Advances in Solar and Stellar Physics: Space Studies

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Abstract. We highlighted at the workshop the impact on solar and cool star physics of current and future space missions (with emphasis on ESA-related missions). We focus here on informations about the most recent ESA missions. We summarise the main science objectives of these missions, and refer to some solar and stellar physics results or prospects, with illustrations of performances and scientific advances.

1. Introduction

The European space science programme is rich of missions relevant to solar/stellar science, either still in operation in space (IUE, HST, Ulysses), completed with success (HIPPARCOS), just launched with success after this workshop (ISO, SOHO), to be launched soon (SAX, CLUSTER), or at the turn of the century (XMM, INTEGRAL). We refer the reader to other papers of the conference describing solar and stellar results from IUE, ROSAT, HST, EUVE, YOHKOH, ASCA and other space missions. We concentrate in the written version on the summary of results from Ulysses, and on performances and first results from the recently launched ISO and SOHO missions.

2. The Ulysses Mission

Ulysses, launched on 6 October 1990, was carried jointly by ESA and NASA to study the properties of the solar wind and interplanetary medium as function of heliographic latitude (Wenzel et al 1992). It encompasses also the study of the heliospheric magnetic field, solar radio bursts and plasma waves, solar and galactic cosmic rays, interstellar/interplanetary gas and dust. A gravity-assist manoeuvre at Jupiter in February 1992 placed the spacecraft in its heliocentric out-of-ecliptic orbit with a perihelion of 1.3 AU and aphelion of 5.4 AU, with orbital period of 6.2 years. Ulysses reached a maximum heliographic latitude of 80.2 degrees and spent 234 days (about nine solar rotations) above 70 degrees. The main scientific results of the Ulysses mission include:

1. the study of high-speed stream structures dominating at high latitudes;
2. the measurements of ionised interstellar pick-up ions;
3. the detection of fluctuations at all scales in the high-latitude heliospheric magnetic field, as indication of unevolved turbulence;

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4. the unexpected little variation with latitude of the radial component of magnetic field;

5. the unexpectedly small increase of cosmic ray particles over the pole;

6. the unexpected persistence over the pole of the 26-day modulation of energetic particles.

The reader is referred to the Ulysses homepage for further references and informations on the mission:

http://helio.estec.esa.nl/ulysses/mission.html

3. Results from the Infrared Space Observatory (ISO)

Ground-based infrared observations are limited by atmospheric absorption as well as photon noise associated with the thermal emission of the warm telescope optics and atmosphere. A cooled telescope in orbit like ISO overcomes these limitations with a sensitivity increase more than thousand.

The ISO coverage of the spectrum from 2.5 μm to beyond 200μm allows to study the bulk of emission of cool objects (15-300 K), but also a rich variety of atomic, ionic, molecular and solid state spectral features. Infrared observations are very suited to the study of embedded objects. Stellar evolution will be studied via observations of circumstellar shells, especially around cool giant stars, and estimates of mass-loss rates. ISO will study protostars and regions of stellar formation. It will provide a way to diagnose premain sequence evolution in clusters through colour-colour diagrams.

The ISO spacecraft is 5.3 tons and includes essentially a large cryostat filled with 2300 liters of superfluid helium, which was designed to provide an in-orbit lifetime of at least 18 months. Some of the infrared detectors are directly coupled to the tank at a temperature of 2K. In the middle of the tank is suspended a 60 cm Ritchey-Chretien telescope, diffraction limited at 5 μm. The ISO instruments consist of a camera (ISOCAM), an imaging photopolarimeter (ISOPHOT) and two spectrometers at short and long wavelengths (SWS and LWS). The instruments view adjacent areas on the sky via a light-dispatching pyramid.

ISO was launched successfully on 17 November 1995, and the instruments are working properly. The latest helium loss estimate is such that the lifetime of ISO (6 months longer than nominal) will allow astronomical work until November 1997. All systems in the spacecraft are working nominally, and the scientific exploitation is just starting for more than a thousand of astronomers involved. Early results from the 4 ISO instruments include images of colliding galaxies, detection of solid state ice spectral features in the protostar GL2591, or imaging of the infrared emission from the MSH 11-54 supernova remnant, and the planetary nebula NGC 6543. The reader is referred to the ISO homepage for further information:

http://isowww.estec.esa.nl/
4. SOHO, the Solar Heliospheric Observatory

SOHO, a collaborative ESA-NASA mission, is designed to study the internal structure of the Sun, its extensive corona and the origin of the solar wind (Fleck et al 1995). It will give solar physicists their first long term, uninterrupted view of the Sun.

That view of the Sun is achieved by operating SOHO from a permanent vantage point 1.5 million kilometers ahead of the Earth in a halo orbit around the L1 Lagrangian point. SOHO will observe the Sun continuously for at least two years.

Three instruments will be devoted to helioseismology, for deriving the temperature, composition, and motions deep in the Sun:

- **GOLF (Global Oscillations at Low Frequencies)** will obtain observations of the global solar velocity field with a sensitivity better than 1 mm/s over periods from 3 minutes to 100 days.

- **VIRGO (Variability of Solar Irradiance and Gravity Oscillations)** will perform solar intensity oscillations with an accuracy better than 1 ppm (per 10s). It will also measure the solar constant with absolute accuracy of 0.015 %.

- **SOI (Solar Oscillation Imager)** will focus on the intermediate to very high degree harmonics pressure modes. It will provide high precision solar images 1024x1024 of line-of-sight velocity, line intensity, continuum intensity, longitudinal magnetic field and limb position. It can be operated in full disk mode (2 arcsec pixel) or high-resolution mode (0.62 arcsec pixel). SOI will run four different observing programmes:
  1. "structure programme": spatial and temporal averages of the full disk velocity and intensity images;
  2. "dynamics programme": a full disk velocity/intensity image every min during 60 days;
  3. "campaign programme": 8 consecutive hours each day when high-rate telemetry is available;
  4. "magnetic field programme": several real-time magnetograms per day for planning purposes and correlative studies.

The Coronal instruments allow spectroscopic measurements and high resolution images for temperature, density and velocity diagnostics from the chromosphere to the corona:

- **SUMER (Solar Ultraviolet Measurements of Emitted Radiation)** is an UV telescope with normal incidence spectrometer in the range from 50 to 160 nm, with velocity field resolution of 1 km/s, designed to study the dynamics of the chromosphere and corona.

- **CDS (Coronal Diagnostics Spectrometer)**, equipped with a normal incidence spectrometer and a grazing incidence spectrometer, will cover the range 15 to 80 nm with resolving power between 2000 and 10000.
• EIT (Extreme-ultraviolet Imaging Telescope) will obtain full-sun high-resolution EUV images in 4 emission lines (FeIX 171 Å, FeXI Å, FeXV 284 Å and He II 304 Å) corresponding to 4 different temperature regimes. The wavelength selection is done by multilayer reflecting coatings deposited on the telescope mirrors.

• UVCS (Ultraviolet Coronagraph Spectrometer) is an occulted telescope with high resolution spectrometers to observe the corona out to 10 solar radii, for study of the sources of the solar wind, and processes for its acceleration and for coronal heating.

• LASCO (Large Angle and Spectrometric Coronograph) is a triple coronagraph with respective fields 1.1-3, 1.5-6 and 3-30 solar radii. The inner coronograph will be the first spaceborne mirror coronograph, and also the first to carry spectroscopic capabilities (Fabry-Perot).

• SWAN (Solar Wind Anisotropies) will measure the latitude distribution of the solar wind mass flux by mapping the interplanetary Ly-alpha light.

In addition three instruments will measure the solar wind "in situ" near L1 the Lagrangian point to study the energy release and particle acceleration processes as well as particle propagation in the interplanetary medium.

SOHO was launched successfully on 2 December 1995. The spacecraft was perfectly injected on it cruise trajectory towards the Lagrangian L1 point. The nominal duration of the mission is of 2 years of operations, with a possibility of extension after approval. The spacecraft acts nominally, and the experiments have received their first light. SOHO will cooperate closely with ground-based observatories, and with other space missions. A call for Guest-investigator programme is to be released shortly after the insertion in the final halo orbit around L1 and start of nominal continuous science operations.

The reader is referred to the SOHO home page for further information: accessible from

http://helio.estec.esa.nl/

5. Future missions and mission studies

We refer the reader to the description elsewhere of future missions (XMM, AXAF, FUSE) and mission studies of relevance for solar and stellar physics.

There are solar/stellar missions under study as well at ESA (STARS for asteroseismology), advanced camera for HST, solar physics on low-Earth orbit platforms, solar probe, solar stereo missions, interferometry).

References
