

# A SOHO User Manual

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**Abstract.** This paper is intended to serve as the first version of the “SOHO User Manual”, a “how to” guide for those interested in analyzing existing SOHO data, or proposing new SOHO observations. Questions addressed are, how to use the SOHO catalogs, where to find the appropriate data analysis software, how to request permission to use proprietary data, how to propose and prepare SOHO observing programs.

In an outlook to the future I will emphasize the potential for joint observations during the rising phase of the cycle in the extended SOHO mission, collaborations with Yohkoh, Ulysses, and TRACE, as well as with the ISTP spacecraft.

## 1 SOHO Data Libraries

### 1.1 Description

Four SOHO data libraries (archives) are under construction, one in the US, at the SOHO Experiment Analysis Facility (EAF) at Goddard Space Flight Center, and three in Europe, at Medoc in Orsay, Rutherford Appleton Laboratory in the UK, and in Torino. The libraries at Goddard and Medoc are operational, and the one at Goddard is accessible via the Web. The SOHO data libraries contain the data from all the SOHO experiments, except for the MDI helioseismology data, that are stored in a separate facility at Stanford, and also retrievable via a Web interface.

The purpose of these data libraries is to facilitate multi-experiment SOHO data analysis, and to make the data easily accessible (via the Internet) for the widest possible group of scientific users. To achieve this goal the SOHO data library features:

- a uniform data format (FITS)
- uniform access to all experiment archives
- a campaign catalog that cross-links experiment data of coordinated observations
- a complete set of supporting synoptic data
- a complete set of analysis software, regularly updated with user contributions

The data library is completed by a set of catalogs, with open access again via the Web. These catalogs are:

- SOHO Main Catalog
- Event Catalog
- Campaign Catalog
- Picture Catalogs:
  - SOHO Summary Data (A set of daily representative images)
  - Synoptic Data (Daily images from other observatories and spacecraft)

For access see the SOHO Homepage at <http://sohowww.nascom.nasa.gov>, and press the button *Data Archive*. A more detailed description of SOHO science operations and data products can be found in St. Cyr et al. (1995).

## 1.2 Data Library versus Data Archive

Data from space missions are often archived after the mission has been completed. The tremendous growth in storage and processing speed of workstations, as well as the explosive growth in the use of the Internet, has made it feasible and desirable to have a “live” archive, also called data library. The desirability is most easily understood by considering figure 1, which is a hypothetical curve of the data-use for an average space mission. Data use is a hard to measure quantity, but one may assume that it is roughly proportional to publication rate, and precedes that by a year or two. Clearly it will take off rapidly as data become available after launch. It will even grow more as data enter the public domain, which is typically one year after the observation. One may assume it will continue growing at a smaller speed until around the end of the mission when a gradual decline sets in. Data use curves will of course vary from mission to mission, but it is to be expected that most of it has occurred two or three years after the completion of the mission, at which time a “traditional” archive would become operational.

Prior to launch the ESA and NASA SOHO Project Scientist’s teams have set themselves the goal of having a SOHO data library operational at the start of SOHO’s science operations. The SOHO archive was declared operational in early January 1997, well within the early phase of the mission. Thus the goal of preparing a “live” archive has been largely achieved.

## 1.3 Data Analysis Software

SOHO data analysis software is embedded in “SolarSoft”. According to its Web page at [http://www.space.lockheed.com/solarsoft/ssw\\_whatitis.html](http://www.space.lockheed.com/solarsoft/ssw_whatitis.html), “the SolarSoft system is a set of integrated software libraries, data bases, and system utilities which provide a “common” programming and data analysis environment for Solar Physics. The SolarSoftWare (SSW) system is built from

**Fig. 1.** Figure 1: A hypothetical data use curve for a space mission

Yohkoh, SOHO, SDAC and Astronomy libraries and draws upon contributions from many members of those projects. It is primarily an IDL based system, although some instrument teams can and do integrate executables written in other languages. The SSW environment should provide a consistent look and feel at various Co-I institutions (SOHO, Yohkoh, etc) which will facilitate sharing and exchange and minimize “coming-up-to-speed” time when doing research away from your home institute.”

One of the primary goals of the SSW is to “promote the use of certain standards which facilitate coordinated data analysis”.

Some of the capabilities of SSW are: time series analysis, spectral fitting, image and image cube (movies) display, IDL data manipulation (structure, string, array, mathematics...), FITS, solar limb fitting, grid overlay, and coordinate transformations.

Solarsoft accepts user contributed software, after testing, and if sufficiently documented in the required format.

#### 1.4 Data Access

Access to SOHO data in the Public Domain is open to everyone via the Web interface given above, while access to proprietary data is limited in accordance with the rules set by the SOHO Science Working Team. For the current availability see: <http://sohowww.nascom.nasa.gov/whatsnew/archivenews.html>.

MDI data are public immediately and in the extended mission, after May 1998, the data from all US experiments (MDI, UVCS, LASCO) will be in the public domain immediately.

Other ways to gain access to SOHO data, or to propose new observations are:

- The official ESA/NASA Guest Investigator program with funding through national agencies in Europe. For more information see:  
*[http://sohowww.nascom.nasa.gov/operations/guest\\_investigators/](http://sohowww.nascom.nasa.gov/operations/guest_investigators/)*
- Collaborations between SOHO and Ground Based Observatories or other spacecraft, usually with exchange of data
- SOHO workshops and symposia, with open participation
- Collaborations through SOHO experiment teams on data analysis and new observing programs
- Visits to Goddard and MEDOC to participate in daily operations, develop observing programs, and for data analysis.

### 1.5 Searching for SOHO Observations

The starting point in finding SOHO observations are the SOHO catalogs, either the SOHO main catalog, campaign catalog, or the individual experiment catalogs. These are accessed via the SOHO Archive Web pages, at the URL given above, via Web forms.

If one is interested in multi-experiment coordinated observations, often in collaboration with other spacecraft or Ground Based Observatories (GBO's), the campaign catalog is the best starting point. It can be searched on “keyword”, for example the date and time of the observations, or a significant word in the name of the campaign, e.g. “filament”, or “coronal hole”. One can also search on the names of participating experiments or observatories, campaign type (Joint Observing Program, Intercalibration, collaboration, or campaign), the name of the campaign coordinator, or a word match in the campaign objective or comments fields.

This search will yield the campaign descriptions of the matching entries, and the Coordinated Observation ID #'s. These numbers can then be used as entries in the main catalog to retrieve the desired experiment data, according to the procedure described below.

For most specific searches the main catalog will be used directly. Here too searches are by “keyword”, such as the time and date of observations, SOHO instrument, object of the observations (e.g. Sunspot), observing mode, wavelength, detector, coordinates of the target, campaign ID #, etc. Submitting the search will yield a page called the “Database Query Result”, with links to the relevant experiment observing programs. For example, a recent search on the object keyword “Comet” produced 194 matching program numbers. Following these links one arrives at the file names of the data in the experiment catalogs, which then can be retrieved over the Web.

If the observing programs listed contain data that are not yet in the Public Domain, and one is not authorized by the instrument Principal Investigator to

access these data, this will be indicated in the list for each relevant observing program, and further access to the data files will be blocked.

The Web interfaces for SOHO catalog searches and data retrieval are being enhanced to reflect lessons learned from a comparison with other on-line data libraries, and in response to comments and requests from the user community. The goal is to reach a stable interface in early 1998.

## 2 Planning of SOHO Observations

### 2.1 Preparing New Observations

Often, for a very specific research project, the exact data needed do not exist, and new observations have to be proposed. In this section I will present guidelines on how to propose new observations with the SOHO experiments.

For single experiment investigations the procedure is rather simple. Contact the PI of the experiment in question with a brief proposal and scientific justification, or apply to the SOHO Guest Investigator Program. Several experiments have set up a mechanism for submitting observing proposals on their Web pages (see <http://sohowww.nascom.nasa.gov/instruments.html>). If your observing proposal is accepted, the PI will link you with a technically competent team member to develop observing sequences. The observing sequences will need to be worked out in detail and tested, and the observations will be scheduled when appropriate in the experiment schedule.

For multiple experiment studies – anything from a collaboration between two SOHO experiments to full fledged multi-site, multi-spacecraft campaigns more coordination will be required

For SOHO observations one should contact the PI's of the relevant experiments and the Science Operations Coordinator (SOC) with a brief proposal and scientific justification, or apply to the Guest Investigator Program. Simultaneously one should contact the relevant people for other spacecraft (Ulysses, Yohkoh, TRACE, etc.), and any Ground Based Observatories. If your proposal is accepted you will be linked up with technically competent SOHO team members to develop observing sequences, and your campaign will be reviewed and scheduled at the monthly planning meeting.

If the campaign is sufficiently complex, or if it is intended to be repeated several times, you will be asked to write it up as a SOHO Joint Observing Program (JOP), which will be posted on the SOHO Web pages. You will be assigned as JOP or campaign leader, and must negotiate the observing dates and times with all parties involved, and keep the SOC informed. Your final observing times will be listed on the Monthly Calendar after approval at the monthly meeting. In the weekly meeting prior to your observations, a detailed timeline for the SOHO observing program will be created, including your JOP. During the observations you must be either present at the EOF, or closely in touch, to coordinate target selection and deal with last

minute issues. When the observations have been completed you are required to complete the campaign information in the campaign catalog.

In this section several resources for SOHO Planning have been introduced, such as the monthly calendar, the weekly timeline, the daily target list, the JOP list, and the campaign catalog. All of these can be found from the SOHO Operations Page at: <http://sohowww.nascom.nasa.gov/operations/>.

## 2.2 Ingredients of a SOHO JOP

A SOHO JOP proposal must contain the following information:

- Title, Author(s), Update History
- Participating SOHO Experiments, and Other Observatories
- Scientific Objective
- Scientific Justification
- Detailed Observing Sequences per Experiment
- Operational Considerations (e.g. direct S/C contact required, method for target selection, fall-back strategies)

For specific examples see again the SOHO Web pages. At present there are more than 70 “official” SOHO science JOPs, and 13 intercalibration JOPs.

## 2.3 Scientific Analysis

Once data have been obtained the JOP or campaign leader will normally be given proprietary data rights for a year or so by the PI’s of the experiments involved. Feedback and guidance with the scientific analysis can be obtained from team members of the experiments involved or through presentations and discussions at the numerous SOHO related workshops and symposia. Informal workshops intended for multi-experiment (SOHO and non-SOHO) data analysis are quite frequent. A current list of meetings relevant for the SOHO community can be found by following the link from the SOHO Homepage.

One is requested to enter papers resulting from data analysis or theoretical work based on SOHO results in the SOHO Bibliography & Publications Database at <http://sohowww.nascom.nasa.gov/bibliography/>.

Little has been said in the above about the observations of the SOHO helioseismology experiments (GOLF, VIRGO, and MDI). The reason is that these experiments are mainly devoted to obtaining long time series of the same observable. Little or no coordination with other experiments is required for that. A very active program of scientific analysis of SOHO helioseismology data is being carried out, and those interested should either visit the experiment Web sites or visit one of the many helioseismology workshops and conferences to find out how to get involved.

### 3 Future Observations

SOHO will be operated for probably at least four more years beyond the end of its nominal mission in May 1998. This puts it in an excellent position to study the rising part of cycle 23. Some of the studies proposed for the rising part of the cycle are summarized below.

First there is the study of the large scale structure of the solar corona the goal of which is to understand the large-scale, stable, coronal structure of equatorial helmet streamers and polar coronal holes that can persist for several solar rotations at solar minimum. This study has been run for a whole month continuous in August 1996 (Whole Sun Month) and will be repeated several times during the remainder of the SOHO mission, to provide a unique data set for the study of the evolution of the large scale corona as a function of the phase of the Solar cycle.

Second there is the study, and the effort of early detection, of earth directed CME's, a key part of the overall International Solar Terrestrial Physics Program (ISTP) to study the Sun-Earth system. As the magnetic activity in cycle 23 rises, CME's will become more frequent and stronger, and the SOHO experiments, through their coordinated "CME-watch" observing programs, will be able to build up a statistically significant database of predictions versus occurrence for earth-directed CME's. At the same time the collaborating ISTP missions will collect data to study the observed strength and impact on the magnetosphere of CME's as a function of the physical parameters at their Solar origin.

Thirdly, and somewhat related to the second goal, there is the question of the relation between the eruption of filaments, CME's, and X-ray flares. Even in the present, quiet part of the cycle, SOHO experiments have regularly observed filament eruptions and subsequent CME's, but large X-ray flares, detected by Yohkoh and GOES, have been relatively rare. As the cycle progresses X-ray flare activity will increase, and a key issue is whether CME's and filament eruptions will increase by the same percentage, or whether the nature of the filament eruption/CME/flare events changes in that relatively more energy is expended in high energy X-ray and gamma-ray emission.

Figure 2 shows the timelines for SOHO, Ulysses, Yohkoh, and TRACE. Yohkoh will keep on observing for as long as possible, and many of its observations are done jointly with SOHO. Ulysses will have a second perihelion passage over both poles early in the next century and joint observations with the other spacecraft will most certainly enhance our knowledge of the solar polar regions.

TRACE (the Transition Region and Coronal Explorer) is one of NASA's "faster, cheaper, better" missions, scheduled for launch in early 1998. It will operate in a polar orbit with 8 month intervals of continuous Sun viewing. For more information see <http://www.space.lockheed.com/TRACE/welcome.html>. The TRACE mission operations team intends to merge its daily meeting with that of SOHO, use the same planning tools and procedures as SOHO,

**Fig. 2.** Timelines for four major coronal and heliospheric science missions

and in general use the SOHO UV quicklook data as a reference for target and program selection for their high resolution, high cadence, UV and EUV partial field-of-view studies.

Finally ACE, the Advanced Composition Explorer, a solar wind studies mission, is also located near the first Lagrangian point. ACE science data will complement and enhance the data from SOHO's solar wind analyzers, CELIAS, COSTEP, and ERNE.

New GBO's such as the new French-Italian vector magnetograph THEMIS at the Canary Islands, and the Chromospheric Helium Imaging Photometer (CHIP) operating at the Mauna Loa Solar Observatory, as part of the HAO Advanced Coronal Observing System, will further expand the range of potential science objectives for joint studies.

## References

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