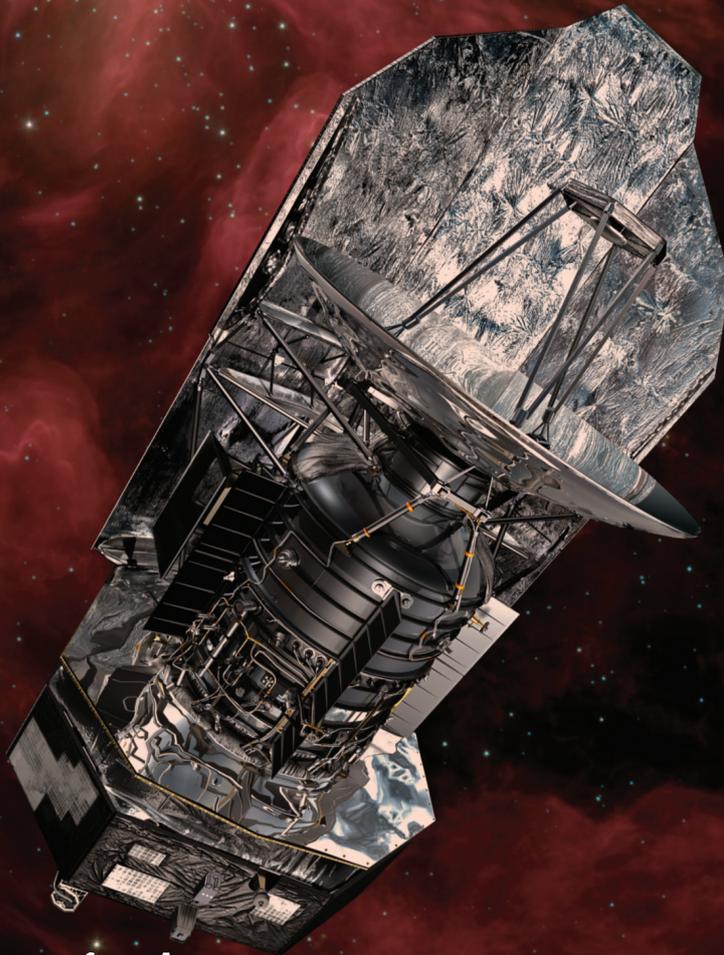


*Unveiling hidden
details of star and
galaxy formation
and evolution*



About ESA

The European Space Agency (ESA) was formed on 31 May 1975. It has 18 Member States: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

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Cluster, which is a four-spacecraft mission to investigate in unprecedented detail the interaction between the Sun and the Earth's magnetosphere.



Double Star, following in the footsteps of the Cluster mission, with its two spacecraft it studies the effects of the Sun on the Earth's environment.



Giotto, which took the first close-up pictures of a comet nucleus (Halley) and completed flybys of Comets Halley and Grigg-Skjellerup.



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More information can also be obtained via the ESA Science website at: www.esa.int/herschel

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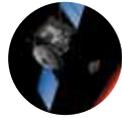
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Infrared Space Observatory (ISO), which studied cool gas clouds and planetary atmospheres. Everywhere it looked, it found water in surprising abundance.



International Ultraviolet Explorer (IUE), the first space observatory ever launched, marked the real beginning of ultraviolet astronomy.



Mars Express, Europe's first mission to Mars, which is providing an unprecedented global picture of the Red Planets' atmosphere, surface and subsurface.



Rosetta, Europe's comet chaser, will be the first mission to fly alongside and land on a comet, probing the building blocks of the Solar System in unprecedented detail.



SMART-1, Europe's first mission to the Moon, which tested solar-electric propulsion in flight, a key technology for future deep-space missions.



Solar and Heliospheric Observatory (SOHO), which is providing new views of the Sun's atmosphere and interior, revealing solar tornadoes and the probable cause of the supersonic solar wind.



Ulysses, the first spacecraft to fly over the Sun's poles.

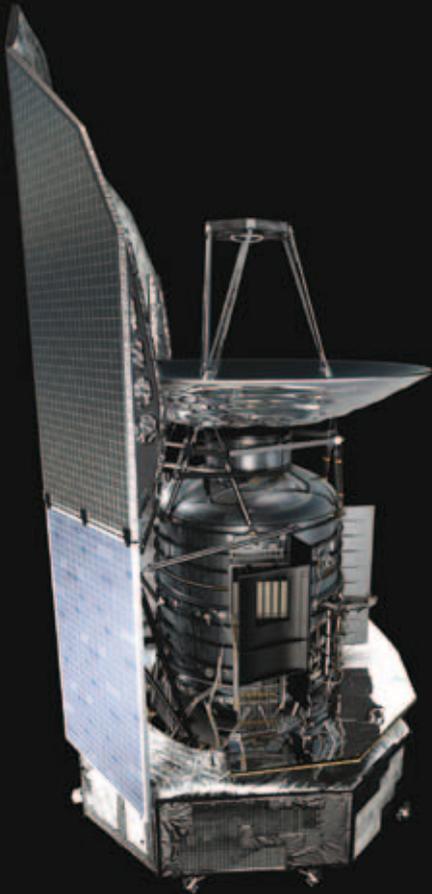


Venus Express, which is probing the mysteries of Venus's atmosphere with a precision never achieved before



XMM-Newton, with its powerful mirrors, is helping to solve many cosmic mysteries of the violent X-ray Universe, from enigmatic black holes to the formation of galaxies.

Unlocking the secrets of galaxy formation and evolution



An artist's view of ESA's Herschel far-infrared and submillimetre space observatory.
© ESA (Image by AOES Medialab)

Today, galaxies fill the Universe. They are distributed in curved walls surrounding huge areas of emptiness – like bubbles in a foam bath. Each galaxy contains several hundred thousand million stars. However, it has not always been like this. There was a time when galaxies simply did not exist. Astronomers have long been wondering when galaxies formed, how they formed, if they all formed at about the same time in cosmic history, and whether the first galaxies were like those we see now. Galaxies are made of stars and interstellar matter, and this raises other questions: did stars form in the same manner throughout cosmic history? Were all kinds of stars present at all times, and did they always form at the same rate?

Does the situation change depending on the type of galaxy and the age of the Universe?

So far, these questions have proved impervious to even the most advanced instruments, and remain some of the key problems in astronomy today. Astronomers have dreamt of a telescope that could help find the answers. Such a telescope would have to fulfil at least two requirements. Firstly, it would have to be a giant, sensitive space telescope, capable of collecting and discerning the light from very faint galaxies. Secondly, it would need to be able to observe visible light reprocessed by dust into infrared light, as even primeval galaxies contain dust.

Some galaxies emit almost all their energy in the infrared. In fact, about half the starlight produced in the history of the Universe has been absorbed and re-emitted in the infrared.

Now the dream is coming true. ESA's far-infrared and submillimetre observatory, Herschel, due to be launched in 2009, is designed specifically to achieve those goals. With its ability to detect infrared light, Herschel will let astronomers see, for the first time, the infrared light emitted by dusty and cold regions that is hidden from the gaze of optical telescopes and previous infrared observatories. With its huge 3.5 m-diameter mirror – the largest ever flown in space – Herschel is the first of a new generation of space giants.

Herschel is named after the German-musician-turned-British-astronomer William Herschel, who discovered infrared radiation in 1800. ESA's Herschel observatory was named in his honour in 2000, the bicentenary of his discovery.

How to revolutionise Astronomy

Baby galaxies at work

Astronomers call the era before 'first light' and galaxy formation 'the dark ages'. It is an appropriate name. No current instrument can peer into that era, since no light was emitted. Not long after the Big Bang, however, the first stars started to form, possibly in small clusters. These stars had no heavy atoms. Most likely they were very massive, therefore subject to a short lifetime and a violent death.

Like a chemical factory, the first stars created the first heavy atoms, enriching the raw material from which the next generation of stars would form. The clusters of stars started to merge and grow, triggering the birth of more stars, which, in turn, created more material for future stars. In this way, the first galaxies were born as vast collections of star clusters. These galaxies would often collide and merge to form larger galaxies, triggering new intense bursts of star formation, and space quickly became the Universe of galaxies we see today.

However, this scenario of galaxy formation and evolution leaves many open questions. For instance, with the arrival of the space observatories, we now know that when the Universe was half its present age, galaxies were quite different. Fundamental new insights into galaxy formation and evolution came from the NASA/ESA Hubble Space Telescope, from pioneering infrared observatories such as the international Infrared Astronomical Satellite (IRAS), ESA's Infrared Space Observatory (ISO), and more recently, JAXA/ISAS's Akari and NASA's Spitzer space telescope. IRAS made the completely unexpected discovery that some galaxies emit almost all their energy

in the infrared. These are usually galaxies that are forming stars at a very high rate: up to thousands of times faster than the rate in our Galaxy today. To peer into the unsolved mysteries of galaxy formation, astronomers needed a much larger infrared space telescope. Herschel will be able to see the emission from dust heated by the Universe's stellar 'baby booms' at the epoch of most intense star formation – inside 'baby galaxies' at work.

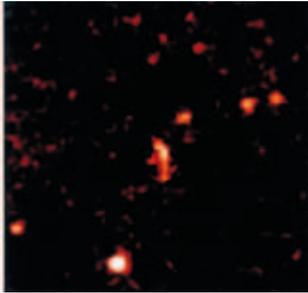
Starbirth in dark and cold clouds of gas and dust

Stars are shy, at least during their early lives. They begin to form inside clouds of gas and dust, within thick dust cocoons that protect them until the moment they hatch. In the pre-stellar core, as these cocoons are called, gravity squeezes gas and dust into the centre of the clump. This heats the gas. The heat must radiate into space before the embryonic star can complete its collapse and finish its formation.

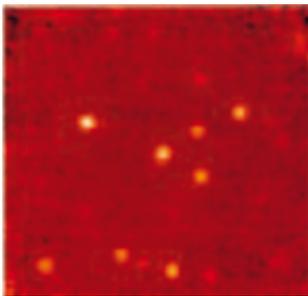
Pre-stellar cores are deeply embedded in clouds that are incredibly cold. This makes them invisible to all telescopes except those designed to collect radio or infrared radiation. ISO unveiled more than a dozen of these cocoons, but astronomers are waiting for Herschel to shed light on the entire process of star and planet formation. With its large telescope and spectral coverage that extends to very long wavelengths, Herschel will be able to study the earliest unknown stages of star birth and take a complete census of stars forming in our galactic neighbourhood.

Recipe for a planet

Making a planet is simple. After a star

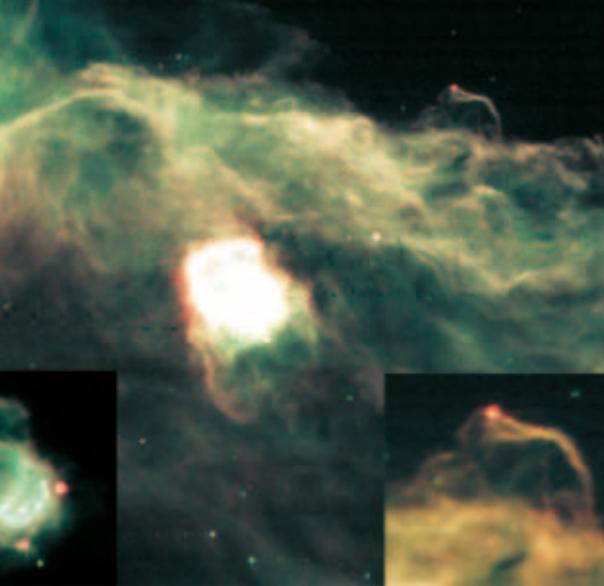


ESA/ISO/SOFCM and L. Mezcade et al.

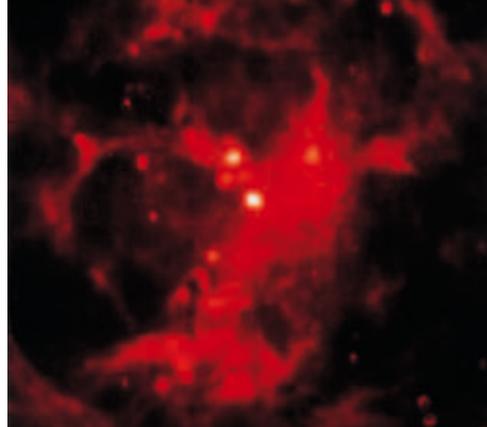


ESA/ISO/SOFCM and L. Mezcade et al.

Gravitational arcs are distorted and magnified images of distant objects. The upper image shows the first gravitational arcs seen at infrared wavelengths, in the galaxy cluster Abell 370. Below, lensed galaxies in galaxy cluster Abell 2390. They might be young galaxies in collision.



ESA/ISO/ISOCAM and L. Wamstler et al.



ESA/ISO/ISOCAM and J. Gemikon et al.

Infrared-bright regions in the Trifid Nebula reveal dense clouds of cool dust which may be sites of new star formation.

Bright dots seen in the Horsehead Nebula in Orion include young, newly formed stars detected by their infrared emissions.

is born, leftover gas and dust remain swirling around the young star, forming a circumstellar disc of gas and dust. The grains of dust in this disc are the seeds of future planets. Once most of the dust has collapsed together to form the planets, the disc disappears, leaving behind only a thin ring of debris.

Both circumstellar discs and debris rings are favourite targets for infrared space telescopes. ISO and Spitzer have shown that the formation of planets around stars must be a common event. Observations by Spitzer show that discs of dust and gas surround almost all young stars, but that their lifetime is fairly short – only a few million years. This indicates that the planet-making process is quite rapid, with smaller bodies contributing to the material that eventually forms planets. There is also evidence that discs of debris can be seen around mature stars. Herschel will thoroughly investigate the nature of the material in circumstellar discs for stars of all ages.

The origin of the Solar System

Our Solar System formed about 4500 million years ago, out of the proto-solar nebula. This primeval cloud contained the raw material that formed both the Sun itself and the planets. To reconstruct precisely how the process took place, astronomers need to study the detailed chemical compositions of the atmospheres and surfaces of the planets and their moons, and especially the chemical composition of the comets. Comets are mostly made of water ice, methane and carbon dioxide. They are the best fossils of the early Solar System

because they are made of unprocessed material from the proto-solar nebula. In the atmosphere of a planetary body, the original components are altered by subsequent chemical reactions; in a comet, they are held in a deeply frozen state.

Studying the chemical composition of comets will also shed new light on the question of the origin of Earth's oceans. According to some hypotheses, impacting objects of various kinds, such as comets and asteroids, brought most of the water to our planet early in the history of the Solar System. Herschel has the unprecedented capability to analyse the chemical composition of the Solar System's various bodies.

The chemistry of the Universe

Stars are the chemical factories of the Universe. Every atom in the Universe (with the exception of the three lightest elements, hydrogen, helium and lithium) is the result of stellar activity. Many chemical elements, including those essential for life such as carbon, nitrogen and oxygen, are created in the nuclear fires that burn inside stars, while elements heavier than iron are produced during violent supernova explosions.



ESA/ISO/ISOCAM and P. Lamy et al.

ISO observations of Comet Hale-Bopp produced valuable information about the composition of the comet's dust and vapour.

When stars age and eventually die, they spread the processed material back to the interstellar medium, either gently or in violent explosions, depending on how massive the star was at the beginning of its life. Many chemical compounds, including those essential for life, are produced around ageing stars, and in the interstellar material enriched by them. Huge amounts of water and complex molecules of carbon, both essential for life, have been detected in the material surrounding stars. Human beings and other life forms on Earth, as well as our planet itself, are literally stardust.

Most molecules show their unmistakable chemical signature at infrared and submillimetre wavelengths. This makes Herschel the ideal tool for detecting and studying them. Herschel will study the chemistry of many regions in the Universe, from stars and their environments to other galaxies. It will observe chemical-rich objects such as molecular clouds, where over a hundred different molecules have been discovered. Some of these molecules need the isolation of space to exist. On Earth, they would rapidly react with other molecules and so can be created only in highly specialised laboratories.

Unveiling the hidden Universe

The dusty revolution

Human eyes are blind to most types of light. They can see neither infrared nor ultraviolet light. Only visible light, i.e. light within a particular small band of wavelengths, registers in our eyes. Because each kind of light reveals different natural phenomena, human vision provides us with only one part of the full story. It is the same with telescopes: optical telescopes detect only visible light.

Previous infrared satellites have allowed astronomers to glimpse the infrared face of the Universe. They have seen enough to realise that the Universe's infrared face is completely different from the visible one. **One of the virtues of near-infrared light is that dust in space does not block its passage.** If a star is enshrouded by dust, an optical telescope will not see it, while an infrared telescope will detect the star's emission.

Herschel has been planned to build on previous successes with its substantially larger telescope and spectral coverage extending into the far-infrared and submillimetre wavelengths.

Composite image showing the dusty central region of the Orion nebula. The upper triangle is an image taken with the The Near Infrared Camera and Multi-Object Spectrometer (NICMOS), a camera on the NASA/ESA Hubble Space Telescope that works at near-infrared wavelengths. Although these wavelengths are close to detectable by optical telescopes, the NICMOS image shows significantly more stars than the optical image of the same region (lower triangle).



The success of the Infrared Astronomical Satellite (IRAS) in 1983, a joint venture between the Netherlands, UK and USA that produced the first map of the entire sky at infrared wavelengths, paved the way for ESA's Infrared Space Observatory (ISO). Launched in 1995, this was the world's first general-purpose infrared space observatory, which operated until 1998.

ESA then participated in the Japanese mission, Akari. During 2006 and 2007, it mapped more than 94% of the sky at infrared wavelengths with higher sensitivity and in more detail than IRAS.

NASA's Spitzer is a general-purpose infrared observatory that is currently operational. It carries a telescope that is slightly bigger than that of ISO, and a new generation of instruments with more sensitive detectors.

Herschel is not just the next step but a giant leap forward in infrared technology. Its telescope is significantly bigger and has the capacity to observe considerably more detail. Herschel will also bridge the gap between wavelengths seen by previous infrared satellites and those studied by submillimetre telescopes on ground. It will thus be able to discover a large number of unknown objects both within and outside our Galaxy. **Herschel will even detect emission from dust itself.** This makes it an ideal tool to study the buildup of galaxies, where interaction often creates massive bursts of star formation in dusty regions that sometimes emit almost exclusively in the infrared.

Infrared astronomy can only become increasingly important to astronomers in the future. ESA is collaborating with NASA on the James Webb Space Telescope, an infrared space telescope designed to look into the very furthest reaches of space, where visible light is stretched into infrared wavelengths because of its vast journey across space and time.

Cold is bright
Infrared telescopes have another advantage: they can detect radiation from cold objects that are invisible to optical telescopes.

Planets and dust discs around other stars, asteroids, brown dwarfs (failed stars) and protostars are all examples of objects that are too cold to shine in the visible but become conspicuous when viewed in the infrared.

The Andromeda galaxy, located two million light-years away, is one of the galaxies closest to our own and a good example of how the infrared can unveil secrets. It is considered a typical spiral galaxy, but ESA's Infrared Space Observatory showed that it is made of several concentric rings. The rings are made of dust at about -260°C , considerably colder than previous estimates. Optical telescopes cannot see this kind of material, so the rings are invisible in the usual views and Andromeda's true make-up is hidden from us. Only in the infrared do the rings become bright.

Sunshade

Telescope

Cryostat

Service Module

How will Herschel work?

The Herschel satellite is composed of three sections. First is the telescope, which has a 3.5 m-diameter primary mirror protected by a sunshade. The telescope focuses light onto three scientific instruments; their detectors are housed in a giant vacuum flask, known as a cryostat. Inside the cryostat, Herschel's detectors are kept at very low and stable temperatures, necessary for the instruments to operate. The cryostat contains liquid superfluid helium at temperatures lower than -271°C , which makes the instruments as sensitive as possible. The instruments' detectors and the cryostat make up the second section, the payload module. The third element of the satellite is the service module located below the payload module. It houses the instrument electronics and the components responsible for satellite function, such as the communication hardware. The service module hosts the data processing units and spacecraft control electronics, operating at ambient temperature.

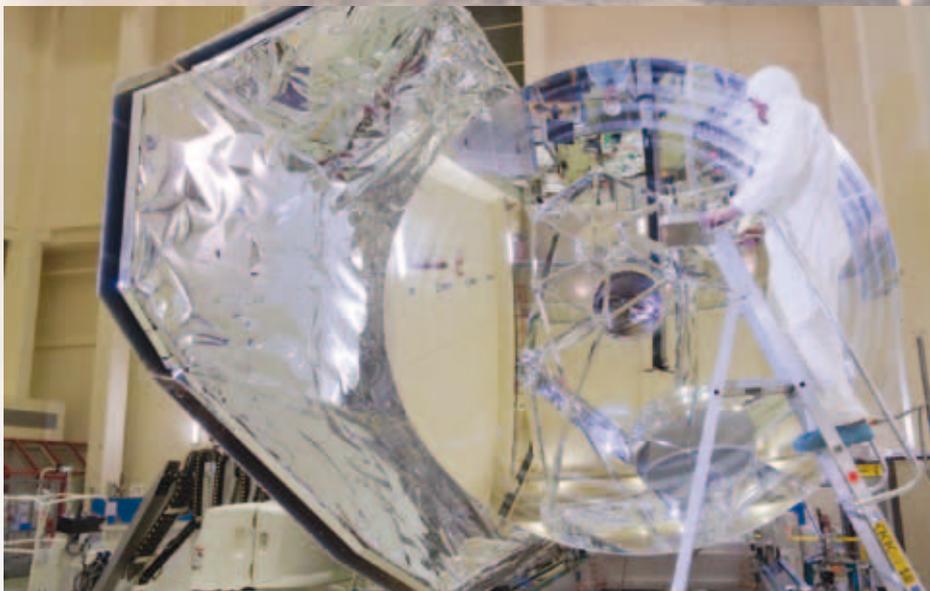
ESA (AOES Medialab)

Harvesting infrared light with the largest mirror

Herschel carries the largest telescope ever flown in space.

Its 3.5 m-diameter primary mirror makes it more than four times larger than any previous infrared space telescope and almost one and a half times larger than the Hubble Space Telescope. It will collect almost 20 times as much radiation as any previous infrared space telescope.

The 3.5m Herschel telescope mirror, the largest ever launched into space.



The primary mirror is the telescope's light collector. It captures light from astronomical objects and directs it towards a smaller second mirror. This focused light is sent to the instruments, where it is detected and analysed. The size of the primary mirror is the key to a telescope's sensitivity: the bigger it is, the more light it collects, and so the fainter the objects it sees. It also determines the telescope's ability to distinguish fine details. The surface of the mirror is equally important. It has to be precisely shaped and perfectly smooth; the slightest roughness can distort the final image.



Herschel's superfluid helium tank, where the helium is kept at its boiling temperature (1.65K or -271.5°C). The helium cools the focal plane unit of the scientific instruments and the three thermal shields. The liquid boils and produces gas that slowly flows from the tank into pipes around the payload, cooling it to between 1.7K (-271.4°C) and 4K (-269°C).



The gas continues into the rings of the shields, cooling them down to 30K (-241°C), 50K (-221°C) and 60K (-211°C), respectively.



The cryostat vacuum vessel containing the superfluid helium tank. The gas is ejected into space. The cryostat vacuum vessel is cooled down to about 70K (-203°C) by radiating heat into space.

Building Herschel's mirror was a real technological challenge that was met successfully. The mirror must be very light (as must all satellite components); it has to withstand the extreme conditions of launch and the low temperatures of outer space; and any irregularities on its surface must be less than thousandth of a millimetre high.

Three powerful eyes

A telescope's instruments turn it from a mere light collector into a set of technological eyes. The instrument detectors form the retina, where light from astronomical objects is really seen. The instruments detect and analyse the light in many different ways.

Herschel carries three scientific instruments:

- **HIFI** (Heterodyne Instrument for the Far Infrared), a high-resolution spectrometer (*);
- **PACS** (Photoconductor Array Camera and Spectrometer), a camera and an imaging spectrometer;
- **SPIRE** (Spectral and Photometric Imaging REceiver), a camera and an imaging spectrometer.

(*) A spectrometer captures and splits the radiation emitted by an object into its constituent wavelengths for analysis, creating a fingerprint. The analysis of this fingerprint provides information on the chemical nature of the emitting body.

These instruments were developed by nearly 40 institutes, mainly European, with US and Canadian participation.

The coolest detectors

An infrared detector must be cooled to extremely low temperatures to function. The temperature of some astronomical objects is close to absolute zero (-273.15°C or 0K), so trying to observe them with a warmer instrument would be like trying to see a star against the glare of the midday Sun.

All three Herschel instruments will be cooled by the cryostat. This sophisticated vacuum flask will be filled with more than 2000 litres of superfluid helium at launch, at temperatures below -271°C . Further cooling – down to 0.3K – is necessary for the SPIRE and PACS bolometric detectors (a bolometer is a device capable of detecting and measuring small amounts of thermal radiation). The role of the cryostat is key because it determines the lifetime of the observatory. The helium evaporates at a constant rate, gradually emptying the tank. When it has all gone, the temperature of the instruments will start to rise and Herschel will no longer be able to perform observations. However, its data will keep astronomers busy for decades.

Herschel's eyes

Herschel's three instruments are complementary: each instrument is designed to study gas and dust, but at different temperatures and states. Thanks to the large range of wavelengths covered, they will be able to witness the entire process of star formation, from the earliest stages of condensation to the moment at which the protostar emerges from its cocoon and is born.

The Heterodyne Instrument for the Far Infrared (HIFI), a high-resolution spectrometer, is designed to observe unexploited wavelengths. With its high spectral resolution – the highest ever in the

range of wavelengths it covers – HIFI will observe an unprecedented level of detail: it will be able to observe and identify individual molecular species in the enormity of space, and study their motion, temperature, and other physical properties. This is fundamental to the study of comets, planetary atmosphere in our solar system, star formation and the development of distant and nearby galaxies.

HIFI can produce high-resolution spectra of thousands of wavelengths simultaneously. It covers two bands (157–212 microns and 240–625 microns), and uses superconducting mixers as detectors. It was designed and built by a nationally-funded consortium led by SRON Netherlands Institute for Space Research (Groningen, the Netherlands). The consortium includes institutes from France, Germany, USA, Canada, Ireland, Italy, Poland, Russia, Spain, Sweden, Switzerland and Taiwan.

The Photoconductor Array Camera and Spectrometer (PACS) consists of a colour camera and an imaging spectrometer. Within its wavelength range (55–210 microns), the PACS camera is the first instrument capable of obtaining the complete image of a target at once. The PACS spectrometer has a lower resolution than that of HIFI, but it is perfectly suited to seeing young galaxies and the gas clouds from which stars form.

PACS operates either as a special camera (photometer) in two colours simultaneously, or as a spectrometer, using either its bolometer or its photoconductor array detectors. It was designed and built by a nationally-funded consortium led by the Max Planck Institute for Extraterrestrial Physics (Garching, Germany); the consortium includes institutes from Belgium, Austria, France, Italy and Spain.

The Spectral and Photometric Imaging Receiver (SPIRE) also operates at wavelengths that have not been exploited before (194–672 microns). Like PACS, it consists of a colour camera and an imaging spectrometer, and it covers a complementary range of wavelengths. It is designed to study the star formation history of the Universe.

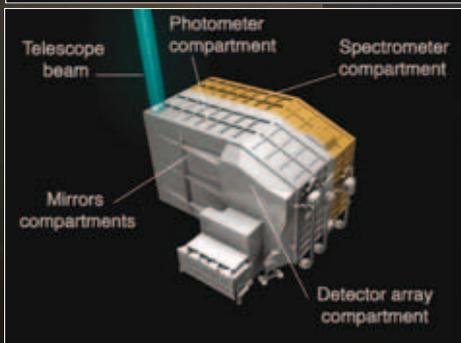
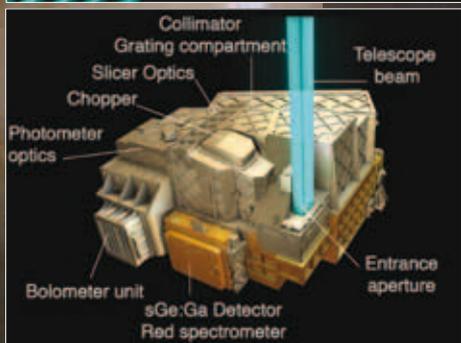
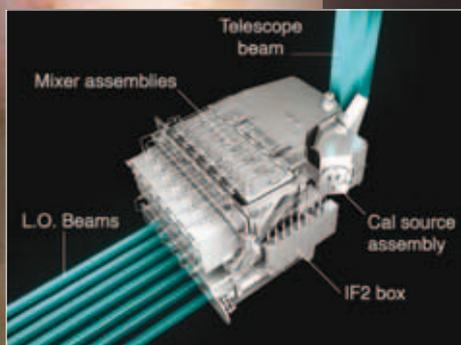
SPIRE performs photometry; that is, it measures the intensity of the radiation emitted by an astronomical object, in three bands simultaneously, centred on 250, 350 and 500 microns. It can also be operated as an imaging spectrometer. It was designed and built by a nationally-funded consortium led by Cardiff University (Cardiff, UK); the consortium includes France, Canada, China, Italy, Spain, Sweden and the US.

Together, PACS and SPIRE cover six colours of the infrared rainbow.

Top: The Heterodyne instrument for the Far Infrared (HIFI). © ESA (Image by C.Carreau)

Centre: The Photoconductor Array Camera and Spectrometer (PACS). © ESA (Image by C.Carreau).

Bottom: The Spectral and Photometric Imaging Receiver (SPIRE). © ESA (Image by C.Carreau)



Who built Herschel?

Developing Herschel has been a technological and engineering challenge: it is the largest space telescope ever, and a sophisticated spacecraft that is maintained at amazingly low temperatures.

ESA has designed and built Herschel under a common engineering programme with Planck, ESA's mission to study the relic radiation of the Big Bang. The two satellites will share more than just a launcher: they have undergone a joint development process aimed at optimising resources by using the same industrial teams and shared design of spacecraft components whenever possible.

ESA's prime contractor for Herschel is Thales Alenia Space (Cannes, France), which leads a consortium of industrial partners with Astrium (Friedrichshafen, Germany) responsible for the payload module, and Thales Alenia Space (Turin, Italy) responsible for the service module. Astrium (Toulouse, France) provided the telescope. There is also a host of subcontractors spread throughout Europe.

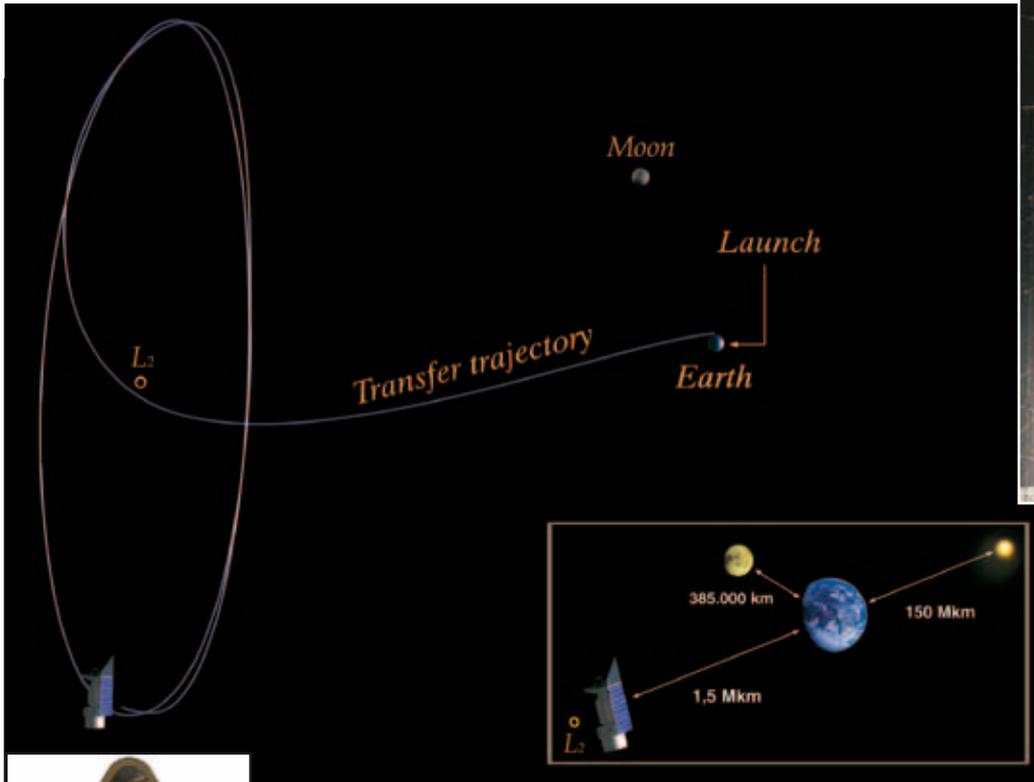


Herschel being prepared for acoustic tests in June 2008.

ESA's industrial partners.



Leaving behind Earth and the Moon



Herschel will be launched on an Ariane 5 along with ESA's Planck observatory, which will study the Cosmic Microwave Background. At launch, the Herschel-Planck combination will measure approximately 11 m high and 4.5 m wide, weighing about 5700 kg. After separating from the upper stage, the two spacecraft will head towards their respective orbits. They will be operated independently.

It will take Herschel about 60 days to enter its operational orbit around the second Lagrangian point (L2) of the Sun-Earth system, a virtual point in space. This point is located some 1.5 million km from Earth (about four times the distance to the Moon), on Earth's night-side. This orbit has three important advantages: firstly, Herschel

and its instruments will not be disturbed by the strong far-infrared emission from Earth and the Moon. Secondly, because Earth and the Sun are in the same general direction, it offers good sky visibility for astronomical observations. Thirdly, it keeps Herschel outside Earth's radiation belts, which can disturb observations.

Herschel's orbit around L2 is much larger than that of the Moon around Earth. Because of this large orbit, Herschel's distance to Earth will vary between 1.2 and 1.8 million km. In addition, orbits around L2 are unstable and subtle changes in Earth's orbit will cause the satellite to drift away. Herschel will have to perform small orbit correction manoeuvres every month.

Operating Herschel

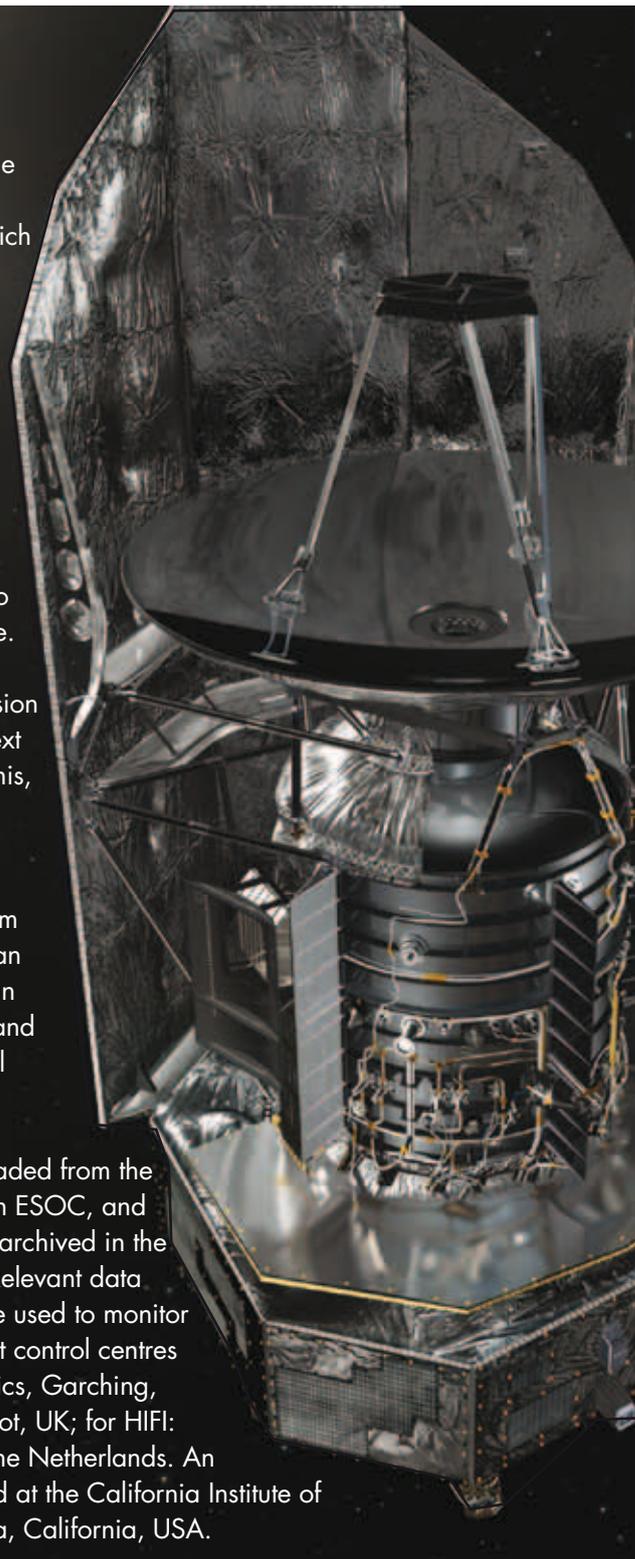
Herschel will be operated by the mission operations team at the Mission Operations Centre (MOC) located at ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, which is responsible for the health and safety of the spacecraft. The team also maintains all necessary contact with the spacecraft, via ESA's New Norcia (Australia) deep space antenna. From its orbit around L2, it takes about 10 seconds for Herschel to communicate with Earth (two-way).

Herschel operations are arranged in 24-hour cycles. The spacecraft carries out science observations for about 21 hours every day. The data collected are recorded on the onboard computer. The remaining three hours are dedicated to communication with Earth, while science observations continue.

At the beginning of the three-hour communication slot, the mission control team uploads the mission operations timeline for the next day, which the satellite will execute autonomously. Following this, all scientific data stored on board is downloaded.

The mission operations timeline is based upon a schedule of observations produced by the Herschel science operations team in the Herschel Science Centre (HSC) located at ESA's European Space Astronomy Centre (ESAC) in Villanueva de la Cañada in Spain. The HSC is the science office responsible for Herschel and is the centre for all interaction with the worldwide astronomical community that uses the observatory.

The spacecraft's housekeeping and scientific data are downloaded from the spacecraft and routed from the receiving station to the MOC in ESOC, and from there to the HSC at ESAC. Here the data are processed, archived in the Herschel Science Archive, and made available to observers. Relevant data are distributed to the instrument control centres, where they are used to monitor and optimise instrument performances. The Herschel instrument control centres are: for PACS: the Max Planck Institute for Extraterrestrial Physics, Garching, Germany; for SPIRE: the Rutherford Appleton Laboratory, Didcot, UK; for HIFI: SRON Netherlands Institute for Space Research, Groningen, the Netherlands. An additional centre is the NASA Herschel Science Center located at the California Institute of Technology Infrared Processing and Analysis Center, Pasadena, California, USA.



Herschel in a nutshell

Concept:

Herschel is a cutting-edge space observatory that will work at far-infrared and submillimetre wavelengths. It will be able to see dusty and cold regions that are opaque to other telescopes, unveiling a face of the early Universe that has been hidden until now. Herschel's main goal is to study the formation and evolution of galaxies and stars. Other targets include clouds of gas and dust where new stars are being born, discs from which planets may form, and cometary atmospheres packed with complex organic molecules.

Herschel highlights:

- The largest telescope ever flown in space
- Three new, powerful and complementary instruments
- The first space observatory to observe the entire range of wavebands from the far-infrared to submillimetre
- The highest sensitivity ever achieved in its wavelength range
- The first observatory capable of studying the earliest stages of star formation
- The first observatory to take an ongoing census of forming stars in our galactic neighbourhood
- The most powerful tool to search for water throughout our Galaxy
- The first observatory to take a census of primarily infrared-emitting star-forming galaxies throughout the Universe, at the peak of star formation

Primary mirror:

3.5 m in diameter.

Launch:

Herschel will be launched in 2009 together with another ESA mission, Planck, on board an Ariane 5 from Europe's Spaceport in Kourou, French Guiana. The satellites will operate independently from different orbits.

Orbit:

Herschel will follow a Lissajous orbit around the second Lagrangian point of the Sun–Earth system (L2), a virtual point located 1.5 million km from Earth.

Instruments:

HIFI (Heterodyne Instrument for the Far Infrared), a high-resolution spectrometer; PACS (Photoconductor Array Camera and Spectrometer) and SPIRE (Spectral and Photometric Imaging REceiver). PACS and SPIRE are both cameras and imaging spectrometers. Together, these instruments cover wavelengths of 55–672 microns. Their detectors will be cooled to temperatures very close to absolute zero.

Launch mass:

About 3.4 tonnes.

Dimensions:

About 7.5 m high and 4 m wide.



ESA (image by AOTIS Mediafoto); background image: ESA/NASA/HST

Operations:

Herschel will be operated as an observatory. About two-thirds of its observing time will be available to the worldwide scientific community. The rest of the observing time has been allotted to the instrument consortia. It will operate autonomously, sending acquired data to Earth over a three-hour period every day.

Primary ground station:

ESA's deep space antenna in New Norcia, Australia.

Operational lifetime:

A minimum of three years for routine science observations.

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