CFD-MHD Journal Club

Herschel mission, review & current status

CERN LHC-review, status

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Herschel Mission Objectives

-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

-Observe the chemical composition of the atmospheres and surfaces of comets, planets and satellites

-Examine the molecular chemistry of the universe

Observations are performed across the far infrared and sub-millimetre wavelengths (55 - 672 μm) (previously unobtainable)

Infrared astronomy

-Most of infrared band is absorbed in Earth atmosphere, except for a narrow ranges that make it through to ground-based instruments. Earth's atmosphere radiates it's own infrared radiation, adding to problem in observing.

Why infrared is so special?

-many of the things we would like to investigate are far too cold to radiate at optical or shorter wavelengths, but radiate strongly in infrared, for example, the cold atoms and molecules that drift in interstellar space. To observe e.g. star formation, very early steps, we need infrared because formation processes very often happen in cool and dusty places.

-our view to star formation locations is blocked because the dust grains are very effective at scattering or absorbing visible light. Longer infrared wavelengths can get through the dust.

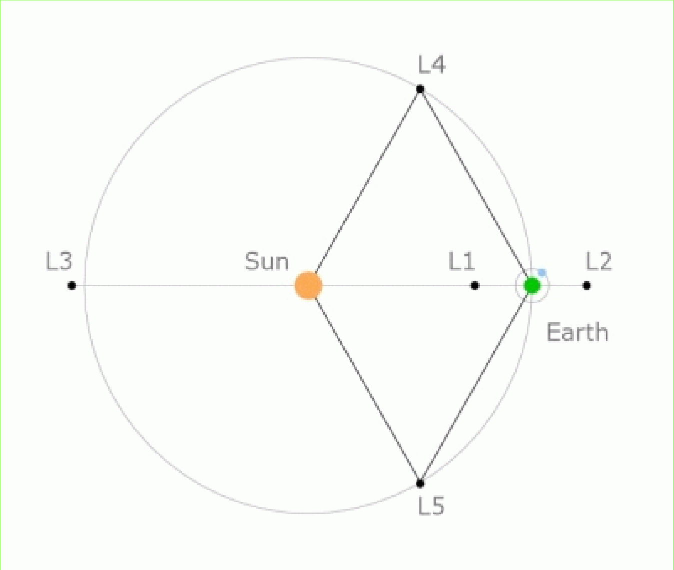
Herschel

Herschel satellite:
http://sci.esa.int/science-e/www/object/i

Launch

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

Launch video:
http://www.videocorner.tv/videocorner2



-60 days travel to L2 point

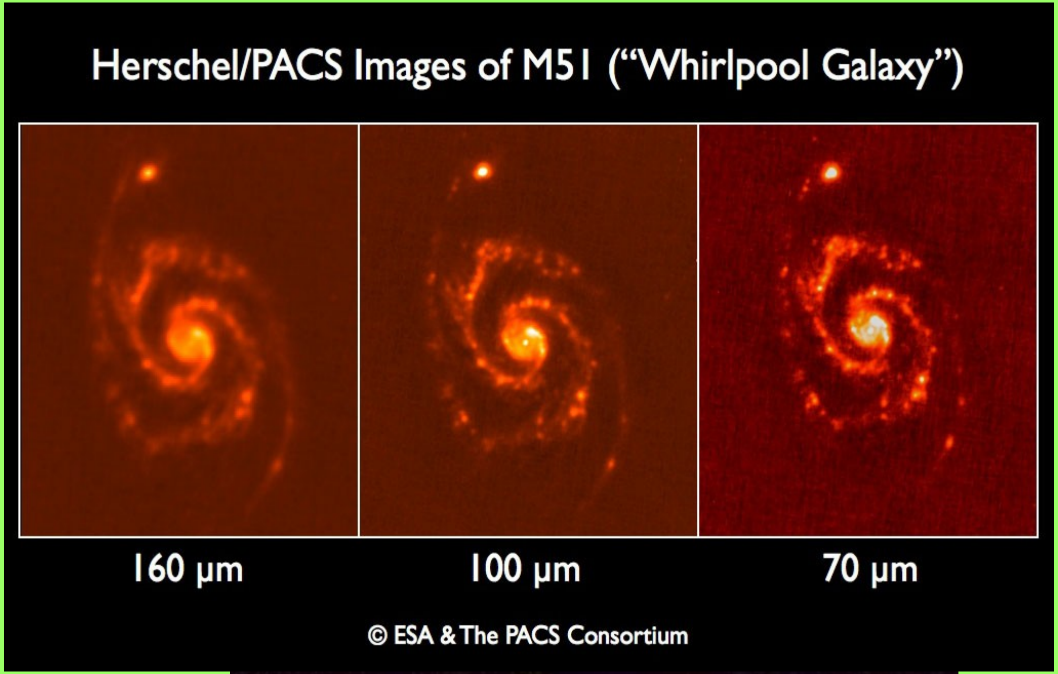
-opening of cryostat lid, verification phase of instruments

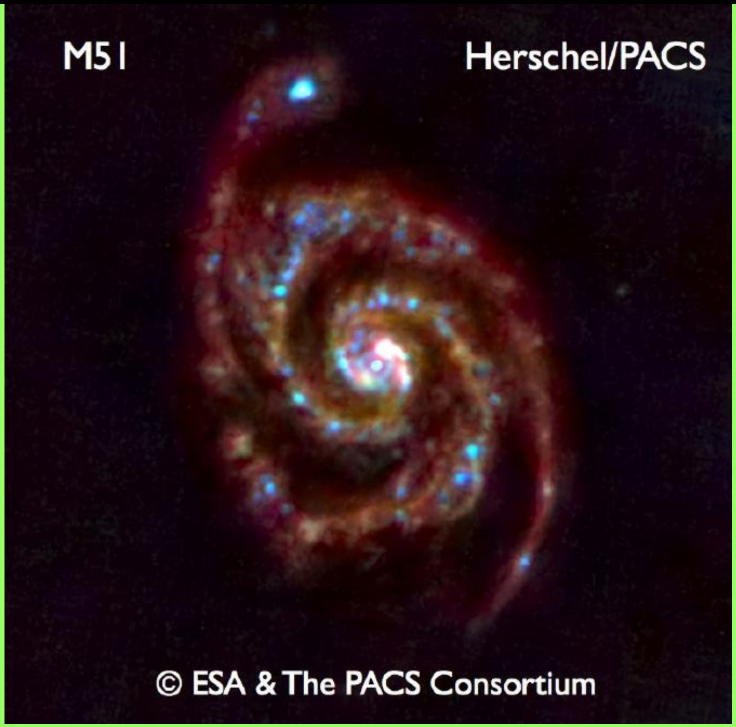
-all OK

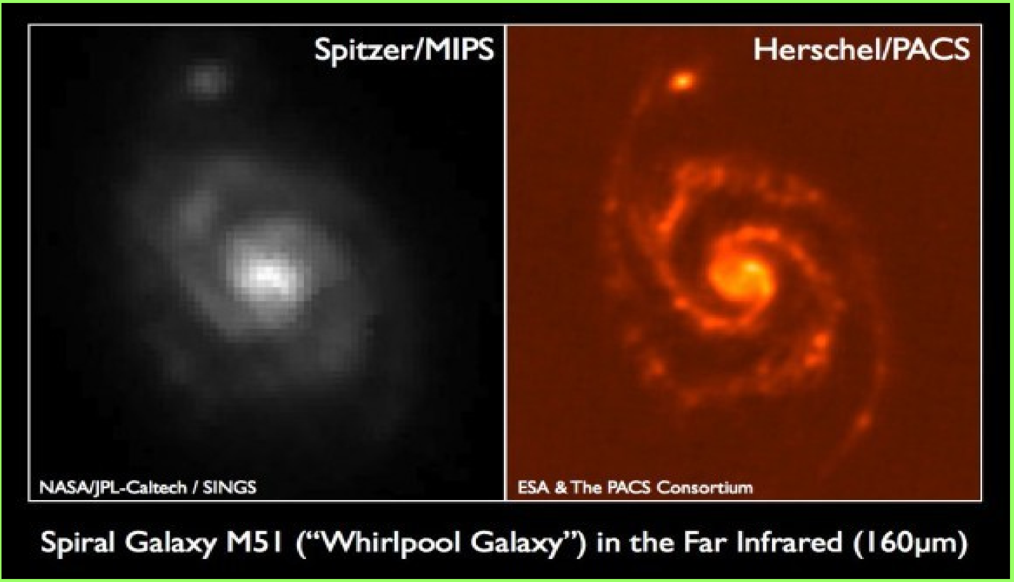
Sneak preview

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.





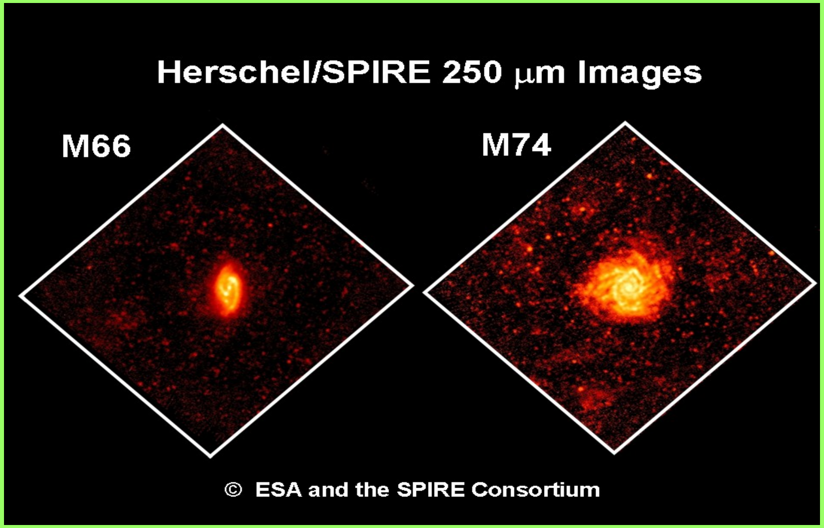


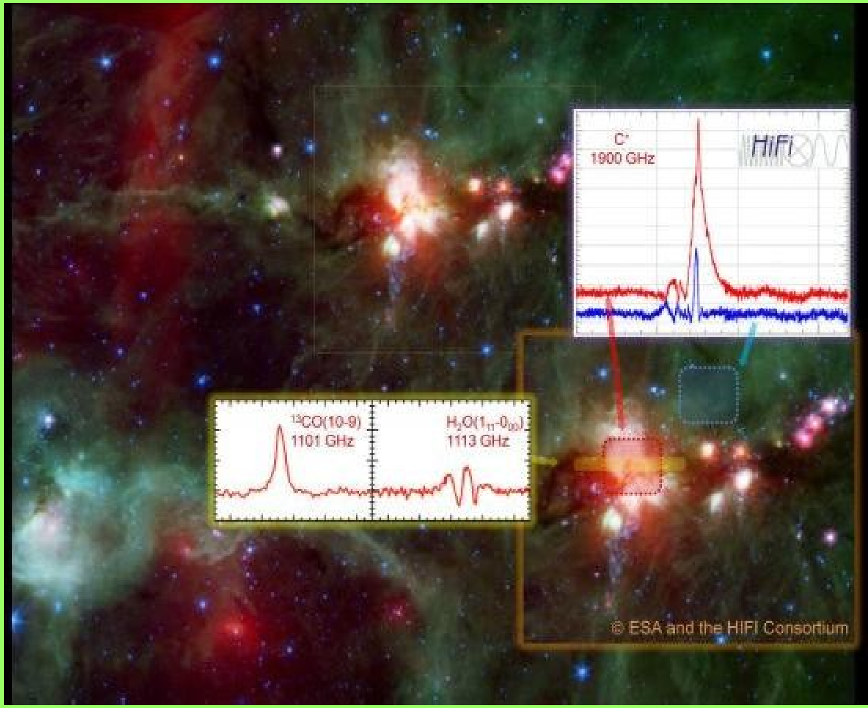
First light for SPIRE and HIFI

-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.





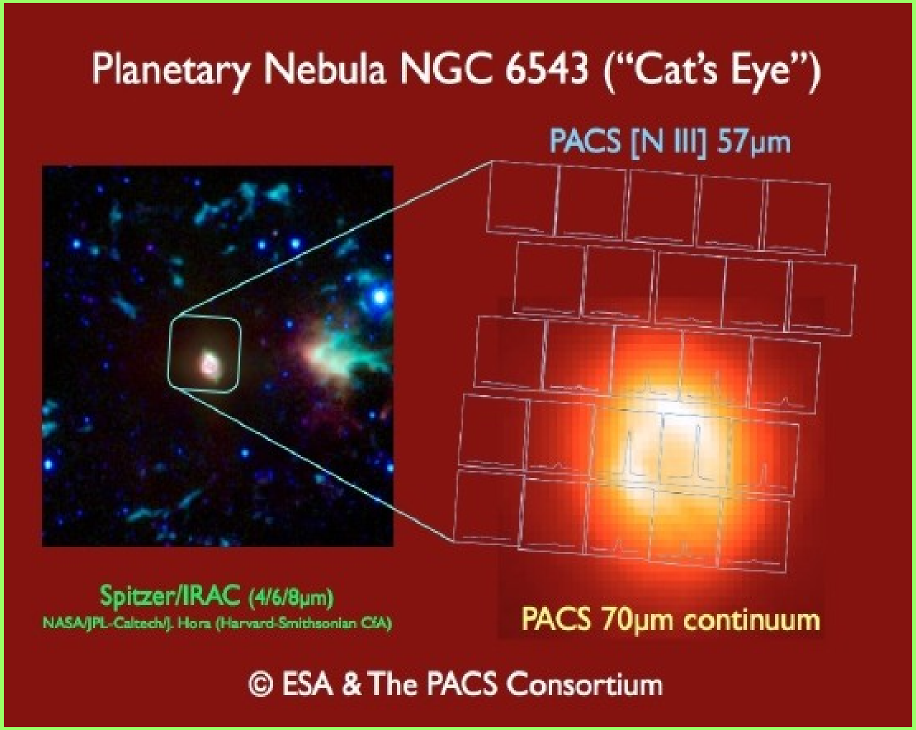
First light for PACS

-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.

Trouble with HIFI

-On 3 August 2009 it was discovered by HIFI that on the day before the local oscillator control unit (LCU) had developed an anomaly leading to HIFI shutting down.

-HIFI does have a duplicate, or redundant, set of electronics that will be used and which provides full functionality. The engineering and science team is working to understand the cause of the anomaly before switching to the duplicate set of electronics.

-Sep. 11, 2009, the team established by ESA and HIFI trying to piece together what appears to be a complex puzzle of events which includes, but seems to be more complex than, failure of a DC/DC converter. By correctly understanding the failure scenario we hope to be able to minimise the risk when we switch HIFI back on, possibly using its redundant signal chain.

-Oct. 05, 2009: report about the progress that is being made towards re-enabling HIFI operations. HIFI Project Manager cautions that switching the instrument back on may still be a few weeks in the future: We must ensure that we have taken all conceivable measures to minimize the risk of such a chain of events from happening again. One of these measures may require changes in on-board software, the validation of which would have to be performed with the utmost care.

CERN LHC-goals, status

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

-By colliding the two hadron (either protons or lead ions) beams physicists will use the LHC to recreate the conditions just after the Big Bang, by colliding the two beams head-on at very high energy.

-many theories as to what will result from these collisions, but what's for sure is that a new physics will emerge from the results.

-Standard Model of particle physics has served physicists well as a means of understanding the fundamental laws of Nature, but it does not tell the whole story. Only experimental data using the higher energies reached by the LHC can push knowledge forward.

Science before LHC

-In the 1960s Steven Weinberg, Abdus Salam and Sheldon Glashow, proposed a theory. They believed that two of the four fundamental forces – the electromagnetic force and the weak force – were in fact different facets of the same force. Under high-energy conditions (such as in a particle accelerator), the two would merge into the electroweak force.

The first evidence in support of the theory emerged when the Gargamelle detector at CERN found the neutral current, an essential ingredient to the electroweak theory. Further observations followed to secure the three theorists a Nobel Prize in 1979.

However, there were still three hypothetical force-carrier particles described by the theory that no one had managed to find. The W+, W- and the Z0 bosons remained tantalisingly out of reach until an accelerator could be built with high enough energy to carry out the search – a problem solved by the conversion of the SPS accelerator proposed by C. Rubbia into beam collision device=observation done in 1983, so important that awarded Nobel prize in 1984 for Carlo Rubbia as group leader and Simon Van de Meer (who at CERN had invented a way of producing and storing dense beams of protons or antiprotons).

Standard model

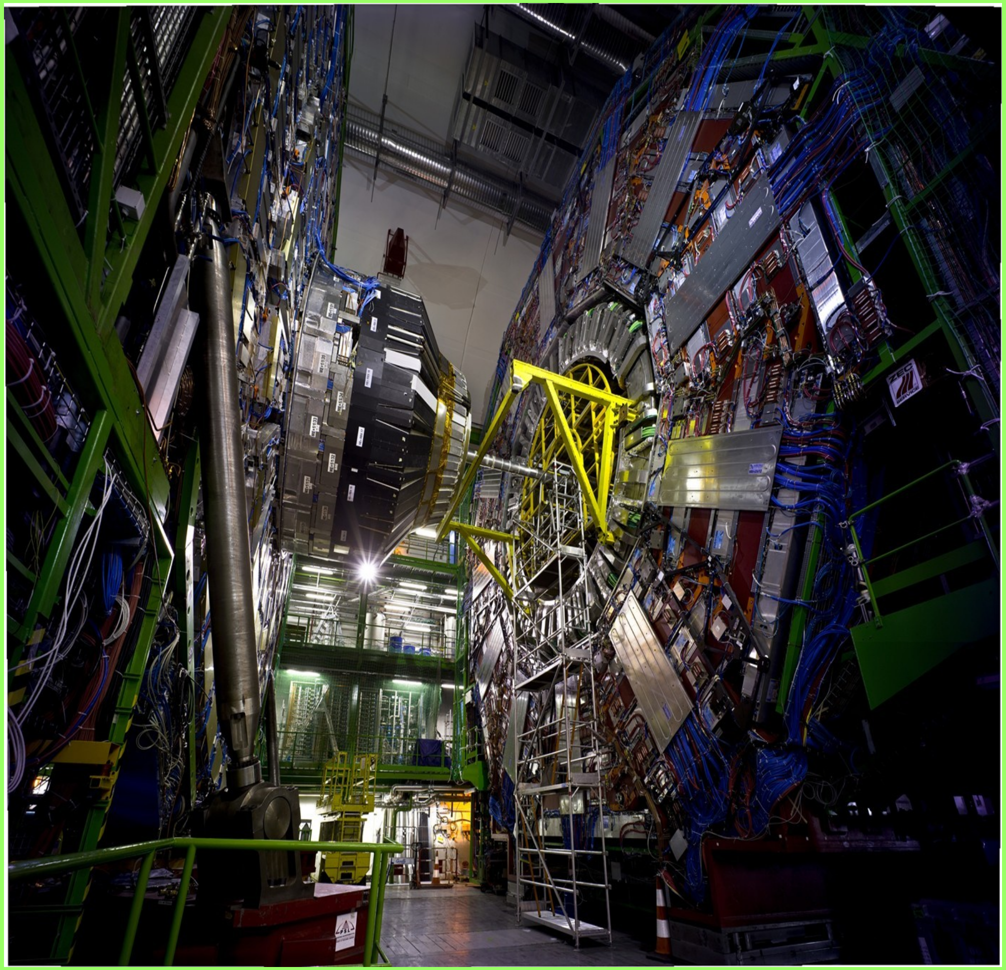
The Higgs particle is a massive scalar elementary particle predicted by the Standard Model. It has no intrinsic spin, and for that reason is classified as a boson (like the force mediating particles, which have integer spin). Because an exceptionally large amount of energy and beam luminosity are theoretically required to observe a Higgs boson in high energy colliders, it is the only fundamental particle predicted by the Standard Model that has yet to be observed.

The Higgs boson plays a unique role in the Standard Model, by explaining 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.

Large Hadron Collider

-The precise circumference of the LHC accelerator is 26 659 m, with a total of 9300 magnets inside. Not only is the LHC the world's largest particle accelerator, just one-eighth of its cryogenic distribution system would qualify as the world's largest fridge. All the magnets will be pre-cooled to -193.2°C (80 K) using 10 080 tonnes of liquid nitrogen, before they are filled with nearly 60 tonnes of liquid helium to bring them down to -271.3°C (1.9 K).

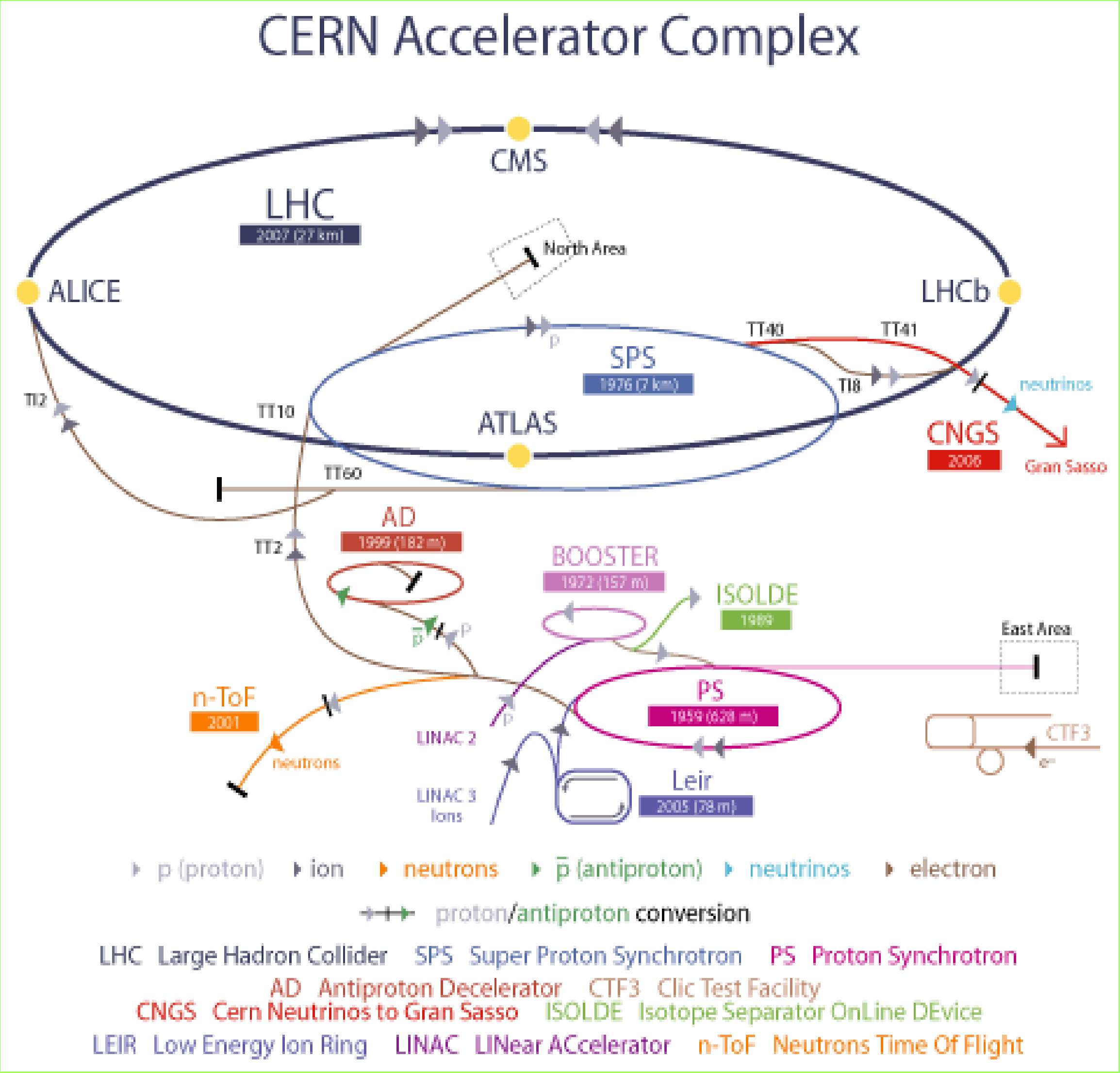
-a machine of extreme hot and cold. When two beams of protons collide, they will generate temperatures more than 100 000 times hotter than the heart of the Sun, concentrated within a minuscule space. By contrast, the 'cryogenic distribution system', which circulates superfluid helium around the accelerator ring, keeps the LHC at a super cool temperature, even colder than outer space!



View of the CMS cavern, 20 May 2009.

Large Hadron Collider

-Protons are obtained by removing electrons from hydrogen atoms. They are injected from the linear accelerator (LINAC2) into the PS Booster, then the Proton Synchrotron (PS), followed by the Super Proton Synchrotron (SPS), before finally reaching the Large Hadron Collider (LHC). Protons will circulate in the LHC for 20 minutes before reaching the maximum speed and energy. Lead ions for the LHC start from a source of vaporised lead and enter LINAC3 before being collected and accelerated in the Low Energy Ion Ring (LEIR). They then follow the same route to maximum acceleration as the protons.



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.

Technical problems to solve

-loooong list of “first”, “largest” and “strongest” during construction

-largest refrigerator with longest (27km) cryogenic distribution line- helium in liquid and gas phases

-the world's largest silicon tracking detector

-May 2003: a record for backing up data on tapes is beaten, rate transfer of 1.1 GB/sec over a period of several hours=reading a whole film stored on DVD every 4 sec!

-June 2003: also a record for transfer of data: 1TB sent over 10,000 km to California in 1hr, 2.38GB/sec=200DVD films sent from EU to USA in one hour

Construction timeline and current status

-Dec.16, 1994 CERN approves construction

-built-in into the LEP (Large Electron Positron collider) ring, which stop operating in Nov 2000

-additional smaller rings excavated, connected, facilities built-in and tested (ATLAS, CMS, ALICE...)

-during construction various rings tested

-Sep. 2008: test of collimation and acceleration of beams in both directions-the quench occurred during final testing of the last of the LHC's electrical circuits to be commissioned. Failure heated 100 super-cooled magnets to 100 Cels and beam made hole on one of liquid helium tanks, 1 T leaked into the tunnel. Instrument must be cooled to 1.9K (-271 Cels), colder than deep space

-"2 mths" to repair-but it restarted test running of beams in 2 of 8 sectors (each sector 3.5 km long) of a big LHC ring few days ago, 23 & 25 Oct 2009 at 450x10^12 eV, and will circulate the full ring in Nov. 2009. It is cooled down to 1.9 K again, and will be accelerated in stages to 3.5x10^18eV(TeV), and then, from 2011, ultimately to 7 TeV.