

# Extract of Herschel section



## ESA's Report to the 37th COSPAR Meeting

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## 4.2 Herschel

The Herschel Space Observatory, the fourth of the original Cornerstone missions in the ESA Horizon 2000 science plan, is a multi-user observatory-type mission that will provide unrivalled observing opportunities for the general astronomical community in the relatively poorly explored 55–672  $\mu\text{m}$  part of the far-IR and sub-mm range. It will bridge the wavelength gap between earlier IR missions such as IRAS, ISO, AKARI, and Spitzer, and ground-based observatories. About two thirds of Herschel's observing time is open time, available to the general community through a standard competitive proposal process.

Herschel (Fig. 4.2.1) is the only space facility dedicated to the far-IR and sub-mm part of the spectrum. It has the potential for discovering the earliest epoch proto-galaxies, revealing the cosmologically-evolving AGN/starburst symbiosis, and unravelling the mechanisms involved in the formation of stars and planetary system bodies.

The major strengths of Herschel are its photometric mapping capability for performing unbiased surveys related to galaxy and star formation and its spectral coverage for follow-up observations. Red-shifted ultra-luminous IR-dominated galaxies, with spectral energy density functions (SEDs) that 'peak' in the 50–100  $\mu\text{m}$  range in their rest frames, as well as class 0 proto-stars and pre-stellar objects in our own and nearby galaxies, have SEDs that peak in the Herschel 'prime' band. Herschel is also well-equipped to perform spectroscopic follow-up observations to characterise further any particularly interesting individual objects.

The key science objectives emphasise the formation of stars and galaxies, and their interrelation. Example observing programmes with Herschel will include:

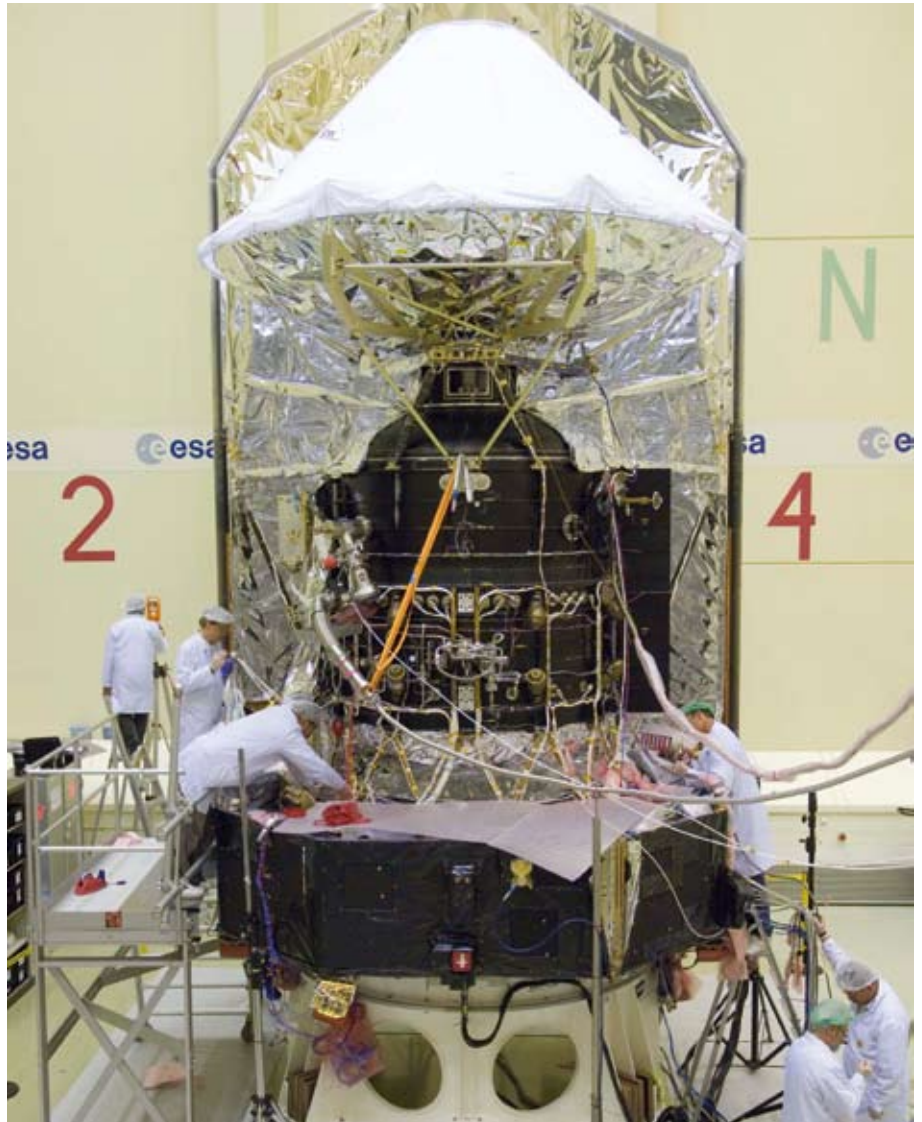
- deep extragalactic broadband photometric surveys in six colours spanning the Herschel wavelength coverage and related research. The main goals include further resolving the IR background into discrete sources, performing a detailed investigation of the formation and evolution of galaxy bulges and elliptical galaxies in the first third of the present age of the Universe, and determining how the star-formation rate and galaxy luminosity functions evolve with cosmic time;
- follow-up spectroscopy of especially interesting objects discovered in the survey. The far-IR/sub-mm band contains the brightest cooling lines of interstellar gas, which give important information on the physical processes and energy-production mechanisms (for example, AGN versus star formation) in galaxies;
- detailed studies of the physics and chemistry of the interstellar medium in galaxies, both locally in our own Galaxy as well as in external galaxies, by means of photometric and spectroscopic surveys and detailed observations. This includes implicitly the important question of how stars form out of molecular clouds in various environments using galaxies as 'laboratories' providing, for example, different levels of metallicity;
- observational astrochemistry (of gas and dust) as a quantitative tool for understanding the stellar/interstellar lifecycle and investigating the physical and chemical processes involved in star formation and in both early and late stages of stellar evolution in our own Galaxy. Herschel will provide unique information on most phases of this lifecycle, including the study of the evolution of circumstellar discs during the planet-forming era;
- detailed high-resolution spectroscopy of a number of comets and the atmospheres of the cool outer planets and their satellites;

*For further information, see <http://herchel.esac.esa.int/>*

### Introduction

### Scientific objectives

**Figure 4.2.1.** The mechanically-integrated Herschel flight satellite in the ESTEC Test Centre on 23 April 2008. Inside the cryostat (with the black radiator) the focal plane units of the science instruments are mounted on the optical bench on top of the superfluid helium tank. The telescope protected by its cover is on top of the cryostat and the service module below, all protected by the sunshade/solar array. A sequence of functional, environmental, and performance verification tests will be conducted before shipment to the launch site in Kourou for the launch campaign. (ESA)



— studies of Kuiper belt objects, and comparisons with the global properties of those observed around nearby stars.

From experience, it is also clear that the discovery potential is significant when a new capability is being implemented for the first time. Observations have never been performed in space in the prime band of Herschel. The total absence of (even residual) atmospheric effects – enabling both a much lower background for photometry and full wavelength coverage for spectroscopy – together with a cool, low-emissivity telescope open up a new part of the phase-space of observations. Thus, a space facility is essential in this wavelength range and Herschel will be breaking new ground.

In order to exploit fully the favourable conditions offered by being in space, Herschel has a precise, stable, low-background telescope, and a complement of capable scientific instruments. The telescope (Fig. 4.2.2) is passively cooled (placing it



**Figure 4.2.2.** The Herschel flight telescope during incoming inspection in the ESTEC Test Centre in late Jan 2008. (ESA)

outside the cryostat maximises its size), while the instrument focal plane units are mounted on a common optical bench housed inside a cryostat containing superfluid helium below 1.7K. The bolometer arrays in PACS and SPIRE are cooled to  $\sim 300$  mK using dedicated instrument-provided sorption coolers.

During operations, the telescope must have a total wave front error (WFE) of no more than  $6 \mu\text{m}$ , corresponding to diffraction-limited operation at about  $85 \mu\text{m}$ . It also has a very low emissivity to minimise the background signal, and the whole optical chain is optimised for high stray light rejection. Protected by a fixed sunshade, the telescope will radiatively cool to an operational temperature of around 80 K. The design is a classical Cassegrain with a 3.5 m-diameter primary and an ‘undersized’ secondary. The telescope, manufactured by EADS Astrium (Toulouse, F), is made almost entirely of silicon carbide (SiC). The primary mirror blank was made out of 12 segments brazed together to form a monolithic mirror. This was then ground, lapped and polished to the required accuracy, and finally metallised to provide the required high reflectivity and low emissivity. The secondary was machined out of a single piece of SiC, including an integrated scattercone in its centre for standing-wave suppression, and metallised in the same way as the primary. The secondary support structure, consisting of a hexapod and a barrel-like structure, is also made of SiC, carries the launch loads and is optimised for adequate stray light and standing-wave performance.

## Telescope and science payload



**Table 4.2.1. Herschel scientific payload**

<i>Acronym</i>	<i>Instrument</i>	<i>Principal Investigator</i>
PACS	Imaging camera & grating spectrometer, spectral coverage ~55-205 $\mu\text{m}$	A. Poglitsch, MPE, Garching (D)
SPIRE	Imaging camera & FTS spectrometer, spectral coverage ~200-672 $\mu\text{m}$	M. Griffin, U. Cardiff (UK)
HIFI	High-res heterodyne spectrometer; spectral coverage 157-212 & 240-625 $\mu\text{m}$	Th. de Graauw, SRON, Groningen (NL)

The scientific payload consists of three instruments (Table 4.2.1), provided by consortia led by Principal Investigators (PIs) in return for guaranteed observing time.

PACS (Photo detector Array Camera and Spectrometer) is a short-wavelength camera and low- to medium-resolution spectrometer covering wavelengths up to about 205  $\mu\text{m}$ . It employs four detector arrays: two bolometer arrays for photometry, and two photoconductor arrays for spectroscopy. PACS can be operated either as a photometer, fully sampling an FOV of 1.75x3.5 arcmin on the sky simultaneously in two broadband colours (either of the 60–85 or 85–130  $\mu\text{m}$  bands plus the 130–210  $\mu\text{m}$  band), or as an integral field line spectrometer covering just under 1 arcmin square on the sky with a resolution in the range 1000–4000 depending on wavelength.

SPIRE (Spectral and Photometric Imaging REceiver) is a long-wavelength camera and low- to medium-resolution spectrometer covering wavelengths longer than 200  $\mu\text{m}$ . It comprises an imaging photometer and a Fourier Transform Spectrometer (FTS), both of which use bolometer detector arrays with individual feedhorns for each detector. There are five arrays in total: three dedicated to photometry, and two for spectroscopy and spectrophotometry. As a photometer, SPIRE covers a large 4x8 arcmin field on the sky that is imaged in three colours (centred on 250  $\mu\text{m}$ , 360  $\mu\text{m}$ , 520  $\mu\text{m}$  simultaneously), and in spectroscopy a field approximately 2.6 arcmin across with a resolution of order 100.

HIFI (Heterodyne Instrument for the Far Infrared) is a heterodyne spectrometer. It offers very high velocity-resolution spectroscopy using auto-correlator and acousto-optical spectrometers, combined with low noise detection using superconductor-insulator-superconductor (SIS) and hot electron bolometer (HEB) mixers. Five dual polarisation SIS mixer bands cover the frequency range 490–1250 GHz, and two HEB bands cover 1410–1910 GHz. HIFI covers a single pixel on the sky, and builds up images either by raster scanning or by on-the-fly mapping.

## Spacecraft and in-flight operations

Herschel is based on the well-proven ISO cryostat technology. It is modular, consisting of the ‘extended payload module’ (EPLM) comprising the superfluid helium cryostat (housing the optical bench with the instrument focal plane units) that supports the telescope, the sunshield/shade, and payload associated equipment; and the service module (SVM), which provides the infrastructure and houses the warm payload electronics. Herschel is about 7.5 m high and 4 m wide, and has a launch mass of around 3000 kg.

An industrial consortium led by Thales Alenia Space (Cannes, F) as Prime, with Astrium (Friedrichshafen, D) responsible for the EPLM, and Thales Alenia Space (Torino, I) for the SVM, and a host of subcontractors from all over Europe, are

**Table 4.2.2. Principal characteristics of the Herschel mission.**

<i>Type of mission:</i>	Far-IR and sub-mm observatory; ~2/3 open time available to the general user community; 4th ESA Cornerstone mission
<i>Science goals:</i>	Star and galaxy formation, interstellar medium physics and chemistry, Solar System body studies
<i>Telescope:</i>	3.5 m-diameter Cassegrain telescope of silicon carbide
<i>Spacecraft:</i>	3-axis spacecraft with superfluid helium cryostat for instrument focal plane unit cooling
<i>Size:</i>	Height 7.5 m x width 4 m, launch mass 3 t
<i>Science data rate:</i>	130 kbit/s average production rate
<i>Lifetime:</i>	3 years of routine science operations
<i>Operational orbit:</i>	Lissajous orbit around L2
<i>Launch:</i>	Dual launch (with Planck) on Ariane-5 ECA in late 2008

building the spacecraft. Arianespace will provide the launch services in Kourou. For a summary of principal mission characteristics see Table 4.2.2.

An Ariane-5 ECA launcher, shared with Planck, will inject both satellites into a transfer trajectory towards the second Lagrangian point (L2) in the Sun–Earth system. They will then separate from the launcher and subsequently operate independently, from orbits of different amplitudes around L2. L2 offers a stable thermal environment with good sky visibility. Since Herschel will be in a large orbit around L2, which has the advantage of not costing any orbit injection delta-v, its distance to Earth will vary from 1.2–1.8 million km. For the first few weeks after launch, while cooldown and outgassing take place, the telescope will be kept warm by heaters to prevent it acting as a cold trap for the outgassing products. It will then be allowed to cool down, and the opening of the cryostat door (thus providing ‘first light’) will take place about a month after launch. Although formally Herschel will take about 4 months to reach its operational orbit, at the time of ‘first light’ it will already be more than 1 million km away from the Earth. Commissioning and performance verification will take place en route to L2, followed by a science demonstration phase. Once these crucial mission phases have been accomplished, Herschel will begin routine science operations.

Herschel will be a multi-user observatory open to the general astronomical community. It will perform routine science operations for a minimum of 3 years, until depletion of the helium. The available observation time will be shared between guaranteed time (one third) owned by contributors to the Herschel mission (mainly by the PI instrument consortia), and open time allocated to the general community (including the guaranteed time holders) on the basis of calls for observing time.

The scientific operations of Herschel will be conducted in a decentralised manner. The operational ground segment comprises six elements:

- the Herschel Science Centre (HSC), provided by ESA;
- three dedicated Instrument Control Centres (ICCs), one for each instrument, provided by the respective PIs;
- the Mission Operations Centre (MOC), provided by ESA;

## Science operations

— the NASA Herschel Science Center (NHSC), provided by NASA.

The HSC acts as the interface to the science community and outside world in general, supported by the NHSC (primarily) for the US science community. The HSC provides information and user support related to the entire lifecycle of an observation, from calls for observing time, the proposing procedure and proposal tracking, to data access and data processing, as well as general and specific information about using Herschel and its instruments.

All scientific data will be archived and made available to the data owners. After the proprietary time has expired for a given dataset, these data will be available to the entire astronomical community in the same manner as they were previously available only to the original owner. The accumulated experience from earlier observatory missions (particularly ISO and XMM-Newton) is being used in the implementation of the infrastructure by ESA and the PIs together. An important conclusion is to build one single system that evolves over time, rather than having separate systems for different mission phases. The first functional version of this system is already being used in connection with instrument-level tests.

On 1 February 2007 the initial Announcement of Opportunity (AO) for key programme observing time was issued. In response to this AO a total of 42 observing programmes have been selected by the Herschel Observing Time Allocation Committee, by coincidence equal numbers of guaranteed and open time programmes. These programmes represent slightly more than half of the Herschel observing time nominally available and address a wide range of science issues. More information about these observing programmes can be found on the Herschel Science Centre website (<http://herchel.esac.esa.int/home.shtml>).

## Status and schedule

The PIs and science payload were provisionally selected in 1998 and confirmed a year later. The focal plane unit cryogenic qualification models were delivered in late 2004 for integration and testing in the engineering qualification model (EQM), and avionics models provided for testing together with the SVM. The instrument flight models were tested, characterised, and calibrated before delivery in spring/summer 2007.

The telescope activity began in mid-2001, and the mid-term review was held in November 2001, paving the way for the telescope CDR in April 2002. The telescope was aligned and characterised in warm conditions in summer 2005, immediately followed by successful mechanical qualification. An extensive cryogenic test campaign was completed in 2006 in Centre Spatial de Liège (B).

The industrial contract for the Herschel spacecraft for Phases-B, C/D and E1 was awarded in April 2001, marking the start of Phase-B. The System Requirements Review took place in autumn 2001, after which the industrial consortium was formed by the selection of subcontractors, involving in excess of 100 procurement activities. The next major step, the Preliminary Design Review, took place a year later. The mission-level CDR was held in early 2005, and the Qualification Review (QR) in early 2007.

The first spacecraft hardware to arrive for testing in the ESTEC Test Centre was the SVM structural thermal model (STM), in spring 2005. It was followed by the proto-flight model cryostat, which was tested in the Large Space Simulator in late autumn. The entire spacecraft in STM configuration underwent mechanical qualification in early 2006. The various spacecraft elements were then returned for upgrading to flight standard.

The flight science payload was delivered in the first half of 2007 and integrated into the payload module. The spacecraft payload and service module were mated in September 2007 in Astrium, Friedrichshafen. The spacecraft arrived in the ESTEC Test Centre in early January 2008 for final integration, cooldown, and instrument and environmental tests. The cooldown to 'normal' (not superfluid) helium conditions was achieved on 1 March and mechanical integration was completed in April 2008. A sequence of functional, environmental and performance verification tests will be conducted before shipment to the launch site in Kourou, leading to the launch in late 2008. Routine science operations are planned to begin about 6 months after launch.