SCIENCE OBJECTIVES WITH SDO/HMI MAGNETOGRAMS

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MAGNETIC STRUCTURES AND EVOLUTIONS ON VARIOUS SCALES.

1. EVOLUTION OF SMALL-SCALE STRUCTURES AND MAGNETIC CARPETING.

The quiet Sun is covered with small regions of mixed polarity, termed “magnetic carpet”, contributing to solar activity on short timescales. As these elements emerge through the photosphere, they interact with each other and with larger magnetic structures. They may provide triggers for eruptive events, and their constant interactions may be a source of coronal heating. They may also contribute to irradiance variations in the form of enhanced network reconnection.

HMI will allow global scale observations of the small-scale element distribution, their interactions, and the resulting transformation of the large-scale field.

Figure 1: Theoretical predictions for the structure and heating of the magnetic field above the solar surface using data for magnetic field in HMI are compared to the heating observed by EIT. The white magnetic field lines emanate from the magnetic carpet and form arches from one magnetic polarity to the other (Credit: LMSAL).

2. LARGE-SCALE CORONAL FIELD ESTIMATES.

Models computed from line-of-sight photospheric magnetic maps have been used to reproduce coronal forms that show multi-scale closed field structures as well as the source of open field that starts from coronal holes but spreads to fill interplanetary space. Modeled the heliospheric current sheet and a region sandwiched between the like-polarity open field regions. There is evidence that most CMEs are associated with helmet streamers.

HMI will provide uniform magnetic coverage at a high cadence, and together with simultaneous AIA, STEREO coronal images will enable the development of coronal field models and study of the relationship between pre-existing patterns, newly opening fields, long distance connectivity, and CMEs.

Figure 2: The coronal open (colored dot areas) and closed (the areas consisting of blue-red field lines) field regions below 1.25 solar radius near maximum activity (CR1981) (top panel), the radial extension of the boundaries of open field regions to the surface source at 2.5R (middle panel), and the two kinds of boundary layers open field regions at the source surface: bipolar (coincident with the black neutral line) and coronal holes and open field regions (bottom panel) (Zhao & Webb, JGR, 108, 2012).

3. CORONAL MAGNETIC STRUCTURE AND SOLAR WIND.

MHD simulation and current-free coronal field modeling based on magnetogram maps are two ways to study solar wind properties and their relations with coronal magnetic field structure. These methods have proven effective and promising, showing potential in applications to real-time space weather forecasting. It has been demonstrated that the solar wind can be significantly improved with increased cadence of the input magnetic data.

By providing full-disk vector magnetic field data at high cadence, HMI will enable these models to better describe the distribution of the solar wind, coronal holes and open field regions, and how magnetic fields in active regions connect with interplanetary magnetic field.

Figure 3: Left—MHD model of the solar corona and heliosphere driven by the observed line-of-sight photospheric magnetic field (Riley et al., JGR, 106, 10588, 2001). Right—Solar wind seen from above the Sun’s north pole. The red and green color scales show where the coronal field is directed inward or outward, respectively. The brighter the color, the faster the wind. Wind speed is calculated based on a modified PFE model-based Wang-Sheeley model (Credit: LMSAL).

4. DETERMINATION OF MAGNETIC CLOUD B events.

Potentially valuable information for geomagnetic forecasts—predictions of magnetic clouds are two ways to study solar wind properties and their relations with coronal magnetic field structure. These methods have proven effective and promising, showing potential in applications to real-time space weather forecasting. It has been demonstrated that the solar wind can be significantly improved with increased cadence of the input magnetic data.

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Figure 4: Highly idealized view of the proposed magnetic cloud geometry of a typical magnetic cloud on a global scale (Lepping et al., JGR, 95, 9119, 1990).

MAGNETIC ENERGY AND INSTABILITY FOR SOLAR TRANSIENT EVENTS.

1. COMPLEXITY AND ENERGETICS OF THE SOLAR CORONA.

Observations have shown a variety of complex structures and eruptive events in the solar corona. However, categorizing complex structures has not revealed the underlying physics of the corona and coronal events. Two mechanisms have been proposed to build-up energy in the corona: photospheric shear motions and emerging stressed magnetic flux, and both may, in fact, be at work on the Sun, but which plays the dominant role and how the energy injection is related to eruptive events is unknown. Magnetic helicity is an important characteristic of magnetic complexity and its conservation intrinsically links the generation, evolution, and reconstructions of magnetic field.

HMI will provide data to allow estimations of magnetic field and helicity. Observations from AIA will show the subsequent reconnection and propagation of fields, correlating to the release of energy and helicity. Observations from AIA will show the subsequent reconnection and propagation of fields, correlating to the release of energy.

Figure 5: top—emerging magnetic flux and corresponding changes in magnetic fields and electric currents. The computed non-linear force-free-field lines (yellow lines) are overplotted on the magnetograms. The color contours represent vertical currents. The emerging flux regions are marked by EFR. Bottom—TRACE observation of an active region at the edge of the Sun shows complex structures of the loops that connect one magnetic polarity to the other (Credit: LMSAL).

2. EMERGENCE OF MAGNETIC FLUX AND SOLAR TRANSIENT EVENTS.

Emergence of magnetic flux is closely related to solar transient events. This suggests that magnetic flux emergence into the solar corona interacts with pre-existing fields leading to loss of magnetic field stability. Observations of magnetic field and current topology between emerging and pre-existing fields will likely lead to the understanding of why emergent flux causes solar transient events.

Vector poloidomy provided by HMI will enable these quantitative studies.

Figure 6: top—Time-series magnetogram s of the active region AR8100. Magnetic field strength and its change over time (marked by O'PH99). Bottom—GOES observation shows increase of X-ray radiation during the procedure of emergence. Also shown are several major flares.

3. MAGNETIC CONFIGURATION AND MECHANISMS OF SOLAR FLARES AND CMEs.

Vector magnetic field measurements are needed to infer field topology and vertical current, both of which are essential to understand the RareCME processes. Observations are required that can continuously track changes in magnetic field and electric current with sufficient spatial resolution to reveal changes of the field. CMEs and solar wind—longitudinal field—are observed at the footpoints of the CMEs. HMI will provide these unique measurements of the vector magnetic field over the whole solar disk with reasonable accuracy and at high cadence.

Figure 7: Top: The post-flare arcades of the 2007 July 14 event seen in EVE wavelength taken by TRACE. Bottom: A CME clearly shows helical magnetic field structure, observed by the LASCO C2 coronagraph (Credit: TRACE & LASCO teams).