

STEREO MISSION: OVERVIEW, THE PLASMA INSTRUMENT, CALIBRATIONS AND DATA

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Abstract

This is an overview of the next generation solar space mission called STEREO. We focus on the plasma instrument and its calibrations at the University of Bern. The management of the plasma data is also discussed briefly.

KEYWORDS: *solar-terrestrial mission, space physics*

1. Mission overview

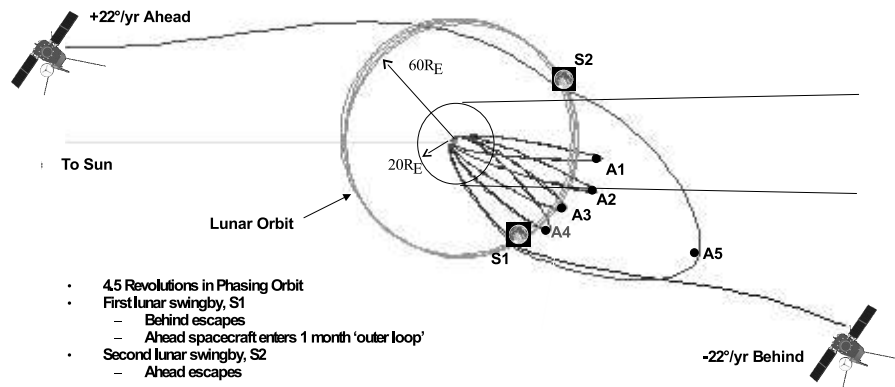


Figure 1: STEREO launch trajectory (figure provided by JHU/APL under NASA contract NAS5-97271 Task Order 28).

Solar Terrestrial Relations Observatory (STEREO) is the third mission in NASA's Solar Terrestrial Probes (STP) program. Its primary goal is to advance

the understanding of the three dimensional structure of the Sun's corona and its temporal evolution, especially regarding coronal mass ejections (CME). This mission will provide a totally new perspective on solar eruptions by imaging from two nearly identical space-based observatories simultaneously. One observatory will be placed ahead of the Earth in its orbit and the other behind using a series of lunar swingbys (see Figure 1). The launch is currently scheduled for February 2006.

The overall objective of the STEREO mission is to obtain the necessary measurements and observations to develop an understanding of the fundamental nature and origin of CMEs, which are the most energetic eruptions on the Sun and the primary cause of major geomagnetic storms.

The specific science objectives of STEREO are to understand the causes and mechanisms triggering CMEs, to characterize their propagation through the heliosphere, to discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium, and to develop a 3-dimensional, time-dependent model of the magnetic topology, temperature, density and velocity structure of the ambient solar wind.

2. Instrumentation

There will be two nearly identical observatories both containing four instrument packages: SECCHI, SWAVES, IMPACT and PLASTIC.

2.1. SECCHI

Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) combines a suite of five optical telescopes that will image the Sun and the heliosphere up to Earth orbit. It consists of three types of telescopes: an extreme ultraviolet imager, two LASCO-type coronagraphs and a heliospheric imager.

2.2. SWAVES

STEREO/WAVES (SWAVES) consists of three radio receivers (fixed, high and low frequency receivers) and a time domain sampler. It will track electromagnetic disturbances through the heliosphere.

2.3. IMPACT

In-situ Measurements of Particles and CME Transients (IMPACT) consists of two packages. The solar wind electron analyzer, the suprathermal electron telescope and the magnetometer are located on a mast anti-sunward. The solar energetic particle experiment consists of a solar electron proton telescope, a suprathermal ion telescope, a low and a high energy telescope. This experiment will focus on *in situ* observations of energetic particles.

2.4. PLASTIC

Plasma and Suprathermal Ion Composition (PLASTIC) consists of an entrance system containing an electrostatic analyzer (ESA) connected to a time-of-flight (TOF) chamber (see Figure 2). It is the primary *in situ* solar wind instrument.

3. PLASTIC instrument

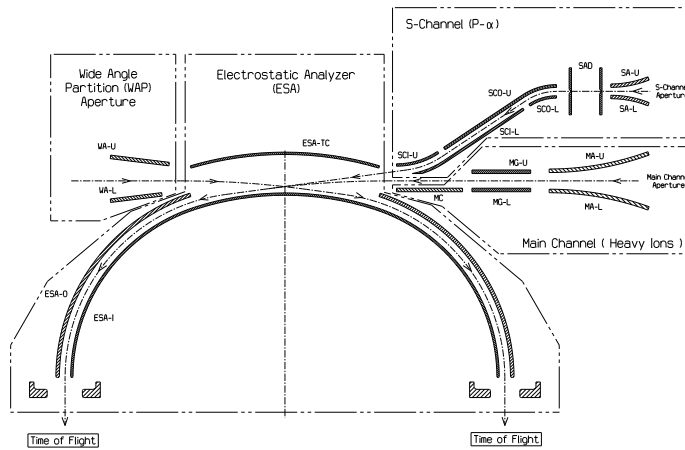


Figure 2: Drawing of the PLASTIC entrance system.

The instrument will measure *in situ* various solar wind species in the energy-

per-charge range of 0.2 to 100 keV/e. There are three science measurements combined into one instrument: S-channel, main channel and WAP (Allegrini, 2002).

3.1. S-channel

The Solar Wind Sector S-channel will measure the distribution functions of solar wind protons and alpha particles providing density, velocity, kinetic temperature and its anisotropy. The time resolution will be about one minute.

3.2. Main channel

The Solar Wind Sector main channel will measure the elemental composition, charge state distribution, kinetic temperature and velocity of the more abundant solar wind heavy ions (e.g. C, O, Ne, Mg, Si, and Fe) on at least five minute resolution.

3.3. WAP

The Wide Angle Partition (WAP) will measure the distribution functions of suprathermal ions ($E > 10\text{keV/nucleon}$) with a comparatively large geometrical factor that allows the study of suprathermal particles including shock-accelerated particles and pick-up ions.

4. Calibrations of the PLASTIC entrance system

Several calibration activities of the STEREO PLASTIC entrance system are performed at the Physikalisches Institut at the University of Bern. Namely the partial discharge tests, vibration, thermal cycling, ion optics and UV suppression. In this section, after a brief description of the calibration facilities we focus on measurement functionality, thus discuss the ion optical and the UV suppression calibrations.

4.1. Calibration facilities at the University of Bern

There are two main calibration facilities for solar wind instrumentations at the University of Bern: CASYMS and MEFISTO.

4.1.1. CASYMS

CASYMS stands for CALibration SYstem for Mass Spectrometers. This facility provides a large-area ($\sim 250 \text{ cm}^2$), parallel beam of ions over the energy per charge (E/q) range from 5 eV/e up to 100 keV/e (Ghielmetti et al., 1983). The gas atoms (e.g. argon, helium, hydrogen) are ionized by an electron filament and then redirected and accelerated by electrostatic lenses.

The beam is guided into a vacuum chamber, where an instrument can be mounted on a x-y-z-table, which can also be rotated either in α - or the perpendicular β -direction. All table manipulation are controlled by computer as well as the beam energy and monitoring.

4.1.2. MEFISTO

MEFISTO stands for MEsskammer für FlugzeitInStrumente und Time-Of-Flight (calibration facility for solar wind instrumentations). This system provides a well focused ion beam at a beam energy per charge up to 100 keV/e (Marti et al., 2001). The ions are produced in an electron-cyclotron-resonance ion source (ECRIS) operating at 2.45 GHz from elements in gaseous or solid phase. For solid elements, a high temperature furnace emits vapor into the ion source. Highly charged ions can be produced with this device, which are guided by electrostatic lenses towards the main vacuum chamber. The desired mass per charge is selected with a velocity filter and the energy per charge is selected by the electrostatic analyzer.

In the vacuum chamber the instrument or sample can be mounted on a table, which can be turned either in α - or β -direction. There is also an ultraviolet light source in the chamber suitable to simulate the solar coronal UV radiation.

4.2. Ion optics

The entrance system of PLASTIC is calibrated at the University of Bern in the two calibration facilities described above (MEFISTO 4.1.2. and CASYMS 4.1.1.).

For the ion optical calibrations a monoenergetic Ar^+ or He^+ ion beam is used to simulate incident solar wind. During the calibration tests the voltage of the entrance system electrodes (ESA, SCO-L, SCI-U, etc.; see Figure 2) were tuned to particular voltages so that the ions were deflected through the entrance apertures and the ESA-hemisphere. The ratio between beam energy per charge E/q and the tuned voltage difference over the ESA-hemisphere voltages is called *analyzer constant*: $k = \frac{E/q}{V_{\text{electrode}}}$ (Allegrini, 2002 and Blush et al., 2003).

The ion optical calibrations are in progress. Preliminary results show good agreement with the data obtained when calibrating the engineering qualification model and the simulation results.

4.3. UV suppression

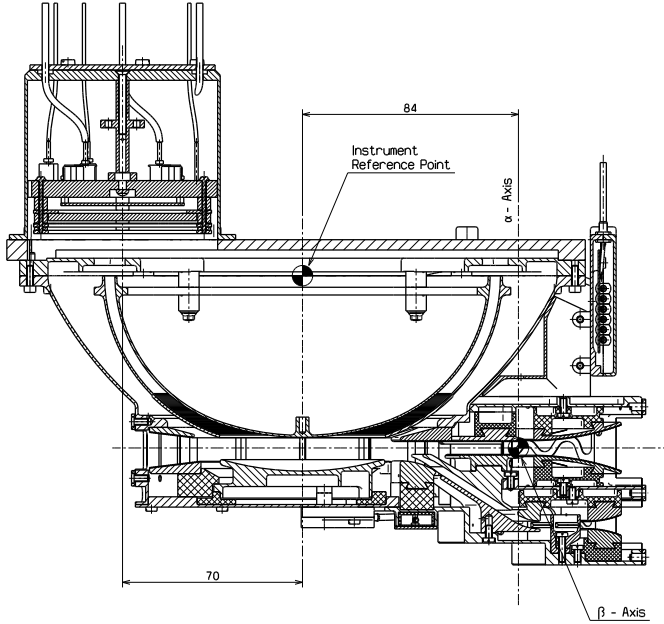


Figure 3: UV suppression calibration setup of the PLASTIC entrance system.

Ion measurements might be contaminated by energetic ($> 5\text{eV}$) photons. Solar UV can generate spurious detector counts on the carbon foil and the multi channel plates (MCP). Hence the ultraviolet radiation arriving onto the detectors must be suppressed as much as possible. We define the suppression factor as the ratio of the flux on the entrance slit and the flux on the exit slit.

The solar UV flux is approximately $2.5 \cdot 10^{14} \frac{\text{photons}}{\text{cm}^2 \cdot \text{s}}$ from the photosphere,

and subtends an angle of 0.5° at 1 AU. The entrance system is specially designed that photons entering at an angle lower than 1.24° cannot get into the instrument, hence photons from the photosphere are excluded. Photons with a coronal origin of 1.24° to 4.1° may enter the hemisphere, thus they might affect the measurements. The coronal UV flux is lower than the photospheric flux by a factor of 10^6 . As a result, a suppression factor of 10^8 - 10^9 is necessary if we want $1 \frac{\text{photon}}{\text{cm}^2 \cdot \text{s}}$ to avoid a high background caused by energetic photons.

That's why the inner surfaces of the PLASTIC entrance system were blackened by CuS. It is a rough surface, which isotropically scatters and absorbs photons. Due to the blackening only a very small portion of the incoming photons can get through the instrument and affect the measurement count rate, which was confirmed by the calibrations done in the MEFISTO laboratory. The suppression factor is of the order of 10^9 .

5. PLASTIC data

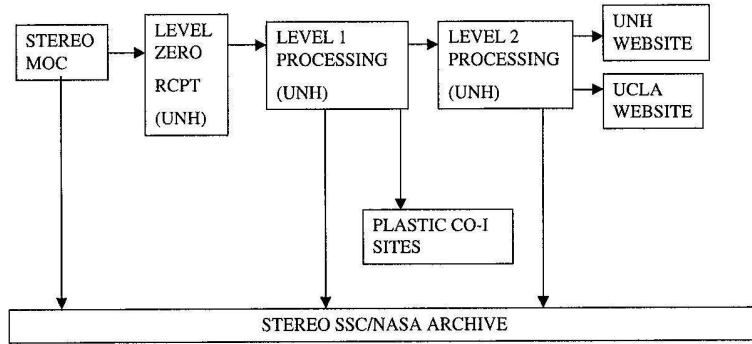


Figure 4: PLASTIC data flow from receipt from the STEREO Mission Operation Center through to the data archive at the STEREO Science Center.

The data products from PLASTIC are the composition, distribution functions, and time history of the solar wind and suprathermal positive ions. Solar wind measurements and identification of structures will be possible under nearly all types of solar wind conditions, including high-speed streams, interplanetary CMEs, and slow solar wind. The PLASTIC Data Center at the University

of New Hampshire will collect the Level-0 (binary) data and a software will automatically convert it into Level-1 (ASCII) data. Level-2 data consists of one-minute summary data sets containing solar wind proton density and speed, and proton temperatures, proton anisotropy referenced to the magnetic field, major ion species' densities, and suprathermal ion fluxes and anisotropies in several energy ranges, and beacon data for comparisons with the calibrated and cleaned final values of the same quantities. The Level-2 data will be available on the website of the University of California at Los Angeles (UCLA). Level-3 products result from basic scientific analyses of the PLASTIC Level-2 data with cooperation with the IMPACT, SWAVES and SECCHI teams. The planned dataflow is shown in Figure 4 (Kistler, personal communication).

6. Summary

A new solar mission has been discussed, which will give a three dimensional view on the solar corona. The STEREO mission is in progress and will be launched in February 2006. The flight models of the PLASTIC instrument were manufactured and are being calibrated. Preliminary results indicate that the instruments meet the specifications.

Acknowledgments

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