THE SOLAR AND HELIOSPHERIC OBSERVATORY

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In the past years several space missions have been proposed for the study of the Sun and of the Heliosphere. These missions were intended to clarify various different aspects of solar physics. For example, the GRIST (Grazing Incidence Solar Telescope) mission was intended as a means to improve our knowledge of the upper transition region and low corona through the detection of the solar EUV spectrum with a spatial resolution larger than in previous missions; the DISCO (Dual Spectral Irradiance and Solar Constant Orbiter) and SDO (Solar Dynamics Observatory) missions were proposed to gat observational data about the solar oscillations better than those obtained from ground based instruments; the SOHO (Solar and Heliospheric Observatory) mission was initially proposed to combine the properties of GRIST with the study of the extended corona (up to several radii of heliocentric distance) by observing the scattered Ly-alpha and OVI radiation, which was also the basis of the SCE (Solar Corona Explorer) mission proposal; the development of the interest about the variability of the Sun, both in itself and for its consequences in the history of the Earth, led to propose observations of the solar constant (included in DISCO).

It has become apparent, at a certain stage, that the purposes of all these missions could be accomplished by a single spacecraft with the appropriate orbit and that this spacecraft could also accomplish extended measurements of the physical parameters of the interplanetary plasma and therefore include the concept of interplanetary missions (like, for example, IPL (Interplanetary Plasma Laboratory)). This led to the concept of the present SOHO mission.

The SOHO mission is therefore the product of a considerable process of criticism and synthesis accomplished on several previous projects.

A process of this kind has also been accomplished on a larger basis by a reconsideration of all the space projects proposed in the field of solar-terrestrial physics. This has led to the formulation of the International Solar-Terrestrial Physics (ISTP) Program as a collaborative effort of the American, European and Japanese space agencies. The present plans envisage a "core" ISTP program which consists of 6 spacecraft: of these SOHO would investigate solar oscillations and coronal features and monitor the solar wind; WIND, GEOTAIL, EQUATOR and POLAR would measure the plasma in the regions of origin and storage near the Earth; and CLUSTER (an ensemble of 4 close spacecraft) would observe the small scale structure of the plasma in the polar and middle magnetosphere and in the solar wind. This is considered at present the minimum requirement for the study of solar-terrestrial physics in the 1990's. Beyond this core program, and coordinated with it, other spacecraft, balloon and ground based observations are expected to take place.

Therefore, although originally proposed within ESA, where a phase A study on it is now under way, the SOHO mission will very likely become a joint ESA-NASA effort in the frame of the ISTP program.

The scientific aims of the mission, which sum up the purposes of several previously proposed missions, as said above, can be divided into 4 categories:

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(a) constitution of the solar interior;
(b) high resolution structure of the transition region and low corona;
(c) structure of the extended corona and acceleration of the solar wind;
(d) structure of the heliosphere.

To fully meet the requests of the coronal observations and to avoid any phase problem caused by an observational window in the oscillation observations, the orbit should stay permanently in sunlight. The study of the variations of the solar constant requires an observation time of the order of a few years, and a similar period of time is needed by the study of the solar oscillations, to enhance the signal to noise ratio. An observation time as long as this is highly desirable by the other investigations.

An orbit close to L1 (1.5×10^6 km from Earth) satisfies all these requirements. (A positioning exactly at the libration point must be avoided because of solar interference on radio links.)

Therefore SOHO is planned as a three-axis stabilized spacecraft to be placed in a halo orbit around the Lagrangian point L1. It has a payload module dedicated to Sun pointing instruments and a "housekeeping" module carrying not only spacecraft subsystems but also some solar wind instruments. The spacecraft is pointed toward the Sun with an accuracy of 10 arcsec and the payload module is designed as a rigid lightweight structure in order to provide accurate mutual alignment between the various scientific instruments. The mission is planned to last 2 years.

(a) The solar interior will be studied by SOHO by means of the following instruments:

1. High resolution spectrometer (HRS)
2. Solar oscillation imager (SOI)
3. Solar irradiance monitor (SIM)

The first two instruments permit to probe the solar interior by seismological techniques. These consist in the observation of the oscillations of the entire Sun through their photospheric effect. The quantity observed is the periodic wavelength shift of a photospheric spectral line, which is measured by comparing the signals from a double pass band obtained by the Zeeman effect from the resonance absorption line of a vapour. The observations of the oscillations of the global Sun (HRS) give information on the solar core, while two dimensional observations (SOI) should permit the identification of oscillatory modes of intermediate spherical harmonic degree which give information on the intermediate solar layers.

With ground based instruments, oscillations with periods from several minutes to hours have been detected by these Doppler techniques. Most of these oscillations have velocity amplitudes as small as a few cm/sec or less. Observations from SOHO will be a considerable improvement over ground based observations because free from the noise due to the Earth atmosphere and rotation. Therefore photospheric oscillations with speeds of less than 1 mm/sec are expected to become observable, since the orbit properties include a sufficiently small motion towards or away from the Sun and the possibility of uninterrupted observation, to enhance the signal to noise ratio.

The third instrument (SIM) is devoted to the study of the time variations of the solar irradiance. It includes a high precision radiometer measuring the total solar irradiance and 5 photometers operating at different wavelengths, having a relative precision of 10^{-6}. It also includes a combination of two absolute radiometers which will achieve an absolute accuracy of better than 0.2% over the duration of the mission.

The Solar Maximum Mission has shown that the solar constant is in fact a varying quantity, and that its decreases are associated with the appearance of sunspot groups and may be explained by blocking of the output by the sunspots. Variations with longer time scales (for example associated to the solar cycle) are possible. The study of these variations would give information upon the dynamics of the convective zone and other internal solar layers.

(b) The instruments proposed for SOHO for the study of the solar chromosphere, transition region and low corona are the following:

	Wavelength range (A)	Spectral res. (mA)	Spatial res. (arcsec)
4. Grazing incidence spectrometer (GIS)	65-500	40	1
	138-998	65	
	514-1277	65	
	719-1750	100	
5. Normal incidence spectrometer (NIS)	584-625	14	1
	770-835	14	
	900-1300	10	
6. EUV imaging telescopes (EIT) (2)	284(FeXV),304(HeII)		10
7. Soft X-ray telescope	2-100		1,5

These instruments would permit the study of the solar atmosphere with continuous observations and long term coverage, as required by the evolving phenomena. It would be possible not only to study the geometry of the features, but also to determine the physical parameters in all the layers from the chromosphere to the low corona with high spatial resolution. Electron density and temperature can be obained by looking at the density and temperature sensitive line ratios; hence the emission measure can be deduced, and thus the ion abundance by the line total intensity, if the geometry of the emitting region is known by means of the scanning capability of the spectrometers and from the images provided by the EUV and soft X-ray telescopes. Temperature and emission measure can also be obtained from the X-ray telescope, the former by comparing the continuous emission in different spectral regions, the latter from the temperature and the absolute emission.

Beyond having the capability of determining these physical parameters, SOHO has also that of measuring the velocity field, by means of the normal incidence spectrometer, with high sensitivity (3 km/sec at 1000 A). This is very important because it has become more and more evident, in recent years, that the solar chromosphere, transition region and corona are highly structured and have complicated velocity patterns. It is therefore essential, for the understanding of many basic problems, to take this character into account and thus to make continuous observations with high spatial resolution and velocity sensitivity in all the layers from the chromosphere to the low corona. Other important information that can be

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provided by the normal incidence spectrometer concerns the turbulent motions, since line profiles can be measured, given the spectral resolution of this instrument.

(c) The study of the outer solar atmosphere by SOHO continues at higher levels by means of the following two instruments:

	Wavelength range (A)	Spectral res. (mA)	Spatial res. (arcsec)
8. UV coronal spectrometer (UVCS)	1216(Lyα),1025(Lyβ) 1032, 1037 (OVI)	80	10-60
9. White-light coronagraph (WLC)	w.l. plus selected spectral regions		48

Recent rocket observations with a combination of coronal instruments similar to those which are planned for SOHO have shown that density, temperature and outflow speed can be determined by the observation of the white light intensity, the Ly-alpha intensity and profile and by the intensity of the OVI doublet at 1032 and 1037 A. Furthermore the Hanle effect method of magnetic field diagnostics would permit the determination of the magnetic field in some (higher field) coronal regions. Since, at present, the Doppler dimming technique, employed by SOHO, appears to be the only technique that can be used to determine the coronal outflow speed in the heliocentric distance range 1.2-5 solar radii, and since, furthermore, determinations of physical parameters above 1.4 solar radii are very scanty, except for the electron density, the importance of SOHO observations of this region is evident.

The main interest appears at this moment to lie in the determination of the outflow speed, temperature and density in the coronal holes, i.e. in the regions where the high speed wind originates. The height interval studied by SOHO will be particularly important because there the wind suffers its main acceleration. The determination of the physical parameters, as a function of the heliocentric distance, would be a powerful constraint on solar wind models, capable of strong information on the mechanisms of deposition of energy and momentum in the wind.

Besides strongly increasing our knowledge of these solar regions, also the knowledge of the regions of slow outflow--the streamers--can be greatly enhanced by the determination of density, temperature and magnetic field by the SOHO instruments.

(d) The SOHO instruments are also intended to continue the study of the solar wind at a much higher heliocentric distance by probing the interplanetary plasma with in situ measurements. These will add the necessary constraints to solar wind models. The instruments devised to this aim in the model payload will only be quoted here: 10. Solar wind analyzer; 11. Suprathermal particle analyzer; 12. Energetic particle analyzer; 13. Magnetometer; 14. Plasma wave analyzer.

REFERENCES

See the ESA publication SCI (83) 3, September 1983.