Research and Scientific Support Department

Research Highlights

Scientific research in the Department is a necessary activity to fulfil its tasks, namely supporting the study and development of science missions, managing them during operational phases and contributing to the technology and communications activities of the Directorate. Thus, the 'user-driven' nature of the Department must include a healthy scientific environment in which staff can pursue their research within a balanced programme. This research activity also helps in maintaining contact, at an appropriate level, between RSSD and the scientific community at large. A measure of the scientific output of the Department lies in the publication of papers in the scientific literature, currently running at typically 400 per year, about half being in refereed journals.

RSSD highlights in 2001 included:

Research in the high-energy domain has focused on XMM-Newton data analysis of X-ray binaries and Active Galactic Nuclei (AGNs), in particular the discovery of X-ray absorption from binaries. In addition, a first detection of X-rays from the ionised jet of a young stellar outflow was measured for L1551 and a new study of the relation between X-ray emission and rotational velocities in giant stars has been made. With respect to HST exploitation, the census of planets in globular cluster M22, the galactic bulge survey of Large Magellenic Cloud (LMC) planetary nebulae or the study of nuclear star clusters in late-type galaxies should be noted, together with new results on the spectral energy distribution of radio galaxies and cosmological parameters from Type Ia supernovae at high red shift.

Scientists in the Department have been awarded observing time on both space-based and ground-based (e.g. VLT, Caltech Submillimeter Observatory) observatories. Ongoing analysis of VLT-UVES spectroscopic observations showed evidence of the evolution of large organic molecules when subjected to the harsh ultraviolet environment of our Milky Way or of the Magellanic Clouds. VLT observations of the bare nucleus of Rosetta's target comet, 46P/Wirtanen, at around 5 AU heliocentric distance have been obtained together with the ESO VLT team. In addition, the Leonid 2001 observing campaign in November in Australia was very successful.

'Data mining' of archived data sets continues to become a much more significant activity. ISO science activities included the exploitation of the ISOCAM parallel mode survey data (9000 h) yielding a 7 micron survey of 30 square degrees of the sky, one hundred times deeper and with 50 times the spatial resolution of the IRAS survey. An archive study of spectra from 400 sources allowed the study of scenarios of dying stars from the AGB to the planetary-nebula phase. Data on several asteroids obtained with three ISO instruments allowed refinement of the thermo-physical models.

The analysis of data from operational ESA missions concentrated on Cluster, SOHO and Ulysses. For example, the analysis of the performance of the Cluster/ASPOC data demonstrated the considerably improved plasma measurements due to the active spacecraft potential control. Data from the Ulysses/COSPIN instrument at solar maximum have been used to investigate the influence of the Sun's magnetic field on energetic charged particles at high solar latitudes.

Advanced image recognition techniques were applied to SOHO EIT and LASCO data to detect Coronal Mass Ejections (CMEs) automatically in a more effective and systematic way than previously done by eye. This will be relevant for future operational space-weather studies and onboard CME detection in space missions. Observations and modelling of wave-particle interactions inside a CME using WIND spacecraft data were carried out.

A major milestone was achieved with the completion of the Rosetta flight instrumentation, developed in close cooperation with groups in the external science community and now integrated into the flight spacecraft. This comprised MIDAS (Micro-Imaging Dust Analysing System), OSIRIS (Scientific Imager), a plasma sensor for RPC and the Rosetta Lander permittivity probe. Instrumentation is in preparation for flight on Demeter and COROT (France) and STEREO (NASA). Contributions were also made to SMART-1 (SPEDE Plasma Dust Electron Diagnostic Experiment, AMIE imaging and X-ray fluorescence elemental geochemistry).

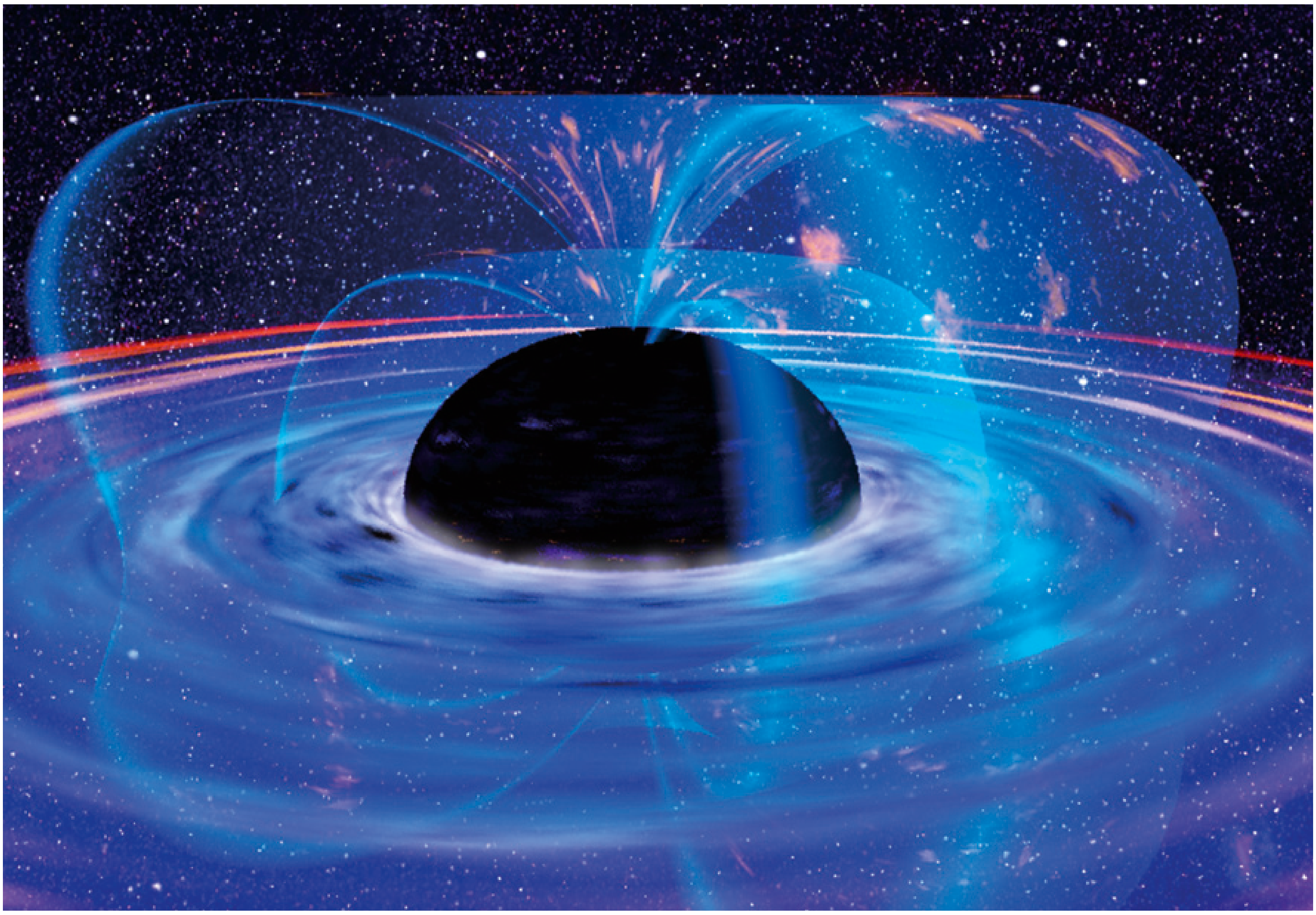
In the laboratories, research has continued on the development of lightweight X-ray optics, of superconducting tunnel junction arrays (STJs) for both X-ray and optical astronomy, and of compound semiconductors for high-energy astrophysics applications. This latter development led to the production of a microchip fabricated in epitaxial gallium arsenide for a high-energy X-ray camera. The same technique may find a powerful application in medical diagnosis techniques.

Using the 4 m William Herschel Telescope at La Palma, in the Canary Islands, an ESA team conducted a series of week-long campaigns at the telescope from late 1999 through 2000 with the Superconducting Camera (SCAM). One result shows colour changes in a binary star system due to light being absorbed by material streaming from the red star down onto a spot on the white dwarf. Another observation has determined the redshift of 10 quasars for the first time with the use of a filter or spectrograph.

Cluster

The Cluster mission launched in 2000 is designed to study the three-dimensional, small-scale structure of the Earth's magnetosphere and its environment. In early 2001 it started its nominal two-year operational phase. The four identical spacecraft are flying in a tetrahedral formation and the separations between them have been varied between 600 and 2000 km, depending on the particular nature of the scientific investigation of the various magnetospheric regions to be undertaken.

The four-point, relatively closely spaced measurements with identical instruments have already yielded unparalleled views of space-plasma processes in key regions of the magnetosphere. For example, Cluster observed three-dimensional waves on the outside skin of our Earth’s magnetic field for the first time. These waves are formed by the solar wind and the flow of electrons and ions coming from the Sun, blowing on the Earth’s magnetic field. Another observation took place above the ‘black’ aurora. Aurorae are produced when charged particles radiated by the Sun interact with the Earth's atmosphere. The black auroras occur when charged particles are accelerated away from Earth into space. From the ground this phenomenon is seen as black spots in a faint aurora. Cluster has observed the evolution of the black aurora, with the four spacecraft following each other as a ‘string of pearls’ at about three-minute intervals. The first three spacecraft observed the black aurora growing in power and the fourth observed it vanishing. Understanding the development and growth of dynamic structures associated with an aurora is a major goal of the Cluster mission, and something that cannot be solved by single satellite measurements.



This image depicts the flow of matter just before it disappears into the black hole. From the observed X-ray spectrum it is derived that the number of photons and their energies observed by XMM-Newton far exceed what could be expected from the established models for such systems

XMM-Newton

XMM-Newton is an X-ray observatory providing the community with access to an unprecedented X-ray collecting area. It provides medium-resolution dispersive spectroscopy and a high-throughput imaging spectroscopic capability. The mission also provides a co-aligned optical telescope, the data from which supplements the X-ray data.

In the course of 2001, the mission started routinely delivering high-quality science data, and a stream of scientific discoveries resulted from this. One discovery came from measurements of the X-ray spectrum of a spiral galaxy named MCG-6-30-15. Observations of the spectral shape of an emission line from highly-excited iron in this source were used to show that energy is being extracted from a black hole through magnetic field coupling, a mechanism known as the Blandford-Znajek effect. This result was widely reported in newspapers and on news websites.

During 2001, use of some of the earliest XMM-Newton observations showed that there is a serious flaw in the hitherto assumed cooling flow model, which described the density structure of hot matter in clusters of galaxies.

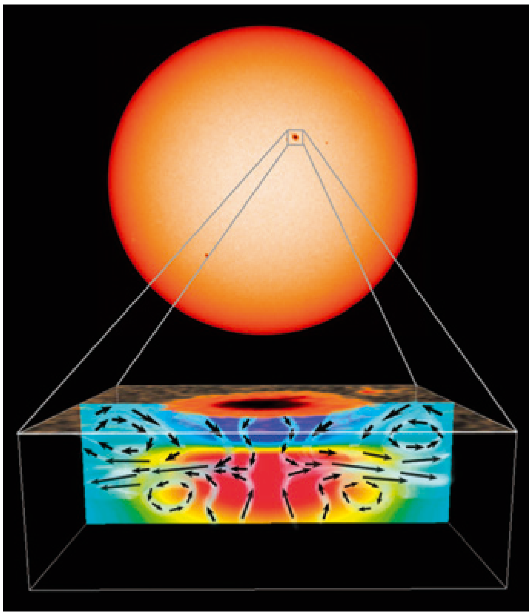
Over 300 participants attended a symposium held at ESTEC in Noordwijk (NL) on 26-30 November, entitled 'New Visions of the X-ray Universe in the XMM-Newton and Chandra Era'. The majority of the 335 presentations (published in ESA SP-488) were on new XMM-Newton results.

SOHO

With its round-the-clock view of the Sun, SOHO continued to produce a number of 'firsts' in several areas in 2001.

The SWAN instrument provided the first estimate of the total amount of water ice in a comet (3.3 million tonnes). The SWAN observations, taken

SOHO's MDI reveals the maelstrom beneath a sunspot. Observations taken in the vicinity of the sunspot on the solar surface (top) are displayed in a cross-section going down 12 000 km below this surface (bottom). The arrows indicate flow. Inflow of cool gas (blue) near the surface concentrates the magnetic field and suppresses hot gas (red) trying to rise from below

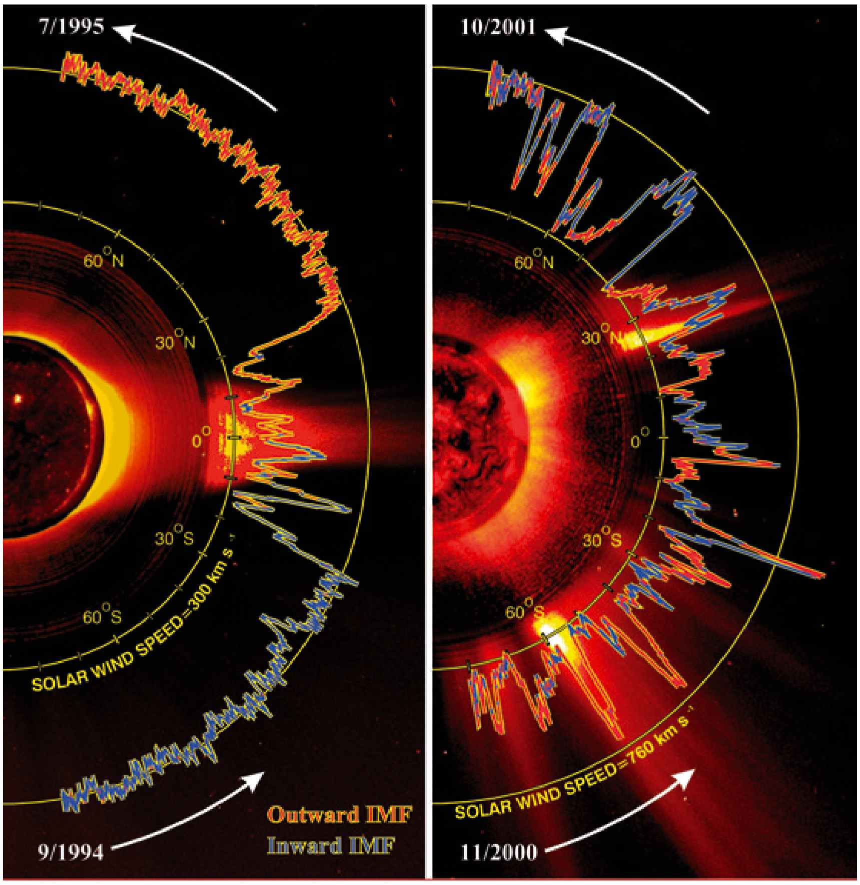


together with Hubble Space Telescope observations of the same comet (C/1999 S4 LINEAR), indicate a remarkably low value for the density - just 15 kg/m^3.

The SUMER spectral atlas released in August is the best-ever analysis of the ultraviolet light from the Sun, spanning wavelengths from 670 to 1609 Å (67 to 160.9 nm). Among the 1100 distinct emission lines, more than 150 had never before been recorded or identified – a very valuable product for both the solar and stellar communities for the foreseeable future.

Using a novel technique known as acoustic tomography, analysis of data from the MDI instrument provided new clues for a long-standing problem in solar physics: Why do sunspots stay organised for several weeks, instead of disintegrating much more rapidly the way plasma physics dictates. The answer appears to be subsurface inflows. Inflowing material had already been invoked by theorists in explaining the longevity of sunspots, despite the commonly observed surface outflows. The analysis also revealed that sunspots are surprisingly shallow, changing from cooler to hotter than the surroundings only 5000 km below the surface.

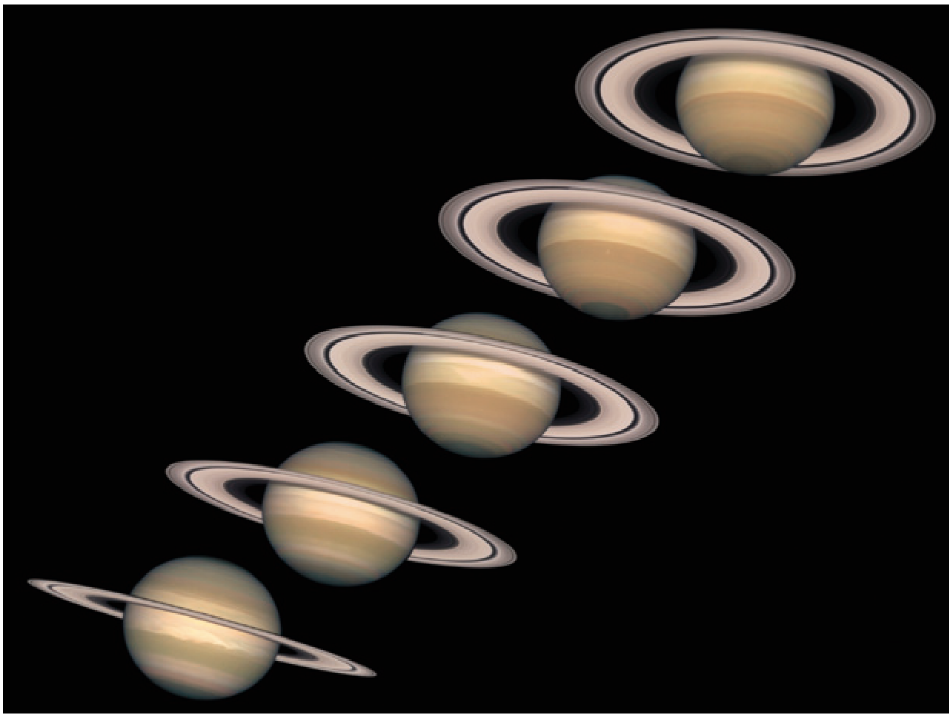
Comparison of the two 'fast latitude scans' (pole-to-pole transits) made by Ulysses near solar minimum (left panel) and solar maximum (right panel). Plots of solar wind speed and magnetic polarity from Ulysses are superimposed on SOHO images of the Sun (courtesy of D.J. McComas)



Ulysses

Ulysses is an exploratory mission launched in 1990 having as its primary goal the study of the inner heliosphere as a function of solar latitude and solar activity. In 2001, the spacecraft completed a second rapid transit from the Sun's south to north pole (the first was in 1994/95), and its second North Polar Pass.

From the beginning of September, Ulysses was continuously immersed in uniform, fast solar wind. The change to more stable conditions occurred as the spacecraft climbed above 70° north latitude, after more than four years of exposure to variable, slow- to intermediate-speed wind. The source of the fast (~750 km/s) flow is a large-scale polar coronal hole that has recently developed over the Sun's north pole. The latest magnetometer data are consistent with a reversal in the large-scale polarity of the Sun's magnetic field, and show a predominance of the new (negative) polarity in the north.



Saturn's rising seen from the Hubble Space Telescope

Hubble Space Telescope

Hubble Space Telescope (HST) has provided a wealth of new astrophysical information, including data on the Solar System's planets.

HST Wide-Field Planetary Camera 2 (WFPC2) images, obtained between 1996 and 2000, show Saturn's rings opening up from just past edge-on to nearly fully open. The first image in this sequence, on the lower left, was taken soon after the autumn equinox in Saturn's northern hemisphere (spring equinox in its southern hemisphere). By the final image in the sequence (upper right), the tilt is nearing its extreme, or winter solstice in the northern hemisphere (summer solstice in the southern hemisphere). The analysis of this set of images is in progress. The study of the detailed variations in the colour and brightness of the rings will help in clarifying such mysteries as the rings' composition, how they were formed, and how long they might last.

NGC 1850 as seen by the Hubble Space Telescope

The double-star cluster NGC 1850 provides an ideal astrophysical laboratory for stellar studies. Imaged with WFPC2, it is an unusual double cluster that lies in the bar of the Large Magellanic Cloud (LMC). After the 30 Doradus complex, NGC 1850 is the brightest star cluster in the LMC, and is representative of a special class of objects, namely young, globular-like star clusters that have no counterpart in our galaxy. NGC 1850 splits into NGC 1850A (centre) and NGC1850B (lower right), which are both young (50 and 4 million years, respectively) but are quite distinct in terms of stellar mass and spatial distribution. Their study provides invaluable clues to star formation and evolution. For example, supernova explosions of NGC 1850A massive stars appear to have triggered star formation in the younger NGC 1850B. The latter contains several hundred solar-type stars in such an early evolutionary stage that they still display their original gaseous cocoons.

Cassini-Huygens

A joint ESA/NASA Huygens Recovery Task Force was set up in early 2001 to study mission-recovery options and to advise ESA and NASA management on which course to take by the end of June. After six months of intensive work, which also involved the Huygens industrial partners, the Task Force recommended a new Huygens mission scenario that required changes to the first three orbits of Cassini after arrival at Saturn. The Huygens Probe mission will now be conducted during the third orbit on 14 January 2005. The modified trajectory includes two Titan flybys before the Probe mission. Titan observations will be carried out by the Orbiter during those two early flybys. The recovery mission has no impact on the Cassini mission beyond the third orbit around Saturn.

All Huygens science is expected to be recovered under the revised mission scenario as it allows the Huygens Probe to transmit radio signals that fall within the acceptable performance range of the Probe's telecommunications system. The propellant cost of the Huygens recovery mission will range between 80 and 100 m/s, which has been allocated from the Cassini mission reserves.

The implementation of the Huygens recovery mission started in September under the responsibility of a joint ESA/NASA team. The current work plan foresees the details of the recovery mission being finalised during 2002.

Bi-annual Probe checkouts were successfully carried out in March and September. An in-flight verification of the performances of the telecommunications system for the revised mission scenario was carried out in November.

A spectacular ISOCAM view into the heart of the Eagle nebula (M16). This map combines 7.7 micron (shown as blue) and a 14.5 micron (shown as red) infrared exposures

ISO

As ISO's Post-operations Phase wound to a close, anticipating the start of the five-year Active Archive Phase, exploitation of the ISO archive continued with some 120 refereed papers being published.

Amongst the highlights in 2001 was a first space detection of the aromatic hydrocarbon ring-molecule benzene in a protoplanetary nebula, suggesting a link to the postulated complex polycyclic aromatic hydrocarbon (PAH) molecules thought to be the source of unidentified emission bands seen throughout our own and other galaxies. The PAHs could form during a star's transition from the protoplanetary to planetary nebula phase. Hydrogen cyanide, a sensitive indicator of the onset of star-formation activity in cold clouds was detected. Water was found to be abundant in cold regions of the galaxy, where stars like the Sun form.

Thirty brown dwarfs, elusive objects at the boundary between planets and stars, were found in the rho Ophiuchi cloud. Results suggested they form, star-like, by accretion from a gaseous sphere, rather than forming, planet-like, out of a disk-orbiting a star. Many brown dwarfs have their own disks. ISO observers looked deep into the Eagle nebula, revealing, in huge amounts, the cold dust that enshrouds newborn stars.