Herschel: The first science highlights

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Herschel in space, close up on its mirror. Credits: ESA (Image by AOES Medialab)

This week, Astronomy & Astrophysics is publishing a special feature devoted to the first science results obtained with Herschel, an ESA space observatory with science instruments provided by European-led Principal Investigator consortia and with important participation from NASA. It includes 152 articles dealing with various subjects based on the first few months of science observing. A few papers describe the observatory and its instruments, and the rest are dedicated to observations of many astronomical targets from bodies in the Solar System to distant galaxies.

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Herschel was launched on 14 May 2009, and progress since launch with various webreleases can be followed on the Herschel Science Centre Latest News webpage at http://herschel.esac.esa.int/latest_news.shtml.

Herschel has a 3.5m diameter, passively cooled Cassegrain telescope and a complement of three science instruments, whose focal plane units are cryogenically cooled inside a superfluid helium cryostat. The PACS and SPIRE instruments provide broadband imaging photometry in six bands centred on 75, 100, 160, 250, 350, and 500 μm and imaging spectroscopy over the range 55-672 μm. The HIFI instrument provides very high-resolution heterodyne spectroscopy over the ranges 157-212 and 240-625 μm.

Beginning in October 2009 Herschel gradually - as more and more observing modes were validated and released for use - started to perform observations from the various approved science programmes using the PACS and SPIRE instruments. Owing to an anomaly, the HIFI instrument was unavailable from August 2009 to January 2010, and science using HIFI only started in earnest in February 2010.

This volume of *Astronomy & Astrophysics* contains 152 papers that were submitted by end of March 2010 highlighting Herschel's first science results. A few papers describe the observatory and its instruments, and the rest are dedicated to observations of many astronomical targets from bodies in the Solar System to distant galaxies.

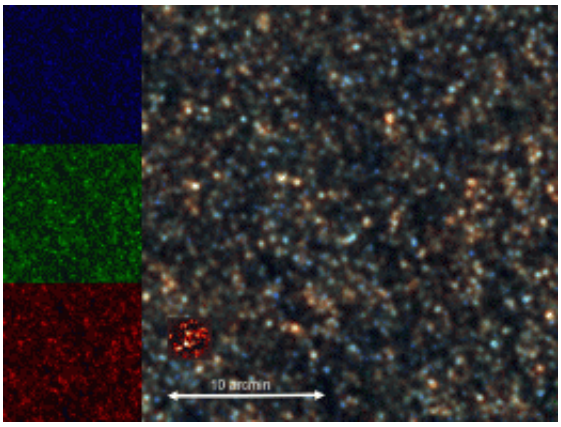

Fig. 1 - An area of GOODS-N as observed by Herschel/SPIRE. Inset the famous previous JCMT/SCUBA observation (ESA/SPIRE/HerMES/S. Oliver).

The prime science objectives of Herschel are intimately connected to the physics of and processes in the interstellar medium (ISM) in the widest sense: near and far in both space and time, stretching from Solar System objects and the relics of the formation of the Sun and our Solar System, through star formation in and feedback by evolved stars to the ISM, to the star formation history of the Universe, galaxy evolution, and cosmology. The very first observational results from Herschel already show that it will have strong impact on research in these fields as exemplified by the following three observational results.

The 'Great Observatory Origins Deep Survey' (GOODS), is a field that has been observed by many telescopes in a range of wavelengths, seen now by Herschel/SPIRE in submillimetre wavelengths (Fig. 1). This area of sky is devoid of foreground objects, such as stars within our Galaxy or any other nearby galaxies, which makes it ideal for observing deeper into space. Each fuzzy blob is a very distant galaxy seen as they were three to ten billion years ago when star formation was very more widespread throughout the Universe. The image is made from the three SPIRE bands, with blue, green, and red, corresponding to 250, 350, and

500 μm, respectively.

Fig. 2 - Herschel image of an area in the stellar nursery of the constellation of Aquila (ESA/SPIRE & PACS/P. André).

Herschel has imaged (Fig. 2) a stellar nursery around 1000 light-years away in the constellation Aquila (the Eagle). This cloud, 65 light-years across, is so shrouded by dust that no infrared satellite has been able to see into it, until now. Thanks to Herschel's greater sensitivity at the longest infrared wavelengths, astronomers have their first picture inside this cloud. Using Herschel's PACS and SPIRE instruments at the same time, the image shows two bright regions where large newborn stars are causing hydrogen gas to shine. Embedded in the dusty filaments are 700 condensations of dust and gas that will eventually become stars. Astronomers estimate that about 100 are 'protostars', that is, celestial objects in the final stages of formation. Each one just needs to ignite nuclear fusion in its core to become a true star. The other 600 objects are not developed enough to be called protostars, but eventually they will become another generation of stars. Observing these stellar nurseries is a key programme for Herschel, which aims to uncover the demographics of star formation and its origins, or in other words, the quantities of stars

that can form and the range of masses for these newborn stars.

A part of a Herschel/HIFI spectral scan is shown in Fig. 3. The observation is towards the Orion Nebula, a relatively nearby star-forming region, the 'sword' in the constellation of Orion. A characteristic feature is the spectral richness: among the organic molecules identified in this spectrum are water, carbon monoxide, formaldehyde, methanol, dimethyl ether, hydrogen cyanide, sulphur oxide, sulphur dioxide, and their isotope analogues. It is expected that new molecules will also be identified. This spectrum is the first glimpse of the spectral richness of regions of star and planet formation. It harbours the promise of a deep understanding of the chemistry of space once the complete spectral surveys are available.

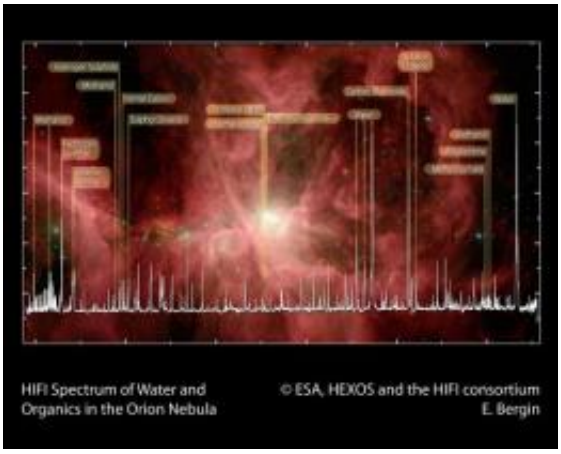

Fig. 3 - A part of a Herschel/HIFI spectral scan (the white curve) overlaid on a background Spitzer Space Telescope image (ESA/HIFI/HEXOS/E. Bergin).

These three examples are but the tip of the iceberg of what has been achieved in only a few months of science observing. The current best estimate of the total mission lifetime - from the launch onward - is in the range 3.5-4 years. Although the initial science results from Herschel are

just appearing and are very exciting, they represent only a very small fraction of what is still to come.

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