Department & Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309, USA)

Robert E. Ergun (Astrophysical and Planetary Sciences Department & Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309, USA)

The Parker Solar Probe is investigating the formation and evolution of the solar wind, with perihelion near 10 solar radii and aphelion near 1 AU. Plasma waves and turbulence are expected to result from the acceleration and heating of the solar wind and from the merging of strongly inhomogeneous coronal outflows into the relatively uniform solar wind near 1 AU. Recent observations show the generation of trains of ion acoustic wave packets with typically have a rising tone and relatively broadband character but falling tones sometimes. A numerical dispersion solver with a slow proton beam showed growth but the origin was unclear. Here we show analytically using kinetic theory that a cold proton beam instability exists and can explain several aspects of the numerical calculations and the observations. In detail, the instability is a reactive (or fluid-type) instability associated with a beam mode and the instability is favored when the proton beam speed is close to but below the ion acoustic speed and the beam is relatively dense and cold. Numerical solutions confirm and generalize the analytic results for the cubic and quartic approximations to the dispersion equation. Inclusion of Landau damping is ongoing. Applications to ion beams produced in reconnection regions and at shocks, as well as the solar wind's two-peak proton distributions, will be considered. Qualitatively, the instability is expected to heat and slow the ion beam when active. In principle the theory allows the ion beam speed and relative number density to be determined by comparing the wave observations with the theory, thereby constraining the origin of the proton beam.

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SCHEDULE OF TALKS

Wednesday, March 27: 8:00 AM – 8:25 AM
Presenter: Wijsen, Nicolas

Recent advances in modeling solar energetic particle events using PARADISE

Nicolas Wijsen, Centre for Mathematical Plasma Astrophysics, KU Leuven, Belgium
Alexander Afanasiev, Department of Physics and Astronomy, University of Turku, Finland
Athanasios Kouloumvakos, The Johns Hopkins University Applied Physics Laboratory, USA

Solar energetic particles (SEPs), generated during solar eruptive events, traverse the inner heliosphere at high speeds while spiraling along the interplanetary magnetic field (IMF). Upon impact, these SEPs may pose a significant threat to the health of astronauts and spacecraft microelectronics and software, potentially causing irreversible damage. Developing predictive models for SEP events is crucial for mitigating these risks. Our presentation highlights recent advancements in the PARADISE (Particle Radiation Asset Directed to Interplanetary Space Exploration; Wijsen 2020) model. By solving the focused transport equation, PARADISE propagates energetic proton and electron distributions within a background thermal plasma simulated by a magnetohydrodynamic (MHD) model. We examine its application in modeling energetic particle transport throughout the heliosphere, including recent efforts to simulate gradual SEP events such as the notable event on September 5, 2022, coinciding with the transit of the Parker Solar Probe through the solar corona. Additionally, we introduce PARASOL, a novel model for SEP forecasting, by integrating the particle acceleration model SOLPACS (Afanasiev et al., 2015) with PARADISE.

SCHEDULE OF TALKS

Wednesday, March 27: 8:25 AM – 8:50 AM
Presenter: Leske, Rick

Comparison of Heavy Ion Behavior at Parker Solar Probe and Solar Orbiter During the 5 September 2022 Solar Energetic Particle Event

R.A. Leske, California Institute of Technology, USA
Z. Xu, California Institute of Technology, USA
C.M.S. Cohen, California Institute of Technology, USA
E.R. Christian, NASA/Goddard Space Flight Center, USA
A.C. Cummings, California Institute of Technology, USA
G.A. de Nolfo, NASA/Goddard Space Flight Center, USA
M.I. Desai, Southwest Research Institute, USA
J. Giacalone, University of Arizona, USA
M.E. Hill, Johns Hopkins University Applied Physics Laboratory, USA
A.W. Labrador, California Institute of Technology, USA
D.J. McComas, Department of Astrophysical Sciences, Princeton University, USA
R.L. McNutt Jr., Johns Hopkins University Applied Physics Laboratory, USA
D.G. Mitchell, Johns Hopkins University Applied Physics Laboratory, USA
J.G. Mitchell, NASA/Goddard Space Flight Center, USA
G.D. Muro, California Institute of Technology, USA
J.S. Rankin, Department of Astrophysical Sciences, Princeton University, USA
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T. Sharma, Department of Astrophysical Sciences, Princeton University, USA
M.M. Shen, Department of Astrophysical Sciences, Princeton University, USA
J.R. Szalay, Department of Astrophysical Sciences, Princeton University, USA
M.E. Wiedenbeck, Jet Propulsion Laboratory, California Institute of Technology, USA
O. Romeo, University of California at Berkeley, USA
G. Ho, Southwest Research Institute, USA
J. Rodríguez-Pacheco, Universidad de Alcalá, Space Research Group (SRG-UAH), Spain
R. Wimmer-Schweingruber, Institute of Experimental and Applied Physics, Kiel University, Germany

A solar energetic particle (SEP) event associated with a backside active region was observed on 5 September 2022 by particle detectors on both Parker Solar Probe and Solar Orbiter. At the time, Parker was only 0.07 au from the Sun's center, while Solar Orbiter was 10 times farther away at 0.7 au. Both spacecraft were well-positioned in longitude, with Parker 66 degrees away from the flare site and Solar Orbiter 30 degrees closer. In the EPI-Hi instrument on Parker, peak heavy ion intensities at 2-3 MeV/nucleon were among the highest yet seen on this mission, reaching ~9 orders of magnitude above the quiet-time galactic cosmic ray background. EPI-Hi autonomously reduces its sensitivity to light particles such as H, He, and electrons to preserve live-time when count rates are high, but it was still capable of measuring heavy ions from C to Fe and changes in their anisotropies, spectra, and composition throughout this large event. Some interesting characteristics of this event are that upstream of the shock the spectra were very soft (falling roughly as E^-8) and extremely depleted in iron (the Fe/O ratio was ~2 orders of magnitude less than the average value seen in large SEP events). Surprisingly, intensities dropped by an order of magnitude when the shock arrived, only to recover later inside a magnetic cloud with much harder spectra (E^-4) and sunward flows. Parker was on the flank of the coronal mass ejection and shock, while Solar Orbiter was closer to the nose and farther from the Sun where the shock may have been better developed. Preliminary examination of the Solar Orbiter observations suggests that the event there was not as iron-poor and had harder spectra than were seen at Parker. We present details of the energetic heavy ion behavior observed throughout this event at both Parker and Solar Orbiter, and discuss the implications for particle acceleration and transport.

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SCHEDULE OF TALKS

Wednesday, March 27: 8:50 AM – 9:15 AM
Presenter: Servidio, Sergio

Coherent Structures in Solar Wind Turbulence: Models, Measurements, and Future Space Missions

Sergio Servidio, University of Calabria, Italy

Turbulence is generally synonymous with randomness and unpredictability, although this is not quite correct. Persistent, long-living structures indeed emerge from such a chaotic state. This “zoo” of coherent patterns can be qualitatively classified between vortexes and discontinuous layers. In this talk, I will go over some recent advances in our understanding of the role of coherent magnetic structures in the solar wind, focusing on two main cases: (1) the characterization of large-scale flux ropes in the heliosphere, and (2) the paradigm of shock-turbulence interaction, in which coherent structures play a major role. Finally, I will highlight the role coherent patterns as fundamental elements of the energy cascade. On this regard, I will conclude the talk by proposing a novel technique that can accurately measure the energy dissipation rate, appropriately designed for future space missions.

Wednesday, March 27: 9:15 AM – 9:40 AM
Presenter: Ho, George

Multi-spacecraft Observations of Energetic Particle Events Inside of 1 au: Measurements by Solar Orbiter, ACE and STEREO

George C. Ho, SwRI, USA
Glenn M. Mason, JHU/APL, USA
Robert C. Allen, JHU/APL, USA
Athanasios Kouloumvakos, JHU/APL, USA
Robert F. Wimmer-Schweingruber, University of Kiel, Germany
Javier Rodríguez-Pacheco, University of Alcalá, Spain
Raúl Gómez-Herrero, University of Alcalá, Spain

Multi-spacecraft observations stand as the most direct approach for unraveling and comprehending the propagation and evolution of energetic particles within the heliosphere. Specifically, interplanetary (IP) shocks present an excellent avenue for delving into the study of energetic particle acceleration and propagation. Consequently, an examination of in-situ IP shocks and particle distributions in their proximity offers a meaningful means to validate our theoretical understanding of shock acceleration and propagation, particularly when leveraging multi-point measurements. Throughout the current solar cycle, cutting-edge particle instruments aboard ACE, Solar Orbiter, and STEREO spacecraft have meticulously detected a myriad of solar energetic particle (SEP) and energetic storm particle (ESP) events, thereby furnishing us with an ideal dataset to study particle events in the inner heliosphere.

On April 2, 2022, an active region (AR 12975) on the western limb (W80) of the Sun unleashed a substantial SEP event, accompanied by a fast (>1400 km/s) coronal mass ejection (CME) and a CME-driven interplanetary shock (~1900 km/s). At that time, the Solar Orbiter spacecraft cruised in proximity to its perihelion distance (~0.35 au) at W109 relative to the Earth-Sun line, while the STEREO Ahead spacecraft was positioned at E35, and ACE was at L1. Collaboratively, the particle instruments on these spacecraft recorded the SEP/ESP, while the plasma and field instruments captured the associated interplanetary shock/CMEs on April 2-3, 2022. This paper presents the multi-spacecraft observations of this event as measured by Solar Orbiter, delving into the intricate details of the propagation and transport of SEPs from 0.3 to 1 au.

SCHEDULE OF TALKS

Wednesday, March 27: 9:40 AM – 10:05 AM
Presenter: Bellan, Paul

Energetic electron tail production from binary encounters of discrete electrons and ions in a sub-Dreicer electric field

Paul M. Bellan, Caltech, USA

During transient instabilities in a 2 eV, highly-collisional MHD-driven plasma jet experiment, evidence of a 6 keV electron tail was observed via x-ray measurements. The cause for this unexpected high-energy tail is explored using numerical simulations of the Rutherford scattering of a large number of electrons and ions in the presence of a uniform electric field that is abruptly turned on as in the experiment. When the only active processes are Rutherford scattering and acceleration by the electric field then, contrary to the classical Fokker-Planck theory of plasma resistivity, it is found that no steady-state develops and instead, the particle kinetic energy increases continuously. However, when a power loss mechanism is introduced mimicking atomic line radiation, then a near steady-state can develop and, in this case, an energetic electron tail similar to that observed in the experiment can develop. The reasons underlying this behavior are analyzed and it is shown that an important consideration is that Rutherford scattering is dominated by the cumulative effect of grazing collisions whereas atomic line radiation requires an approximately direct rather than a grazing collision. It is shown that the traditional interpretation of scattering by Rutherford encounters using cross-section arguments is intrinsically inconsistent with the cross-section concept, namely that something either does or does not happen (a particle hits or misses a target). This conflict arises because plasma collision theory invokes the cross-section concept but then argues that “collisions” are produced by the cumulative effect of grazing encounters so there is no actual hitting or missing of a target. In the case of a true cross-section (actual hitting or missing) there will be a subset of “lucky” particles that repeatedly fail to hit another particle but if the cumulative effect of grazing encounters dominates there would be no such lucky particles. The tail is shown to result as a result of there being “lucky” electrons that repeatedly do not come close enough to target ions to excite line radiation and so are continuously accelerated in an electric field. This excitation of line radiation is a quantum process that either does or does not happen and so can be considered to be a true hitting or missing situation. Details have been presented in Bellan, P. M. Phys. Plasmas 30, 103901 (2023) https://doi.org/10.1063/5.0167004.

Wednesday, March 27: 10:30 AM – 10:55 AM
Presenter: Pierrard, Viviane

Origin of the Solar Wind: Acceleration by Ambipolar Electric Field

Viviane Pierrard, Royal Belgian Institute for Space Aeronomy, Belgium
Maximilien Péters de Bonhome, Université Catholique de Louvain, Belgium

Kinetic exospheric models have revealed that the solar wind is accelerated by an ambipolar electric field up to supersonic velocities. The presence of Suprathermal Strahl electrons at the exobase can further increase the velocity to higher values, leading to profiles comparable to the observations in the fast and slow wind at all radial distances. Such Suprathermal electrons are observed at large distances and recently at low distances as well. The new observations of Parker Solar Probe (PSP) and Solar Orbiter (SolO) from launch to now can be used to determine the characteristics of the plasma in the corona so that the model fits best to the averaged observed profiles for the slow and fast winds. The observations at low radial distances show Suprathermal electrons already well present in the Strahl in the antisunward direction and a deficit in the sunward direction, confirming the exospheric feature of almost no incoming particles. The Suprathermal electrons are introduced into the kinetic exospheric model using Kappa distributions. The importance of the exobase's altitude is also underlined for its ability to maintain the electric potential to a higher level for slower winds, conversely to what is induced through the effect of a lower kappa index only. In fact, the exobase is located at lower altitude in the coronal holes where the density is smaller than in the other regions of the corona, allowing the wind originating from the holes to be accelerated from lower distances to higher velocities.
The new observations of Parker Solar Probe and Solar Orbiter are used to determine the solar wind profiles and the characteristics of the plasma in the corona and compare with exospheric models that fit best to the averaged observed profiles for the slow and fast winds. The observations at low radial distances show Suprathermal electrons already well present in the strahl and a deficit in the sunward direction, confirming the exospheric feature of almost no incoming particles.

Wednesday, March 27: 10:55 AM – 11:20 AM
Presenter: Micera, Alfredo

Heat flux regulation by collisionless processes in the solar wind

Alfredo Micera, Institut für Theoretische Physik, Ruhr-Universität Bochum, Bochum, Germany
Daniel Verscharen, Mullard Space Science Laboratory, University College London, Dorkin, UK
Maria Elena Innocenti, Institut für Theoretische Physik, Ruhr-Universität Bochum, Bochum, Germany

We provide a picture of the global role of electrons in the inner heliosphere through the study of non-linear dynamics driven by the non-thermal features of the solar wind electron velocity distribution function (VDF).
In-situ observations of the solar wind have shown that the electron VDF exhibits four distinct features: 1) a quasi-Maxwellian core, comprising most of the electrons, 2) a halo, which is formed by Suprathermal and quasi-isotropic electrons, 3) an escaping beam population, the strahl and 4) the deficit, i.e., a depletion in the sunward region of the VDF.
By employing Particle-in-Cell simulations, we study electron VDFs that reproduce those typically observed in the inner heliosphere and investigate collisionless processes that have a fundamental role in regulating the Heliospheric heat flux.
Our simulation results show that the strahl electrons drive oblique whistler waves unstable, which in turn scatter them, leading to the formation of a halo population. As a consequence of these scattering processes, the Suprathermal electrons can occupy regions of phase space where they fulfil resonance conditions with the parallel-propagating fast-magnetosonic/whistler wave.
The Suprathermal electrons lose kinetic energy, resulting in the generation of unstable waves. The sunward side of the VDF, initially depleted of electrons, is gradually filled as wave-particle interaction processes, triggered by the depletion itself, take place.

As this initial deviation from thermodynamic equilibrium is reduced, a decrease in the electron heat flux occurs.
Our findings are compared and validated against current observations, chiefly from the Parker Solar Probe and Solar Orbiter missions.

SCHEDULE OF TALKS

Wednesday, March 27: 11:20 AM – 11:45 AM
Presenter: Baratashvili, Tinatin

A novel full MHD forecasting model chain from Sun to Earth: COCONUT+ Icarus

Tinatin Baratashvili, Centre for mathematical Plasma-Astrophysics, KU Leuven, Belgium
Michaela Brchnelova, Centre for mathematical Plasma-Astrophysics, KU Leuven, Belgium
Luis Linan, Centre for mathematical Plasma-Astrophysics, KU Leuven, Belgium
Andrea Lani, Centre for mathematical Plasma-Astrophysics, KU Leuven, Belgium
Stefaan Poedts, Centre for mathematical Plasma-Astrophysics, KU Leuven, Belgium,
Stefaan Poedts, Institute of Physics, University of Maria Curie-Skłodowska, Lublin, Poland

Space weather events can affect Earth. In order to mitigate damage, space weather modelling tools have been implemented. In this study, the full MHD chain is presented, starting from the Sun, with a 3D MHD data-driven coronal model COCONUT up to 0.1 AU, where the code is coupled to Icarus, an ideal 3D MHD Heliospheric modelling tool.

COCONUT (Perri, Leitner et al. 2022, COolfluid COrona Unstructured) is a data-driven coronal model that was recently developed at the Centre for Mathematical Plasma Astrophysics, KU Leuven. It is a global 3-D MHD model based on the COOLFluiD code (Yalim et al. 2011, Lani et al. 2014). The advantage of the COCONUT model lies in its efficient, optimized implementation. It uses a time-implicit backward Euler scheme and unstructured computational grid, which avoids singularities near the poles and enables using high CFL numbers to rapidly converge to steady state for realistic simulations on modern HPC systems. In order to obtain realistic solar wind conditions at 0.1AU, the source terms have been implemented in the MHD equations, namely, the approximated coronal heating function, radiative losses and the thermal conduction. The output of the COCONUT coronal model is used as input boundary conditions for plasma variables in the Heliospheric model Icarus.

Icarus (Verbeke et al. 2022, Baratashvili et al. 2022) is a new Heliospheric wind and CME evolution model that is implemented within the framework of MPI-AMRVAC (Xia et al., 2018) and introduces new capabilities for better and faster space weather forecasts. Advanced numerical techniques, such as solution adaptive mesh refinement (AMR) and radial grid stretching are implemented. These techniques result in optimized computer memory usage and a significant execution speed-up, which is crucial for forecasting purposes.

The modelled 3D data are presented for assessing the model capabilities. The density profiles near the Sun are compared to tomography data. The time-series profiles of different variables at Earth are compared to observational data. As a result, the COCONUT+Icarus model chain represents the full MHD model covering the domain from Sun to Earth, which allows more in depth studies and understanding of different physics phenomena, e.g. shock formation, erosion, and deformation, compared to empirical or semi-empirical models.

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SCHEDULE OF TALKS

Wednesday, March 27: 11:45 AM – 12:10 PM
Presenter: Wang, Linghua

Energy Spectrum of Solar Energetic Electron Events

Linghua Wang, Peking University, China
Wen Wang, Peking University, China
Säm Krucker, University of California at Berkeley, USA
Robert F. Wimmer-Schweingruber, Kiel University, Germany

Solar energetic electron events are the most common solar particle acceleration phenomenon observed in the interplanetary space. Their energy spectrum carries crucial information on the electron acceleration process at the Sun. Utilizing a pan-spectrum fitting method, we investigate the peak flux energy spectrum of 458 solar energetic electron (SEE) events with a clear velocity dispersion detected at energies from 4.2 keV to 108 keV by Wind/3DP from 1994 December through 2019 December. According to the fitted spectral parameters, these 458 events are self-consistently classified into five spectrum types: 304 downward double-power-law (DDPL) events, 32 upward double-power-law (UDPL) events, 23 single-power-law (SPL) events, 44 Ellison-Ramaty (ER) events and 55 logarithmic-parabola (LP) events. The DDPL events can be further divided into two types: 231 events and 73 events, since their break energy exhibits a double peak distribution separated by a dip at ~20 keV. The six spectrum types also behave differently in the relationship between spectral parameters and in solar cycle variations. These results suggest that the formation of SEE events can involve complex processes/sources.

Wednesday, March 27: 12:10 PM – 12:35 PM
Presenter: Strauss, Du Toit

On the parallel mean-free-path of solar energetic particle protons and electrons

Du Toit Strauss, Centre for Space Research, South Africa
Jaclyn Lang, Centre for Space Research, South Africa
Eugene Engelbrecht, Centre for Space Research, South Africa
Jabus van den Berg, Centre for Space Research, South Africa

Using magnetically well-connected solar energetic particle (SEP) observations, we derive the particle parallel mean-free-path (MFP) by comparing in-situ observations to one-dimensional simulation results. These inferred MFPs are then compared to the theoretical estimates of Teufel & Schlickeiser using observed solar wind turbulence conditions as inputs for these expressions. We show that these derived and theoretical values are mostly consistent (assuming the so-called damping model for dynamical turbulence) for protons and electrons, but do show significant inter-event variations which can be explained by changing solar wind turbulence conditions. The sensitivity of the electron results to the solar wind turbulence dissipation range is especially highlighted, as well as how this influences the results for energetic electrons.

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SCHEDULE OF TALKS

Wednesday, March 27: 1:30 PM – 1:55 PM
Presenter: Pitna, Alexander

Turbulent Heating Downstream of Collisionless Shock Waves

Alexander Pitna, Charles University, Czech Republic
Jana Safrankova, Charles University, Czech Republic
Zdenek Nemecek, Charles University, Czech Republic
Gilbert Pi, Charles University, Czech Republic
Gary Zank, University of Alabama in Huntsville, USA
Masaru Nakanotani, University of Alabama in Huntsville, USA
Ling Ling Zhao, University of Alabama in Huntsville, USA
Laxman Adhikari, University of Alabama in Huntsville, USA

Interplanetary shocks are thought to have a significant impact on both enhancing turbulent fluctuations in the background and heating the solar wind. This research delves into the thermodynamic characteristics of regions downstream of interplanetary shocks. Our focus lies on tracking the temperature, density, and specific entropy changes within the shocked plasma, while considering the geometric complexities of interplanetary shock propagation through the expanding solar wind. Specifically, our analysis acknowledges that a given temporal window for measurement may correspond to vastly different relevant temporal and spatial dimensions, such as the age of the shocked plasma or the radial distance from where the plasma encountered the shock. Consequently, our approach resolves discrepancies in previously reported temperature and specific entropy profiles in downstream regions and indicates that these regions experience more intense turbulent heating compared to the pristine solar wind, potentially contributing to overall solar wind plasma heating. The paper introduces a phenomenological parameter for predicting specific entropy profiles and demonstrates the model's consistency with observations. We also discuss the implications of these findings for solar wind thermodynamics beyond 1 AU.

Wednesday, March 27: 1:55 PM – 2:20 PM
Presenter: Isenberg, Philip

Kinetic model of solar wind generation by imbalanced turbulence with helicity barrier effects

Philip A. Isenberg, University of New Hampshire, USA
Bernard J. Vasquez, University of New Hampshire, USA
Trevor A. Bowen, University of California, Berkeley, USA

Understanding the microphysical processes that heat and accelerate solar coronal ions to generate the fast solar wind requires kinetic models of an inhomogeneous coronal hole. Observed distribution functions of protons in the fast solar wind consistently exhibit perpendicular anisotropies and secondary parallel beams. Additionally, heavy ion measurements often show these populations to move away from the Sun faster than protons, with greater than mass proportional temperatures. A valid heating mechanism should be able to reproduce these kinetic properties when combined with the effects of the global forces acting on the emerging, accelerating plasma. Here, we use our kinetic guiding-center model to test a particular hypothesis of turbulent cascade and dissipation to heat protons as they advect outward in a collisionless coronal hole under the influence of gravity, charge-separation electric field, ponderomotive force of large-scale Alfvén waves, and the mirror force in an expanding flux tube. The microphysical heating is provided by quasilinear diffusion due to the resonant cyclotron and Landau interactions with a critically balanced spectrum of highly oblique kinetic Alfvén waves (KAWs). We have previously shown [Isenberg & Vasquez, SW16] that a plausible radial profile of KAW intensity does not, on its own, lead to sufficiently heated coronal hole protons to yield a fast solar wind, either in balanced or imbalanced turbulent conditions. We now modify the model KAW spectrum to represent the expectations of the helicity barrier hypothesis in imbalanced turbulence, such that the more intense outward-propagating fluctuations can only cascade from the inertial wavenumber range to the dissipation range if their intensities first fall to the level of the inward fluctuations. The resulting deficit in power is transferred to outward parallel-propagating ion-cyclotron waves, as suggested by plasma simulations and by recent observations at Parker Solar Probe. We will report results of these computations and discuss the development of kinetic features required for describing the small-scale structure of the fast solar wind.

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Wednesday, March 27: 2:20 PM – 2:45 PM
Presenter: Mazelle, Christian

Bow shocks and foreshocks around induced magnetospheres in the solar wind: recent advances

Christian Xavier Mazelle, IRAP CNRS - Univ. Toulouse - CNES, France

Unmagnetized or weakly magnetized bodies interacting with the supermagnetosonic solar wind are surrounded by a bow shock in order to divert the incident plasma flow around their induced magnetospheres and dissipate the associated kinetic energy as for magnetized planets. This has been investigated for many decades now at Mars, Venus, active comets and also at the main moon of Saturn, Titan, when it is transiently located in the pristine solar wind by the strong increase of the dynamic pressure during a solar event. This presentation will display some recent advances on the present knowledge of the main processes at work at the bow shock and the foreshock of these bodies for different solar wind conditions including extreme events. These plasma structures display common features with the terrestrial analogs but also significant differences. They include the relative scales of these shocks with respect to the body size, the relative extension of their exosphere, the orientation of the interplanetary magnetic field (especially the quasi-radial case with the relevance of microscopic processes) and the properties of low frequency waves. In particular, recent studies at Mars from MAVEN observations will be presented.

Wednesday, March 27: 2:45 PM – 3:10 PM
Presenter: le Roux, Jakobus

Tempered Superdiffusive Shock Acceleration at a Perpendicular Shock

Jakobus le Roux, University of Alabama in Huntsville, USA
Rubaiya Khondoker, University of Alabama in Huntsville, USA

The analysis of a number of Heliospheric shock events suggested a power-law decay of the accelerated energetic particle flux upstream instead of the exponential decay predicted by standard steady-state diffusive shock acceleration (DSA) theory. This was interpreted to indicate Superdiffusive energetic particle transport (Lévy flights) upstream as part of a Superdiffusive shock acceleration process (see publications by Zimbardo and coworkers). To investigate this problem further, a recently derived tempered fractional Parker transport equation for energetic particle interaction with quasi-2D turbulence was solved analytically. It was used to model tempered Lévy flights in the vicinity of a planar perpendicular shock and study its consequence for Superdiffusive shock acceleration in the steady-state limit. The following results will be presented that highlight interesting differences compared with the results of standard steady-state DSA theory: (i) A power-law decay of the upstream energetic particle distribution with increasing distance from the shock followed by an exponential rollover as particle transport transitions from standard superdiffusion (Lévy flights) toward normal diffusion beyond a critical transport distance from the shock (tempered Lévy flights). (ii) A downstream energetic particle distribution that decays with increasing distance from the shock and converges to a plateau further downstream instead of just forming a plateau as in standard steady-state DSA theory. The decay is a consequence of a reduced particle escape probability downstream caused by superdiffusion back to the shock (see previous work by Zimbardo and coworkers). (iii) A reduction in the upstream modulation of accelerated particles compared to normal steady-state DSA theory. (iv) An expression for the time scale of tempered Superdiffusive shock acceleration suggesting that tempered Lévy flights increase the efficiency of the Superdiffusive shock acceleration process.

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Wednesday, March 27: 3:10 PM – 3:35 PM
Presenter: Medvedev, Mikhail

Quasi-nonlinear approach to the Weibel instability in the upstream medium of a collisionless shock

Mikhail Medvedev, IAS, PU, KU, MIT, USA

Astrophysical plasmas, such as in collisionless shocks in gamma-ray bursts, and high-energy-density laboratory plasmas often have large-amplitude, sub-Larmor-scale electromagnetic fluctuations excited by various kinetic-streaming or anisotropy-driven instabilities. The Weibel (or the filamentation) instability is particularly important because it can rapidly generate strong magnetic fields, even in the absence of seed fields. Particles propagating in collisionless plasmas with such small-scale magnetic fields undergo stochastic deflections similar to Coulomb collisions, with the magnetic pitch-angle diffusion coefficient representing the effective ``collision'' frequency. We show that this effect of the plasma ``quasi-collisionality'' can strongly affect the growth rate and evolution of the Weibel instability in the deeply nonlinear regime. This result is especially important for understanding cosmic-ray-driven turbulence in an upstream region of a collisionless shock of a gamma-ray burst or a supernova. We demonstrate that the quasi-collisions caused by the fields generated in the upstream suppress the instability slightly but do not shut it down completely.

Wednesday, March 27: 3:55 PM – 4:20 PM
Presenter: Raouafi, Nour E.

Role of Small-Scale Solar Activity in the dynamics of the Coronal and Solar Wind Plasma

Nour E. Raouafi, Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA

Recent studies have revealed that small-scale solar activity, including bright points, jets, and spicules, plays a significant role in shaping the plasma dynamics within the solar atmosphere. Furthermore, this activity acts as both the source and driving force behind the solar wind while also accelerating energetic particles. This growing body of evidence is supported by high-quality observations of magnetic fields, extreme ultraviolet (EUV) emissions, and X-rays in the solar atmosphere. In situ measurements obtained near the Sun through instruments like Parker Solar Probe further contribute to our understanding. Modeling efforts have also emphasized the importance of small-scale activity in influencing plasma dynamics and energetics within the solar atmosphere and wind. Gaining a comprehensive understanding of these pervasive small-scale dynamics holds immense potential for providing critical insights into the nature and origin of the solar wind and shedding light on how this wind evolves from its source on the Sun to its journey through the near-Sun heliosphere. I will provide an overview of recent advances in understanding how small-scale solar activity impacts atmospheric dynamics and highlight promising prospects for future research in this area.

SCHEDULE OF TALKS

Wednesday, March 27: 4:20 PM – 4:45 PM
Presenter: Trueba, Nicolas

Understanding Energetic Electrons in Coronal Shocks via EUV and Radio Diagnostics

Nicolas Trueba, Harvard & Smithsonian Center for Astrophysics, USA
John Raymond, Harvard & Smithsonian Center for Astrophysics, USA

Coronal shock waves are efficient accelerators of solar energetic particles (SEPs). Both coronal shocks and their associated SEP events are well observed (EUV and in situ, respectively), yet much of the theory on coronal shocks remains disconnected from observational diagnostics. The mechanisms and conditions conducive to electron acceleration in shock waves remain open questions, as is the elusive nature of the Type II radio emission they produce. In this talk we discuss how EUV and radio observations can be used to find the locus of electron acceleration events, and understand which specific coronal conditions are favorable to acceleration. Our 3D model reproduces the EUV behavior of the shock wave by leveraging sophisticated simulations of pre-eruption corona with a kinematic model of the shock wave from EUV images, and accounting non-equilibrium ionization effects. The EUV emission is diagnostic of pre- and post-shock coronal conditions, and the efficiency of electron heating. We then compare our model densities with observations of Type II radio bursts, which offer a uniquely powerful diagnostic of the density at the site of electron acceleration in the shock.

Wednesday, March 27: 4:45 PM – 5:10 PM
Presenter: Song, Paul

Formation of the Transition Region for the Quiet Sun

Paul Song1, Jiannan Tu1, and David B. Wexler1
1 Space Science Laboratory and Department of Physics, University of Massachusetts Lowell, Lowell, MA 01854, USA;
paul_song@uml.edu

We propose a partially ionized collisional two-fluid model of the formation of the transition region in between the cool-dense chromosphere and hot-tenuous corona for the quiet Sun. The chromosphere is treated as an isothermal gravity-bound two-fluid stratified atmosphere without appreciable vertical flow on average. The different scale heights of the two fluids result in vertical evolution of the ionization state and the transition region can be defined according to the ionization fraction. The transition region starts at the altitude where the ionization fraction reaches 0.5, the demarcation between the weakly and strongly ionized gas. The upper border of the region is defined as the temperature at which the particles possess enough energy for ionization, i.e., the first ionization potential. Within the transition region is a diffusion process in which the cold chromospheric particles gain energy and ionize through random collisions with hot coronal particles diffusing upward into the corona, whereas, when colliding with cold chromospheric particles, hot coronal particles lose energy, recombine, and fall into the chromosphere. The type-II spicules can be generated when and where the local heating rate is so high that the conditions for a stratified chromosphere are not satisfied; upward flow is formed penetrating the corona where the chromospheric gas in the spicule is ionized and dispersed. The enhanced radiation via those chromospheric neutral particles cools the coronal gas, and more recombination occurs, producing enhanced downward diffusion. The model reproduces key structural features of the transition region from first principles and a minimum of arbitrary parameters.

SCHEDULE OF TALKS

Thursday, March 28: 8:00 AM – 8:25 AM
Presenter: Guzman, Juan

Galactic Cosmic Ray Modulation in the Heliosheath: The Effect of Magnetic Sectors and Unipolar Regions

Juan G Alonso Guzman, University of Alabama in Huntsville, USA
Vladimir A Florinski, University of Alabama in Huntsville, USA
Gabor Toth, University of Michigan, USA
Merav Opher, Boston University, USA
Chika Onubogu, Boston University, USA
Marc Kornbleuth, Boston University, USA

During their respective journeys through the Heliosheath (HS), Voyager 1 (V1) observed relatively steady trends of energetic charged particle intensities, while Voyager 2 (V2) measured multiple long periods (several months) of significant particle flux variations. These modulation episodes were temporally coherent across a wide range of energies and species, with anomalous cosmic rays (ACRs) and ~50 keV electrons displaying the most severe variations. Although the dominant mechanisms at play are still uncertain, it has been suggested that the differences in the Voyager observations can be explained by considering that V2 sampled two fundamentally different magnetic subregions of the HS, the unipolar Heliosheath (UHS) and the sectored Heliosheath (SHS). The former is characterized by a mostly constant magnetic polarity from open field lines anchored on high latitude regions of the Sun, while the latter exhibits a rapidly switching magnetic field direction across many sector boundaries delimited by the folding Heliospheric current sheet. The goal of our research is to validate this paradigm and gain further insight into the effect of the HS magnetic topology on energetic charged particle transport and modulation in this region. To this end, we performed galactic cosmic ray (GCR) simulations using the SPECTRUM software in order to solve the Parker transport equation on a numerically derived MHD background of the VLISM-heliosphere system from BATS-R-US. We also tested several empirical and semi-empirical diffusion models to check which gave the best qualitative agreement with the data. In this event, we present an analysis of our findings so far.

SCHEDULE OF TALKS

Thursday, March 28: 8:25 AM – 8:50 AM
Presenter: Arrò, Giuseppe

Energy transfer and space-time properties of plasma turbulence from magnetohydrodynamics to kinetic scales

Giuseppe Arrò, Los Alamos National Laboratory, USA
Hui Li, Los Alamos National Laboratory, USA

The study of turbulence in magnetized plasmas is an extremely complex problem, involving the transfer of kinetic and magnetic energy over a huge range of scales, extending from large fluid magnetohydrodynamic (MHD) scales, down to small ion and electron kinetic scales. In turbulent systems such as the solar wind and planetary magnetosheaths, energy is typically injected at MHD scales, driven by the large-scale plasma bulk motion, and nonlinearly cascades to ion and electron scales, where it is finally converted into heat and dissipated. Dissipation is intermittent in nature, i.e. it is not homogeneous in space and takes place in small ion and electron scale structures (such as thin reconnecting current sheets), embedded inside the large scale MHD flow. In addition to these complex spatial properties, very recent numerical and theoretical works have shown that plasma turbulence has also nontrivial temporal properties. Specifically, it has been shown that most of the turbulent energy is stored in very low frequency fluctuations that propagate in the plane perpendicular to the global guide field. The nature of these low frequency, perpendicular fluctuations and their role in the turbulent cascade are still under debate. Therefore, studying plasma turbulence requires a multi-scale approach both in space and time, which represents a very challenging problem both on the theoretical and computational sides.

In our work, we investigate plasma turbulence from MHD to kinetic scales, combining different numerical methods and novel analysis techniques, in order to analyze the cascade of energy from injection to dissipation scales both in space and time. We use fully kinetic numerical simulations to study the cascade of energy in space and characterize the energy transfer and spectral properties of plasma turbulence at sub-ion scales. We find that electrons are mainly responsible for shaping the magnetic field spectrum below ion scale, while the ions do not significantly contribute to the energy transfer. Once the cascade has reached electron gyroscales, dissipation becomes more efficient that the nonlinear transfer of energy (lead by the electrons alone), causing the development of an exponential decay in the energy spectra, consistent with a number of solar wind observations. In order to investigate low frequency, large scale perpendicular turbulent fluctuations, we employ high resolution MHD simulation and apply novel space-time filtering techniques to unravel the origin of such perturbations and their role in the turbulent cascade. We finally discuss implications and applications to the physics of the solar wind.

SCHEDULE OF TALKS

Thursday, March 28: 8:50 AM – 9:15 AM
Presenter: Hegde, Dinesha

MHD Modeling of the Ambient Solar Wind with Quantified Uncertainties: Multi-Spacecraft Validation in the Inner Heliosphere

Dinesha V. Hegde, UAH, USA
Tae K. Kim, UAH, USA
Nikolai V. Pogorelov, UAH, USA
Shaela I. Jones, NASA GSFC/ CUA
Charles N. Arge, NASA GSFC

The solar wind (SW) is a vital component of space weather, serving as a background for solar transients such as coronal mass ejections and energetic particles propagating toward Earth. Models attempting to simulate and explain space weather events require a precise description of the ambient SW. However, observational and model uncertainties inevitably impact even the most sophisticated data-driven magnetohydrodynamic (MHD) models of the SW. Proper uncertainty quantification is thus an important step towards improving the accuracy of global SW models. In this work, we perform an ensemble of simulations of the global 3D Heliospheric SW using an empirically data-driven MHD model developed within the framework of the Multi-Scale Fluid-Kinetic Simulation Suite (MS-FLUKSS). We compare our inner Heliospheric MHD simulations with data from the Parker Solar Probe (PSP), Solar Orbiter (SolO), Solar Terrestrial Relations Observatory (STEREO-A), Advanced Composition Explorer (ACE), and Wind missions along their trajectories. We conduct a quantitative analysis to evaluate the model performance in reproducing SW observations, while also analyzing how the quantified uncertainties, derived with an ensemble modeling approach, propagate throughout the Heliospheric domain and vary across the models. Such multi-spacecraft validations help improve our understanding of SW propagation and optimize our data-driven MHD model for space weather forecasting

Thursday, March 28: 9:15 AM – 9:40 AM
Presenter: Zhao, Siqi

First Observational Evidence of the Weak-to-strong Transition in Alfvénic Turbulence

Siqi Zhao, Deutsches Elektronen Synchrotron DESY & Potsdam University, Germany
Huirong Yan, Deutsches Elektronen Synchrotron DESY & Potsdam University, Germany
Terry Z. Liu, University of California, Los Angeles, USA
Ka Ho Yuen, Los Alamos National Laboratory, USA
Huizi Wang, Shandong University, People’s Republic of China

Plasma turbulence is a ubiquitous dynamical process that transfers energy across many spatial and temporal scales in astrophysical and space plasma systems. Although the theory of anisotropic magnetohydrodynamic (MHD) turbulence has successfully described natural phenomena, its core prediction of an Alfvénic transition from weak to strong MHD turbulence when energy cascades from large to small scales has not been observationally confirmed. Here we report the first observational evidence for the Alfvénic weak-to-strong transition in small-amplitude, turbulent MHD fluctuations in Earth's magnetosheath using data from four Cluster spacecraft. Our observations demonstrate the universal existence of strong turbulence accompanied by weak turbulent fluctuations on large scales. Moreover, we find that the nonlinear interactions of MHD turbulence are crucial to the energy cascade, broadening the cascade directions and fluctuating frequencies. Our work takes a critical step forward in understanding the complete picture of turbulence cascade, connecting weak and strong MHD turbulence systems. It will have broad implications in star formation, energetic particle transport, turbulent dynamo, and solar corona or solar wind heating.

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Thursday, March 28: 9:40 AM – 10:05 AM
Presenter: Li, Hui

Compressible Turbulence in near-Sun Solar Wind: Lessons from 3D MHD Simulations

Hui Li (LANL)
Zhaoming Gan (NMC)
Senbei Du (UBoston)
Xiangrong Fu (LANL)
Lingling Zhao (UAH)
William Matthaeus (UDel)

Recent observations made by Parker Solar Probe have offered new results on near-Sun solar wind turbulence, particularly in the low beta regime. Density fluctuations are consistently observed to exceed 10% and the turbulent Mach number can become relatively large. Motivated by these observations, we have carried out both local and global MHD simulations to study the evolution of SW turbulence, including the density fluctuation properties. We perform high-resolution global 3D compressible MHD simulations of the solar winds up to 40 solar radii. These simulations are compared in detail with the Parker Solar Probe observations, in terms of their mean radial profiles as well as the fluctuating magnetic, velocity and density fields. These comparisons enable us to quantify the heating rate of the solar wind, along with the evolution of turbulent quantities. In addition, we will discuss the properties of regions where B_R undergoes significant reductions in the turbulent solar wind.

Thursday, March 28: 10:30 AM – 10:55 AM
Presenter: Wilson, Lynn

Electron velocity distribution functions in the solar wind

Lynn B Wilson III, NASA GSFC, USA

We discuss observations of electron velocity distribution functions (VDFs) in the solar wind observed by the Wind spacecraft near 1 AU. Emphasis will be placed on deviations from isotropic Maxwellian VDFs and the importance of the kinetic features in each subcomponent of the distributions.

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Thursday, March 28: 10:55 AM – 11:20 AM
Presenter: Che, Haihong

Electromagnetic electron Kelvin–Helmholtz instability

H. Che & G. P. Zank

On electron kinetic scales, ions and electrons decouple, and electron velocity shear on electron inertial length $\sim d_e$ can trigger electromagnetic (EM) electron Kelvin-Helmholtz instability (EKHI). In this paper, we present an analytic study of EM EKHI in an inviscid collisionless plasma with a step-function electron shear flow. We show that in incompressible collisionless plasma the ideal electron frozen-in condition $\mathbf{E} + \mathbf{v}_e \times \mathbf{B}/c = 0$ must be broken for the EM EKHI to occur. In a step-function electron shear flow, the ideal electron frozen-in condition is replaced by magnetic flux conservation, i.e., $\nabla \times (\mathbf{E} + \mathbf{v}_e\times \mathbf{B}/c) = 0$, resulting in a dispersion relation similar to that of the standard ideal and incompressible magnetohydrodynamics KHI. The magnetic field parallel to the electron streaming suppresses the EM EKHI due to magnetic tension. The threshold for the EM mode of the EKHI is $(\mathbf{k}\cdot\Delta\mathbf{U}_e)^2>\frac{n_{e1}+n_{e2}}{n_{e1} n_{e2}}[n_{e1}(\mathbf{v}_{Ae1}\cdot\mathbf{k})^2+n_{e2}(\mathbf{v}_{Ae2}\cdot\mathbf{k})^2]$, where $\mathbf{v}_{Ae} =\mathbf{B}/(4\pi m_e n_e)^{1/2}$, $\Delta\mathbf{U}_e$ and n_e are the electron streaming velocity shear and densities, respectively. The growth rate of the EM mode is $\gamma_{em} \sim \Omega_{ce}$, the electron gyro-frequency.

Thursday, March 28: 11:20 AM – 11:45 AM
Presenter: Salem, Chadi

New Insights on Solar Wind Electrons at 1 AU: Collisionality, Heat Flux, and Thermal Force

Chadi Salem, University of California, Berkeley, USA
Marc Pulupa, University of California, Berkeley, USA
Daniel Verscharen, University College of London, UK
Peter Yoon, University of Maryland College Park, USA

The origin and evolution of non-equilibrium characteristics of electron velocity distribution functions (eVDFs) in the solar wind are still not well understood. They are key in understanding heat conduction and energy transport in weakly collisional plasma, as well as in the scenario at the origin of the solar wind. Due to low collision rates in the solar wind, the electron populations develop temperature anisotropies and velocity drifts in the proton frame, as well as Suprathermal tails and heat fluxes along the local magnetic field direction. These non-thermal characteristics are highly variable, and the processes that control them remain an open question.

We present here a recent work on enhanced measurements of solar wind eVDFs from Wind at 1AU. This work is based on a sophisticated algorithm that calibrates eVDFs with plasma Quasi Thermal Noise data in order to accurately and systematically characterize the non-thermal properties of the eVDFs, as well as those of their Core, Halo and Strahl components. Indeed, the core, halo and strahl populations are fitted to determine their densities, temperatures and temperature anisotropies as well as their respective drift velocities with respect of the ion velocity (or solar wind speed). The density, temperature and temperature anisotropy, as well as the parallel heat flux of the total eVDFs are also computed.

We use a 4-year-long dataset composed of all these parameters at solar minimum to enable statistically significant analyses of solar wind electron properties. We estimate collisional proxies such as collisional age and Knudsen number, and discuss usually neglected effects. In addition to the total electron heat flux, we also compute the heat flux contributions from the core, halo and strahl and discuss the interplay between these three components. We finally show estimates of the so-called Thermal Force, a drag or Coulomb friction between ions and the electron components that arises naturally from the non-thermal character of the eVDFs, even in the absence of current. This TF enhances the parallel electric field and plays an important, but usually neglected, role in two fluid energy transfers between electrons and ions. It is parallel to the heat flux that causes it, however its role in understanding the observed heat flux remains to be explored. This statistically-significant work allows a local, quantitative measure of Coulomb coupling that maybe important with possibly other microphysical processes to locally control non-thermal properties.

SCHEDULE OF TALKS

Thursday, March 28: 11:45 AM – 12:10 PM
Presenter: Richardson, John

Voyager observations of the interstellar medium

Voyager Team: S. Krimigis, A. Cummings, R. Decker, M. Hill, J. Belcher, W. Kurth, D. Berdichevsky, L.. Jian, J. Park, J. Rankin, A. Szabo, L. Spilker, K Dialynas

The Voyager spacecraft have been in the local interstellar medium (LISM) since 2012 and 2018, with Voyager 1 now about 40 AU past the heliopause. We discuss recent observations and their implications for how the LISM interacts with the heliosphere. Examples are pressure fronts and shocks which produce changes in the magnetic field and density and sometimes generate electron plasma oscillations. Other puzzles are the magnetic field direction, which is rotating away from the predicted LISM direction, and plasma density and magnetic field magnitude, which are higher than LISM expectations.

Thursday, March 28: 12:10 PM – 12:35 PM
Presenter: McComas, David

Energetic Neutral Atom Observations from IBEX to IMAP

D. J. McComas, Princeton University, USA

The Interstellar Boundary Explorer (IBEX) has been observing the outer heliosphere and its interactions with the very local interstellar medium (VLISM) through measurements of energetic neutral atoms (ENAs) since the end of 2009. In this talk, we briefly summarize some of the most notable discoveries. We also describe the recent extension of IBEX-Hi (0.5-6 keV FWHM) observations through 2022 (McComas et al. 2024 ApJS) to show the continuing evolution of the heliosphere's four-dimensional structure (3-D plus time evolution) and we provide the first IBEX team validated scheme and maps for separating the IBEX Ribbon from the Globally Distributed Flux (GDF). This technique includes the uncertainty in separating different line of sight integrated sources, to provide not just best guess (Median) maps, but also maps with Upper and Lower reasonable values of Ribbon and GDF fluxes, along with bounding fluxes that add the uncertainties to the Upper and Lower values. This allows theories and models to be compared with a range of possible values that the IBEX team believes are consistent with data. The maps in this IBEX study were made using the Combined Analysis, Visualization, and Access (CAVA) tool currently being developed for the upcoming Interstellar Mapping and Acceleration Probe (IMAP) mission, which is slated to launch around May 1st, 2025. We will also show a new CAVA tool – Statistically Animated Maps and Images (SAMIs) – that provide interesting visual insights into the statistically limited ENA observations. Thus, a hopefully continuous, and overlapping IBEX/IMAP data set, along with the CAVA toolchest, should enable continued excellent scientific productivity and the next major steps in understanding our Heliosphere and its VLISM interaction through remote, global imaging of ENAs. For more information about IMAP and the great contributions from all of our 25 institutions, see https://imap.princeton.edu/. Follow, Like, and Share on Facebook.com/IMAPMission and Instagram@IMAPSpaceMission.

21st Annual International Astrophysics Conference

Turin, Italy; March 25 – 29, 2024

SCHEDULE OF TALKS

Thursday, March 28: 1:30 PM – 1:55 PM
Presenter: Pogorelov, Nikolai

Topology and Structure of the Solar Wind Interaction with the Local Interstellar medium

Nikolai Pogorelov, The University of Alabama in Huntsville, USA
Ratan Bera, The University of Alabama in Huntsville, USA
Federico Fraternale, The University of Alabama in Huntsville, USA
Jacob Heerikhuisen, University of Waikato, New Zealand
Michael Gedalin, Ben-Gurion University of the Negev, Israel
Vadim Roytershteyn, Space Science Institute, USA
Ming Zhang, Florida Institute of Technology, USA

The solar wind (SW) emitted by the Sun, which moves through the local interstellar medium (LISM), creates the heliosphere whose shape and structure strongly depend on the properties of the interacting media. This includes the SW time dependence and angular structure, as well as the physical parameters of the LISM. We discuss the effects of Heliospheric and interstellar magnetic field, non-thermal ions and electrons, and LISM composition on the topology and structure of the SW-LISM interaction region. Special attention is paid to the plasma and neutral atom flow in the Heliosheath and heliotail, as well as to the ways the presence of the heliosphere affects the LISM. Simulation results are compared with spacecraft observations and high-energy cosmic ray data. Both realistic and hypothetical scenarios are considered.

Thursday, March 28: 1:55 PM – 2:20 PM
Presenter: van der Holst, Bart

Multi-fluid Outer Heliosphere Model with Pickup Ions and Turbulence Transport

Bart van der Holst, University of Michigan, USA
Gabor Toth, University of Michigan, USA
Merav Opher, Boston University, USA

The outer heliosphere model in the Space Weather Modeling Framework (SWMF) describes the dynamics of the thermal solar wind, pickup ions, electrons and neutrals. We have extended this multi-fluid model with turbulence transport to better capture the interaction of the solar wind with the interstellar medium. We analyze the effects of pickup ions and turbulence transport on the global heliosphere.

SCHEDULE OF TALKS

Thursday, March 28: 2:20 PM – 2:45 PM
Presenter: Zhang, Ming

Exploring the magnetic field structure of the heliosphere and surrounding local interstellar medium with TeV cosmic ray anisotropy

Ming Zhang and Noufel Mall, Florida Institute of Technology, USA
Nick Pogorelov, University of Alabama in Huntsville, USA

The anisotropy of TeV cosmic rays measured by ground-based air shower experiments is influenced by heliosphere magnetic field structure. With particle gyroradii comparable to the size of the heliosphere, the distortion of cosmic ray anisotropy caused by the heliosphere is not too stochastically and complicated, and it can be determined with a mapping technique with Liouville theorem. Using a heliosphere model up to 12,000 AU large, we can calculate the trajectory of cosmic rays and remove the effects of the heliosphere. That produces a map of cosmic ray anisotropy that can fit observations very well. The investigation allows us to explore the magnetic field structure surrounding the heliosphere up to a few thousand AU and the interstellar magnetic field up to tens of pc.

Thursday, March 28: 2:45 PM – 3:10 PM
Presenter: Nakanotani, Masaru

Application of a kinetic PUI-multifluid model to the Heliospheric termination shock

Masaru Nakanotani, University of Alabama in Huntsville, USA
Gary P. Zank, University of Alabama in Huntsville, USA
Lingling Zhao, University of Alabama in Huntsville, USA

Several plasma models have been devised to investigate the structure of the Heliospheric termination shock (HTS) and the acceleration of pickup ions (PUIs) there. For instance, Mostafavi et al. 2017 used a PUI-single fluid (MHD) model that included the PUI heat conduction and viscosity based on the transport formulation of Zank et al. 2014 to obtain a smooth transition of the HTS. Zieger et al. 2015 and 2020 found trailing wave structures downstream of the HTS using a three-fluid (PUIs, solar wind (SW) protons, and electrons) model. Standard kinetic hybrid simulations, treating PUIs and SW protons as kinetic species, have been used to investigate the generation of anomalous cosmic rays at the HTS (Giacalone and Decker 2010, Giacalone et al. 2021). The most self-consistent and first-principles treatment can be achieved using fully kinetic Particle-in-Cell (PIC) simulations. They provide the detailed energy partitioning between species (Kumar et al. 2018, Lembege et al., 2020) and microinstabilities, such as for instance, the modified two-stream instability (Matsukiyo and Scholer 2014) found in the foot region.

Several kinetic simulations (Matsukiyo and Schoeler 2014, Yang et al., 2015, Lembege and Yang, 2016 and Swisdak et al. 2023) indicate that the SW proton component tends to behave adiabatically at the shock front of the HTS due to the presence of PUIs, unlike shock waves without PUIs, such as the Earth's bow shock and interplanetary shock waves near 1 au. This motivates us to treat the SW proton component as a fluid but retain the PUI component as a kinetic species. To this purpose, we adopt a generalized quasi-neutral hybrid model (Amano 2018) for the HTS. We solve PUIs as a particle through a PIC approach and the SW proton and electron components as a separated fluid coupled with Maxwell equations and a generalized Ohm's law, assuming the Darwin approximation and quasi-neutrality. In this presentation, we compare the new model with a standard hybrid model for three test 1D simulations: ring instability, quasi-perpendicular HTS, and quasi-parallel HTS. We find that the result of the new model is reasonably consistent with that of a hybrid model, and especially the structure of the quasi-parallel shock and evolution of PUIs agree very well between the new and hybrid models due to the adiabatic behavior of the SW proton component. We also observe reflected PUIs upstream of the quasi-parallel HTS and wave excitation due to them. Since no reflected SW protons are observed in the hybrid simulation, this also justifies the use of the kinetic PUI-multifluid model.

SCHEDULE OF TALKS

Thursday, March 28: 3:10 PM – 3:35 PM
Presenter: Matsukiyo, Shuichi

Generation of nonthermal pickup ions in an oblique Heliospheric termination shock

Shuichi Matsukiyo, Kyushu Univ., Japan
Yosuke Matsumoto, Chiba Univ., Japan

The initial acceleration process of pickup ions at the Heliospheric termination shock is investigated by using a two-dimensional full particle-in-cell simulation. We tracked the long-term evolution of an oblique shock, including solar wind electrons, ions, and pickup ions, with a system length significantly larger (2000 times the ion inertial length) in the shock normal direction than in previous studies. An oblique shock refers to a shock with an angle between the shock normal direction and the upstream magnetic field vector (in this case, 50 to 70 degrees). We successfully reproduced the self-consistent generation of nonthermal pickup ions.

Pickup ions reflected at the shock and backstreaming towards the upstream excite large-amplitude waves through resonant instability. The excited waves are convected and impact the shock front, leading to shock reformation and altering the downstream electromagnetic structure. Some pickup ions were accelerated to nonthermal energies over a time scale of about 100 times the inverse ion gyro frequency. Orbit analysis of the accelerated particles revealed that the shock surfing acceleration mechanism operated during the initial stages of acceleration, followed by the shock drift acceleration mechanism.

While shock surfing acceleration has been considered ineffective in a perpendicular termination shock of the heliosphere, our findings indicate that electrostatic potential associated with the large-amplitude upstream waves contributes to the manifestation of this acceleration mechanism in oblique termination shocks.

Thursday, March 28: 3:55 PM – 4:20 PM
Presenter: Fraternale, Federico

Time dependence of compressible turbulence observed by Voyager in the inner and outer Heliosheath

Federico Fraternale, The University of Alabama in Huntsville, USA
Alan C. Cummings, California Institute of Technology, USA
Nikolai V. Pogorelov, The University of Alabama in Huntsville, USA

The inner and outer Heliosheath (IHS, OHS) offer a unique opportunity to study compressible turbulence in distinct, highly dynamic plasma environments. The solar wind in the IHS is energetically dominated by pickup ions (PUIs) and influenced by the termination shock. The very local interstellar medium (VLISM) in the OHS is strongly affected by the presence of the heliosphere and heliopause motions.

We examine the temporal and spatial turbulence properties in these regions using Voyager magnetic field data, plasma data (PLS), and proton and electron Galactic cosmic ray data (GCR). In the IHS, we observe long-term changes in the fine-scale magnetic field turbulence intensity and intermittency around PUI gyroscales. Additionally, we establish a correlation between the turbulence intensity and larger-scale changes in the thermal-plasma quantities measured by Voyager 2. We explore a potential role of enhanced charge exchange due to time-dependent solar activity in the generation of fine-scale magnetic turbulence and identify local enhancements near pressure pulses. By conditioning spectral analysis on the angle between the magnetic field and velocity vectors, we estimate turbulence anisotropy in the IHS. Moreover, the power-law behavior of the frequency spectra of the proton and electron Galactic cosmic ray count rates reflects the turbulence influence. We conduct a time-frequency analysis of Voyager 1 & 2 magnetic field and GCR rates in the OHS, discussing the temporal evolution of magnetic turbulence and polarization of magnetic fluctuations. Notably, we observe increases in the fine-scale transverse turbulence intensity and intermittency at Voyager 1, starting in late 2018 and peaking in 2019, which is potentially linked to the solar cycle.

SCHEDULE OF TALKS

Thursday, March 28: 4:20 PM – 4:45 PM
Presenter: Elliott, Heather

Solar Wind in the Outer Heliosphere

Heather A. Elliott, Southwest Research Institute, San Antonio TX, USA
John Richardson, Massachusetts Institute of Technology, Cambridge, MA, USA
Tae K. Kim, University of Alabama, Huntsville, AL, USA
Maher A. Dayeh, Southwest Research Institute, Boulder CO, USA
Justyna M. Sokół, Southwest Research Institute, Boulder CO, USA
Pontus C. Brandt, Applied Physics Laboratory, Laurel, MD, USA
Merav Opher, Boston University, Boston, MA, USA
Dave J. McComas, Princeton University, Princeton, NJ, USA
Matt E. Hill, Applied Physics Laboratory, Laurel, MD, USA
Peter Kollmann, Applied Physics Laboratory, Laurel, MD, USA
Fran Bagenal, University of Colorado, Boulder, CO, USA
Andrew Poppe, University of California, CA, USA
S. Alan Stern, Southwest Research Institute, Boulder CO, USA
Ralph McNutt, Applied Physics Laboratory, Laurel, MD, USA
Kelsi N. Singer, Southwest Research Institute, Boulder CO, USA
G. Randall Gladstone, Southwest Research Institute, San Antonio TX, USA
Tracy M. Becker, Southwest Research Institute, San Antonio TX, USA

Different source regions on the Sun emit solar wind parcels with different speeds. The fastest wind originates in large coronal holes. Smaller coronal holes emit moderately fast wind. The slow wind has a variety of possible sources such as coronal streamers and edges of coronal holes. As these differing speed parcels leave the Sun, they interact with one another altering the solar wind properties with distance. Fast parcels catch up with (run away from) slower ones emitted at an earlier (later) time forming a compression (rarefaction). This interaction between causes the variability of the solar wind speed, density, and temperature to decrease rapidly between 1 and 20 au. Eventually, the solar wind is so far from the Sun that it begins to interact with incoming interstellar material. As interstellar material is ionized and picked up by the solar wind, the solar wind slows and heats. We quantify how much the solar wind slows in the outer heliosphere relative to 1 au. Recently, New Horizons (NH) observed a distinct decrease in the solar wind speed. By comparing NH solar wind observations to those at 1 au, we find that the recent slow and steady wind in the outer heliosphere is a result of three factors: 1) the solar wind emanating from the Sun was slow, 2) solar wind structures merged and were worn down as they propagated away from the Sun, and 3) the solar wind continued to slow as additional interstellar material was picked up as the solar wind moved farther away from the Sun. Previously, between 30 and 43 au, the slowing at NH relative to 1 au ranged from 5 -7%. In the more recent NH observations between 50 and 57 au, the amount of slowing at NH relative to 1 au ranged from about 13 to 15%.

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SCHEDULE OF TALKS

Thursday, March 28: 4:45 PM – 5:10 PM
Presenter: Hill, Matthew

Future New Horizons Encounter with the Solar Wind Termination Shock

M.E. Hill[1], R. Nikoukar[1], R.B. Decker[1], H. A. Elliott[2], J. D. Richardson[3], P. Kollmann[1], P. Mostafavi[1], R.L. McNutt[1], Jr.[1], F. Bagenal[4], P. C. Brandt[1], L. Brown[1], D. J. McComas[5], M. Opher[6], J.W. Parker[7], A. Poppe[8], E.A. Provornikova[1], S. A. Stern[7], K. N. Singer[7], A.J. Verbiscer[9], X.C. Guo[10], L. Ying[10], and C. Wang[10]
[1] Johns Hopkins Univ. Applied Physics Lab. [2] Southwest Research Institute, San Antonio [3] MIT [4] Univ. of Colorado, Boulder [5] Princeton Univ. [6] Boston Univ. [7] Southwest Research Institute, Boulder [8] Univ. of Berkeley [9]Univ. Virginia. [10] National Space Science Center, Chinese Academy of Science

The first and second observed spacecraft encounters with the solar wind termination shock (TS) took place at the turn of the millennium when Voyager 1 (V1) entered the Heliosheath on 16 December (DOY* 351) 2004 at 94.0 AU (V1TSX†) and, owing to the motion of the TS, Voyager 2 (V2) crossed the boundary multiple times on 31 August to 1 September 2007 (DOY 243-244) at 83.6 AU (V2TSX†). Launched in 1977, the Voyagers continued making measurements and are both now in the very local interstellar medium. The Pioneer 10 & 11 (P10 & P11) probes, launched before the Voyagers, were no longer returning data when they were likely in the vicinity of the TS (it is possible that the heliotail-directed P10 has not yet crossed the TS). The fifth spacecraft certain to be leaving the solar system and very likely to be responsible for the next observable encounter with the TS (NHTSx†) is New Horizons (NH), launched in 2006, which currently follows a similar heliolongitudinal trajectory as V2, but near the helioequator, distinct from the comparatively high northern and southern heliolatitudes V1 and V2 reached (respectively), subsequent to their planetary encounters. We will summarize results from V1TSX and V2TSX and new observations from NH that bear on the probable time and position of the future NHTSx encounter. Specifically, though preliminarily, we will present the mission profiles of Suprathermal and energetic particles observed by the NH/PEPSSI instrument from 5 AU (2007) to 59 AU (2024) as compared with the closest matching observations from V1 and V2 before their aforementioned TS encounters. Both V1 and V2 revealed a deep intensity valley where the radially decreasing solar energetic particle (SEP) intensities reach a minimum and then fall below the radially increasing Heliospheric energetic particle (HEP) intensities‡. We will present the PEPSSI measurements within the context of the observed slowdown of the solar wind speed as observed by the SWAP instrument on NH and compare to available global MHD models calculations of the location of the termination shock. There are early indications that NH could currently be at the floor of the energetic particle valley identified by V1 and V2. As temporal (solar cycle) and spatial (mostly radial) effects play a role in understanding location of the TS, we will discuss PEPSSI galactic cosmic ray observations and ongoing efforts to detect anomalous cosmic ray with PEPSSI. The New Horizons mission team, with the help of collaborators, is working towards estimating when NHTSx will likely occur both because of the innate scientific interest and, importantly, to allow for operational preparations. Preliminarily, an encounter in 2028 appears to be well within the range of reasonable expected encounter years.

** DOY refers to the integer day of year*
† Shorthand for the three spacecraft crossings of the termination shock, where a lower-case x is a reminder that the NH spacecraft has not yet crossed the TS.
‡Here we use SEPs to mean energetic particles accelerated by or near the sun or structures emanating from the sun and HEPs to mean energetic particles accelerated anywhere else in the heliosphere. SEPs would include particles associated with coronal mass ejections or with transient shocks and HEPs would include particles accelerated at or beyond the termination shock (termination shock particles) or at other unspecified locations (such as the higher energy anomalous cosmic rays).

SCHEDULE OF TALKS

Friday, March 29: 8:00 AM – 8:25 AM
Presenter: Guo, Xiaocheng

Numerical Simulation of Galactic Cosmic-Rays during the Heliopause Crossing for Voyager 2

Xiaocheng Guo, National Space Science Center, Chinese Academy of Sciences, CHINA

Voyager 2 crossed heliopause in 2018 and observed a small-amplitude modulation of galactic cosmic-rays beyond heliopause, being within a boundary layer with a thickness of ~ 0.57 au. Here, we investigate the modulation of cosmic-rays near heliopause by means of the numerical simulations, in which a magnetic boundary layer is taken into account near heliopause. Our simulation results confirm that the existence of boundary layer leads to a decrease of diffusion coefficient for cosmic-rays, and thus cause the modulation of cosmic-rays beyond helipause. This construction of boundary layer is essential to interpret the observation of galactic cosmic-rays by Voyager 2.

Friday, March 29: 8:25 AM – 8:50 AM
Presenter: Scott, Roger

The Dynamic Evolution of Solar Wind Streams Following Interchange Reconnection

Roger B. Scott, US Naval Research Laboratory

Interchange reconnection is thought to play an important role in determining the dynamics and material composition of the slow solar wind that originates from near coronal hole boundaries. To explore the implications of this process we simulate the dynamic evolution of a solar wind stream along a newly-opened magnetic flux tube. The initial condition is composed of a piecewise continuous dynamic equilibrium in which the regions above and below the reconnection site are extracted from steady-state solutions along open and closed field lines. The initial discontinuity at the reconnection site is highly unstable and evolves as a Riemann problem, decomposing into an outward-propagating shock and inward-propagating rarefaction that eventually develop into a classic N-wave configuration. This configuration ultimately propagates into the heliosphere as a coherent structure and the entire system eventually settles to a quasi-steady wind solution. In addition to simulating the fluid evolution we also calculate the time-dependent non-equilibrium ionization of oxygen in real time in order to construct in situ diagnostics of the conditions near the reconnection site. This idealized description of the plasma dynamics along a newly-opened magnetic field line provides a baseline for predicting and interpreting the implications of interchange reconnection for the slow solar wind. Notably, the density and velocity within the expanding N-wave are generally enhanced over the ambient wind, as is the O7+/O6+ ionization ratio, which exhibits a discontinuity across the reconnection site that is transported by the flow and arrives later than the propagating N-wave.

SCHEDULE OF TALKS

Friday, March 29: 8:50 AM – 9:15 AM
Presenter: Heidrich-Meisner, Verena

Pickup-ion measurements with STEREO-A/PLASTIC and Solar Orbiter/EPD/STEP

Verena Heidrich-Meisner, Kiel University, Germany
Duncan Keilbach, Kiel University, Germany
Lars Berger, Kiel University, Germany
Maximilian Hecht, Kiel University, Germany
Robert F. Wimmer-Schweingruber, Kiel University, Germany

After entering the heliosphere, the neutral component of the local interstellar medium can be ionized and picked up by the solar wind. The properties of the resulting pickup ions still encode their interstellar origin, i.e. the inflow speed, direction and temperature.
As initial velocity distribution function (VDF) a narrow torus is expected which is oriented depending on the local magnetic field direction. Such a torus distribution has been observed in 2-dimensional projections in Drews 2015 based Plasma and Suprathermal Ion Composition observations (PLASTIC) onboard the Solar Terrestrial Relations Observatory-Ahead (STEREO-A). The torus distribution then evolves due to pitch angle scattering, cooling and acceleration processes.
However, the times scale of these processes are not well-understood.
In our work, we approach these questions from two directions. We investigate the changes in the helium pickup ion pitch angel distributions depending on the position of STEREO-A in its orbit.
This is complemented by pickup ion observations by the Suprathermal electrons and protons instrument (STEP) which is part of the energetic particle detector (EPD) onboard Solar Orbiter. Depending on the solar wind conditions, STEP frequently observes He pickup ions. Interestingly, STEP allows to observe freshly injected pickup ions and an evolved population of scattered and cooled pickup ions simultaneously.

Friday, March 29: 9:15 AM – 9:40 AM
Presenter: Livadiotis, George

Entropy defect in thermodynamics: Theory and applications in space plasmas

George Livadiotis, Princeton University, USA
David J McComas, Princeton University, USA

We present the physical foundations of the “entropy defect” as a basic concept of thermodynamics and some applications in the heliosphere. The entropy defect measures the missing entropy between the sum of entropies of a system's constituents and the entropy of the combined system; this decrease of entropy corresponds to the order induced by the additional long-range correlations developed among the constituents of the combined system. It is closely analogous to the mass defect that arises when nuclear particle systems are assembled. The formulation of the entropy defect stands on three fundamental properties: each constituent’s entropy must be (i) separable, (ii) symmetric, and (iii) bounded. We show that these properties provide a solid foundation for the entropy defect and for generalizing thermodynamics. In particular, the most generalized entropy function that is consistent with the entropy defect is the one associated with kappa distributions, however, the entropy defect applies even more broadly, in stationary and nonstationary states. We also present an application of the entropy defect for space plasma particle populations exchanging entropy, such as the solar wind and pickup protons. In particular, we formulate the transport equation of kappa as a function of the rate of entropy change; then, derive the particular case of exchanging plasma ions with low-dimensionality, e.g., newly born pickup protons, which interact and decrease the entropy of the flow of otherwise kappa-distributed plasma protons. Finally, the developed transport equation of kappa is applied to the solar wind plasma protons, which leads to the radial profile of kappa values, as well as the radial evolution of the kappa distributions through the heliosphere.

SCHEDULE OF TALKS

Friday, March 29: 9:40 AM – 10:05 AM
Presenter: Davidson, Katherine

Dependence of High-Latitude Neutral Wind Responses on Geomagnetic Conditions

Katherine Davidson, Department of Space Science, University of Alabama in Huntsville, AL, USA
Ying Zou, Johns Hopkins Applied Physics Laboratory, MD, USA
Mark Conde, Department of Physics, University of Alaska Fairbanks, AK, USA
Asti Bhatt, SRI International, CA, USA

High-latitude ionospheric convection is driven by electromagnetic coupling between the magnetic field and solar wind, causing the ionospheric convection pattern and strength to be highly dependent on local solar wind conditions. F-region thermosphere winds, however, have drivers of both solar and magnetospheric origins, and therefore do not experience a direct response to changes in solar wind conditions. Thermospheric winds generally follow changes in ionospheric convection via the ion-drag force, but will experience a lag in their response, with response times in the range of tens of minutes to hours. The dependence of the neutral wind response on geomagnetic activity levels is not well understood. Therefore, we perform a statistical analysis of neutral wind response times compared to various geomagnetic indices. We use the newly developed weighted windowed time-lagged correlation (Weighted WTLC) technique on horizontal plasma flow and neutral wind vectors from the Poker Flat Incoherent Scatter Radar (PFISR) and Scanning Doppler Imagers (SDIs), respectively, to calculate neutral wind response times. These response times are then binned according to various global and local geomagnetic indices, such as the AE index, ground magnetometer perturbations from the THEMIS ground observatory, and electron density data from PFISR. Correlations between the neutral wind response time and geomagnetic indices will help develop an understanding of the neutral wind response's dependence on geomagnetic conditions.

Friday, March 29: 10:30 AM – 10:55 AM
Presenter: Huang, Zhenguang

The Energy Deposition Rate in the Open Field Region from MHD Simulations

Zhenguang Huang, University of Michigan, USA
Gabor Toth, University of Michigan, USA
Nishtha Sachdeva, University of Michigan, USA
Lulu Zhao, University of Michigan, USA
Ward Manchester, University of Michigan, USA
Bart van der Holst, University of Michigan, USA
Igor Sokolov, University of Michigan, USA
Tamas Gombosi, University of Michigan, USA

The energy deposition rate into the solar atmosphere is critical in determining the solar wind acceleration and terminal velocity. However, this quantity is difficult to observe and has a large uncertainty. Sokolov et al. (2013) suggested that the Poynting flux per B ratio for the Alfven wave energy density to be approximately 1.1 MWm-2T-1 based on the Hinode observations by De Pontieu et al. (2007). Recently, Huang et al. (2023) and Huang et al. (2024) used the Alfven Wave Solar atmosphere Model (AWSoM) to simulate different phases of the last solar cycle with ADAPT-GONG and GONG magnetograms. They found that the required Poynting flux per B ratio necessary to reproduce the observed solar wind must be adjusted based on the area of the open field regions so that the simulated solar wind can best match the OMNI solar wind observations. Moreover, the average Poynting flux for the Alfven wave energy density, which is described as the energy deposition rate for the model, is approximately constant in the open field regions. This new discovery needs to be validated with observations and can shed light on how Alfven wave turbulence accelerates the solar wind during different phases of the solar cycle.

SCHEDULE OF TALKS

Friday, March 29: 10:55 AM – 11:20 AM
Presenter: Harvey, Rebecca

Observational analysis of small-scale structures across the Earth's bow shock

Rebecca Harvey, Department of Space Science, The University of Alabama in Huntsville, USA
Qiang Hu, Center for Space Plasma and Aeronomic Research (CSPAR), The University of Alabama in Huntsville, USA

Solar wind turbulence belongs to a complex group of phenomena to study, and has implications in coronal heating, cosmic ray transport, and magnetic reconnection. The intermittent processes within this turbulence are energy sources for the formation of small-scale localized coherent structures in the solar wind. These coherent structures can be identified through analyses such as wavelet analysis and reconstruction algorithms utilizing Grad-Shafranov type equations by using high-resolution in situ observations. This work identifies and categorizes magnetic structures as they move in near-Earth space across the bow shock into the magnetosheath and investigates the difference between the properties of magnetic structures in different near-Earth regions. High time-resolution magnetic field and plasma data from the MMS and THEMIS-ARTEMIS missions are used to identify these structures and their associated parameters such as scale size, duration, and average plasma temperature. These parameters are summarized through statistical analysis and the changes from the solar wind into the magnetosheath are discussed in the context of the transmission/generation of turbulence/structures across the bow shock.

Friday, March 29: 11:20 AM – 11:45 AM
Presenter: Gautam, Sujan Prasad

Turbulence properties in upstream and downstream regions of interplanetary shocks

Laxman Adhikari, Center for Space Plasma and Aeronomic Research, USA
Gary P Zank, Center for Space Plasma and Aeronomic Research, USA
Ashok Silwal, University of Alabama in Huntsville, USA

Interplanetary shocks play a crucial role in amplifying and generating turbulence within the heliosphere. The local properties of turbulent solar wind plasma may be significantly impacted by these shocks, both in upstream and downstream regions. This study performs a statistical analysis of turbulence properties in the vicinity of parallel, quasi-parallel, perpendicular, and quasi-perpendicular shocks using data from the WIND spacecraft. By selecting a total of 130 fast forward shock events, we analyze the total turbulent energy (ET), total turbulence cascade rate (εET), cross helicity (σc), and residual energy (σr) in both upstream and downstream regions. We find that: (i) The downstream region exhibits larger fluctuating energies and cascade rates compared to the upstream region, (ii) σr is higher in the downstream region than in the upstream region, (iii) σc is minimally affected by the shocks, (iv) εET is larger near θUB = 90 degrees and smaller near θUB = 0 or 180 degrees, (v) εET is higher near θBn = 0 degrees and lower near θBn = 90 degrees, (vi) large values of the total turbulent energy are found at lower spectral indices, and vice versa, (vii) total turbulent energy is positively correlated with Mach number and shock compression. Finally, ET and εET in both upstream and downstream regions are found to vary over the solar cycle, being higher during the solar maximum and lower during the solar minimum.

Friday, March 29: 11:45 AM – 12:10 PM
Presenter: Asgari-Targhi, Mahboubeh

Study of Non-thermal Velocities and Their Comparisons with Alfven Wave Turbulence Model in Solar Active Regions

M. Asgari-Targhi - Harvard-Smithsonian Center for Astrophysics, MA, USA

We present a study of spectral line width measurements from the Extreme Ultraviolet Imaging Spectrometer (EIS) on Hinode. We used spectral line profiles of Fe xvi 262.984 ˚A, Fe xiv 264.787 ˚A, Fe xiv 270.519 ˚A, Fe xiv 274.203 ˚A, and Fe xv 284.160 ˚A and studied 11 active regions. Previous studies of spectral line widths have shown that in hot loops in the cores of active regions, the observed non-thermal velocities are smaller than predicted from models of reconnection jets in the corona or shock heating associated with Alfv´en waves. The observed line widths are also inconsistent with models of chromospheric evaporation due to coronal nanoflares. We show that recent advances in higher resolution Alfv´en wave turbulence modeling enables us to obtain non-thermal velocities similar to those measured in active regions. The observed non-thermal velocities for the 11 active regions in our study are in the range of 17−30 km s−1, consistent with the spectral line non-thermal widths predicted from our model of 16 interacting flux tubes, which are in the range of 15−37 km s−1.

21st Annual International Astrophysics Conference

Turin, Italy; March 25 – 29, 2024

POSTER PRESENTATIONS

Baruwal, Prashant	**Evolution of Turbulence Fluctuations during Parker Solar Probe and Solar Orbiter Radial Alignment** Baruwal, Prashant – The University of Alabama in Huntsville
Baruwal, Prashrit	**Identification of Turbulent Modes in the Magnetosheath** Baruwal, Prashrit – The University of Alabama in Huntsville
Giordano, Silvio	**Solar Wind Speed Maps thought a Full Solar Cycle from UVCS/SoHO and Recent Metis/Solar Orbiter Results** Giordano, Silvio – INAF/Astrophysical Observatory of Torino
Tasnim, Mst Ismita	**Mode Decomposition in Hydrodynamics** Tasnim, Mst Ismita – The University of Alabama in Huntsville

21st Annual International Astrophysics Conference

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