

Summary of Working Group 3 sessions – SHINE 2005

Monday PM (WG3)

Session #1: Sources of Suprathermal Ions in the Solar Corona and the Interplanetary Medium

This session was focused toward understanding the production and evolution of the ubiquitous but relatively unexplored suprathermal energy region between ~2-10 times the solar wind speed that provides the seed population for CME-driven IP shocks. George Ho presented evidence that CME-driven interplanetary shocks near 1 AU accelerate ions out of a suprathermal tail rather than from the more abundant solar wind peak. Using ACE and Ulysses data, Thomas Zurbuchen showed that properties of suprathermal tails are different in the slow, fast, and CME-related solar wind, and that the mere presence of suprathermal ions is not sufficient for a shock to accelerate particles. Matthew Hill analyzed Cassini data and showed that pickup ions are the dominant seed population for CME-driven shocks beyond Earth orbit and that their contribution may remain constant beyond ~3.5 AU. Nathan Schwadron showed that statistical acceleration/transit-time damping could produce suprathermal tails in the IP medium with constant He⁺ abundance beyond 5 AU. He also applied the solar wind scaling law and suggested that low-energy or thermal plasma remains bound while suprathermals can escape out into the solar corona. Lennard Fisk invoked the diffusion of magnetic field lines on the Sun to show that statistical acceleration can occur continuously on coronal loops and also produce power-law suprathermal tails near the Sun. Such suprathermal tails in the corona could provide the seed population for CME-driven shocks near the Sun.

An important goal for the NSF-SHINE community is to understand the cause and effect of spatial and temporal variations of the suprathermal tail. Observationally, this means identifying and characterizing the properties of various ion sources, quantifying their relative contributions to the suprathermal tail, and investigating their relationship with CME-related particle events through the heliosphere over the course of a solar cycle. From a theoretical perspective, solar wind acceleration models must produce coronal suprathermal tails with composition like SEPs and not the solar wind. Models also need to account for the spatial and temporal evolution of various ion sources and their contributions to the suprathermal tail through the inner heliosphere.

Wednesday AM (WG3)

Session #2: Mechanisms of Particle Acceleration near the Sun

This session focused on the physics of particle acceleration mechanisms that are relevant to our

understanding of the most general properties of energetic particles from solar flares and CMEs. Chee Ng discussed new theory and modeling efforts to address the important question of how rapidly particles can be accelerated by parallel shocks driven by expanding CMEs. This issue is important because for rapid acceleration, the particle mean-free path must be very short near the Sun (less than 10^{-7} AU for a 1 MeV proton in a 0.1 G magnetic field), which is not consistent with observations at 1 AU (closer to 0.3 AU). He discussed preliminary results from a new time-dependent model and noted that the results were strongly dependent on the injection rate input into the model. This is related to topics discussed in the first working group session on the sources of particle acceleration. Randy Jokipii discussed the physics of shock acceleration and noted that this is the only mechanism that predicts a universal power law that is consistent with a wide variety of energetic particle populations in space. For instance, even energetic particles from impulsive solar flares exhibit power-law-like spectra below a characteristic energy. The spectral index of this power law is remarkably similar from one event to the next (not varying by more than about 50%). Thus, he suggested that diffusive shock acceleration may be responsible for SEPs from impulsive solar flares, as well as CME driven shocks. Two issues that were raised by the audience were that impulsive events are rich in ³He which has yet to be explained by shock-acceleration models, and also that these events are proton poor (relative to electrons). This also must be reconciled by shock acceleration models. Vahe Petrosian discussed the physics of stochastic acceleration and noted that this mechanism is the only one that is successful for accelerating ³He. He discussed recent attempts to explain the origin of ultra-heavy ions. Preliminary results show promise, but still cannot account for the observations of these ion species. Yuri Litvinenko discussed the physics of particle acceleration by direct electric fields associated with reconnection current sheets. This mechanism produces a power-law spectrum naturally because of the geometry. Those particles that reach the center of the reconnection geometry, where the electric field is the strongest, reach the maximum energy (equal to the potential difference). Particles that do not reach the maximum energy do not drift in as close to the center of the reconnection geometry. Open issues with regards to this mechanism include: (a) what determines the injection threshold? And (b) what is the effect of plasma turbulence, perhaps created by the accelerated particles themselves, on the reconnection geometry and resulting energy spectrum of accelerated particles? Finally, Jim

Miller noted that the cross-terms appearing in the momentum diffusion equation, often used in stochastic acceleration models, can be modeled using a stochastic integration technique. This approach has also been used with much success in the study of cosmic-ray transport in the heliosphere, but has not yet been applied to acceleration in solar flares.

Thursday PM (WG3)

Session #3: The Effect of the Sun in the Outer Heliosphere

This session was aimed at understanding the solar influence seen in the outer heliosphere. John Richardson showed that simple one- and two-dimensional hydrodynamic models using inputs based on observations in the inner heliosphere can be used to model structures in the outer heliosphere. Often, the exact timing of the events are off, but the general characteristics of the events seem to be qualitatively similar. He also discussed the recent Voyager 1 observations of the termination-shock crossing in December, 2004. There is clear evidence of the crossing in the magnetometer data. Devrie Intriligator also discussed the effect of explosive solar events on the observed plasma and fields in the outer heliosphere. Using semi-empirical models that use solar magnetic fields as input, she showed the effect of the solar storms of Oct./Nov. 2003 and late 2004 on the outer heliosphere. There was qualitative agreement between the observations and the model predictions. Moreover, while solar events can influence the location of the termination shock, to some degree, solar storms can significantly alter the plasma inside the termination shock so that the connection of magnetic field lines from an observer (e.g. Voyager 2) and the termination shock deviates from that expected from a nominal Parker spiral. In fact, she (and coworkers) suggested that the recently observed energetic-particle events seen at Voyager 2 are related to solar events, and not the particles coming from the termination shock. Additionally, they predict that the termination shock will again re-cross Voyager 1 (this time moving outward so that the spacecraft will once again be in the solar wind) in August/September of 2005. Nathan Schwadron discussed the importance of magnetic-footpoint motion on the surface of the Sun in determining the resulting configuration of the heliospheric magnetic field. He showed that when a footpoint moves across a coronal hole boundary, so that the solar wind speed varies at the base for a given field line, the resulting field in the heliosphere can deviate from the usual Parker spiral field and become "underwound." This is commonly observed in rarefaction regions that trail corotating interaction regions and has been modeled successfully. Schwadron discussed the extension of this concept into

the outer heliosphere, showing that there may be regions on the termination shock where the field is more radial than the nominal Parker-spiral value. This may lead to more efficient particle injection. Trevor Sanderson discussed observations of corotating interaction regions. He noted that there are many CIRs observed during solar maximum (often 2-4 per solar rotation). Using anisotropy observations of energetic particles associated with CIRs he showed that the observed time-intensity profiles that typically cover a substantial fraction of the solar rotation period can be easily understood in terms of particle transport *along* magnetic field lines that connect the CIRs and Ulysses at various distances.