Working Group 1: Numerical Models of CME Initiation

Working Group 1 held a half-day session on Numerical Models of CME Initiation. This is a topic that has featured prominently at previous SHINE workshops. We had two main objectives for this session:

1. Elucidate the main features of each of the major models for CME initiation that can be tested against observations.
2. Devise a 'shootout' based on model predictions for selected events.

Progress was made on the first objective during the session, but the objective of establishing a shootout between competing models for selected events remains out of reach. The discussion was inconclusive as to whether this is because the models are too simple or the data are inadequate to make realistic comparisons.

The session featured four invited speakers. Dana Longcope (Montana State University) discussed the role of magnetic field topology in energy storage and release in the corona. He focused on the minimum current corona (MCC) model. In this model, the photospheric field consists of a distribution of isolated sources that anchor the coronal field. The coronal field is formed by connections between these sources that evolve slowly over time. The topological constraints on the coronal field evolve by reconnection at one or more current sheets in this 'flux constrained equilibrium'. Steady reconnection (Sweet-Parker) in a typical active region occurs slowly, over several months. Fast reconnection only occurs in extraordinary circumstances, and can lead to the release of $\sim 10^{31}$ ergs in a typical active region. The model results compared well with observations of the magnetic evolution of real active regions.

Spiro Antiochos (NRL) presented the latest advances in the breakout model for CME initiation. In this model, reconnection between the magnetic field overlying a filament channel and neighboring flux systems disrupts the force balance between the filament channel field and the overlying quasi-potential field, leading to eruption. The reconnection process is driven by shearing motions on either side of the photospheric neutral line. Earlier versions of the breakout model had been confined to 2D, however recent work by Ben Lynch has extended the model to 3D. Antiochos showed a 3D simulation of an eruption driven by breakout reconnection.

Terry Forbes (University of New Hampshire) discussed CME initiation by ideal MHD processes. The basic topology of this type of model is a flux rope in the corona that achieves stable equilibrium by line-tying to the photosphere. A variety of triggers involving both ideal MHD and reconnection processes can lead to a sudden loss of equilibrium and eruption of the flux rope.

Jon Linker (SAIC) discussed CME initiation by flux cancellation, focusing on an idealized model of the coronal field in AR 8038 (May 12, 1997). He cited an observational definition of flux cancellation from Sara Martin as 'mutual disappearance of magnetic fields of opposite polarity at the neutral line separating them'. Flux cancellation in this active region leads to the formation and eruption of a flux rope. The

erupting structure achieves a speed in excess of 900 km/s, with a shock wave driven ahead of the CME. The CME decelerates when the erupting field interacts with the overlying field.

Jon Linker also showed the following table of observables for the flux cancellation and breakout models. After some discussion, the audience concluded that the observables in this table do not adequately distinguish between the models, given the currently available observations. It was also noted that this table is disappointingly similar to the matrix prepared by Jim Klimchuk at the 2000 SHINE workshop in Lake Tahoe.

Observable/Characteristic	Flux Cancellation	Breakout
Multipolar Field Topology	Allowed but not required	Required
Location of Reconnection	Below the arcade	Above the arcade
Sheared Field at Neutral Line	Required	Required
Shearing or Twisting Flows	Allowed but not required	Required
Converging Flow at Neutral Line	Required	Allowed but not required
Presence of a Flux Rope	Forms prior to eruption	Forms after eruption

The group was able to reach a consensus on a number of key features in common between all the major models of CME initiation:
- The pre-event coronal structure is characterized by a competition between magnetic tension and pressure forces.
- Free magnetic energy present in the corona is stored over a long time and released rapidly when tension is reduced and/or pressure is increased beyond a critical point.
- The main differences between the models are in the topology of the pre-eruption field and the trigger used to achieve the energy release.

The group also identified key unanswered questions that need to be answered to make significant progress in understanding:

- Is there a characteristic evolution of the pre-eruption magnetic configuration?
- What is the topology of the filament channel prior to eruption?
- What is the relative timing of the CME and the filament eruption?
- What is the structure of the post-eruption field?

In summary, working group 1 had a lively and useful discussion of the issues involved in modeling the initiation of CMEs. Significant differences exist between the models, but either the data are not sufficient to distinguish between the models (cadence, resolution, vector field data) and/or the models are too simple to allow detailed comparison with real solar observations.