MAX PLANCK SOCIETY

Press Release

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Taking a peek into the hidden universe

Instruments developed at Max Planck Institutes at work on Herschel, the largest space telescope ever built

We are into the final countdown for Herschel: May 14th will see the launch of the ESA European Space Agency satellite, which will orbit the Sun at a distance of 1.5 million kilometres from Earth during the next three and a half years. The space probe's instruments will capture and investigate light in the extreme infrared. On board Herschel are two instruments developed by researchers from the Max Planck Institutes for Extraterrestrial Physics, for Astronomy, for Radio Astronomy and for Solar System Research.

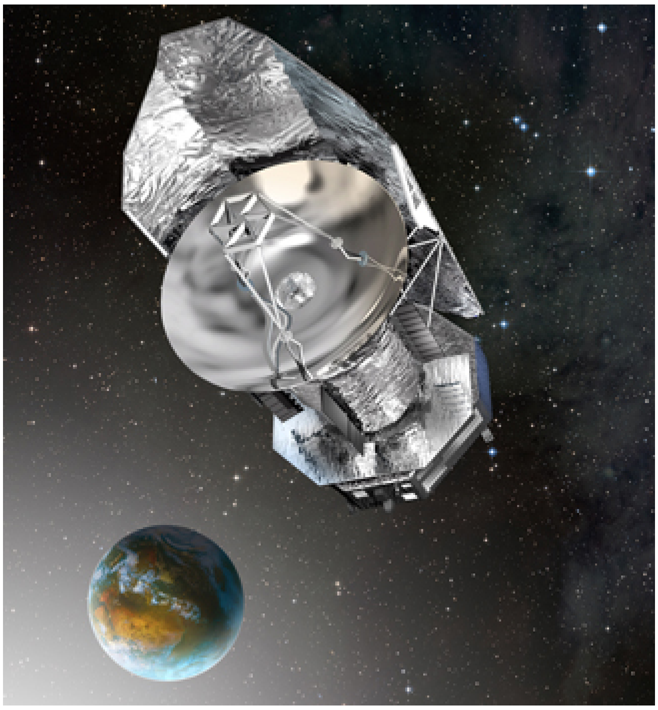

Fig. 1: *Gigantic eye for the infrared: May 14th is the date planned for the launch of the Herschel European satellite, which will open up a new window into space.*

Image: ESA

The universe reveals many of its secrets in the infrared. Just like every object on Earth, the icy nebulae, galaxies and stars from the depths of the universe emit infrared heat radiation - however, because of the low temperatures, at a

Max Planck Society
for the Advancement of Science
Press and Public Relations Department

Hofgartenstrasse 8
D-80539 Munich
Germany

PO Box 10 10 62
D-80084 Munich

Phone: +49-89-2108-1276
Fax: +49-89-2108-1207
presse@gv.mpg.de
Internet: www.mpg.de

Head of scientific communications:
Dr. Christina Beck (-1275)

Press Officer / Head of corporate communications:
Dr. Felicitas von Aretin (-1227)

Executive Editor:
Barbara Abrell (-1416)

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significantly larger wavelength than a human or a badly insulated house, for example. The Earth's atmosphere is impervious to these wavelengths. The instruments aboard the Herschel space probe investigate space in the wavelength range between 55 and 672 micrometers. No other infrared observatory so far has offered such a bandwidth in combination with the spatial resolution of a 3.5-metre telescope.

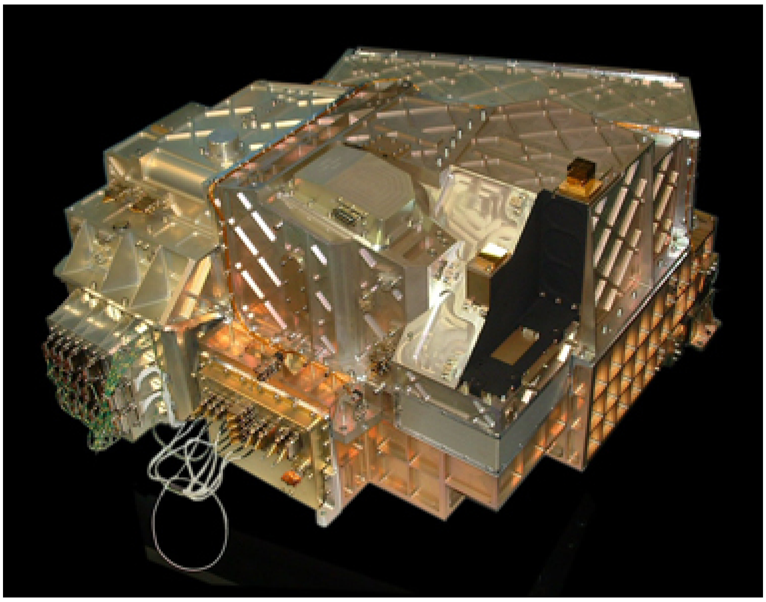

Fig. 2: *The PACS instrument will observe the universe with an accuracy never achieved before in the wavelength range between 57 and 210 micrometres.*

Image: Max-Planck-Institut für extraterrestrische Physik

The scientists want to use this satellite to resolve the diffuse cosmic infrared background into its individual sources and thus determine the development of the universe. Herschel is intended to provide information on the formation of the stars and galaxies, the formation of planetary systems, the history of our Solar System and the chemical composition of molecular clouds, stars and galaxies.

The Max Planck researchers played a crucial role in creating two of the three scientific instruments: the PACS instrument was designed and built by the Max Planck Institute for Extraterrestrial Physics (MPE) in Garching in cooperation with the Max Planck Institute for Astronomy (MPIA) in Heidelberg and further partners from six European countries. HIFI was developed by a global consortium, coordinated by the Dutch Institute for Space Research, and with significant input from the Max Planck Institutes for Radio Astronomy (MPIfR) in Bonn, for Solar System Research (MPS) in Katlenburg-Lindau and also Cologne University.

PACS ("Photodetector Array Camera and Spectrometer") operates with a never before achieved accuracy and sensitivity in the far infrared, between 57 and 210 micrometers. "For the first time we have been successful in developing relatively large, highly sensitive detectors for this still exotic wavelength range which we can use to record sort of colour images in three larger wavelength ranges for these long wavelengths", says Albrecht Poglitsch, scientist at the MPE and PACS project manager. Furthermore, a new kind of optical instrument has been built that makes it possible to simultaneously resolve an area in the sky into individual pixels and to very finely disperse every pixel into individual spectral colours or wavelengths.

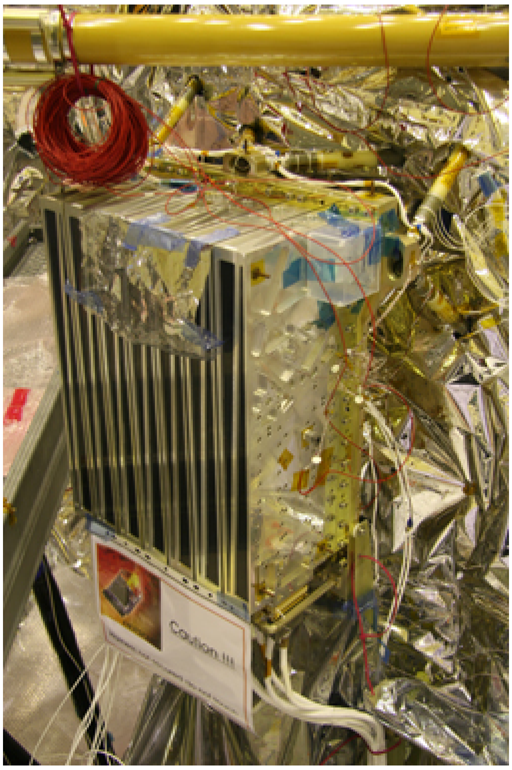

Fig. 3: *The HIFI's local oscillator. The instrument is the most sensitive spectrometer ever built for observations in the far infrared.*

Image: Thomas Klein

Stars are formed in the inside of huge clouds of dust and gas whose interior cannot be seen with visible light. Infrared radiation penetrates the dust and opens up a completely different universe to the astronomers than the one observed in visible light. With its highly sensitive detectors, PACS captures the weak heat radiation only a few degrees above absolute zero (minus 273.15 degrees Celsius), which was emitted at an early stage of the star formation by the so-called protostar, the precursor of the star, and thus offers the researchers a deeper look into the 'infancy' of the stars. "With its huge 3.5-metre mirror, Herschel will provide sharper detailed images of such protostars than ever before", says a delighted Oliver Krause from the MPIA in Heidelberg.

Galaxies from the young universe, billions of light years away from us, have produced up to a thousand times more stars than are produced in current galaxies. This requires large quantities of gas and dust as "building material", which again block the direct view and initially swallow the energy released by the infant stars, only to re-radiate it at much longer wavelengths. Moreover, the wavelength of the emitted light appears much longer due to the expansion of the universe: the infrared radiation of the objects formed shortly after the Big Bang reaches us from the depths of the universe with more than twice the wavelength. About half of the emitted light reaches us in the form of this cosmic infrared background. It is precisely in this range that the PACS sensors will "see" particularly well and resolve the glow into individual sources for the first time.

Herschel also opens up new opportunities for our understanding of the trans-Neptunian region - remains of the disc from which our planets were formed. Pluto is the best-known, but no longer the largest representative of this belt region on the far side of Neptune; there are now more than 1,300 trans-Neptunian objects (TNO) in the catalogues. The TNO have remained virtually unchanged since the early years of the Solar System and are very cold because they are so far from the sun - which is why they are in Herschel’s field of vision.

HIFI ("Heterodyne Instrument for the Far-Infrared") is the most powerful high-resolution spectrometer ever designed for observations in the far infrared. The instrument is also designed to record even the weakest spectral "fingerprints", which every atom and every molecule of the interstellar gas leave behind. In contrast to many laboratory experiments, the signal received is usually extremely weak and is close to the detection limit of even the most sensitive detectors, such as those now used in the HIFI.

Since there is no possibility of recording these fine frequency structures in the infrared directly, the heterodyne principle is used for the subsequent signal processing. This involves heterodyning ("mixing") the frequency of the received signal with a reference wave to shift it into the classical radio range, where the subsequent signal processing occurs. The heterodyne principle makes it possible to use HIFI to spectrally resolve even one millionth of the incident radiation.

The principle has been known since the beginnings of wireless communication and is now used in every VHF radio. "The technical challenge consists in realizing this principle at ten thousand times shorter wavelengths, meaning in the far infrared", says Thomas Klein from the MPIfR. Over a period of ten years, an international consortium headed by the MPIfR in collaboration with the US space agency NASA first created the necessary technical foundations.

One of the centrepieces of the HIFI is a so-called acousto-optical spectrometer (AOS), built jointly by researchers from the MPS and Cologne University. Its special feature consists in the fact that it quadruples the spectral range that could previously be recorded while at the same time reducing the power consumption to about one tenth.

HIFI opens up a new astronomical window: it makes it possible to measure numerous molecular and atomic transitions, which are important for the understanding of the processes in space. "The instrument makes enables the observation of the interstellar and planetary water, whose radiation is otherwise completely absorbed by the Earth's atmosphere, for example, and provides insight into the cold universe, from the comets and the planetary system through to the processes of star and galaxy formation", says Rolf Güsten from the MPIfR. And Paul Hartogh, researcher at the MPS, adds: "It is very important to measure the hydrogen and oxygen isotopes contained in water in both comets and also in the atmospheres of planets. These measurements can be used to draw important conclusions regarding the early history of the Solar System and the development of the planetary atmospheres."

In order to minimize the interfering influence of Sun, Moon and Earth, Herschel will be stationed at the so-called second Lagrange point (L2). This point is 1.5 million kilometres away in a straight extrapolation of the line connecting the Earth with the Sun, and orbits the Sun once a year synchronously with the Earth. All three radiation disturbances, Sun, Moon and Earth, lie in roughly the same direction seen from there and can thus be hidden behind a "sun shade".

The instruments aboard the satellite must be operated at temperatures of between 0.3 and 2 degrees above absolute zero. Two thousand litres of superfluid liquid helium are required for the cooling, and this also limits the duration of the mission of the giant telescope: in about three and a half years,the helium will be used up - and Herschel will become blind. Until then, the scientists hope for a wealth of new findings in a region of the electromagnetic spectrum still virtually uncharted.

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Related Links:

[1] ESA’s Herschel web page

[2] Science with Herschel

[3] Herschel observes the solar system

[4] The PACS instrument

[5] The HIFI instrument

Contact:

Dr. Mona Clerico, Press Officer
Max-Planck-Institute for Extraterrestrial Physics, Garching
Tel.: +49 89 30000-3980
E-mail: clerico@mpe.mpg.de

Dr. Jakob Staude, Press Officer
Max Planck Institute for Astronomy, Heidelberg
Tel.: +49 6221 528-229
E-mail: staude@mpia-hd.mpg.de

Dr. Birgit Krummheuer, Press and Public Relations
Max Planck Institute for Solar System Research, Katlenburg-Lindau
Tel.: + 49 5556 979-462
E-mail: Krummheuer@mps.mpg.de

Dr. Norbert Junkes, Press and Public Relations
Max Planck Institute for Radio Astronomy, Bonn
Tel.: +49 228 525-399
E-mail: njunkes@mpifr-bonn.mpg.de