STEREO: Science and Mission Overview

Michael L. Kaiser

The twin Solar TErrestrial RElations Observatory (STEREO) spacecraft were launched on 26 October 2006, at 0052 UTC. After a series of highly eccentric Earth orbits with apogees beyond the Moon, each spacecraft used close flybys of the Moon to escape into orbits about the Sun near 1 astronomical unit (AU). Once in heliospheric orbit, one spacecraft (Behind) trails Earth while the other (Ahead) leads, continuously separating from each other at ~45° per year as viewed from the Sun. During the very early period of scientific observations, when the two spacecraft were still quite close together, the Sun produced an active series of coronal mass ejection (CME) explosions captured by some of the STEREO instruments. Additionally, serendipity played its usual surprise role, allowing an un-Earthly eclipse to be captured as well as phenomenal images of the very bright Comet McNaught. In the coming months and years, STEREO will undoubtedly revolutionize our understanding of solar storms and will continue to produce a bonanza of data for the entire inner heliosphere.

INTRODUCTION

Over a period of two to three decades, solar physicists have come to realize that the extremely energetic solar storms known as coronal mass ejections (CMEs) are the form of solar activity felt most forcefully at Earth. CMEs impacting Earth's environment are the primary cause of major geomagnetic storms, and they are associated with nearly all of the largest solar proton events, which are streams of protons ejected from the Sun with so much energy that they can pose a significant radiation hazard to men and machines in space. The growth in society's reliance on technology has led to an increased vulnerability to impacts from the space environment and, hence, to an importance in understanding the multifaceted influence of the Sun and CMEs on Earth. More recently, an initiative to return human and robotic explorers to the Moon and to extend a human presence to Mars has been undertaken, making the protection of space travelers from the harmful effects of solar proton events an important goal in "space weather" research and prediction. Unfortunately, to date, we cannot predict reliably when a CME will occur or what its effects will be.

CME RESEARCH AND OBSERVATIONS

Many current and past space missions and ground-based observations have studied CME disturbances from their initial lift-off at the Sun and their propagation in the region near the Sun to 10–15% of their way to Earth. Other spacecraft have measured the effects of CMEs *in situ* near Earth. However, there have not been missions to follow CMEs continuously from the Sun to Earth. The evolution of CMEs in the vast space between the Sun and Earth has been mostly predicted by unvalidated theoretical models resulting in relatively poor accuracy in estimating CME arrival times at Earth.

The report of the Science Definition Team for the Solar TErrestrial RElations Observatory (STEREO) mission[1] listed a number of fundamental questions about the physical causes of CME eruptions that remained to be answered, such as

- Are CMEs driven primarily by magnetic or nonmagnetic forces?
- What is the geometry and magnetic topology of CMEs?
- What key coronal phenomena accompany CME onset?
- What initiates CMEs?
- What is the role of magnetic reconnection?
- What is the role of evolving surface features?

STEREO: A UNIQUE OPPORTUNITY

Because the corona is optically thin at most wavelengths, all previous single-spacecraft observations have suffered from line-of-sight integration effects, which cause ambiguities and confusion about the three-dimensional structure of CMEs. Thus, none of these above questions could be satisfactorily addressed with single vantage point observations. STEREO's capabilities provided a unique opportunity to begin to answer some of these critical questions with the range of view angles accessible to the STEREO telescopes; CMEs and coronal structures, and even the underlying pre-eruption features, can be reconstructed in three dimensions. Early in the mission, STEREO's observations of the extreme ultraviolet emissions from the low corona, especially from the bright loops that outline the magnetic field structures, helped address all the questions posed above. Knowing the three-dimensional structure and behavior of coronal loops, including their exact cross-sectional shape and their interactions with each other, are key to understanding the initiation of CMEs. These same extreme ultraviolet observations should resolve the three-dimensional nature of the enigmatic waves seen in extreme ultraviolet traveling across the "surface" of the Sun immediately after a CME lift-off. These waves do not appear to be "blast waves," but they are intimately involved with CMEs. With the stereoscopic capabilities of STEREO and the rapid cadence of its extreme ultraviolet instrument, the exact relationship to CMEs and the trigger for these waves may be discovered.

The relatively small surface features underlying CMEs are best observed near the disk center, whereas the large and dim CMEs themselves were best observed near the limb where plane-of-sky projection effects are minimal. Some years into the mission, when the STEREO spacecraft are far apart so that their plane of the sky encompasses Earth, they will be able to detect CMEs that originate above surface locations that are at the solar disk center (when viewed from Earth); thus, the STEREO data combined with ground-based and near-Earth spacecraft measurements will give a complete picture of both the small underlying features and the resulting CMEs.

Compounding the problem of incomplete observations of CMEs from the Sun to Earth, the CMEs that most affect Earth also are the least likely to be detected and measured by ground-based or Earth-orbiting coronagraphs because the light from most of their structures is hidden from view by the occulting disk, which must be built to block the overpowering brightness of the solar disk. Earth-bound CMEs are only viewed as an expanding "halo" around the Sun, inhibiting measurement of their speed and even exact direction toward the observer. Arrival times of significant space weather events at Earth have typically only been accurate to approximately ±12 hours in the past. However, with the STEREO spacecraft measuring Earth-directed CMEs from well off the Sun–Earth line, a CME's speed and direction can be determined via triangulation and should greatly improve Earth impact prediction times to perhaps as good as ±3 hours. Furthermore, STEREO's complete observational coverage of CMEs from lift-off to arrival at 1 astronomical unit (AU) and beyond allows for a determination of the instantaneous distribution of matter in the inner heliosphere that modifies the CMEs as they propagate through it, which previously was not possible.

STEREO'S MISSION

Achieving the science goals of the mission required specific measurements as shown in Table 1. These are the STEREO level 1 science requirements. Minimum success for STEREO was defined as being able to make the measurements shown in Table 1 with both spacecraft for a period of 150 days after achieving heliocentric orbit,

Table 1. STEREO level 1 science requirements.

Scientific Objective	Measurement Requirement
Understand the causes and mechanisms of CME initiation	Determine CME initiation time to within 10 minutes
	Determine location of initiation to within 5° of solar latitude and longitude
Characterize the propagation of CMEs through the heliosphere	Determine the evolution of CME mass distribution and the longitudinal extent to within 5° as it propagates
	Determine the CME speeds to within 10% as they propagate
	Determine the direction of the CME propagation to within 5°
Discover the mechanisms and site of energetic particle acceleration in the low corona and interplanetary medium	Develop distribution functions to an accuracy of 10% for electrons and/or ions with energies typical of SEP populations
	Locate regions of particle acceleration in the low corona to within 300,000 km in radius and in interplanetary space to within 20° in longitude
Develop a three-dimensional, time-dependent model of the magnetic topology, temperature, density, and velocity of the ambient solar wind	Obtain a time series of the solar wind temperature to within 10% accuracy at two points separated in solar longitude
	Obtain a time series of solar wind density to within 10% accuracy at two points separated in solar longitude
	Obtain a time series of solar wind speed to within 10% accuracy at two points separated in solar longitude
	Measure global magnetic field topology near the ecliptic by determining the magnetic field direction to within 10°

followed by at least one of the spacecraft continuing to make the full suite of measurements for the remainder of the 2-year prime mission. The minimum success 150-day interval was reached on 21 June 2007. Full success of the mission required the measurements to be made by both spacecraft for the entire 2-year interval of the prime mission, again after reaching heliocentric orbit. Full success was reached on 23 January 2009.

For each of the level 1 science requirement measurements in Table 1, several combinations of instruments from the twin spacecraft contributed so that the loss of any one instrument did not result in STEREO's inability to meet a science requirement. Also, the nominal 2-year STEREO mission scientific goals did not depend on acquiring these measurements during any particular phase of the solar cycle because the CMEs and other phenomena to be studied are common to all phases of the cycle. Although the CME rate varies from ~0.5 per day at solar minimum to several per day at solar maximum, assuming a CME rate consistent with the minimum of the solar magnetic activity cycle, we expected that STEREO would observe at least 60 CMEs in remote-sensing instruments and at least 24 interplanetary events *in situ*. Both of these expectations were met or exceeded.

PAYLOAD DESCRIPTION

The STEREO science payload consists of four measurement packages, each of which has several components, totaling at least 18 individual instruments. Together, this suite of instruments can characterize the CME plasma from the solar surface to Earth's orbit.

- *Sun–Earth Connection Coronal and Heliospheric Investigation (SECCHI)* encompasses a suite of remote-sensing instruments that includes two white-light coronagraphs, an extreme ultraviolet imager (EUVI), and two white-light heliospheric imagers (HIs), all designed to study the three-dimensional evolution of CMEs from the Sun's surface through the corona and interplanetary medium to their eventual impact at Earth. Dr. Russell Howard of the Naval Research Laboratory of Washington, DC leads this investigation.
- *In situ Measurements of PArticles and CME Transients (IMPACT)* was designed, built, and tested by an international team led by Dr. Janet Luhmann of the University of California, Berkeley. It measures the interplanetary magnetic field, thermal and suprathermal solar wind electrons, and energetic electrons and ions. IMPACT is a suite of seven

instruments, three of which [solar wind electron analyzer (SWEA), suprathermal electron instrument (STE), and magnetic field experiment (MAG)] are located on a 6-m boom deployed anti-Sunward. The remaining IMPACT instruments [low-energy telescope (LET), high-energy telescope (HET), suprathermal ion telescope (SIT), and solar electron and proton telescope (SEPT)] are all located on the main body of the spacecraft and are dedicated to measuring solar energetic particles (SEPs).

- *PLAsma and SupraThermal Ion Composition (PLASTIC)*, built by an international consortium led by Dr. Antoinette Galvin of the University of New Hampshire, provides *in situ* plasma characteristics of protons, alpha particles, and heavy ions. PLASTIC supplies key diagnostic measurements of the mass and charge state composition of heavy ions and characterizes the CME plasma from ambient coronal plasma.
- *STEREO/WAVES (S/WAVES)* was built by a team led by Dr. Jean-Louis Bougeret of the Observatoire de Paris and Mr. Keith Goetz of the University of Minnesota. S/WAVES is an interplanetary radio-burst tracker that observes the generation and evolution of traveling radio disturbances from the Sun to the orbit of Earth. As its primary sensors, S/WAVES uses three mutually orthogonal monopole antenna elements, each 6 m in length. The three monopoles were deployed anti-Sunward so that they remain out of the fields of view of Sun-facing instruments.

Table 2 gives more details about these instrument suites.

In addition to these four instrument teams mentioned above, there are several groups devoted to global modeling with the goal of understanding the connection between the solar activity observed near the Sun by SECCHI and S/WAVES and the *in situ* measurements taken by IMPACT, PLASTIC, and S/WAVES when the disturbances finally reach the STEREO spacecraft. This modeling includes the coronal plasma and the solar wind and its expansion outward from the Sun. Modeling of dynamic phenomena associated with the initiation and propagation of CMEs will be given particular emphasis. The modeling of the CME initiation includes magnetic shearing, kink instability, filament eruption, and magnetic reconnection in the flaring lower corona. The modeling of CME propagation entails interplanetary shocks, interplanetary particle beams, SEPs, geoeffective connections, and space weather.

Table 2. STEREO instruments.

Instrument	Suite Component	Purpose
SECCHI	COR1	Image CMEs 1.4–4.0 solar radii
	COR2	Image CMEs 2–15 solar radii
	EUVI	Image CME origins in the corona
	HI	Image CMEs 12–215 solar radii
IMPACT	SWEA	Measure solar wind electrons to 3 keV
	STE	Measure suprathermal electrons 2–100 keV
	SEPT	Measure electrons 20–400 keV and protons 60–7000 keV
	SIT	Measure composition He-Fe 300–2000 keV/nucleon
	LET	Measure protons, He, heavy ions to 40 MeV/nucleon
	HET	Measure protons He to 100 MeV and electrons to 8 MeV
	MAG	Measure vector magnetic field to 65,536 nT
PLASTIC	SWS	Measure protons, alpha distribution functions to 100 keV
		Measure heavy ions to 100 keV
	WAP	Measure wide-angle heavy ions to 100 keV
S/WAVES	HFR	Measure electric field 125 kHz to 16 MHz
	LFR	Measure electric field 2.5–160 kHz
	FFR	Measure fixed frequency 32 or 34 MHz
	TDS	Measure time domain to 250 ksps

SWS, solar wind sector; WAP, wide-angle partition; HFR and LFR, high- and low-frequency radio receivers; FFR, fixed-frequency receiver; TDS, time domain sampler; ksps, kilosamples per second.

STEREO ORBIT CONSIDERATIONS

During the formulation stage of STEREO, scientists from the instrument teams and mission analysts discussed several different mission designs, including drift rates and formations (e.g., both observatories ahead of Earth, both behind, or ahead and behind) for the two spacecraft. Although valid arguments existed for other formations, the selected mission design featured one spacecraft leading the Sun–Earth line while the other lagged. Likewise, scientific arguments for "slow" drift rates (e.g., a few degrees' separation per year) and for "fast" drift rates (e.g., >45° per year) were considered, and an optimum mean rate of ±22° per year (with an uncertainty of ±2° per year) was selected as the requirement. An additional goal was to minimize the eccentricity of the heliocentric orbits in order to minimize the variation in solar diameter as viewed from the spacecraft, an important consideration for the SECCHI coronagraph occulters.

There is no single angular spacing that is best for all STEREO instruments and science goals. The SECCHI coronagraphs best detect CMEs when they are relatively near the plane of the sky as viewed from each spacecraft, which would imply that an overall angle of at least 60° would be best. On the other hand, stereoscopic measurements of small features like loops visible in the SECCHI EUVI can only be made with small angular separations between the spacecraft, approximately 3–4° to perhaps 20°. Triangulation on radio emissions from Earth-directed CME-driven shock fronts would be most accurate in the 60–90° separation range. The *in situ* instruments have a scientific interest in having both spacecraft at different positions inside the same magnetic cloud, which would argue for separation angles less than 50°.

Because of these scientific considerations and the final orbit selections where the spacecraft are continually separating, the mission design had four distinct phases. Phase 1 coincided with the first year when the spacecraft were less than 50° apart when the configuration was optimum for making high-cadence three-dimensional images of coronal structures. Stereoscopic image pairs and sequences captured the three dimensions of the corona before, during, and after CMEs. It was also during phase 1 that intercalibrations between like instruments on the two spacecraft were possible.

Phase 2 was centered on quadrature between the two spacecraft with separations between 50° and ~110°, corresponding to days 400–800. During this interval, triangulation on CMEs was optimal. It was also quite likely that one spacecraft would be able to observe a CME in the plane of the sky that actually impacted the other spacecraft, thereby linking characteristics of a CME (composition, magnetic field orientation, density, and velocity at 1 AU) with its launch and propagation parameters (size, velocity, and source region characteristics).

Phases 3 and 4, corresponding to days 800–1100, would occur during an extended mission period, because the STEREO prime mission was only 2 years after reaching heliocentric orbit. During phase 3, the spacecraft are separated by angles from 110° to 180° and are both able to view Earth-directed CMEs in the plane of the sky. The two spacecraft also have a nearly complete view of the Sun, allowing the longitudinal extent of CMEs and other activity to be measured.

Beyond the 180° of separation point (phase 4), events on the far side of the Sun that launch particles toward Earth will be visible for the first time. Active regions can be tracked and studied for their eruptive potential from their emergence, wherever it occurs on the Sun. These results will have a tremendous impact on our ability to anticipate changes in solar activity and to predict changes in space weather conditions. Such predictive capability is vital if we are to build permanent lunar bases or send astronauts to Mars.

THE STEREO SCIENCE CENTER

The STEREO Science Center (SSC) at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center serves as the central facility responsible for telemetry distribution and archiving and other central functions, such as long-term science planning and coordination with the science teams as well as the central node for education and public outreach activities. The SSC also is responsible for the receipt and processing of the real-time "beacon" data, a more than 600-bit/s stream of selected data from the instruments used by the National Oceanic and Atmospheric Administration (NOAA) for space weather forecasts. The SSC is the principal interface with the scientific community and the public at large. Two STEREO websites are maintained: For the general public, the site is http://stereo.gsfc.nasa.gov; for the scientific research community, the site is http://stereo-ssc.nascom.nasa.gov.

OBSERVATIONS TO DATE

The first instrument to become fully operational was S/WAVES, which has been producing a steady stream of data since 27 October 2006—just ~2 days after launch. Solar radio emissions are caused by either energetic particles or shock waves traveling through the solar wind and exciting plasma waves at the local electron plasma frequency. These plasma waves then are converted via plasma processes into radio waves. Since the solar wind electron density generally falls off because the square of distance from the Sun and the plasma frequency is proportional to the square root of electron density, the plasma frequency also falls, so that solar radio emissions appear as drifting features when displayed in frequency–time plots. Figure 1 shows the frequency–time plots from both spacecraft (Ahead and Behind) in mirror-image format arranged so that they "meet" in the middle at the highest S/WAVES frequency (~16 MHz, corresponding to ~1–2 solar radii in altitude). Thus, from the middle, the frequency scales descend in both directions, corresponding to moving away from the Sun. The color code indicates relative intensity (relative to the instrument background, which is the ambient galactic radiation background). This particular day is from December 2006, the most active period since launch. It shows many radio bursts associated with flares, particularly at 2 hours, 8.5 hours, and 19 hours. Because flare electrons travel at a fair fraction of the speed of light, they appear as very fast drifting features on these spectrograms. Also shown are three instances of radio emission associated with much slower shocks driven by CMEs. Because these are moving at a mere 1000 km/s or so, they drift in radio frequency at a much lower rate. Using the radiospectrograms from the two spacecraft, we are able to track the path of these rapid disturbances in three dimensions.

Figure 2 also is from the active interval in December 2006 and shows observations from several of the IMPACT instruments over a period of several days (not all instruments were fully operational during this interval). The vertical dashed lines show the times of major flares and the start of associated CMEs. Figure 2 A–C show data from particle instruments, and one can see the count rates responding to the CMEs after a day or so. (The very first CME on 5 December took place on the Sun's east limb, so the CME never encountered the spacecraft. The busy period on 12 December is attributable to interference by Earth's radiation belts during a perigee pass.) Figure 2 D and E show the magnetic field data. Note particularly the signature beginning about 15 December. This is a characteristic signature of a magnetic cloud, which is the interplanetary counterpart of a CME. The magnetic cloud looks a bit like an old-time Slinky laid on its side with the helical magnetic field taking the place of the steel-spring coils. As the cloud flows past the spacecraft, the orientation of the detected magnetic field rotates around as shown by the sine wave shape of the *x* and *y* field components, B_x and B_y.

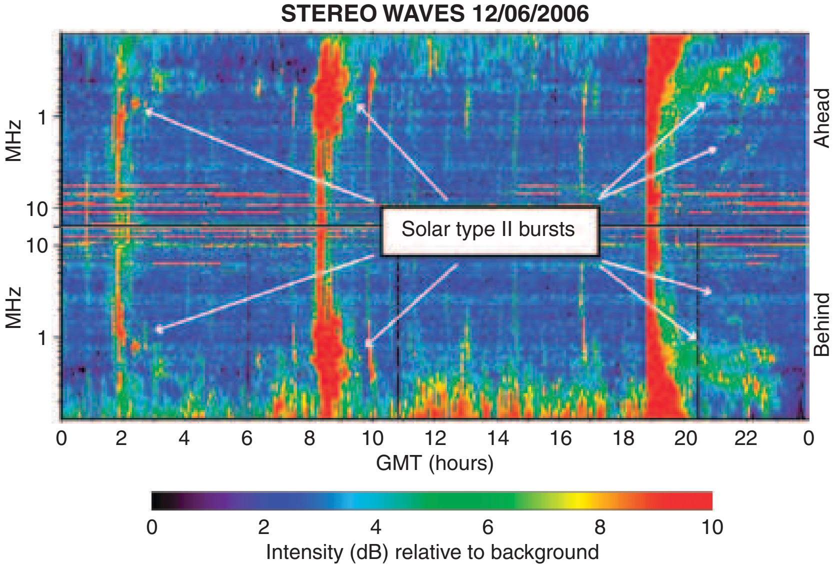

Figure 1. The very first instrument activated after launch was the S/WAVES instrument, which measures radio signals associated with solar activity and a wide variety of other (non-solar) sources. Here, the intensities of radio emissions are shown as a color-coded plot in decibels above instrumental background and as a function of observing frequency (0.125 to 16.025 MHz) versus time. Since there are two spacecraft, they are plotted together as mirror images, i.e., the Ahead plot is upside-down relative to the Behind plot. The many near-vertical streaks are emissions associated with solar flares and are called type III solar radio bursts. Additionally, several emissions associated with CMEs are shown (type II bursts). The intense bands of emission generally below 1 MHz are from high above Earth's auroral zones, the same particle population that causes the Northern and Southern lights. The horizontal streaks around 10 MHz and above are man-made shortwave transmissions. All the terrestrial sources disappeared when the spacecraft were farther from Earth.

The imaging instruments of SECCHI became active in early December and made some spectacular observations early on, not all associated with the Sun. Figure 3 shows an image of the inner corona taken by the COR1 coronagraph. Here, a small CME can be viewed lifting off the Sun. It is the large loop-like structure, much like the above-mentioned Slinky viewed end-on.

At the end of February, the Moon was aligned with the Sun as viewed by the receding Behind spacecraft, and Fig. 4 is an image of the resulting transit as seen by the EUVI instrument. The Sun itself is viewed as a combination of all four individual EUVI narrow-band filters (three in ionized iron lines and one in ionized helium) showing active regions, loops, and prominences. Superimposed is the disk of the Moon in an eerie unearthly eclipse. In addition to being awe-inspiring, this transit, which took 12 hours to complete, was actually quite useful for measuring instrumental scattered light, focus, pointing, etc.

Perhaps the most pleasant surprise has been the spectacular performance of the HI instruments. These instruments, analogous to a fish-eye lens, are the only new instruments onboard the STEREO spacecraft (all others are improved versions of previous instruments). When the doors were first opened

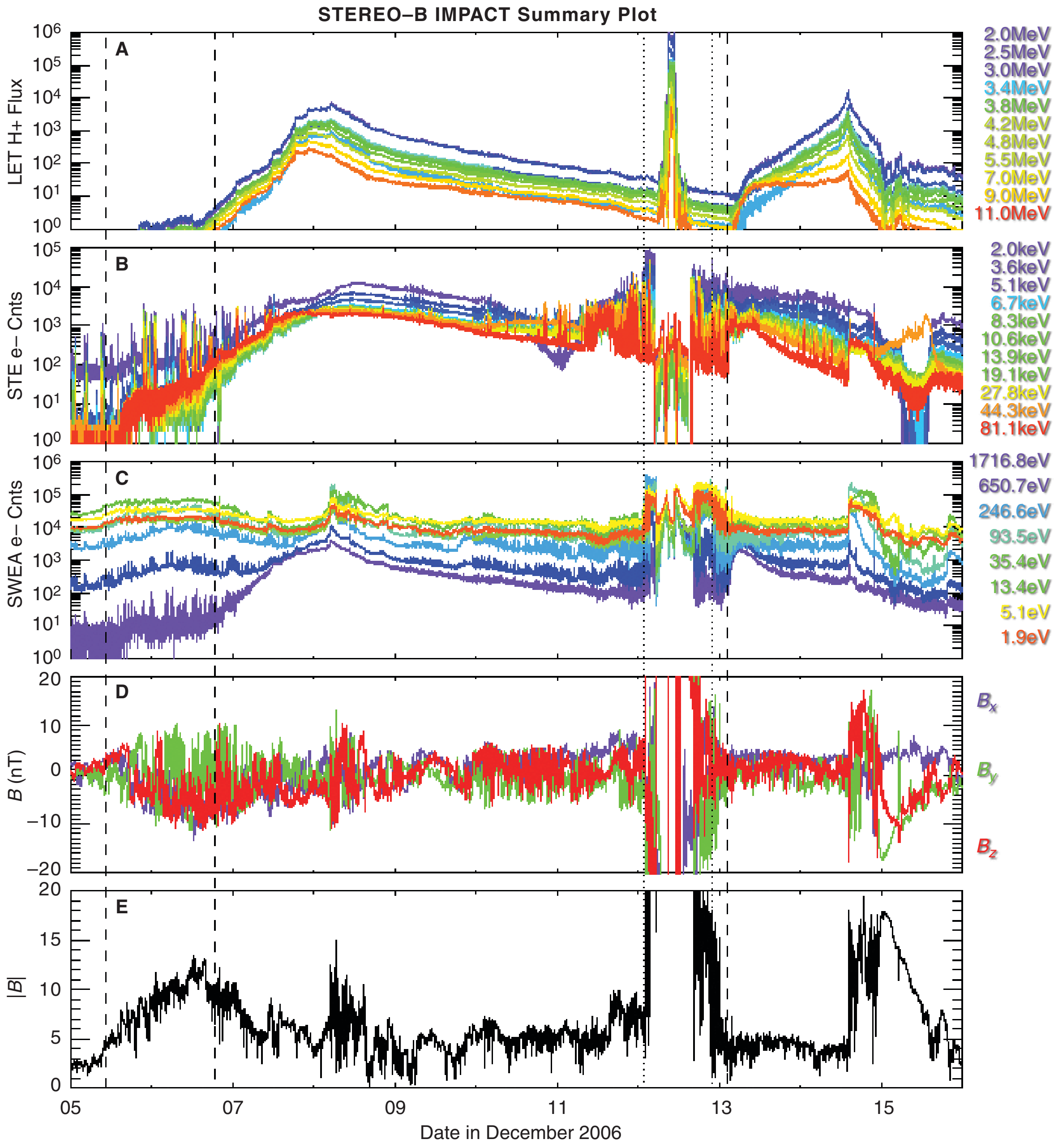

Figure 2. The most intense solar activity in the early mission period occurred during early to mid-December 2006, when many of the instruments were still in their commissioning process. Here, we show several days of data from the IMPACT instrument suite. The vertical dashed lines show the onset of major solar storms at the Sun. The response to these storms can be seen in the protons measured by LET (A) as well as the electrons measured by STE (B) and SWEA (C). D and E show the MAG measurements, individual vector components, and total intensity. The large signal seen in all instruments on 12 December 2006 is associated with a perigee pass and not with solar activity.

on HI in January 2007, Comet McNaught was directly in the field of view. Those of us in the Northern Hemisphere did not hear much about this comet because it was too close to the Sun for us to see it well and it required one to get up at a very early hour. However, our friends in the Southern Hemisphere were treated to a fabulous show. McNaught turned out to be the brightest comet since the mid-1960s, and its tail was seen stretching across a large part of the sky. Figure 5 shows HI's view of the complex, intertwined tail of the comet. The head of the comet was so bright it saturated the instrument. The very first scientific publication from the STEREO mission was, in fact, a Comet McNaught paper.[2]

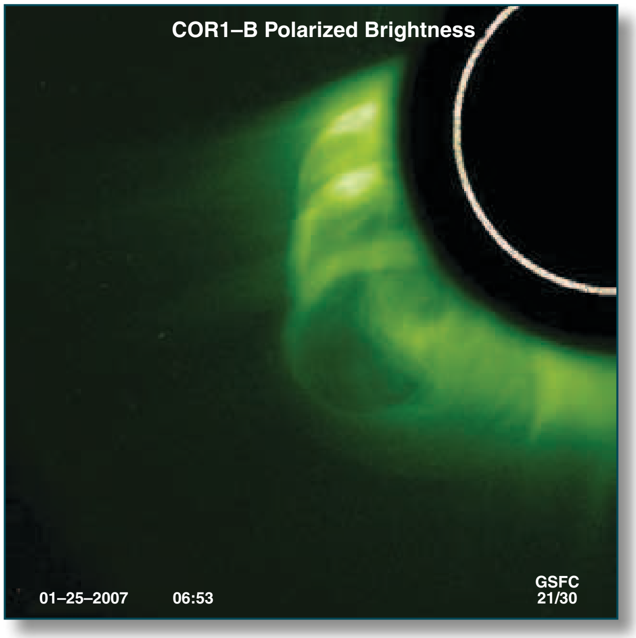

Figure 3. The COR1 coronagraph on the Behind spacecraft recorded this very nice CME, seen as a series of expanding loops. This particular CME was not Earth-directed; rather, it was nearly 90° away off the Sun's eastern limb. This view clearly shows the end-on appearance of many CMEs, similar to looking end-on at a steel Slinky, where the steel bands are replaced by magnetic loops loaded with hot, glowing plasma.

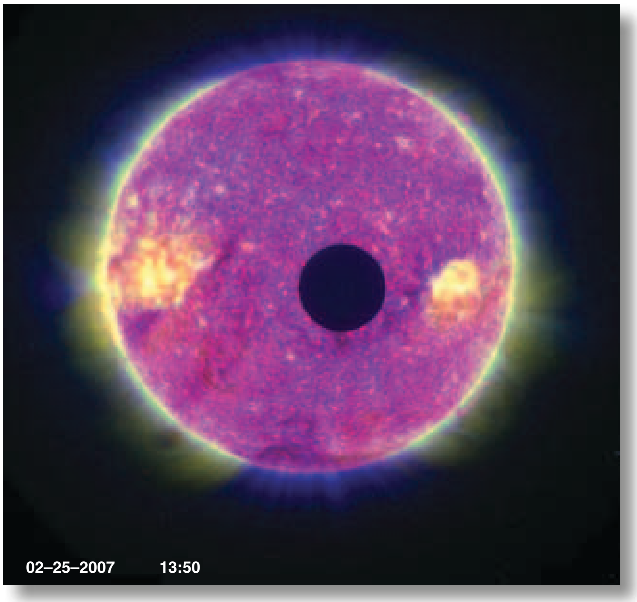

Figure 4. Just 1 month after its final gravitational assist from the Moon, the Behind spacecraft was able to witness an un-Earthly solar eclipse. In the background is the Sun as viewed by the SECCHI EUVI instrument, and superimposed in front is the disk of the Moon. However, the distance of Behind from the Moon was ~4.5 times great than the normal Earth–Moon distance, so the disk of the Moon is much smaller than in our normal solar eclipses. This observation was actually quite useful for calibration purposes, allowing estimates of instrumental scattering and focus to be made.

Figure 5. Just when the doors were opened on the SECCHI HI instrument, the passage of Comet McNaught was occurring. McNaught was the brightest comet since the mid-1960s, although it was viewed most clearly from Earth's Southern Hemisphere. This view from the HI-2 instrument on Behind covers a 70°-wide swath of sky. The Sun is off to the right and out of view. Stars from the Milky Way can be seen. The Andromeda galaxy (M-31) is in the upper left. Superimposed on all of this are filaments from the extended tail of Comet McNaught. Many studies of the details of this tail structure are underway—yet another example of the importance of serendipity in space missions.

Finally, Fig. 6 shows the combined images from all the HI instruments covering a wide swath of the sky—approximately 150° wide. In the center (and out of view) is the Sun itself. The Earth–Moon system can be seen as well as Mercury and Venus and other well-known celestial objects. Even Comet McNaught, now much farther from the Sun than in Fig. 5, can be seen. However, the main goal of the HI system was to view CMEs far from the Sun. CMEs are only visible because sunlight is reflected light by their constituent electrons. The Sun's light intensity falls as distance squared from the Sun, plus the CME is expanding at roughly distance squared from the Sun. Thus, CMEs far from the Sun are extremely dim. Nifty as Fig. 6 is, all that "stuff" has to be carefully subtracted out to see CMEs. A few examples exist thus far, but the Sun has generally been very quiet (near solar minimum), so stay tuned for forthcoming images.

CONCLUSIONS AND FUTURE STEREO RESEARCH

In this article, we have presented some of the very early data obtained by the STEREO spacecraft when they were still quite close together. During the ensuing

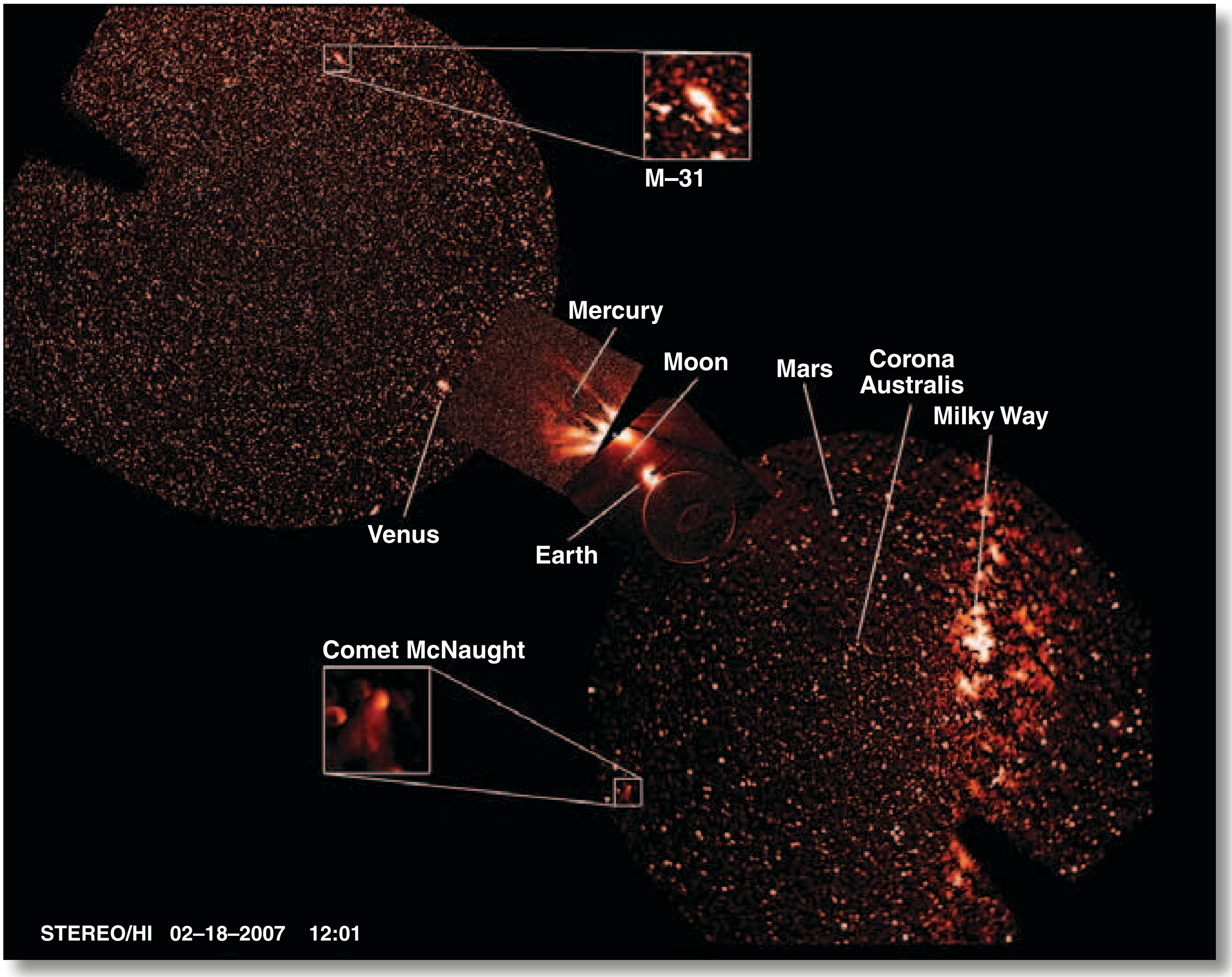

Figure 6. Literally half of the sky in a single view can be made by combining all of the coronagraph and HI images from the two STEREO spacecraft. The view covers the angular range from the Sun in the center out to ~90° in both directions along the ecliptic. Several planets as well as the Earth and Moon can be seen as can Comet McNaught, now much farther from the Sun than in Fig. 5. Again, the Andromeda galaxy (M-31) can be seen at the top left, and the Milky Way is at the right.

months, the widening separation allowed three-dimensional viewing of coronal loops and other small structures to be made and, on a larger scale, two-spacecraft triangulation of solar storms. These three-dimensional and triangulation measurements should greatly improve our understanding of solar storms from their origins to their propagation through space between the Sun and Earth. This research could pave the way to better predictions of the arrival of solar storms at Earth, important for many diverse aspects of our electronic world and likely of importance to future astronauts.

As the spacecraft separated more and more, the Behind spacecraft began to see beyond the Earth-facing eastern limb of the Sun. Since the Sun rotates from east to west, Behind's view can provide a preview of upcoming storms and other solar activity that will eventually rotate around to face Earth. This also will be very important for longer-term forecasts of space weather. Eventually, the two spacecraft will be 180° apart and will provide, for the first time, a complete view of the entire Sun, allowing us to monitor the continually changing solar surface and active regions.

Serendipity will continue to play an important and unpredictable role in the STEREO mission. There is no doubt that the wide-angle views provided by the SECCHI suite will be important for many areas of non-solar research such as comet science and variable star monitoring. Also, the very orbits of the STEREO spacecraft take them through regions of the inner solar system that have been sampled either very rarely or not at all by previous missions and will undoubtedly produce some surprising results about the composition of our solar system.

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The Author

Michael L. Kaiser (not pictured) is a research scientist emeritus with the Heliophysics Science Division at NASA Goddard Space Flight Center. Until his retirement in June 2009, he was the Project Scientist for the STEREO mission and also was the Deputy Principal Investigator of the S/WAVES investigation. In addition, he was the Principal Investigator of the WAVES experiment on the NASA Wind spacecraft and on the Voyager Planetary Radio Astronomy (PRA) experiment performed during Voyager's interstellar mission (1989 to present). He is a co-investigator on the Ulysses Unified Radio And Plasma wave (UARP) experiment and the Cassini Radio and Plasma Wave Science (RPWS) team. Mr. Kaiser received his M.S. in Astronomy from the University of Maryland in 1971. His research interests include low-frequency radio astronomy with particular emphasis on planetary and solar emissions. He is an author of approximately 225 scientific publications and has received the NASA Exceptional Scientific Achievement Medal and numerous group achievement awards. He is a member of the American Geophysical Union, the International Union of Radio Science, the European Geophysical Union, the American Astronomical Society/Solar Physics Division, and the Institute of Electrical and Electronics Engineers. His e-mail address is michael.kaiser@nasa.gov.