SHINE 2003 Workshop Highlights Progress in Solar-Heliospheric Physics

David Webb[1,2] and Nat Gopalswamy[3]

SHINE (Solar Heliospheric Interplanetary Environment) is a grass-roots organization affiliated with the National Science Foundation. It holds annual workshops that provide a unique environment for interactions among solar and heliospheric physicists, modelers and observers, those with global viewpoints and those focused on specific events or techniques.

SHINE 2003 was the fifth annual workshop and by far the most successful in terms of the numbers of speakers, poster papers and attendees, about 150! This enhanced interest was undoubtedly due to the fine program of exhilarating speakers and topics, but was certainly enhanced by the lovely venue: Maui, Hawaii! However, the number of participants at these meetings has grown steadily since the late 1990s.

As usual, the meeting was organized around 3 working groups (WGs) that met individually and in joint sessions to discuss an array of timely topics. The 3 groups were Solar, Interplanetary, and Solar Energetic Particles (SEPs). However, this workshop was different in two respects. First, SHINE hosted its first-ever Student Day, following the lead of the older GEM and CEDAR NSF-sponsored organizations. Twenty students attended the meeting and most of them were provided with travel support. They discussed topics such as flares and CMEs, and related solar wind composition signatures, magnetic clouds and energetic particles, the latter reviewed by Richard Leske. The students also made their own presentations. Second, we had a half-day plenary session introducing Campaigns of coordinated observations and modeling of four specific events. The Campaign events chosen before the meeting were: May 12, 1997, May 1, 1998, April 21, 2002, and August 24, 2002. The first two were selected because they were Sun-Earth connection events with excellent solar data for modeling and simulations. George Fisher reviewed these solar data in the context of the MURI analysis project, and Ian Richardson discussed the interplanetary aspects. The latter two events were west limb CMEs observed by RHESSI that produced large SEP events with very different spectral profiles. Allan Tylka and others discussed these observations in terms of shock propagation models and asked what can the solar observations tell us about these spectral differences. These topics were then discussed in the SEP WG session where no firm conclusions were reached, partly because the solar events were so similar.

The Solar WG concentrated on observations of vector magnetic fields and photospheric flows and what they can tell us about conditions leading to the initiation of a CME. A plenary talk introducing this topic was given by Bruce Lites who discussed the latest developments in observing the solar surface. In particular, he focused on the issues of magnetic structure and formation of prominences. Emergence and evolution of the magnetic field from below the solar surface and leading to the formation of prominence and then to CMEs seem to be within the grasp of present day observations. One session introduced the general issues involved with determining the vector magnetic field and photospheric flow patterns, with local correlation tracking techniques being the main focus. A second session focused on application of these measurements to the CME problem. Two issues were recognized: 1) The importance of using chromospheric lines to measure the vector field in regions where the field is more likely to be

force-free. Such measurements would provide "cleaner" boundary conditions for extrapolations into the corona, required to provide the magnetic topology in the erupting region. 2) What is the relationship between plasma and magnetic field flows on the solar surface? Local correlation tracking techniques follow photospheric plasma emission, whereas we really need to know how the magnetic field elements move to understand helicity injection, magnetic energization and the dynamical evolution of the magnetic topology of flaring and erupting regions.

The Solar WG also participated in joint sessions with the Interplanetary WG on modeling magnetic fields, and with the SEP WG on the role of CME initiation and energetic particles. The joint Solar-Interplanetary session was introduced by a plenary talk by Karel Schrijver on photospheric field evolution and coronal magnetic fields. He emphasized that significant amounts of heliospheric open flux emanate from active regions and, thus, the evolution of active regions can play a role in the IMF. The joint session featured a second year face-off between the Fisk and Wang-Sheeley models of how magnetic flux is transported over the Sun and affects the heliosphere. Conclusions reached were that the global magnetic field is very important, and our representation of it is much improved, that the source of the open magnetic flux is variable and uncertain, that tracking both open flux and individual field lines is important, that stochastic, statistically-tuned flux emergence may explain the activity cycle, and that the motion of flux elements is not necessarily the same as the plasma.

The Interplanetary WG focused on coronal and heliospheric field modeling, areas where great strides have been made recently. A major uncertainty of heliospheric MHD models is introduced by the inputs assumed (i.e., inner boundary conditions). It is important to understand the limitations of a given model and its realm of applicability, and the impacts of magnetic topology on characteristics of the solar wind at 1 AU. Specifically, why does the potential field, source surface (PFSS) model do so well? For example, the ambient solar wind speed, V_{sw}, and IMF polarity can be predicted at 1 AU well with the use of a coupled PFSS+current sheet model and a new empirical velocity relationship that is a function of magnetic field expansion factor (f_s) and the angular distance between an open field footpoint and its nearest coronal hole boundary (θ_b). We don't understand why there is such a good inverse correlation between f_s and V_{sw}, and modelers and theorists need to confront this issue and explain it. Does the θ_b relation imply different heating mechanisms for fast and slow wind, or is it a fudge factor for the PFSS model? Quality control of the input magnetic data was considered essential for improving the predictive success of the models. A brief overview of the new Solar Mass Ejection Imager (SMEI) experiment now imaging the whole sky in white light once per orbit was also presented. SMEI will provide important new data of the inner heliosphere for the models. Although calibration of the instrument is just beginning, the all-sky images already show CME-like transients and should be able to detect other heliospheric features such as corotating structures.

As followup to the discussion about the Campaign events, the SEP WG continued with discussions of particle acceleration mechanisms near the Sun, A plenary talk introducing this topic was given by Marty Lee. After summarizing the observed properties of impulsive and gradual SEP events, he pointed out that shock acceleration is directly observed, while stochastic acceleration is necessarily inferred. After pointing out the important elements of complexities in shock-acceleration, he outlined the following as the outstanding issues: (i) variation of the acceleration efficiency with distance because of the increasing gyroradii of ions, (ii) radial

dependence of the Alfven speed profile of the corona/solar wind, (iii) shock refraction and its relation to phenomena such as Moreton waves, and (iv) the availability of seed particles near the Sun. The SEP WG then focused on the effects of shocks and flares on SEP composition and, particularly, on the spectral variability noted in the 2002 events. The joint session with the Solar WG focused on the acceleration and transport of energetic particles and what we can learn about the relationship between SEP events, CMEs and flares. Joint Solar-SEP topics included understanding the location and strength of shocks in the important range of 2-5 solar radii, the magnetic topology in terms of connections to the flare and the role of interchange reconnection, the pre-eruption history of events having SEPs, especially of the campaign events, the role of blast waves as diagnostics and whether they can accelerate particles to significant energies. Understanding the relative timing of observables in SEP events, especially in the Campaign events, was considered important. Topics involving the SEP group were the need to find more examples and develop more techniques for evaluating the injection profiles of SEPs, to better understand the energy budget of SEPs, especially involving the particles themselves and their associated shocks, and to model parallel and perpendicular shocks to test observational differences between events, such as timing.

The Interplanetary and SEP WGs had joint sessions with invited talks and discussion focusing on two main topics: 1) Suprathermal particles and the magnetic connectivity of CME structures, and 2) Solar wind and energetic particle composition. The first session began with a discussion of heat flux dropouts in the solar wind. Such electrons may disappear or weaken in regions of high density, and the dropouts are a result of coulomb collisions in a sufficiently high density region most likely near the Sun. Coulomb scattering affects low energy electrons the most. A recent concept called "interchange reconnection" is helping us sort out in the heliosphere which field lines have reconnected near the Sun. A folded-back field line can result and a local area of high beta plasma can develop that can cause a dropout because of scattering in the high beta plasma. The intensity of the heat flux electrons is related to the time since the last interchange reconnection. Finally, the use of solar flare electrons as a tracer of the connectivity within interplanetary magnetic clouds was discussed. In several events the flare-onset electrons within a cloud demonstrate the magnetic connection of one leg back to a solar active region, and the field line lengths were consistent with flux tubes. These observations also suggested that one leg was connected to the Sun, while the other was connected to the heliosphere. In fact one never sees a case of both cloud legs connected to the Sun, even though filaments begin with both legs in an active region.

Particle composition and energy states were discussed in the other session. ICMEs tend to be "hot"; e.g., they contain solar wind periods with high Fe charge states. Comparison of Ulysses and ACE data indicates that low latitude CMEs tend to have high Fe charge states, while high latitude CMEs do not. We don't know whether this is associated with the sources of the CMEs, active regions at low latitudes and polar crown filaments at higher latitudes, or something else. There is compositional evidence for energy-dependent acceleration of suprathermal ions; what are the source populations of these particles? Suggestions are remnant particles in the interplanetary medium from previous flare suprathermals or SEP events. Solar wind material cannot be a dominant source for this population. During this solar cycle, the C/O ratio is lower in SEPs than the solar wind, the frequency of 3He-rich shocks has peaked and declined, yet the Fe/O ratio has remained high. How can we understand these differences? In magnetic clouds, the

Fe/O ratio is high, and the Fe charge states are higher than in large IP shock events. Why is this? It was clear to this group, that the Campaign events would be useful for studying the process of flare and shock acceleration close to the Sun.

At the end of each SHINE workshop some specific challenges are named with the intent of encouraging studies before next year's workshop. This year we had many of these and some of the most important are as follows. We need to know what aspects of the photospheric and coronal evolution are necessary and/or sufficient for an eruption to occur. The Solar WG Challenge is to provide simulated magnetograms and flow fields as input to the various techniques used to recover velocity and field information. Projects between Solar and Interplanetary include work on a global solar magnetic field model that assimilates observations, the need to track individual field lines in time from the photosphere through the corona to the heliosphere, how to verify the origin of open field lines, and the need to understand the degree to which flux emergence truly is stochastic. The Solar and SEP Challenge is to exchange ideas on CME/flare initiation and SEPs within each community and to develop topics to investigate during the next year. Between the Interplanetary and SEP groups a prime goal is to study the processes of flare and shock acceleration close to the Sun, especially using the Campaign events. Work on the Campaign events themselves among all the groups will be a prime focus.

This summer SHINE 2004 will be held at Big Sky, MT from June 27- July 2. Information about the meeting is available on the SHINE website at: http://www.shinegroup.org/.

Acknowledgments

This article is based in part on reports from the working group leaders D. Alexander, N. Arge, T. Hoeksema, C. Cohen, T. Holzer and M. Popecki. The complete reports can be found under Meetings at the SHINE website. SHINE 2003 was supported by the U.S. National Science Foundation under Grants ATM 0227732 to the Catholic University of America and NASA's Living With a Star (LWS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

[1] Institute for Scientific Research, Boston College, Chestnut Hill, Mass., USA
[2] Also at Air Force Research Lab, Space Vehicles Directorate, Space Weather Center of Excellence, Hanscom AFB, Mass., USA
[3] Laboratory for Extraterrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA