CFD-MHD Journal Club

Herschel mission & CERN LHC, update

Planck mission, review & status

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Herschel Mission

Observations are performed across the far infrared and sub-millimetre wavelengths in the new window 55 - 672 μm. Observations from Earth are possible for infrared only in narrow windows, because of absorption in atmosphere. Infrared is emitted by colder objects. Also, for objects veiled by dust, infrared, with longer wavelength can easier penetrate through dust. Objectives of the mission are:

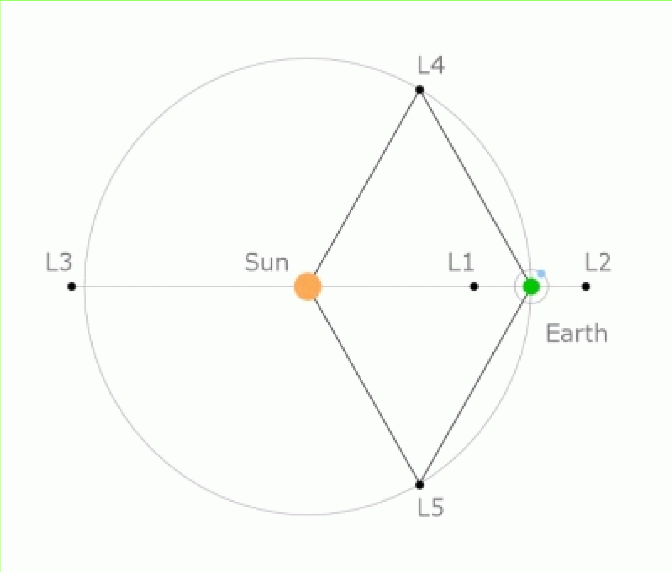
-Studying the formation of galaxies in the early universe and their subsequent evolution, -Investigating the creation of stars and their interaction with the interstellar medium, -Observing the chemical composition of the atmospheres and surfaces of comets, planets and satellites, -Examining the molecular chemistry of the universe.

Herschel

14 May 2009, Herschel and Planck satellite pair lifted off on board an Ariane 5 from Europe's Spaceport in French Guiana

Positioned in L2 point

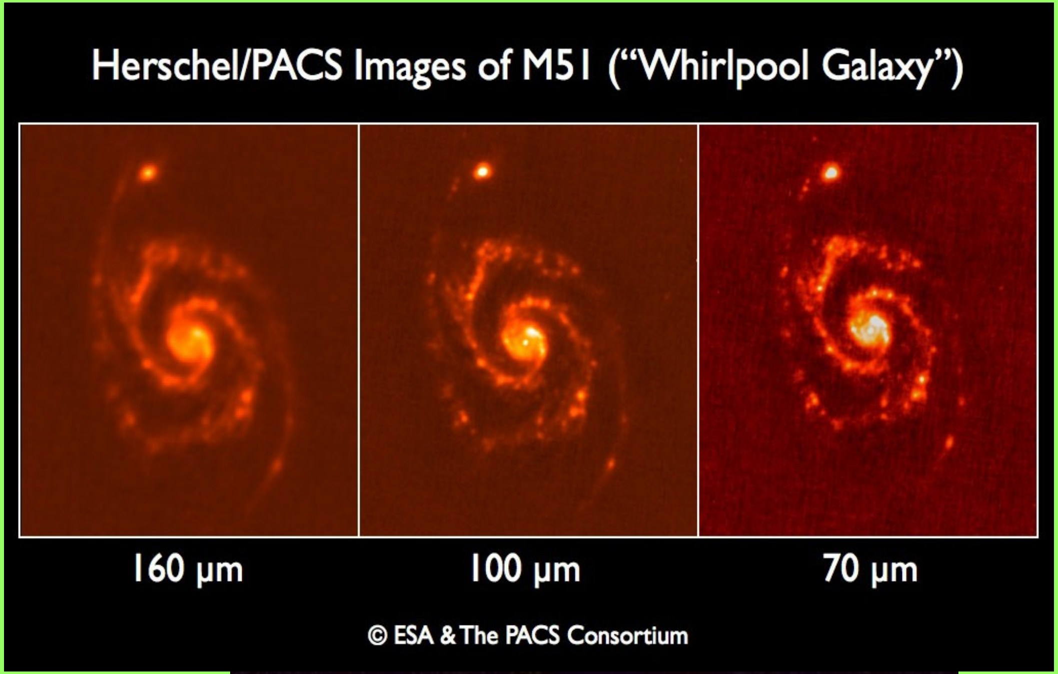
-all OK

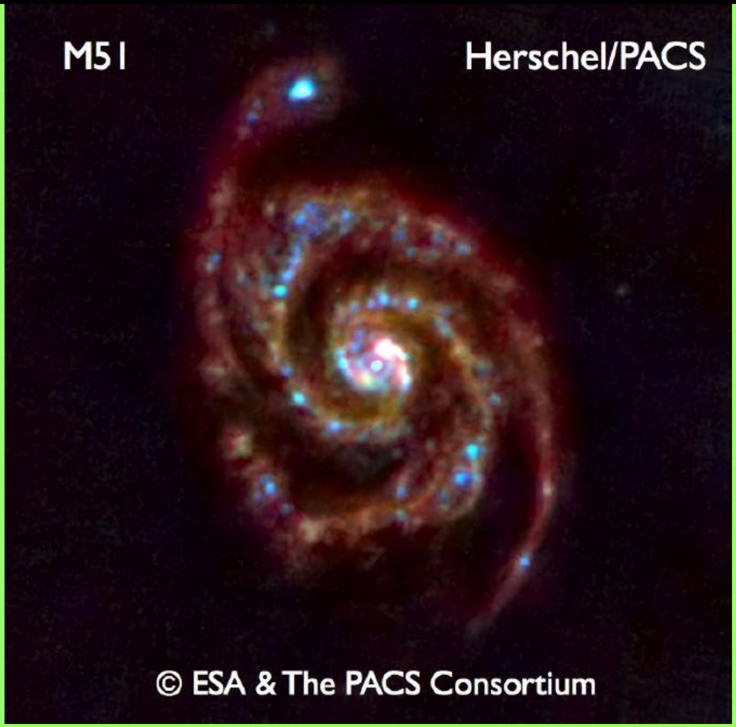


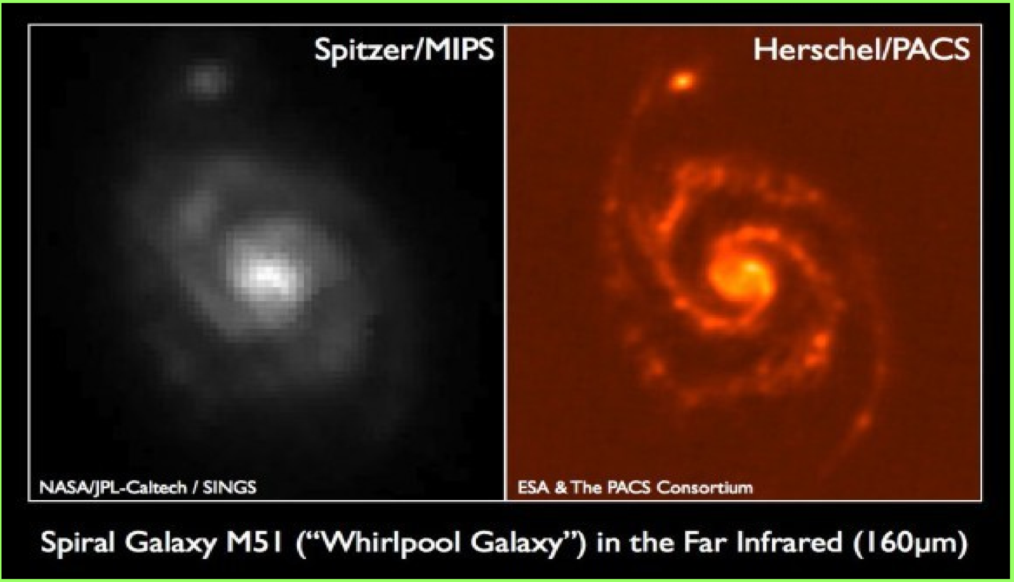
Sneak preview

June 14th, 2009-excellent, well resolved result, comparison with Spitzer data (below) showed benefits of large aperture telescope

-Blue colours indicate regions of warm dust that is heated by nearby young stars, while the colder dust in other parts of M51 shows up in red.





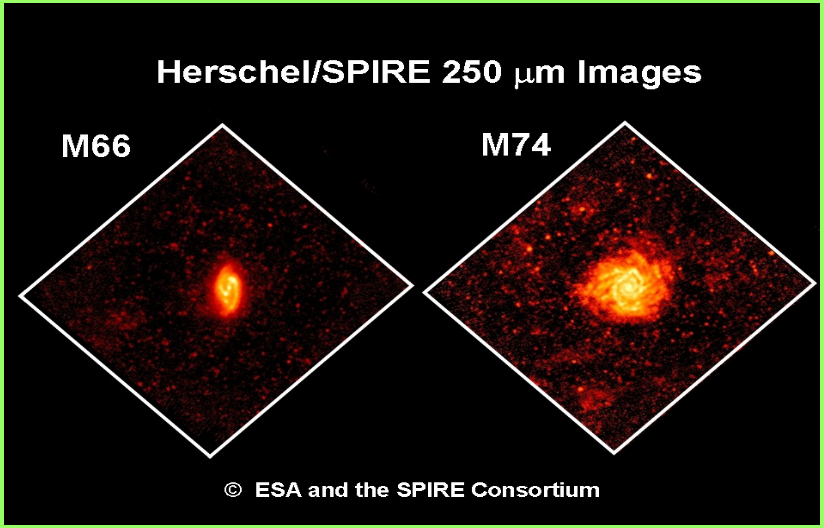


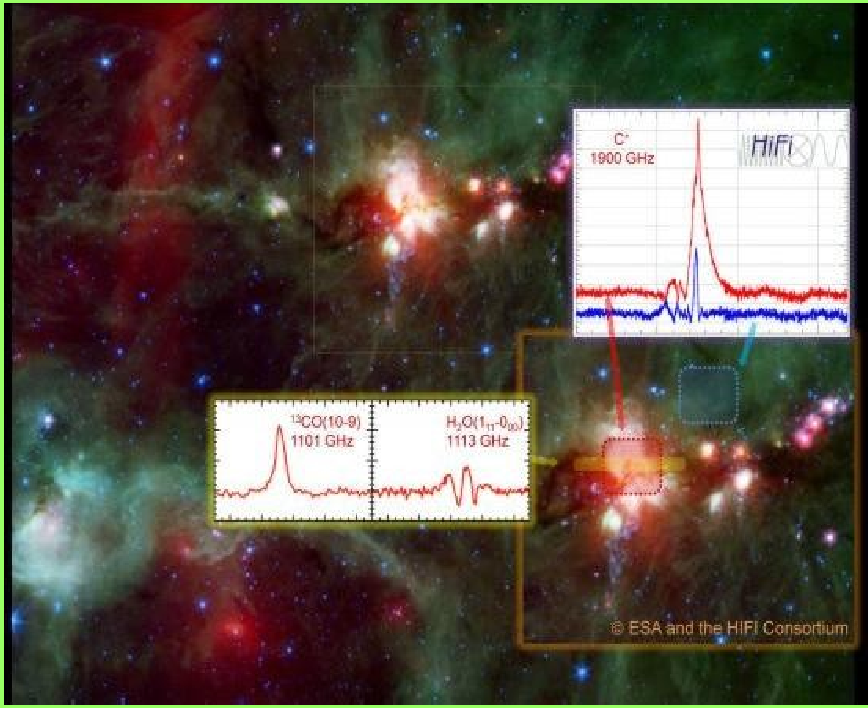
First light for SPIRE and HIFI

-first light: large aperture is important, but equally important is pushing into the sub-mm part of the far infrared spectrum for the first time and providing instrumental capabilities never before realized in a space observatory

-SPIRE: observes emission from clouds of dust in regions where stars are forming in our own and other galaxies

-HIFI terahertz spectroscope, a unique instrument for a space observatory, offering heterodyne spectroscopy at frequencies never before available and with a wide spectral coverage which will enable detailed study of the dynamics and astrochemistry. Here overly of Spitzer picture (shorter wavelenghts than Herschel can observe) and spectra by HIFI.





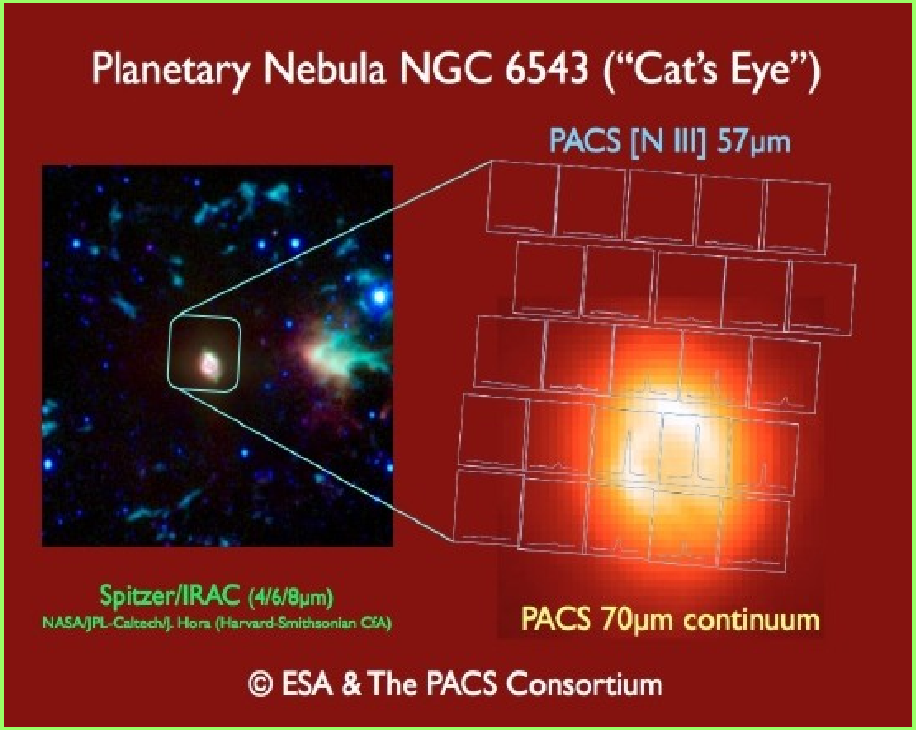
First light for PACS

-Both PACS and SPIRE can be operated as either photometers or imaging spectrometers

-The PACS spectrometer images a field on the sky in the light emitted by an individual spectral line, which can be used to diagnose physical properties and chemical composition.

-PACS observed the nebula in two spectral lines, the fine structure line of doubly-ionised nitrogen (N2+) at 57 µm and the fine structure line of neutral oxygen (O) at 63 µm

-for better orientation the PACS photometer was used to make a small map of NGC6543 in its 70 µm band, showing the structure of a dust ring with an opening on one side



First SPIRE/PACS parallel mode observation

-spectacular views in five different far infrared colours of an area near the galactic plane about 60 degrees away from the direction towards the centre of the Galaxy in the constellation of the Southern Cross

-left is SPIRE, right PACS, below is composite. Images constructed by colour-coding the different observing wavelengths, and creating composite false-colour images. In the SPIRE image blue denotes 250 µm, green 350 µm, and red 500 µm emission, while in the PACS image cyan denotes 70 µm and red 160 µm emission.

-reservoir of cold material in the galactic plane is seen to be in a previously unsuspected state of turmoil. Material is condensing in a continuous and interconnected maze of filaments and strings of newly forming stars in all stages of development. In composite picture the colour-coding allows us to differentiate material that is extremely cold (red) from that which is warmer.

Herschel spectroscopy galore!

In the *sneak preview*, *first light* and *parallel mode* emphasis has been on photometry. While some PACS and HIFI spectroscopy were featured in the 'first light', low unstable instrument temperatures in the early mission prevented SPIRE from performing spectroscopy. However, for some time now both SPIRE and PACS have been producing fantastic spectroscopy which will be featured here, the first time for SPIRE. A note also on HIFI, a plan to bring HIFI back in operation in January 2010.

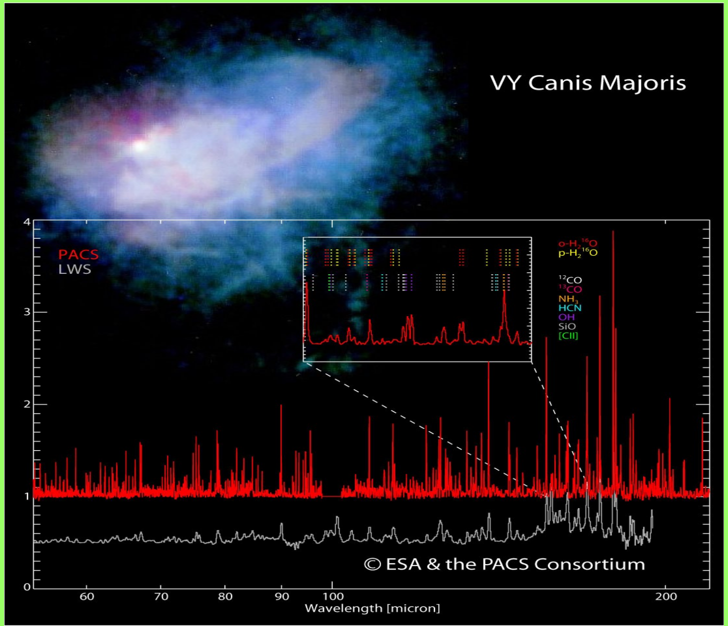
First SPIRE spectroscopy - sub-millimeter FTS observations

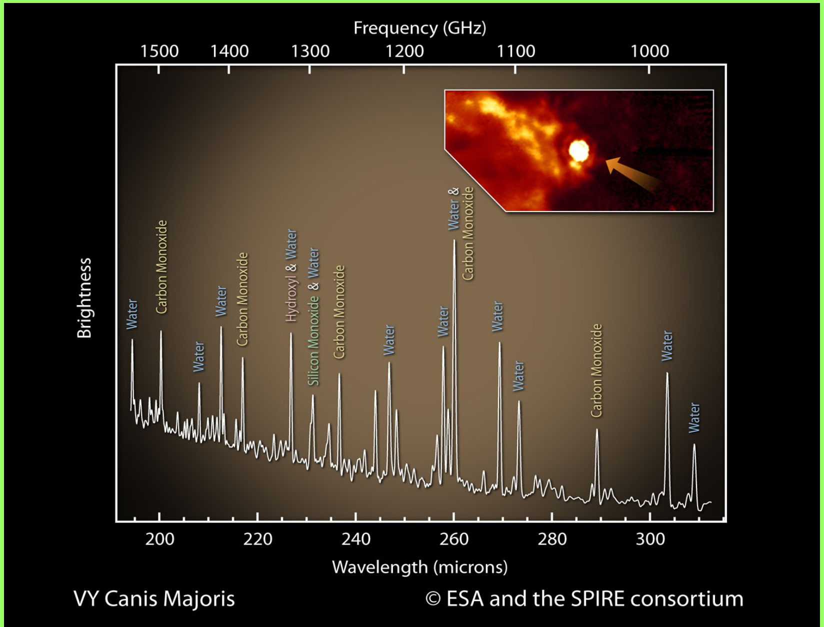
The SPIRE Fourier Transform Spectrometer (FTS) covers the frequency range from about 445 - 1550 GHz (194 - 672 µm), with a spectral resolution of 1.2 GHz. It provides a complete survey of the source spectrum over that whole wavelength range in a single observation (not possible with previous sub-mm instruments)

Several trial observations have been made as part of the commissioning and performance verification of the spectrometer. It is clear from these initial observations that the data are of excellent quality.

VY Canis Majoris - the largest known star

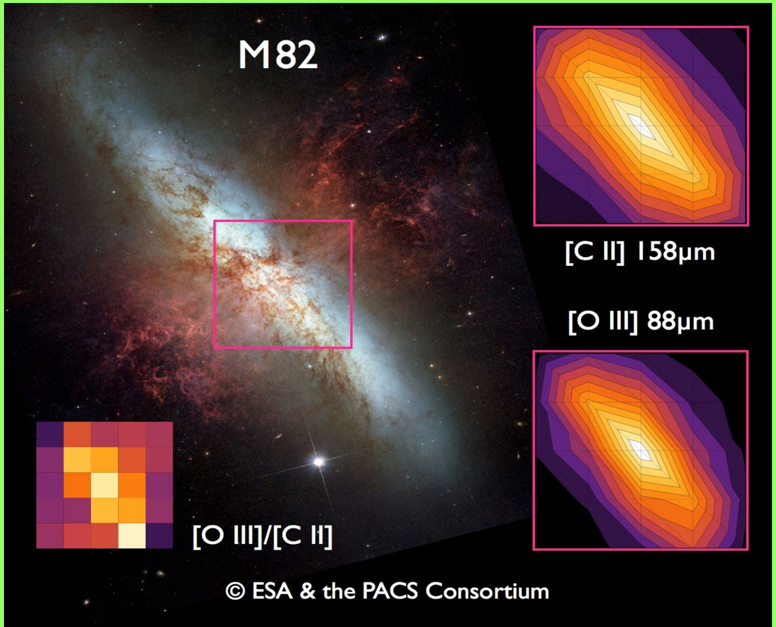
-red hypergiant evolved star, R= 2600 solar radii, the largest known star and also one of the most luminous ones. 4900 ly from Earth, 105 solar luminosities,M= 30-40 Msun, mass-loss rate of 2x10-4 Msun/yr. Circumstellar envelope as here is among the most remarkable chemical laboratories known in the universe, creating a rich set of organic and inorganic molecules and dust species. Through stellar winds, these inorganic and organic compounds are injected into the interstellar medium, from which new stars orbited by new planets may form. Most of the carbon supporting life on Earth was forged by this kind of evolved star. It is close to the end of its life and could explode as a supernova at any time. Left: PACS spectrum (in red) between 50 and 210 µm. In grey, the observation of the ISO Long Wavelength Spectrometer (LWS) is displayed (with an offset of -0.5). Background Hubble Space Telescope image in the optical and near-infrared wavelength as obtained by Smith et al. 2001. The inset shows a zoom into the 156 to 172 micrometer wavelength range. In this short wavelength region, 44 different molecular lines are identified (see coloured thick marks). Right: A portion of the SPIRE spectrum; the inset is a SPIRE camera map of VY CMa, in which it appears as a bright compact source near the edge of a large extended cloud.

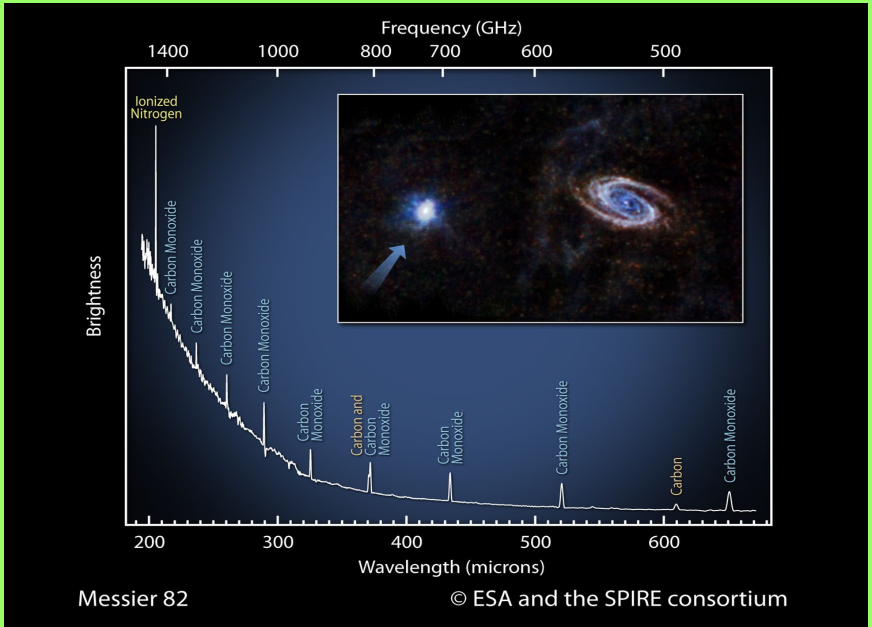




Messier 82 - the nearest star-burst galaxy

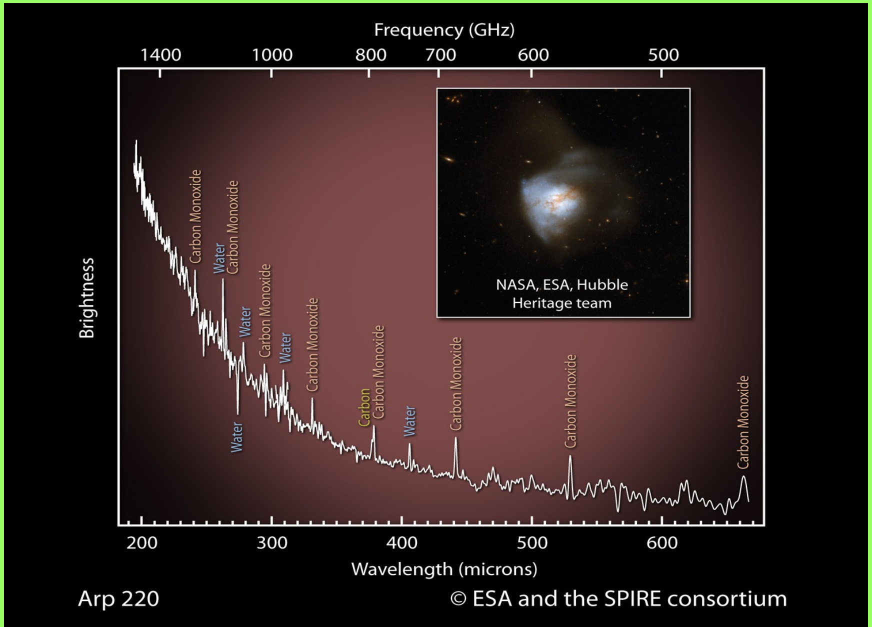
-Left: Hubble Space Telescope image of the starburst galaxy M82 (NASA/ESA/STScI/AURA/The Hubble Heritage Team) with the pink box outlining the area mapped by the PACS spectrometer. The two insets on the right show (colour-coded) intensity maps in the light of spectral lines of carbon and oxygen. The inset in the lower left shows the ratio of the oxygen line over the carbon line. The variation of this ratio reflects the different physical conditions across this galaxy. Right: The SPIRE spectrum of M82. The accompanying image is a spectacular three-colour composite picture of the M81 and M82 pair of galaxies made with the SPIRE camera. M82 is famous for its bi-polar outflow or "super-wind", gas and dust driven outwards by stellar winds and supernovae in the galaxies central regions, where stars are produced at a very high rate. The physical conditions in the interstellar medium (ISM) of such a galaxy vary strongly across the different environments. PACS (Fig. 2 left) provides for the first time the necessary sensitivity and imaging capability with sufficient spatial resolution to study these variations in detail. The ratio [O III]/[C II], a diagnostic of ionized gas vs. neutral gas drops rapidly going outwards from the galaxy centre along the disk. In contrast to this the ratio drops less when going outward in the super-wind direction.The SPIRE spectrum of M82 (Fig. 2 right) shows strong emission lines from CO over the whole wavelength range, as well as emission lines from atomic carbon and ionized nitrogen.

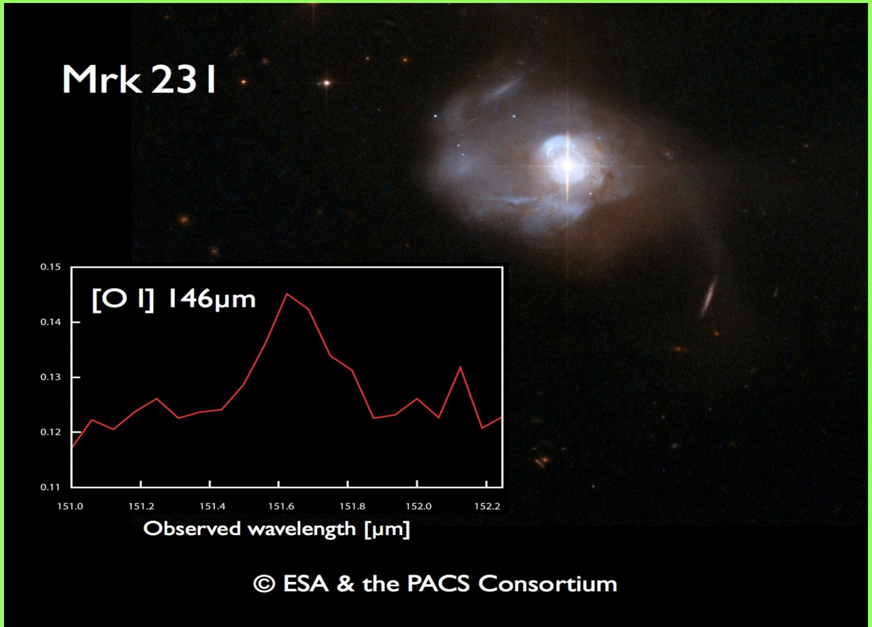




Arp 220 and Markarian 231 - giant mergers

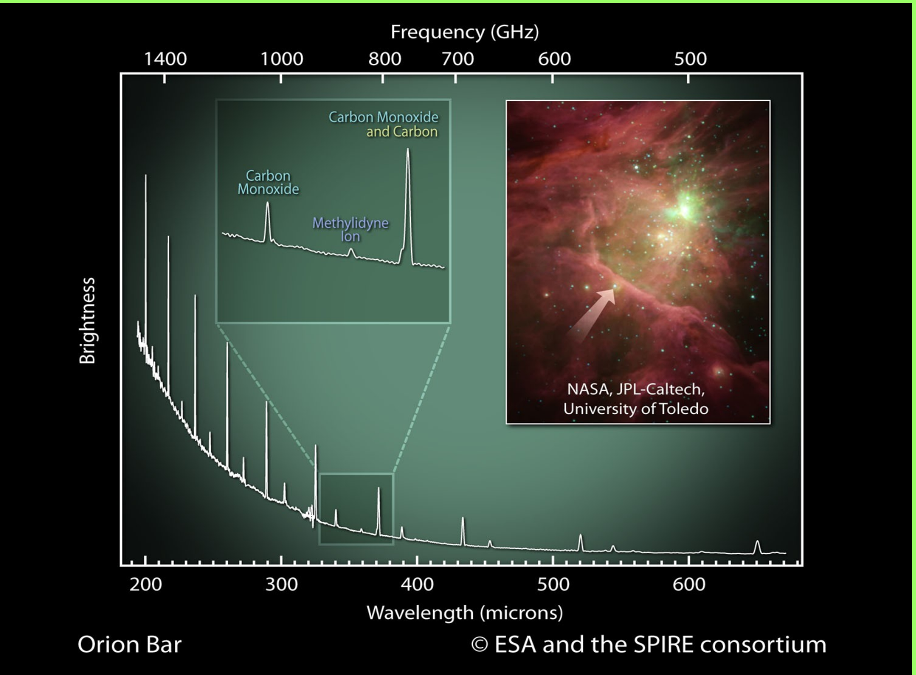
-Previous infrared space missions discovered that collisions and mergers of gas-rich galaxies glow with the luminosity of a quasar. The incredible far-infrared luminosity of these dust-shrouded mergers known as "Ultraluminous Infrared Galaxies" (ULIRGs) is caused by extremely energetic starbursts, producing hundreds of new stars every year, as well as by accreting super-massive black holes in their active nuclei. Two well-known examples Arp 220 and Markarian 231 (Mrk 231) have been observed by Herschel.Left: SPIRE spectrum of the star forming galaxy Arp 220. Right: PACS spectral scan of one of the emission lines detected by Herschel PACS in Mrk 231 is shown superposed on an optical image of this galaxy created using Hubble data. SPIRE FTS capabilities are demonstrated by a spectrum of Arp 220, a galaxy 250 million ly from us, with very active star formation triggered by a merger between two large spiral galaxies. The spectrum shows many emission features of CO, and H2O features are seen both in emission and absorption. The inset is an optical image of Arp 220 made with the Hubble Space Telescope. In addition to intense continuum and strong molecular line emission, starburst galaxies also emit weak far-infrared fine-structure spectral lines. Using PACS on Herschel for the first time these weak emission line signatures from such an object have been measured (right Fig.) in the extraordinary galaxy Mrk 231

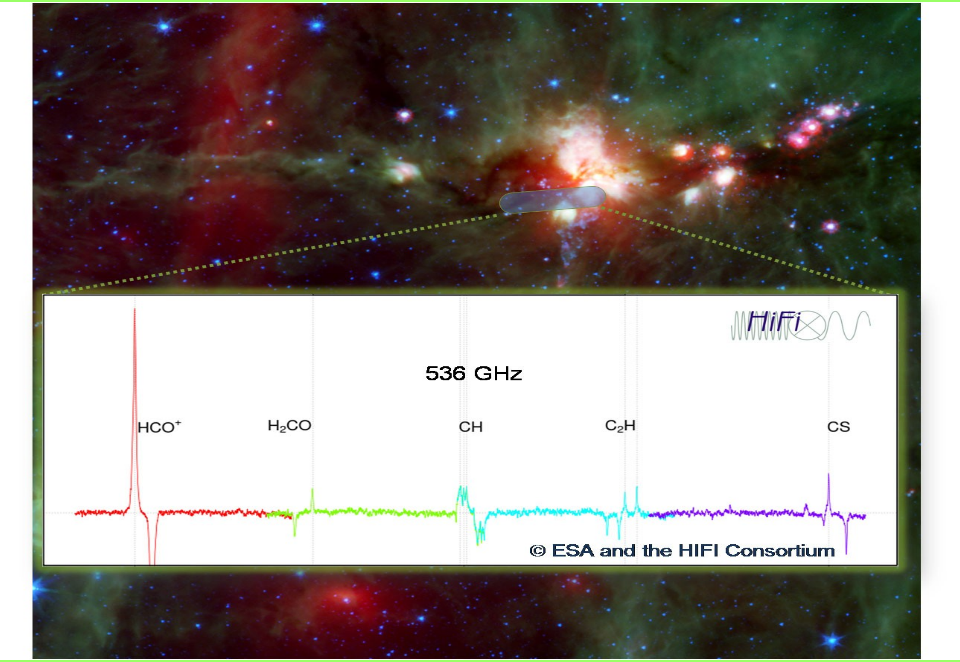




Orion and DR21 - galactic star formation

Orion nebula and DR21 regions are examples of massive star forming regions in the Milky Way. Left: SPIRE spectrum of one position on the Orion Bar, a region in the Orion nebula in which the gas on the edge of the nebula is partly ionised by the intense radiation from nearby hot young stars. Right: The HIFI spectrum on DR21 reveals the fingerprints of a number of key organic molecules (formaldehyde, carbon sulfide, the formyl ion, the ethynyl radical, the methyladyne radical; HCO+, CH, C2H, H2CO and CS). The inset (left) and background (right) are near infrared pictures from NASA's Spitzer Space Telescope. Right: HIFI can for the first time observe the submillimetre spectral regime unhampered by telluric absorption and hence will provide an unbiased inventory of the molecular composition of such regions and new insights in the formation and early evolution of stars. The DR21 spectrum was obtained by the so-called frequency switch mode. In this mode the local oscillator is tuned between two slightly different frequencies reversing one the two spectra, obtaining two phases, that can later be combined. This way all the observing time is spent usefully integrating on the signal.

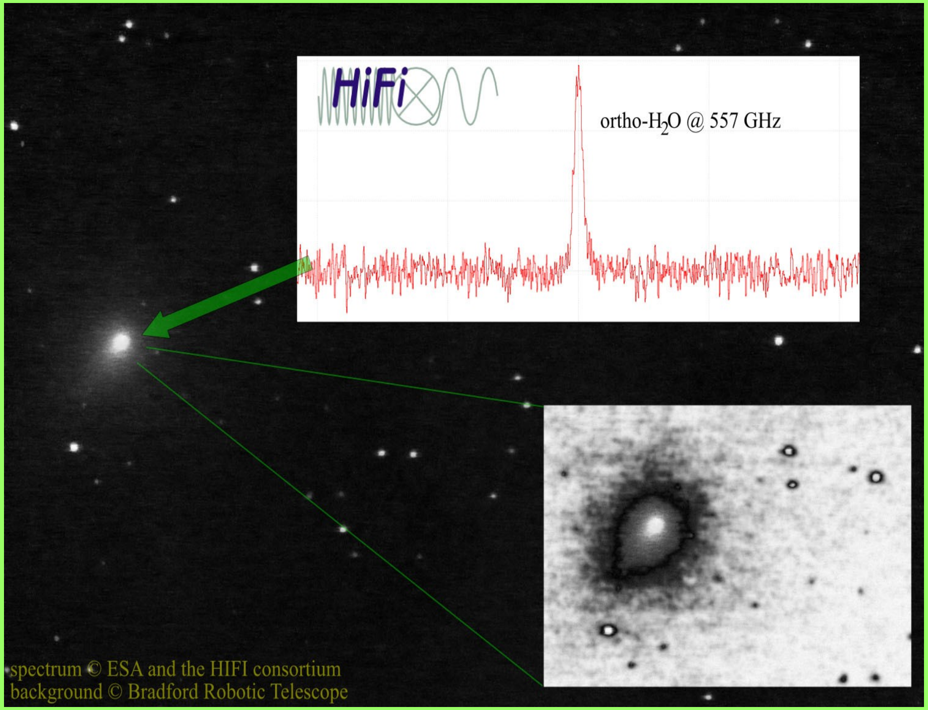




Comet Garradd - water in the Solar system

HIFI spectrum of Comet Garradd, revealing a strong water line. Planned HIFI studies will inter-compare the characteristics of water and volatile organic molecules released by different comets in the Solar system as they approach the Sun.

Small perturbations in their orbit can propel comets inwards. When they approach the Sun, the increased heat releases water and other molecules from the frozen nucleus, allowing us to measure the composition and characteristics of the comet. Comets may have contributed greatly to the inventory of volatiles such as water on the Earth and other terrestrial planets.



A note on HIFI, a plan is to bring HIFI back in operation in January 2010.

CERN LHC-update

-The Large Hadron Collider (LHC): particle accelerator near Geneva, spans the border between Switzerland and France about 100 m underground.

-in it physicists will be colliding the two hadron (either protons or lead ions) beams to recreate the conditions just after the Big Bang.

Some say it is made to hunt for the Higgs particle, the only fundamental particle predicted by the Standard Model that has yet to be observed. It is a massive scalar elementary particle predicted by the Standard Model. It has no intrinsic spin, and for that reason is classified as a boson (like the force mediating particles, which have integer spin). An exceptionally large amount of energy and beam luminosity are theoretically required to observe a Higgs boson in high energy colliders. Higgs boson explains why the other elementary particles, the photon and gluon excepted, are massive. In particular, the Higgs boson would explain why the photon has no mass, while the W and Z bosons are very heavy. Elementary particle masses, and the differences between electromagnetism (mediated by the photon) and the weak force (mediated by the W and Z bosons), are critical to many aspects of the structure of microscopic (and hence macroscopic) matter. In electroweak theory, the Higgs boson generates the masses of the leptons (electron, muon, and tauon) and quarks.

Restart-update

-The first beams circulated smoothly, the first low-energy collisions happened very quickly, and the first ramp up to record energy was exceptionally good.

The focus has been on increasing the number of protons in the circulating beams. 4th December:a beam circulated with more than one proton bunch for the first time. Then operators succeeded in circulating four bunches in both directions around the LHC and announced stable beams. Further work focussed on safety of work and checking that stable conditions can be guaranteed during collisions first at 450 GeV and then at 1.18 TeV per beam. 8 Dec: two bunches per beam circulated for the first time at 1.18 TeV for a short period and ATLAS recorded its first collisions at the record energy of 2.36 TeV (centre of mass).

With four bunches per beam and more protons per bunch, the LHC is providing more and more collisions and all six experiments are recording as much data as possible. 28 Nov the ALICE collaboration submitted its first paper based on the reconstruction and analysis of the 284 collision events at 450 GeV per beam. The results are consistent with measurements performed by previous experiments, in particular with those at the SPS when it worked as a proton-antiproton collider with the same beam energy as the LHC in this first phase of commissioning.

The LHC turned off on 16 December for Christmas/NY break, and it will start up again in 2010-will aim at gently increasing the intensity and energy of the beams until the planned 3.5 TeV for each beam is reached, marking the beginning of the physics programme.

Reminder: List of scientific problems to solve

-What is mass? - The most likely explanation may be found in the Higgs boson, a key undiscovered particle that is essential for the Standard Model to work. First hypothesised in 1964, it has yet to be observed. -The ATLAS and CMS experiments

-search for supersymmetric particles to test a likely hypothesis for the make-up of dark matter and energy.-The ATLAS and CMS experiments

-looking for differences between matter and antimatter to help answer this question. Previous experiments have already observed a tiny behavioural difference, but what has been seen so far is not nearly enough to account for the apparent matter–antimatter imbalance in the Universe.-The LHCb experiment

-recreating conditions similar to those just after the Big Bang, in particular to analyse the properties of the quark-gluon plasma. -The ALICE experiment

-hidden dimensions of space may exist; for example, string theory implies that there are additional spatial dimensions yet to be observed. These may become detectable at very high energies- data from all the detectors will be carefully analyzed to look for signs of extra dimensions.

Planck Mission

Launched together with Herschel atop ArianeV in May 2009. Planck is Europe's first mission to study the relic radiation from the Big Bang.

The Planck spacecraft, weighing about 1900 kilograms at launch, is 4.2 metres high and has a maximum diameter of 4.2 metres. It carries telescope with a 1.5-metre primary mirror. The telescope focuses radiation from the sky onto two highly sensitive detectors called the Low Frequency Instrument and the High Frequency Instrument.

The Low Frequency Instrument (or LFI) is an array of 22 tuned radio receivers that will be operated at –253°C. These receivers will work grouped in four frequency channels, centred between 30 and 70 GHz. They are based on devices called 'HEMTs' (High Electron Mobility Transistors), and work just like transistor radios. The transistors amplify the signal collected by the antenna (the telescope), and the amplified signal is then converted to a voltage. In a normal radio, the detected signal would then be passed on to a speaker, but in Planck it will instead be stored in a computer for later analysis.

Planck Mission - 2

The High Frequency Instrument (or HFI) is an array of 52 bolometric detectors, which work by converting radiation to heat. The amount of heat is then measured by a tiny electrical thermometer, the signal from which is converted to a temperature by a computer. The HFI detectors work in six frequency channels centred between 100 and 857 GHz. They are operated at –272.9°C (only one tenth of one degree above absolute zero). To achieve that temperature a complex system of on-board refrigerators is used, each of which uses a different technology to provide a successively colder temperature.

Planck' routine science observations at L2 will last 15 months, allowing two sky surveys. The mission could in principle be further extended, depending on the resources still available for the instruments cooling.

Planck Mission - 3

Why is the 'first light' of the Universe detected today as microwaves? When the 'first light' CMB was released, the Universe was much smaller than it is now. The waves of that light were much more compressed, their frequency was very high. Since Universe has expanded, the waves of that light have stretched, and frequency is much lower than it used to be=in the 'microwave' range. Planck is designed to 'see' the microwaves and will detect them by measuring temperature, known to be 2.726K, all over the sky to three decimal figures. This degree of accuracy in the measurement may seem good enough, but much more precise measurements are needed. Scientists know, from previous observations, that slightly hotter or colder 'patches' appear in the sky (different by one part in 100 000). These differences in temperature are the imprints left in the CMB by the primeval 'seeds' of today's huge concentrations of matter — the galaxies and galaxy clusters for example.

The information Planck has to gather lies in the pattern formed by these slightly hotter and colder regions, called 'anisotropies' or 'inhomogeneities'. As a consequence, the Planck detectors will have to be highly sensitive and will have to work at temperatures very close to the absolute zero, otherwise their own emission of heat will spoil the measurements.

Planck Mission - 4

Some of the key questions Planck will answer are:

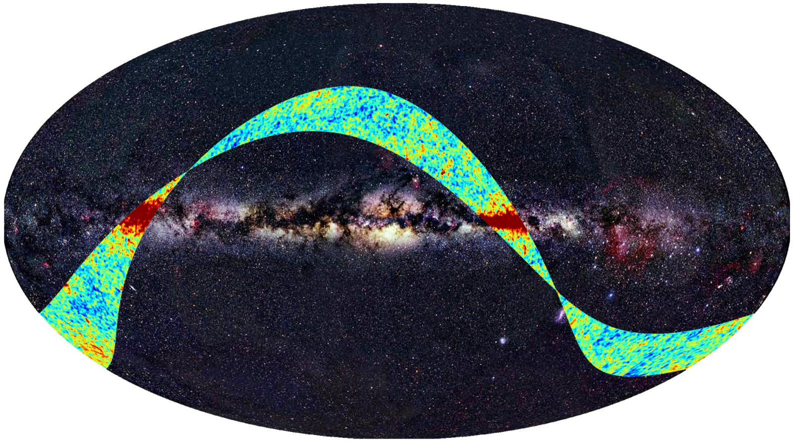
* Will the Universe continue its expansion forever, or will it collapse into a 'Big Crunch'?

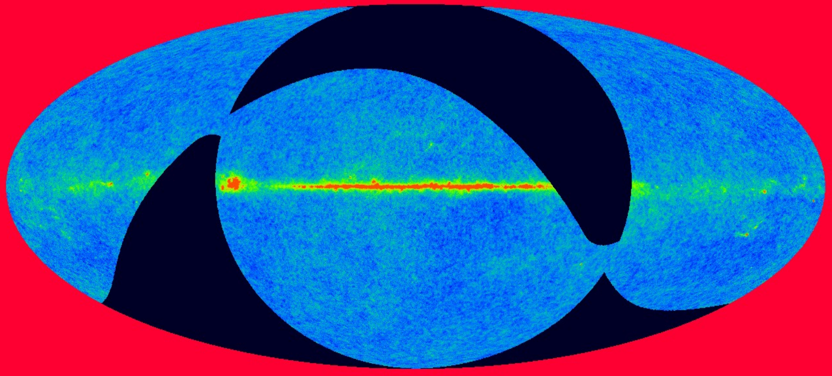
* What is the age of the Universe?

* What is the nature of the so-called 'dark matter' (which may account for more than 90% of the total amount of matter in the Universe but that has never been detected directly)?

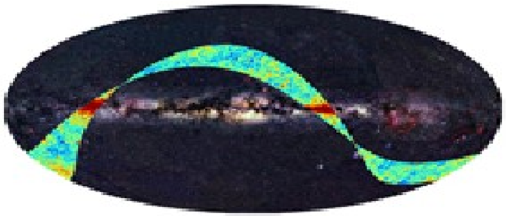
* What is the nature of dark energy (a hypothetical form of energy that may account for the Universe's expansion at an accelerating rate)?

FIRST SKY COVERAGE: Aug13- Dec15, 2009, 72% of the sky displayed

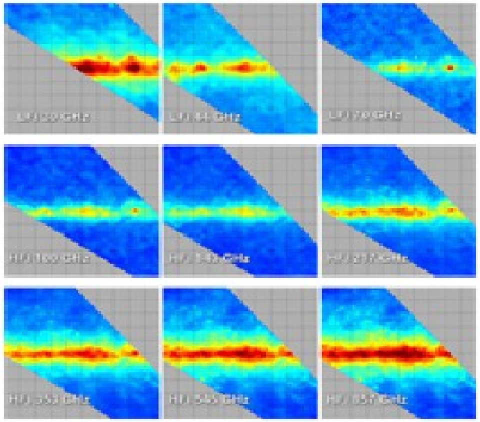




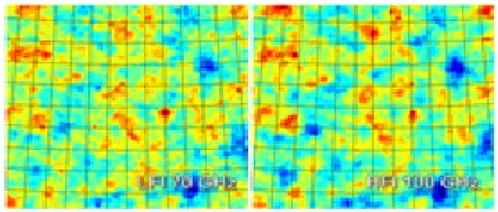
Planck Mission – first results



Planck First Light Survey

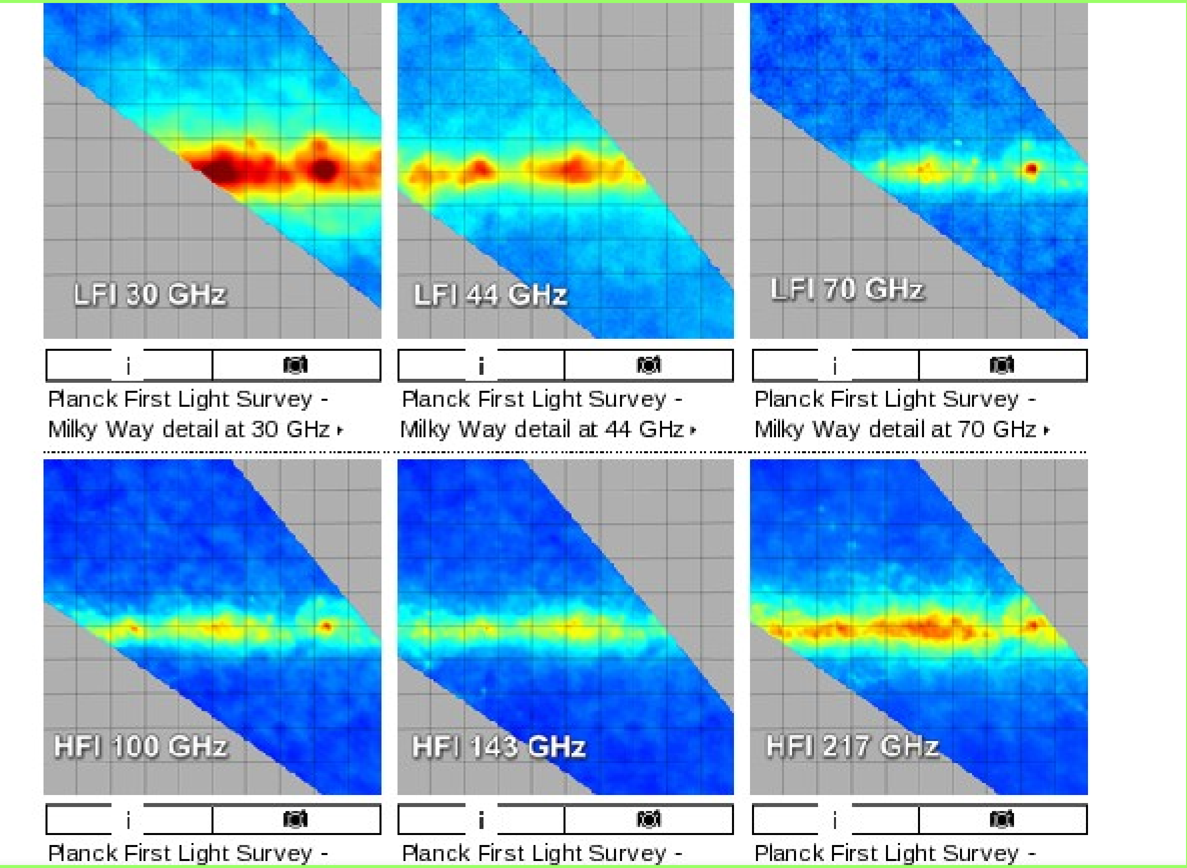


Planck First Light Survey - detail of the Milky Way at nine frequencies



Planck First Light Survey - detail at high galactic latitude

Planck Mission – first results



Planck Mission - Major upcoming milestones

1st half of January 2010: observation of Sun

February: First science release of Planck's internal archive for scientific exploitation within the Planck collaboration.

1st half of March: observations of Crab Nebula

1st half of April:observations of Mars

April:Planck starts its Second All Sky Survey.

1st half of May : observations of Neptune

1st half of June:observations of Saturn

2nd half of June: Uranus and Jupiter

June:Second science release of Planck's internal archive for scientific exploitation within the Planck collaboration.

December: An early all-sky catalogue of compact and point sources extracted from Planck's data is released

2012:Calibrated time-ordered data, full sky maps at each frequency, full sky component maps (CMB, and Galactic emission), and a final compact source catalog are made publicly available.