

SHINE 2002 Workshop Report

The 2002 SHINE workshop was held August 18-22 at the Buffalo Mountain Lodge in Banff, Alberta. For the first time, attendance topped 100 participants (108). The 2002 workshop marked a turning point in the short history of the SHINE workshops, which began as stand-alone meetings in 1999. Whereas the previous workshops focused on space weather, addressing the limited topics of coronal mass ejections (CMEs), their propagation to 1 AU, and their associated energetic particles, the 2002 workshop expanded to include a topic of central interest to the broader heliospheric community, the heliospheric magnetic field and the mechanism for its reversal during the course of the solar cycle. Motivation for this expansion came months earlier from comments by heliospheric physicists attending an unrelated workshop. They complained that solar physicists paid no heed to their findings. In view of the excellent communication between solar and heliospheric physicists established at the SHINE workshops, it was clear that the SHINE community should reach out to those heliospheric physicists and include topics of joint interest beyond CMEs. In so doing, SHINE has been able to attract top heliospheric as well as solar physicists and has truly become the premier venue for scientific exchange in these areas.

Three invited papers were presented at plenary sessions at the 2002 workshop:

- "CME initiation: A zoo, not an animal" Janet Luhmann
- "Complexity of solar eruptions" Nat Gopalswamy
- "Solar magnetic field reversal and its heliospheric consequences" Vic Pizzo

These papers reflect the topics of the working group sessions, summarized below.

Working Group 1: Coronal Mass Ejections

David Alexander and Todd Hoeksema, Working Group Leaders

Topic: CME Initiation

Working Group 1 focused on the integration of modeling and observational efforts in the search to understand the cause and early evolution of CMEs. The aim was to identify the key observational and physical parameters that lead to and result from a CME. Prior to the meeting, the group leaders solicited input using a questionnaire which could be accessed and submitted at a special web site. At the workshop, two topics were addressed in the context of the following questions:

1. CME Acceleration
 - What determines the spatial and temporal form of the acceleration profile?
 - Where does the main acceleration occur?
 - Are there multiple phases of acceleration?
 - What distinguishing physics determines acceleration in the different models?
2. The Pre-Event Solar Atmosphere
 - What aspects of photospheric and coronal evolution are necessary and/or sufficient for an eruption to occur?
 - Is magnetic complexity crucial to CME production?
 - What photospheric motions or emergence/submergence of flux are required for a CME to be initiated?
 - Are there "typical" pre-eruption signatures in the field or field dynamics?

Presentations on CME acceleration were given by Chip Manchester and Holly Gilbert, and presentations on CME pre-eruption conditions were given by George Fisher and Ron Moore. Both observational and

model needs were assessed. For CME acceleration these include high-cadence, low-coronal, multi-wavelength observations and, for models, specification of factors which determine acceleration, appropriate boundary conditions, determining factors for fast versus slow events, and identification of model discriminators in the data. For the pre-event conditions, these include high-cadence vector field and continuum measurements and, for models, incorporation of reconnection, incorporation of the observed field configuration and evolution, understanding the role of emerging flux, and tracking helicity. To facilitate communication, especially between observers and modelers, the group constructed sample dialog templates listing various features, prediction capabilities, assumptions, etc. The session concluded with the formulation of a challenge to be met in the coming year, to model in detail the expected low-coronal acceleration profiles for a few key events, relate these to initial conditions and to the large-scale corona, and test for sensitivity to various model parameters and observational inputs.

Working Group 2: Interplanetary Connections

Tom Holzer and Nick Arge, Working Group Leaders

Topic: Simple and Complex Ejecta

Working Group 2 focused on comparing and contrasting the nature and properties of two types of CME ejecta: simple and complex. The session began with a general overview by Jack Gosling on the boundaries and properties of CME ejecta using solar wind data. Dusan Odstrcil spoke on the interactions of CMEs with themselves and with the steady background solar wind, and Thomas Zurbuchen gave a presentation on the compositional and ionization-state properties of complex and simple ejecta. These presentations and the ensuing discussion addressed the following questions:

- How well can numerical simulations reproduce CME ejecta observed in the solar wind?
- Can simple and complex ejecta be distinguished based on their composition and ionization states?

The participants concluded that focusing on the terms "simple" and "complex" is not very useful. CMEs are inherently complex for a variety of reasons. Instead the focus should be on understanding the physical origins of each aspect of this complex nature. Regarding CME elemental and isotopic composition, anomalies are most significant for [He/H] and [3He/4He]. Understanding of these anomalies likely will require the study of 3He and 4He transport in the upper chromosphere, transition region, and corona, as well as in the CME acceleration process. Time-dependent effects are likely to dominate. Similarly for understanding the origins of CME ionization-state anomalies, an integrated study of solar and interplanetary observations is required.

Working Groups 1 and 2: Joint Session

Todd Hoeksema, Tom Holzer, and Nick Arge, Working Group Leaders

Topic: Solar Mechanisms of the Heliospheric Field Reversal

How does the polar field of the Sun and heliosphere reverse?

This joint session, reflecting the expansion of SHINE interests as discussed in the opening paragraph, turned out to be the highlight of the workshop. It focused on the interactions of photospheric and coronal magnetic fields organized on large and small scales and on implications for the heliosphere. The goal was to identify what observational constraints exist and how they inform our modeling efforts. The sessions addressed the following questions:

What can we learn from

- the solar dynamo and variations of flow patterns?

- interpretation of flux emergence, distribution, and annihilation?
- the interplay of short-lived small-scale features, the global field configuration in the photosphere and corona, coronal holes, and CMEs?
- solar cycle variations of asymmetry, helicity, and total flux?
- how flux escapes into the heliosphere?
- the identifying signatures of its origin that the solar wind carries?
- how the polar field change propagates outward?
- how we can observe its effects out to the bounds of the heliosphere?

Peter Gilman and Yi-Ming Wang gave presentations on the origins of the Sun's polar field reversal, Len Fisk and Randy Jokipii spoke on transport of the polar field structure into the heliosphere, and Nancy Crooker, Dave Rust, John Raymond spoke on the topology and transport of magnetic flux into the heliosphere and the role of helicity. The Wang-Sheeley and Fisk models for the field reversal were pitted against each other in heated discussions, some of which focused on the different predictions they make about the degree to which field lines disconnect from the Sun. The former predicts a high degree of disconnection, whereas the latter requires none. Studies of suprathermal electron signatures of disconnection in the solar wind weigh in favor of little disconnection. Criticisms were voiced against the Wang-Sheeley use of potential field source surface modeling for a dynamic process and against the Fisk model for unrealistic solar fields. It was agreed that ultimately the solar dynamo must be understood before the problem of the field reversal can be fully solved.

Working Group 3: Solar Energetic Particles

Mark Popecki and Christina Cohen, Working Group Leaders

Topic: Solar Cycle Variations

Do characteristics of large SEP events depend on the phase of the solar cycle?

The topic of this session was motivated by observations made during Cycle 23 that hint at qualitative differences in the composition, frequency and size of solar energetic particle events during the rising and declining phases of the cycle. The rising phase exhibited many moderate-sized events with strong fractionation apparent in elemental and isotopic composition, while the declining phase produced more frequent and larger events with little fractionation. These findings raised the following questions:

- Does the suggested cycle dependence hold up under closer scrutiny?
- Is there evidence of such a dependence in other solar observations, e.g., solar wind, CMEs, flares, radio emission?
- Is this peculiar to Cycle 23 or do other cycles exhibit similar behavior?

Toni Galvin, Mihir Desai, Rick Leske, and Mark Popecki gave presentations addressing these questions. They reviewed the convincing trends in SEP composition variability that inspired the topic and showed some evidence in Voyager data of similar trends during the previous cycle. Solar cycle dependences in the solar wind composition were discussed and shown to be due to the solar cycle dependence of ICMEs and coronal hole streams. Discussion focused on possible explanations for why the SEP composition variability seems to follow sunspot number. One possibility is that more CMEs and therefore more interaction between CMEs at solar maximum might influence SEP composition. Another is that more flares at solar maximum might populate the interplanetary medium with suprathermals which, in turn, could result in more Fe-rich large SEPs. Alternatively, the flare material could contribute directly to Fe-rich SEPs. Participants agreed that while the observed variations serve as a valuable set of constraints

on models of the underlying physical processes that operate during the solar cycle, definitive conclusions clearly await further research on the topic.

Working Groups 2 and 3: Joint Session

Nat Gopalswamy and Mark Popecki, Working Group Leaders

Topic: Are there energetic particle signatures of interacting CMEs?

Some observations suggest that CME-driven shocks can propagate through preceding CMEs close to the Sun. This would create a complex environment that could strongly modulate particle acceleration and CME structure. Discussion focused on the following questions:

- Are there prompt energetic particle signatures of colliding CMEs at Earth?
- Is there spectral or compositional evidence for SEP production in colliding CMEs?
- What plasma and compositional signatures are observable at Earth during the passage of complex CMEs created by collision near the Sun?

Two multiple-CME acceleration scenarios were discussed: CMEs that follow each other without direct interaction and CMEs that merge. In the former case, a CME accelerates an ion population and/or traps ions with downstream waves, and a follow-on CME can then more effectively accelerate ions behind the first CME. Examples of these were presented by Chuck Smith and George Simnett. A possible example of the second case, directly interacting CMEs, was presented by Dennis Haggerty. The event consisted of what appeared to be merged flux ropes. Energetic particles demarcated two separate regions within the structure, but the magnetic field showed no comparable signature. How this configuration arose remained an open question.

In earlier sessions of Working Group 3, as preparation for this session, Dennis Haggerty and Dick Mewaldt gave presentations on the search for prompt signatures of interacting CMEs, and Chuck Smith spoke on near-Earth plasma signatures of interacting CMEs. At the joint session, Dusan Odstrcil and Ian Richardson gave presentations on models of merging flux ropes and particle observations, respectively, with the latter highly critical of the hypothesis based upon solar images and radio Type II emissions that SEPs are produced by colliding CMEs. Apparently some SEP events observed at 10-30 MeV/nuc begin before the associated CME interaction while others are observed after the launch of the overtaking CME, at a time that might be consistent with the CME interaction as their source. On the other hand, processes unrelated to the interaction may be responsible for this delayed onset, for example, shock propagation to the field lines at the observing spacecraft, particle scattering, and/or no seed population near Sun.

Overall the SHINE 2002 workshop was highly stimulating. Discussions were inconclusive, as might be expected on cutting-edge topics, but problems became better-defined, and collaborative plans were made for addressing some focused challenges.