Measuring in previously uncharted wavelengths

From 2009 to 2013, astronomers throughout the world were able to use an instrument that made observations in the virtually uncharted transition area between infrared radiation and radio waves, the so-called submillimeter or terahertz radiation. This instrument is called HIFI, the acronym for: Heterodyne Instrument for the Far-Infrared. HIFI, also called the Molecule Hunter, was one of the three scientific instruments on board Herschel, a space telescope of the European Space Agency ESA.

Water and other molecules

HIFI has extracted a wealth of unique information from very different environments – from shells of dying stars to galaxy cores and comets. The Molecule Hunter was able to do this because of an unbeatable combination of uninterrupted spectral coverage, high spectral resolution and calibration accuracy. This combination may not be available for another 40 years.

Water has been one of the most important targets for HIFI because of its rich spectrum and high abundance, and because it plays such an important role in star formation. Due to the high water vapor content of our own atmosphere, the data from space obtained with HIFI are a true legacy for decades to come. Water was found in the tenuous torus of gas released from Saturn’s moon Enceladus, in gas streaming off comets, in planetary atmospheres, external galaxies and around evolved stars.

Besides observations of single molecules, HIFI also excelled in making complete spectral scans. Such scans contain tens of thousands of lines from, in some cases, over 50 molecular species arising from within interstellar gas clouds rich in water and organics. These observations directly characterize the chemical composition of star-forming gas with unparalleled accuracy while offering the unprecedented ability to probe gas physics with hundreds to thousands of lines of a single molecule.

Heritage and market

The scientific and technological heritage of HIFI is impressive already. Thanks to HIFI, scientists now have a much better understanding of the cosmic cycle of gas which leads to the birth of stars and planets and the role water and other molecules play. The terahertz technology used for HIFI has also been applied by NOVA for the receivers of the Atacama Large Millimeter Array (ALMA) in the Atacama Desert in Northern Chile.

The expertise acquired through HIFI has enabled SRON to look at market applications based on the typical characteristics of terahertz radiation (see below). There are application prospects in areas like safety monitoring and quality control, nondestructive testing, security, and biomedicine.
Terahertz technology

The terahertz radiation observed by HIFI has a very high frequency. One of the challenges in processing this high frequency radiation is that there are no electronics available that can directly amplify high frequency signals. In HIFI this problem was solved by mixing the signals from space with a signal generated by a local source (oscillator) in the instrument. The result is a tremolo tone considerably lower in frequency that can be properly processed while still retaining all the scientific information. This is a familiar principle, the heterodyne technique, already used in ancient AM radio amplifiers. The superconducting detectors of HIFI converted the signal into an electrical current that was eventually transmitted to earth.

Technology transfer

In the development of market applications SRON is concentrating its efforts on one of the most important characteristics of terahertz radiation; the ability to penetrate through non-transparent and ‘non-polar’ materials. This ability makes terahertz radiation a good candidate to replace or supplement X-ray imaging and ultrasound imaging for security checks or quality control in nondestructive testing. Unlike X-rays, terahertz radiation is non-ionizing radiation, which makes it safer than X-rays. Its low photon energies in general do not damage tissues and DNA. Terahertz radiation is strongly absorbed by metals and polar materials (e.g. water), which makes it particularly suitable to determine water content in various materials (process control).

An SRON spin-off is developing promising marketable technology combinations through further research and development and will provide services to the market in several areas.
SRON's mission is to bring about breakthroughs in international space research. Therefore the institute develops pioneering technology and advanced space instruments, and uses them to pursue fundamental astrophysical research, Earth science and exoplanetary research. As national expertise institute SRON gives counsel to the Dutch government and coordinates – from a science standpoint – national contributions to international space missions. SRON stimulates the implementation of space science in our society.

SRON is part of the Netherlands Organisation for Scientific Research (NWO).

Address:
Location Groningen
Landleven 12
9747 AD Groningen
The Netherlands
Telephone +31 50 363 4074
Fax +31 50 363 4033
secr-g@sr.on.nl

Location Utrecht
Sorbonnelaan 2
3584 CA Utrecht
The Netherlands
Telephone +31 88 777 5600
Fax +31 88 777 5601

Mail info@sr.on.nl
Web www.sron.nl

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Published by
SRON Netherlands Institute for Space Research