Mem. S.A.It. Vol. 74, 219

Memorie della

Herschel Space Observatory

G. Tofani and V. Natale

IRA - CNR, L.go E. Fermi 5, 50125 Firenze e-mail: tofani@arcetri.astro.it

Abstract. The ESA Cornerstone mission *Herschel Space Observatory*, devoted to photometric and spectroscopic observations in the far-infrared and submillimetric spectral region, is described. Key scientific objectives are summarized. Three state of art instruments developed by International Consortia have been proposed which will allow to observe the Universe from high-z epochs down to very nearby objects such as planets and comets. Finally, the Italian contribution to the project is presented.

Key words. infrared: general – Far Infrared – submillimeter – Space Research

1. Introduction

The *Herschel Space Observatory* is the fourth cornerstone mission in the "Horizon 2000" long term ESA science program plan. *Herschel* is a multi user observatory type mission intended to open the submillimetre and far-infrared part of the electromagnetic spectrum ($85 - 700\mu m$), which is still mostly inaccessible, to the observational astronomy.

Herschel was selected as Cornerstone number 4 by SPC in November 1993. The baseline concept for *Herschel* includes a 3.5 meter, f/9.8, Cassegrain telescope radiatively cooled to an operational temperature of about 80 K in the L2 orbit. Fig. 1 shows the present configuration of the satellite. The mirror will be made of aluminum polished to guarantee the diffraction limited operation at 60 μm. A superfluid helium cryostat will provide cooling power for three focal plane instruments able of doing both photometry and high resolution spectroscopy in the wavelength range $60 - 700\mu m$. The predicted lifetime for the liquid helium has been computed to be about 4.5 years. The unique advantages of *Herschel* can be summarized as follow:

- the low emissivity 80 K telescope will provide an extremely low thermal background, much lower than could ever be achieved with ground based or airborne facilities;
- the high spatial resolution will lower the "confusion" noise due to the presence of several sources in the antenna beam;
- the complete absence of atmospheric absorption;
- the very large sky coverage;
- the large amount of observing time: at least 30000 hours;

Send offprint requests to: G. Tofani
Correspondence to: L.go E. Fermi 5, 50125 Firenze

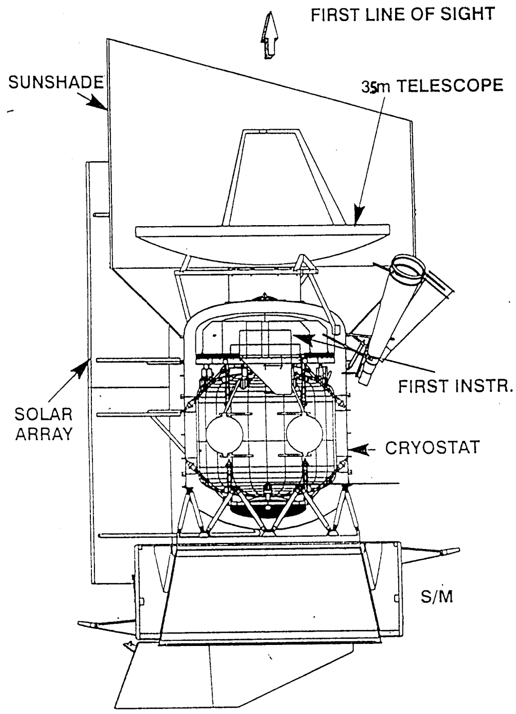

Fig. 1. The *Herschel* Space Observatory.

– the very low radiation environment with the consequent substantial reduction of "spikes" on the detectors.

The proposed instruments are:

– PACS (A Photoconductor Array Camera and Spectrometer) covering the wavelength range $60 - 210\mu m$. [1]
– SPIRE (Spectral and Photometric Imaging REceiver) covering the wavelength region $200 - 670\mu m$. [2]
– HIFI (Heterodyne Instruments for *Herschel*) including five receivers covering continuously the frequency interval 480 - 1250 GHz ($625 - 240\mu m$) plus one receiver for the band 1.41 - 1.91 THz ($213 - 157\mu m$). [3]

The satellite is foreseen to be launched in the early 2007 and will have a predicted lifetime of 4.5 years.

2. Scientific Objectives

Herschel will open the last major part of the electromagnetic spectrum mainly inaccessible from ground-based and airborne facilities. It will perform photometry, medium and high resolution spectroscopy of selected objects, as well as deep surveys. Black bodies with temperatures in the range 5 - 50 K peak in the wavelength interval covered by *Herschel*. In the same wavelength interval, gases with temperature between few K and few hundred K emit their brightest molecular and atomic emission lines. The science objectives were deeply discussed in a number of dedicated Symposia including those which taken place in Segovia (Longdon 1986), Liege (Kaldeich 1990) and Grenoble (Wilson 1997).

Submillimetre and far infrared observations are crucial in having a deeper understanding in the following, among the other, key areas:

– deep broadband photometric surveys in the band $150 - 500\ \mu m$. This program will allows a) several studies from star formation in galaxies up to a redshift of 5 to the large scale structure in the high redshift universe.
– follow-up spectroscopy of selected objects. The observation of the brightest cooling lines of the interstellar gas will give very important information on the physical processes and energy production in galaxies.
– physics and chemistry of the ISM in our Galaxy and in redshifted galaxies.
– high resolution spectroscopy will probe the physical conditions and chemical

[1] Leading Institution : Max-Planck Institute fur Extraterrestrische Physik, Garching; **http://pacs.ster.kuleuven.ac.be**

[2] Leading Institution: Queen Mary and Westfield College, London; **http://www.ssd.rl.ac.uk/SPIRE**

[3] Leading Institution: SRON, Groningen. **http://saturn.sron.nl/hifi/index.html**

processes of the interstellar medium as well the star forming regions in all their evolutive stages. *Herschel* will provide a complete inventory of the atoms, molecules in the various phases in the interstellar medium and determine the cooling rates of the gas. It will be possible to observe, for instance, all the submillimetric H_2O transitions.

- high resolution spectroscopy in comets and outer planets

Most of the observing time will be devoted in the so called "Key Projects" which are under definitions and which includes all the previously mentioned research areas.

3. The Instruments

The instruments proposed for *Herschel* and optimized with respect to the identified key science topics are:

PACS (Photoconductor-Bolometer Array Camera & Spectrometer) Two photoconductor arrays(stressed/unstressed) and two bolometer arrays will perform imaging line spectroscopy and imaging photometry in the 60 - 210 μm wavelength band. $\simeq$ 175 km/s. In both modes backgound-noise limited performance is expected, with sensitivities (5σin1h) of 3 mJy or $2.5 \times 10^{-18}\mathrm{Wm}^{-2}$, respectively.

SPIRE (Spectra and Photometric Imaging REceiver) has three fixed photometric bands with separate bolometer arrays and employs an imaging Fourier transform spectrometer (FTS) to provide variable resolution spectroscopy from 200 to 670 μm. The broad band ($R = \lambda/\Delta\lambda \simeq 3$) photometric channels simultaneously image a field of view of $4' \times 4'$ onto three bolometer arrays centered respectively at 250, 350 and 500 μm. The predicted photometric point source sensitivities are reported in Table 1 (SPIRE proposal). The spectroscopic channel uses a Martin Puplett polarizing interferometer; it images a separate field of view of $2' \times 2'$ into two more bolometer arrays, optimized to cover the bands $200-300\mu m(16\times16 pixels)$ and $300 - 670\mu m(12 \times 12 pixels)$, to perform imaging spectroscopy with a variable spectral resolution of $0.04 - 2cm^{-1}$ corresponding to $R = \lambda/\Delta\lambda \simeq 20 - 1000$ at $250\mu m$. The calculated line flux sensitivities $(1\sigma, 1hour)$, in spectroscopic mode, will be $7 \times 10^{-18}Wm^{-2}$ for point source observations and $1.7 \times 10^{-17}Wm^{-2}$ in the mapping mode ($2' \times 2'$ map).

HIFI (Heterodyne Instrument for *Herschel*) will provide very high resolution spectroscopy. HIFI will combine the spectral resolving power capability of the radio heterodyne technique with quantum noise limited detectors like SIS or HEB. It will be possible to have a continuous frequency coverage in the range 0.48 - 1.25 THz in five bands and in both polarizations using SIS as mixers. A sixth band will provide coverage of 1.41 - 1.91 THz frequency interval in single polarization. This high frequency band have been added for the observation of the peculiar lines of the FeH (1.411 THz) and CII (1.898 THz). Each receiver will have an instantaneous bandwidth of 4 GHz which will be analyzed in parallel by wideband (WBS) and high resolution (HRS) spectrometers. The WBS with acousto-optic technology will provide a frequency resolution of 1 MHz over a bandwidth of 4 GHz for each of the two polarization. The HRS will be based on a digital autocorrelator and will be able of a spectral resolution of 200 KHz over a bandwidth of 1 GHz.

Table 2 summarizes the HPBW and the expected receivers noise temperatures for the six bands (HIFI proposal).

4. Scientific Operation.

Each Consortium must provide, one for each instrument, the Instrument Control Center (ICC) which has the responsibility in the areas of data reduction, instrument calibration and scientific analysis. This is a novel concept on the conduction of Scientific Operation envisaged from ESA for *Herschel*.

Table 1. SPIRE Photometric point source sensitivity.

Wavelength	$\lambda(\mu m)$	250	350	500
Pass-band	$\lambda/\Delta\lambda$	3	3	3
Field of view	*arcmin*	4	4	4
Beam width	*arcsec*	18	25	36
Pixels		32×32	24×24	16×16
Point source	Limiting flux density(mJy)$(1\sigma - 1hour)$	0.6	0.6	0.7
Mapping (4' x 4')	Limiting flux density(mJy)$(1\sigma - 1hour)$	1.4	1.5	1.9

Table 2. HIFI performances.

HiFi Band	1	2	3	5	5	6
Frequency (THz)	0.48-0.64	0.64-0.8	0.8-0.96	0.96-1.12	1.12-1.25	1.41-1.91
HPBW (*arcsec*)	39	30	25	21	19	13
T_{noise} (K)	90	130	160	210	370	650

5. The Italian Participation.

Italian groups (IRA, IFSI, LENS, Observatories of Arcetri, Padova andTrieste) are actively involved in the three consortia with scientific contributions, and in the areas of flying hardware and software, laboratory instrument calibrations and data processing software (ICC). In the following the contributions to the three instruments are briely reported:

- IFSI is developping the Digital Processing Unit (DPU), the electronic interface (Instrument Control Units).
- CAISMI has a collaboration with the Cologne University in the design and construction of the HIFI WBS.
- the spectral calibration of the spectroscopic channel of PACS will be carried out using the TuFIR experiment (Viciani et al. 1998) provided by LENS in collaboration with Osservatorio di Arcetri and IRA.
- contribution to the ICC with two persons for each instrument .

The return of this participation, identified as about 10 % of the total cost of each instrument, will be some percentage of the observing time. However that most of the time will be devoted to the "Key project".

6. Conclusion

The *Herschel* Mission toghether have been presented. The performances of the payload are foreseen to be by far superior to any other existing instruments for submillimetre and far infrared bands allowing to address key topics in astrophysics and cosmology.

References

Longdon, N., editor, *Space-born Submillimeter Astronomy Mission*, Proc. ESA SP-260, Segovia, August 1986.

Genzel, R. 1997, in *The Far Infrared and Submillimetre Universe*, Proc. ESA SP-401, A. Wilson ed., Grenoble

HIFI Proposal

Kaldeich, B., editor, *From Ground-Based to Space-Borne Sub-mm Astronomy*, proc. ESA SP-314, Liège, December 1990

PACS Proposal

SPIRE Proposal

Viciani, S. et al. 1998, Rev. of Sci. Inst., 69, 372

Wilson, A., editor, *The Far Infrared and Submillimetre Universe*, Proc. ESA SP-401, Grenoble, April 1997