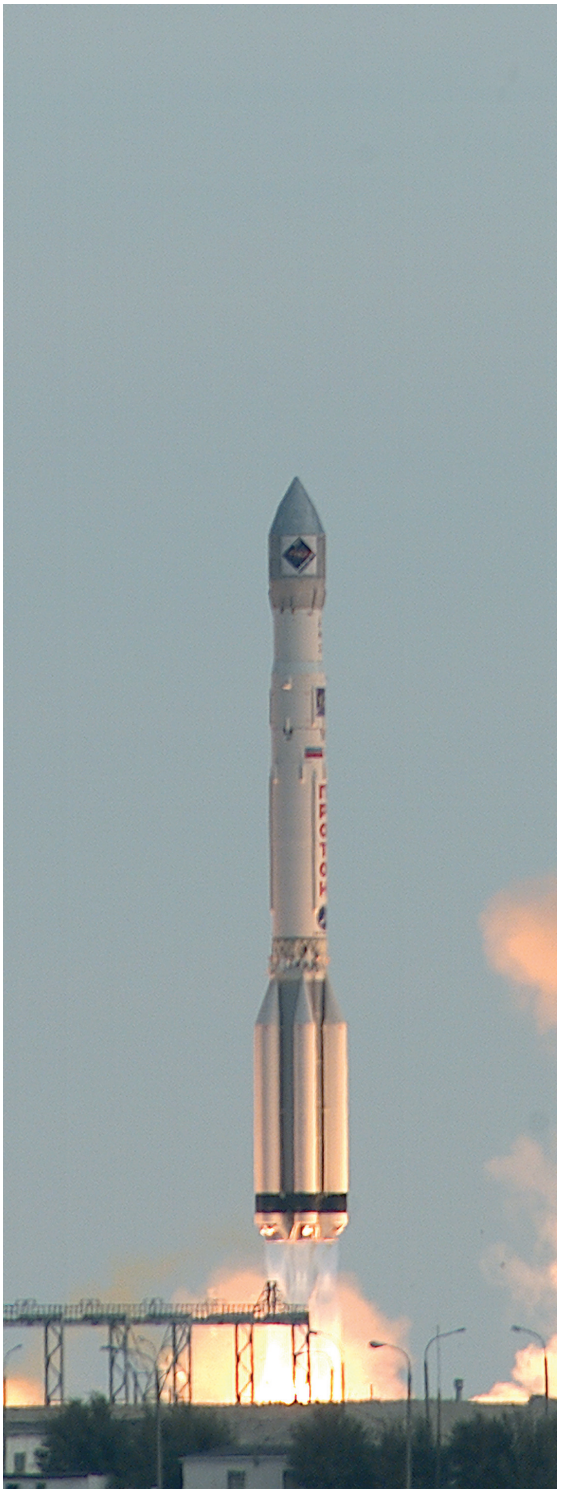
Science

Following the outcome of the Council of Ministers in Edinburgh in November 2001, the Directorate of Science undertook a complete reassessment of the ESA Science Programme, in close collaboration with the science community, represented by the Space Science Advisory Committee (SSAC), industry and Member State delegations. The results of this exercise were presented as a proposal to the 99th meeting of the Science Programme Committee (SPC) in Andenes (Norway) on 22-23 May. The SPC strongly endorsed the proposed Programme, known as 'Cosmic Vision' and encouraged the Executive to proceed with its implementation.

The new Programme presented the missions in 'production groups' which are more than just scientific groupings. Missions within each group will be built synergistically using common technologies and engineering teams wherever possible. The success of this scenario depends on specific commitments to new ways of working:

- The implementation of BepiColombo and Solar Orbiter with international partners. Both missions will be implemented as a single activity.
- The implementation of Herschel/Planck and Eddington in a single project, re-using the same spacecraft bus. This implies launch of Eddington not later than 2008.
- Major technical changes reducing the cost of GAIA with no science loss. GAIA will be launched no later than 2012.
- Significant gains through new technology in the cost-effectiveness of spacecraft development and procurement.
- The timely availability of payloads, one of the current pressing problems.



Integral lifts off from the Baikonur Cosmodrome in October

Scientific Projects Department

Integral

Launched: 17 October 2002

The International Gamma-Ray Astrophysics Laboratory is the most sensitive gamma-ray observatory ever launched.

During the first half of the year, the spacecraft completed its environmental test campaign in the ESTEC test facilities. Based on the results of these and subsequent functional verification tests, the Flight Acceptance Review in July declared the spacecraft ready for shipment to the Baikonur launch site in Kazakhstan.

The launch campaign began in August and Integral was launched as planned on 17 October and precisely injected into the specified orbit by the Proton launcher. Subsequent orbit adjustment manoeuvres transferred it to its operational orbit and commissioning of the satellite and its payload began.

The Mission Commissioning Results Review concluded in December that the spacecraft, payload, and ground segment had been successfully commissioned and that in-orbit performance complied with specifications. The nominal mission duration is 2 years, but the efficient in-orbit commissioning exercise has led to an expected satellite lifetime of more than 5 years.

Rosetta

Launch: January 2003 – postponed

The Rosetta mission, aiming at the detailed observation of a comet nucleus, includes a comet orbiter and a lander.

During 2002, the Rosetta flight spacecraft went through its environmental test programme and final preparations for launch. This started with a long thermal-vacuum test, simulating the extremes of temperature to be encountered in deep space, where it is almost at Jupiter's orbit. During the test programme, full mechanical, electromagnetic and functional testing was performed to demonstrate that the system, including the payload, would operate correctly during all phases of the mission. In addition, system validation testing was performed from ESOC on the flight spacecraft to validate the flight operations procedures.

Due to the schedule constraints and late deliveries, up to five shift teams - three on the flight model and two on the engineering model - worked seven days a week so that in September the flight spacecraft, with all payload and lander elements in flight configuration, could be shipped to Kourou for the launch campaign.

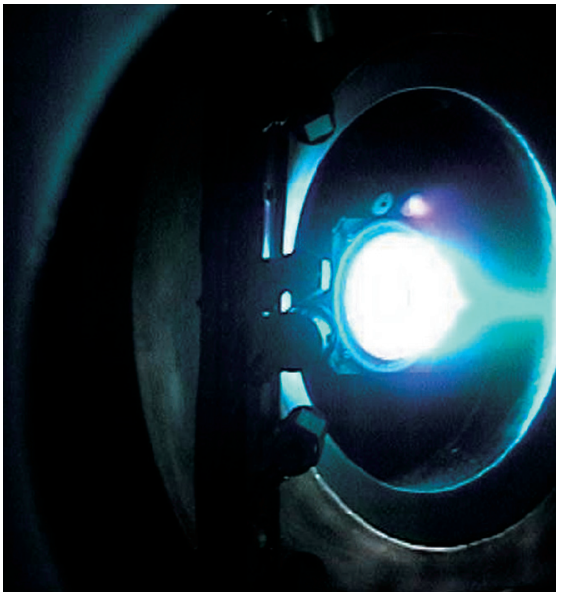
In parallel with the spacecraft testing, the ground segment had also to be prepared. The new 35 m deep-space antenna in New Norcia, Australia, was completed on time and tested using spacecraft already in orbit. Simulations were carried out to train the ESOC operators. By year's end, all elements of the ground segment were ready for the launch.

After the launch postponement, due to the Ariane-V517 launch failure, the spacecraft was kept in the Kourou test facilities. Alternative mission scenarios are being studied and will be presented to the SPC for a decision in May 2003.

SMART-1

Launch: 15 July/15 August 2003

SMART-1 is the first European mission to the Moon and the first of the Small Missions for Advanced Research and Technology. Demonstration of the viability of using electric propulsion as the main means of propulsion is



The SMART-1 firing test in the ESTEC Heat Balance Facility (HBF3), with electric-propulsion engine thrusting at full power (1400 W)

the key objective of the mission, together with other technological and scientific goals. The results of this preparatory mission will be directly transferred to the technology and project offices of the future science missions.

The spacecraft, for which the Swedish Space Corporation is responsible, was initially integrated at the premises of Saab Ericsson Space in Linköping (S), the Assembly, Integration and Testing (AIT) contractor. The final integration took place at ESTEC, where the main test activities – environmental, functional and performance – were also performed. In December, an end-to-end electric-propulsion test was successfully performed in the ESTEC Heat Balance Facility (HBF3), commanding the engine to fire at different power levels, as will be needed during the flight. The engine performed flawlessly and so did the test set-up including the specially equipped chamber. The Flight Acceptance Review, initiated at the end of the year, will be completed in February 2003.

The ground segment, built by ESOC based on existing infrastructure and facilities, was also validated during the year.

Mars Express

Launch: June 2003

Mars Express includes a Mars orbiter spacecraft and a lander, Beagle-2.

Probably the most demanding year in the project's life cycle began with the integration of the subsystems and scientific instruments at Alenia in Turin (I), and ended with a fully integrated spacecraft that had already undergone most of its environmental test campaign at Intespace in Toulouse (F). In September, a major press event took place in Toulouse, which involved the mounting of a small capsule of Ferrari red paint on the spacecraft. The test campaign will run until mid-February 2003 and will be followed by shipment of the spacecraft to Baikonur for its June 2003 launch.

Emphasis was also put during the year on the timely preparation of the ground segment, consisting of the Mission Operations Centre at ESOC and the Payload Operations Service, which includes a major contribution from the Rutherford-Appleton Laboratory. Regular meetings were held with NASA and JPL to ensure telecommunications cross-support between ESA or NASA orbiters and landing vehicles on the planet's surface. NASA will also provide navigation support to ESOC when Mars Express approaches the planet.

Readiness of the launch vehicle and the Baikonur facilities was verified by reviews and inspections of the launch site.

Double Star

Launches: December 2003 (equatorial orbit) and June 2004 (polar orbit)

The Double Star project consists of two spinning spacecraft, designed, developed, launched and operated by the Chinese National Space Administration (CNSA). Each spacecraft will make coordinated measurements with ESA's four Cluster spacecraft. ESA is therefore providing a European payload complement for Double Star, consisting of seven instruments, six of which are very closely derived from those onboard Cluster.

Following the selection of Astrium GmbH (D) as the industrial contractor for payload procurement and pre-integration, the establishment of contracts with the European Principal Investigators was initiated. Pre-integration and testing of the engineering models of the European payload complement was successfully completed at Imperial College in London (UK). The integration of all flight-model experiments will take place in China.

Venus Express

Launch: November 2005

Venus Express consists of a Venus orbiter, with a payload complement and a spacecraft bus derived from Mars Express.

The SPC gave its preliminary approval for the Venus Express mission in July. The project team, together with Astrium SAS in Toulouse (F), immediately initiated the necessary contractual steps to start the project. Progress was rapid as Astrium SAS had already conducted a pre-Phase B study earlier in the year.

The mission was fully approved in November and the System Requirements Review was successfully completed by the end of 2002.

Herschel

Artist's impressions of the Herschel and Planck spacecraft

Herschel/Planck/Eddington

Launch: February 2007

Planck is a mission to study the Cosmic Microwave Background radiation, and Herschel is ESA's next infrared and submillimetre space observatory. The two satellites will be launched together by an Ariane-5 vehicle and will then separate to operate independently at a distance of 1.5 million kilometres, on the opposite side of the Earth, from the Sun, around the second Lagrangian point (L2). Both satellites are being developed under one prime contract awarded to Alcatel Space in 2001.

Activity in 2002 was dominated by the build up of the full industrial consortium that will develop the two spacecraft, with nearly one hundred procurement items being processed jointly by industry and ESA teams.

Work on the baseline spacecraft system and module designs progressed well during the year and the Preliminary Design Review, conducted during the summer, was formally closed just before year end.

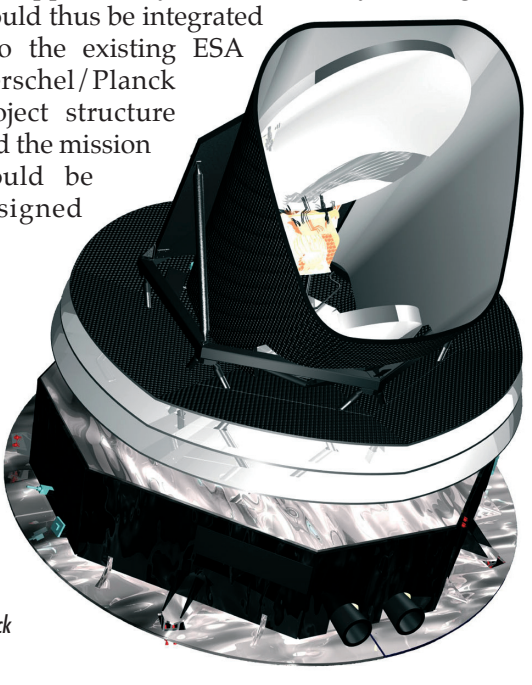
The giant Herschel 3.5-metre silicon-carbide telescope, developed under contract by Astrium SAS in Toulouse (F), successfully completed its Critical Design Review in May. This released the start of the manufacturing of the primary-mirror segments (12 'pie-type' segments that, after sintering, make up a whole primary telescope). Eight such petals were completed by the end of the year.

Work also proceeded at a good pace with the Planck Reflector contract that ESA and the Danish Space Research Institute (DSRI) had placed jointly with Astrium GmbH in Friedrichshafen (D) in 2001. The Critical Design Review for the Planck telescope's two reflectors was successfully completed in June.

In preparation for the very specific and complex cryogenic tests to be carried out on various elements of the project, extensive studies were conducted and a contract was awarded to Centre Spatial de Liège (B) for the upgrading of its test facilities.

The technical development of the Herschel/Planck scientific instruments generally proceeded as planned, although development and manufacturing were hampered by severe national funding problems, leading to difficulties in meeting agreed delivery dates. ESA therefore ultimately agreed to support the instrument teams significantly, which resolved most of the problems.

The proposal by the Executive to include the Eddington mission within the procurement cycle of Herschel/Planck was presented to and approved by the SPC in May. Eddington would thus be integrated into the existing ESA Herschel/Planck project structure and the mission would be designed



Planck

to make use of the recurring Herschel spacecraft bus. The payload's development will be financed by ESA. Eddington, to be positioned at L2, will observe the light oscillations of stars to derive the star's evolution and to detect potential neighbouring planets. Two parallel system definition studies will be awarded to industry in spring 2003.

Corot/Microscope

Participation in two projects under CNES management, namely Corot (a mission to detect Earth-like planets around other stars – launch end-2004) and Microscope (a mission to test the equivalence principle – launch 2005) was followed-up during the year.

Future Science Projects

SMART-2

Two industrial prime contractors studied the SMART-2 mission extensively in 2002 as part of the project's Definition Phase. In parallel, preparatory activities on payload-related items were undertaken in national institutes. Initially, technology test packages for both the LISA and Darwin missions were planned for flight. In December, the decision was made to proceed with only the LISA elements due to funding difficulties in Member States.

GAIA

The GAIA mission spent the first part of the year in a state of suspense, pending resolution of an industrial-policy issue regarding the proposed procurement procedure. The final approval was given in May and the subsequent process to choose the two potential prime contractors led to the selection of Astrium–F and Alenia (I), which are now shadowing the on-going supporting-technology activity for the project.

JWST

The James Webb Space Telescope had a busy year, with the initiation of a number of activities in preparation for NASA's decision regarding the final content of the mission, to be taken in early 2003. The main emphasis was on preparation of the Near-Infrared Spectrometer (NIRSPEC) and the Mid-Infrared Instrument (MIRI). The project will enter its Definition Phase once the NASA decision is taken.

BepiColombo/Solar Orbiter

Following the identification of potential funding shortfalls in Member States and the consequent unwillingness of the SPC to approve the Science Management Plan in preparation for an Announcement of Opportunity, it was decided to re-assess the mission. This reappraisal, which will continue until July 2003, will redefine the science content and identify an instrument payload that could be implemented at an affordable cost to both ESA and the Member States providing the payload instrumentation.

For Solar Orbiter, a detailed payload assessment was carried out prior to the start of mission assessment.

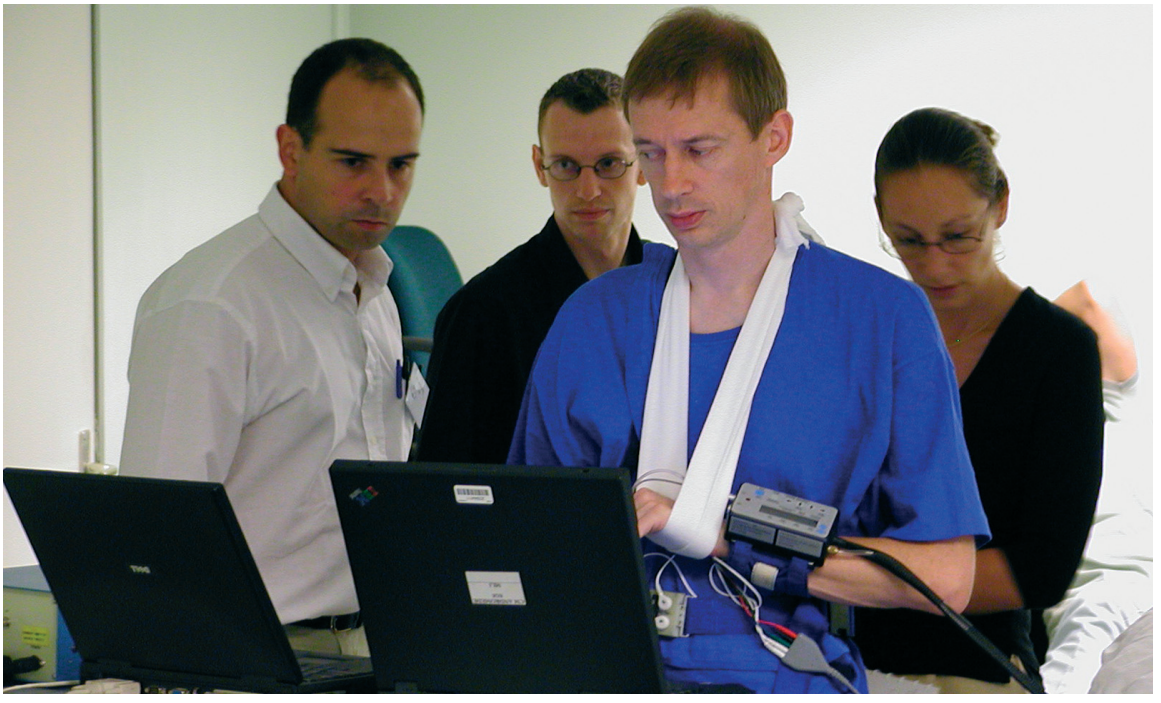
A number of other mission studies continued in 2002 mainly at technology-development level, including Darwin a mission to detect life in extra-solar systems, and LISA a gravitational-wave detector.

Details of all of the science missions under study can be found on the Space Science pages at: www.esa.int.

PRODEX / PECS

PRODEX is an optional Scientific Programme established to provide funding for the industrial development of scientific instruments or experiments proposed by Institutes or Universities and selected by ESA for one of its programmes (in science, microgravity, Earth observation, etc.). The Agency provides both administrative and financial management know-how and technical support. The Member States currently participating in PRODEX are: Switzerland, Belgium, Ireland, Austria, Norway, Denmark, Hungary and the Czech Republic. The projects being developed range from small ERS data-analysis programs to fully-fledged instruments for scientific payloads.

During the year, Belgium approved its PRODEX slice 7 contribution, amounting to 44 MEuro over a period of four years. Once again, this substantial participation in the Programme resulted in an increase in the number of Belgian projects within PRODEX. A major undertaking was the support to the Odissea Mission to the International Space



ESA astronaut Frank De Winne, accompanied by Belgian scientists during a simulation of the PRODEX-funded Cardiocog experiment at the Belgian User Operations Centre in August (photo courtesy of BUSOC, Brussels)

Station (ISS), in which the Belgian ESA astronaut Frank De Winne took part. More than 20 experiments directly related to this mission were initiated and administered by PRODEX in a very short time frame.

In 2002, the following experiments or experiment subsystems were finalised:

Mars Express
- NPD sensor for the ASPERA-3 instrument: Dr. P. Wurz, Bern (CH)

Envisat
- Pilot study on Envisat data used in hydrological/glaciological applications: Dr. J.-G. Winther, Tromsø (N)

PROBA
- CHRIS-BDRF: Dr. W. Debruyn, Mol (B)
- Identification of forest species: Dr. P. Defourny, Gembloux (B)
- Hyperspectral remote sensing of suspended sediments in coastal waters: Dr. J. Monbaliou, Leuven (B)
- Coastal-water chlorophyll mapping by satellite-based imaging spectrometry: Dr. K. Ruddick, Brussels (B)
- MERIS calibration for water-quality monitoring for the Belgian coastal zone: Dr. K. Ruddick, Brussels (B)
- Evapotranspiration data in a soil-vegetation-atmosphere scheme: Dr. F. de Troch, Gent (B)
- Texture and change detection in forest ecosystems: Dr. P. Coppin, Leuven (B).

ODISSEA Mission (Belgium only)
- 7 biology experiments
- 4 human-physiology experiments
- 10 material-science experiments
- 2 fluid-science experiments.

STS-107 Mission
- 5 biology experiments
- 1 human-physiology experiment
- 2 material-science experiments
- 1 space-science experiment.

In addition, 170 scientists received support within the framework of European (mostly ESA) missions.

The PRODEX Office has been entrusted with the setting up and implementation of the arrangements and management structure for the Plan for European Co-operating States (PECS). Good progress has been made with two potential participants: Hungary and the Czech Republic. Information workshops on ESA activities open to the PECS countries, mainly in Earth observation and space software engineering, have were organised in Hungary. In the Czech Republic, an independent consultant was contracted to make an assessment of the Czech space industry's capabilities.

Science Programme Communication Service

In 2002 the Service implemented a new policy to increase the overall public interest in ESA's Science Programme by adopting new ways of promoting its activities based on the principle that 'different target audiences have different needs'. The overall objective is to raise people's interest in space in general. By presenting the information under the 'ESA brand', the public should increasingly associate this brand and Europe with space exploration.

Aside from the regular communication activities (media activities, publications, etc.), the following major activities particularly attracted the general public's attention:

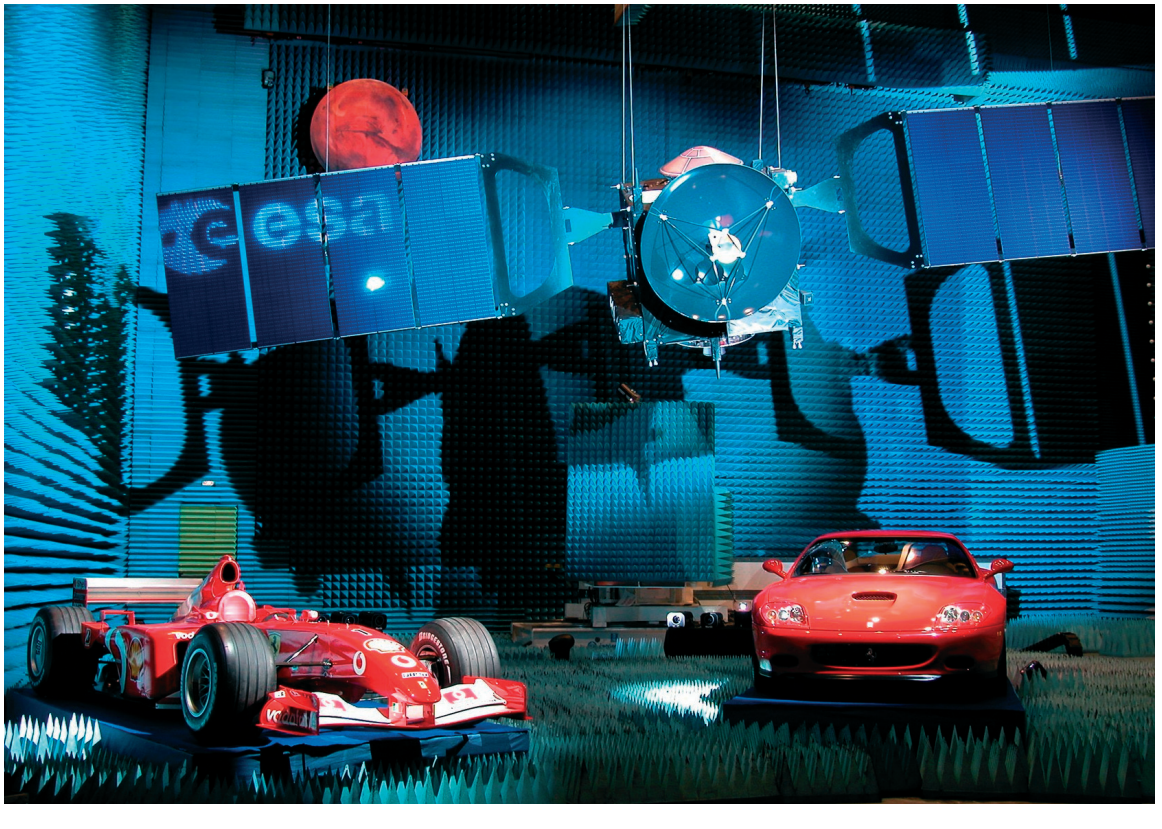
– The Science web site

As a result of the new policy and a much-appreciated new editorial approach, stories published on the site were regularly picked up on the BBC, CNN, Yahoo and NASA Space Science web pages. From July onwards, the ESA Science web site was ranked by Yahoo as the third most popular space science news site, after CNN.com and Space.com and before that of NASA's Marshall Space Flight Center. The number of subscribers increased by an average of 180 per month, to exceed 8000 at year's end.

– The Mondial de l'Automobile

The Science Directorate teamed up with the Industrial Matters & Technology Directorate and the Applications Directorate to participate in the 'Mondial de l'Automobile' which opened in Paris in September. The federating element was the ESA-sponsored, Dutch-entered solar-powered car 'Nuna', which had used space technologies to good effect to win the 2001 'World Solar Challenge' race across Australia at the first attempt. The Science Directorate emphasised its scientific research activities related to the Sun. The Industrial Matters & Technology Directorate promoted the spin-off benefits of space technology through the ESA Technology Transfer Programmme, and the Application Directorate showcased the high-accuracy Galileo navigation system giving cars precise positioning in city streets.

Four Ministers visited the stand, contacts were established with a wide cross-section of the Press, and several radio interviews were given for major broadcasters (RTL, BBC World, etc.).



The ESA Stand at the Red Planet event in Toulouse in September

The stand also attracted lots of young people, mainly students, eager to know more about space and the associated work opportunities.

– The Red Encounter

ESA's Mars Express mission will be launched in June 2003. The Romans named the planet 'Mars' after their god of war because its red colour reminded them of the blood shed on the battlefield. This triggered the idea to develop a promotion initiative focussing on the colour red. Red is the colour allocated by the Fédération Internationale Automobile (FIA) at the turn of the century to all Italian Grand Prix racing cars, including Ferrari.

To try to attract the attention of a new and potentially vast audience, it was proposed to fly a sample of Ferrari-red paint onboard ESA's Mars Express mission to the Red Planet, in a no-exchange-of-funds deal. The first fruits of this collaboration were quickly evident when, following Michael Schumacher's victory in the 2002 F1 Drivers World Championship, Ferrari distributed an ESA Press Release announcing the collaboration. The ESA name immediately appeared in non-scientific newspapers and magazines, with one famous Italian sports paper – La Gazetta dello sport – even running the headline 'Sports fans and scientific research'!

Research and Scientific Support Department

RSSD's primary role is to ensure the best possible scientific performance and return from the missions in ESA's Science Programme. In particular, the Department is responsible for providing scientific expertise to support studies and projects in all of their phases, and for ensuring that maximum scientific return is maintained as a target throughout all phases of a scientific mission.

Highlights in research in 2002 included the following:

The year saw the exploitation of data from XMM-Newton both at ESTEC and at Vilspa, and the preparations for Integral's launch. Advances in high-energy astrophysics research included the detection and characterisation of narrow absorption features in low-mass X-ray binaries, and studies of X-ray emission from young stars and star-forming regions. The landmark detection by XMM-Newton of emission lines from magnesium, silicon, sulphur, argon and calcium, with a velocity shift of about 30 000 km/s in the X-ray afterglow spectrum of GRB011211 clearly indicated that supernovae explosions may be precursors of at least some Gamma-Ray Bursts. Many papers based on XMM-Newton data cover the study of Active Galactic Nuclei (AGN), including the starburst-AGN connection, the revival of fossil AGNs, the spectroscopy of relativistic effects and the discovery of an ionised Fe K edge in a high-redshift quasar. The cosmic diffuse X-ray background has been further constrained and measurements from a sample of high-redshift clusters indicated a significant baryonic contribution from the warm-hot intergalactic medium.

The conference 'Exploiting the ISO Data Archive – Infrared Astronomy in the Internet Age' in June organised by the ISO Data Centre showed that the 'mining' of ISO data continues to be a significant activity in the scientific community. Projects include studies of stars in various evolutionary stages, allowing detailed classification schemes to be drawn up on the basis of solid-state features, fine-structure lines and SEDs, and spectroscopic surveys of galaxies, with diagnostic excitation diagrams made on the basis of the observed fine-structure lines, and systematic study of PAHs and ices.

Research probing the interior and atmosphere of the Sun using helioseismology from SOHO and ground-based data continued. The asteroseismology effort included instrument development for the Corot mission, and concept development for other planned missions (MONS, MOST, Eddington).

The COSPIN instrument on Ulysses, developed in RSSD, has been operating in space since 1990, and has delivered a wealth of data and scientific papers, leading to a rethink about how charged particles move in three dimensions in the heliosphere.

The four Cluster satellites continued to collect unique multi-point measurements in the Earth's magnetosphere, helping to improve our understanding of the physical Sun-Earth connection processes. RSSD contributed significantly to development of the Electric Field and Wave (EFW) experiment on Cluster, and its staff are now actively exploiting these and other Cluster measurements in collaboration with the worldwide scientific community.

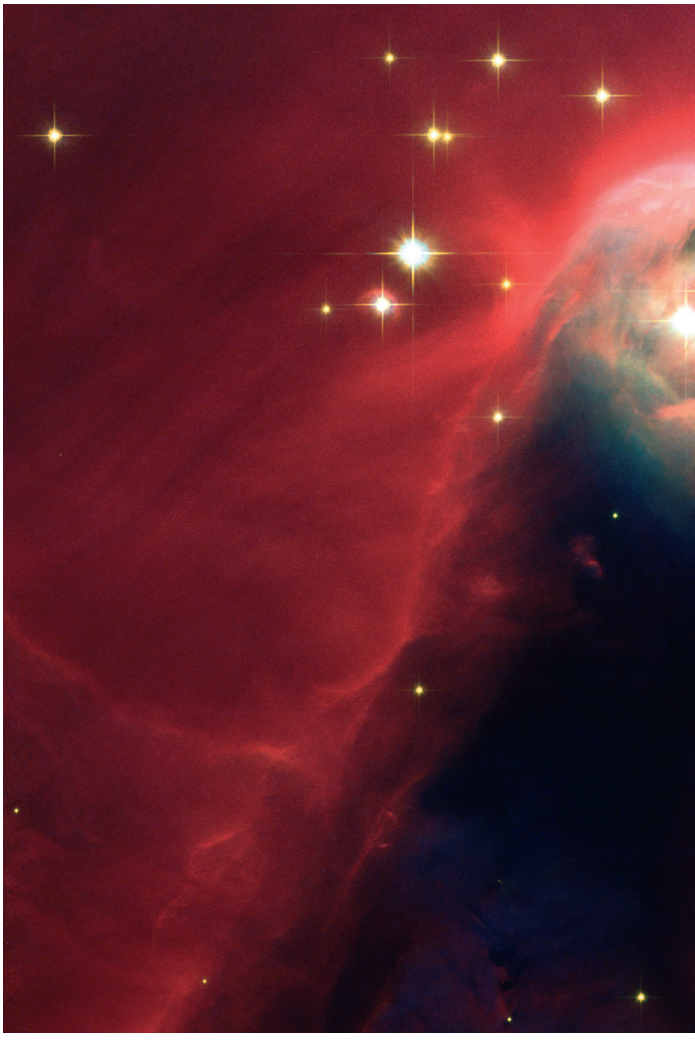
Following the successful launch of Integral in October, very promising first-light images were received from all of its instruments.

The laboratory R&D programme conducted by the Office for Science Payloads and Advanced Concepts, together with European industry, on behalf of future ESA science missions, also logged several achievement milestones in 2002, including:

- development of the Superconducting Camera through the successful fabrication and testing of a larger format (12 x 10 pixel) chip: it is the World's first and only superconducting photon-counting high-speed camera operating in the 300–800 nm

wavelength regime, and could open up the field of optical-UV imaging not only for ESA science missions, but also for numerous ground-based applications;

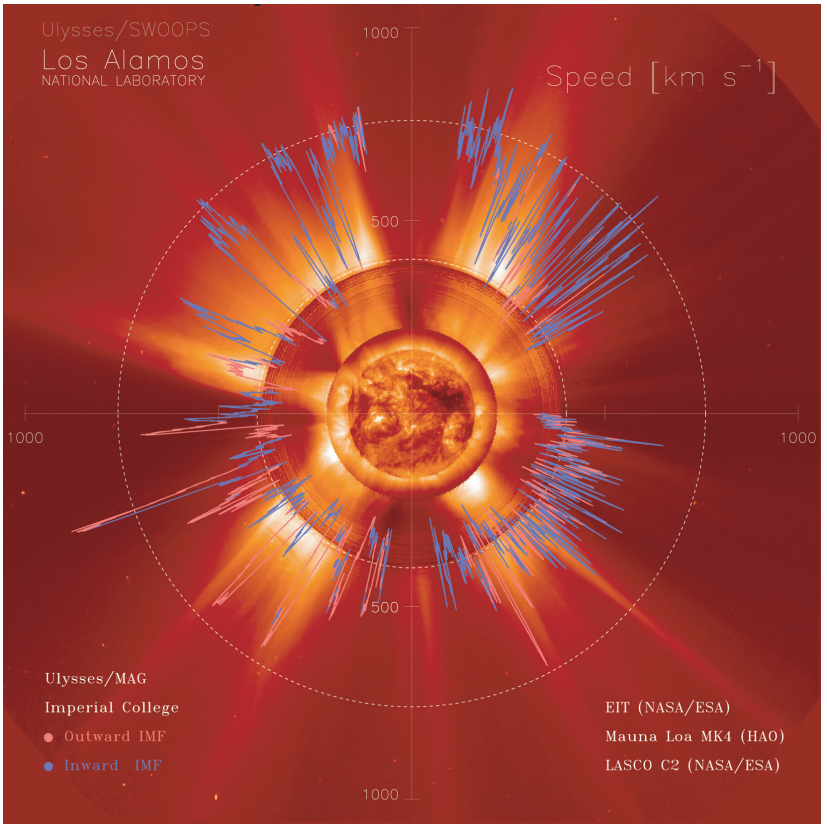
- the successful demonstration of a micropore imaging Wolter-I optic for X-ray wavelengths: such a lightweight imaging system has huge spin-off potential for microscopy and medical imaging, as well as applications for ESA's own planetary and astrophysics missions;
- the development of hard X-ray imaging chips based on compound semiconductors which can operate at room temperature have the potential to simplify spacecraft support systems for future science missions, and to find rapid application in such medical fields as mammography and dentistry.



The solar-wind speed measured by Ulysses throughout its second orbit of the Sun, plotted as a function of solar latitude. Time runs clockwise from April 1998 (03:00 h on the polar plot) to December 2002 (02:00 h). (Courtesy of D.J. McComas, Southwest Research Institute)

Ulysses

The Ulysses spacecraft, launched in 1990, is exploring the Sun's environment from a unique orbit that takes it over the solar poles every six years. Its scientific instruments are teaching us more about the solar wind, magnetic fields, cosmic rays, solar energetic particles, interstellar gas and dust, natural radio waves, and gamma-ray bursts. In 2002, the spacecraft began its slow descent from high northern latitudes, moving away from the Sun towards the furthest point in its orbit, corresponding to the distance of Jupiter. Throughout much of the year, the solar wind at Ulysses showed an alternating pattern of fast and slow streams, controlled by the Sun's rotation. The fast wind, blowing at some 700 km/s, originates in cool regions of the Sun's atmosphere called 'coronal holes'. In the current phase of the solar cycle, the largest coronal holes tend to form at the Sun's magnetic poles. Slower, more variable, solar-wind streams (~400 km/s), on the other hand, have their source closer to the magnetic equator. Because the Sun's magnetic axis is tilted with respect to its rotational axis, the spacecraft is exposed to different solar-wind regimes as the Sun rotates. By measuring the changing structure of the solar wind, Ulysses



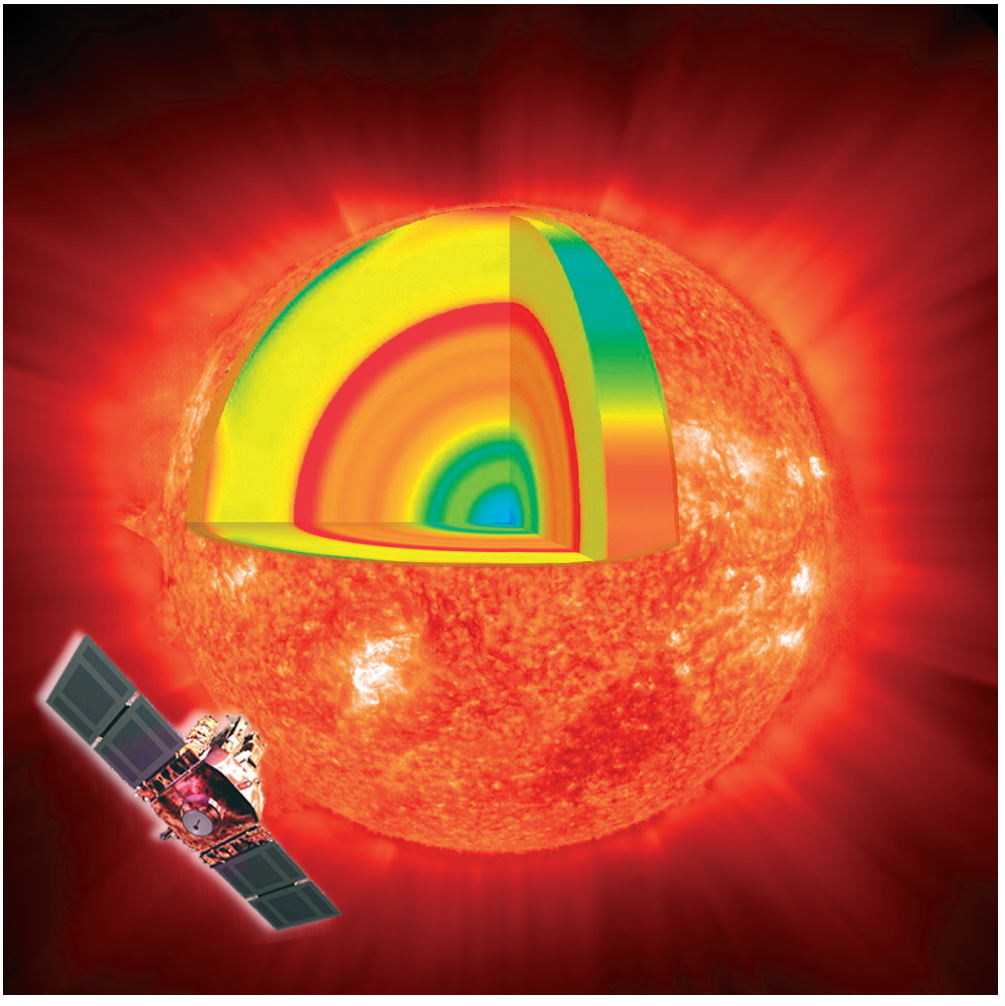
The Cone Nebula in Monoceros was one of the first targets of Hubble's new ACS camera. (Courtesy of NASA, Holland Ford/JHU, the ACS Science Team, and ESA)

Delving into the hidden depths of the Universe, Hubble also snapped the Tadpole Galaxy with the ACS. This short-exposure image shows a stunning backdrop of 6000 galaxies - twice the number in the legendary Hubble Deep Field image. (Courtesy of NASA, Holland Ford/JHU, the ACS Science Team and ESA)

is helping to unravel the complex behaviour of our variable star.

Hubble Space Telescope

The year was marked by the enormous increase in science capacity provided in March by the installation of the new Advanced Camera for Surveys (ACS) and the revival of the Near-Infrared Camera and Multi-Object Spectrograph (NICMOS) during Hubble Servicing Mission 3B. The ACS's field of view is nearly twice as wide as that of Hubble's current workhorse camera, WFPC2, and with its superb image quality and high sensitivity it has increased Hubble's potential for new discoveries by a factor of ten. NICMOS uses near-infrared vision to probe dark, dusty, never-before-seen regions of space with the optical clarity that only Hubble can provide. The European return on investment continued to be very high in 2002, with the HST observing time allocated to Europe being increased to between 16 and 19%.



SOHO is providing an unparalleled breadth and depth of information about the Sun, from its interior, through its atmosphere, and out into the solar wind

ISO

ISO is in its 'Active Archive Phase' (running until 2006) and continued to make groundbreaking contributions to all areas of astronomy, including:

- The observation of emissivity features of asteroid 10 Hygiea, demonstrating a possible spectral similarity with CO carbonaceous chondrites at small grain size.
- The first observation of the HD ground-state transition at 112 microns in absorption outside the Solar System (towards W49).
- The investigation of time variation in water-vapour bands from oxygen-rich Mira variables, interpreted to originate from two layers.

'The ISO Data Archive – Infrared Astronomy in the Internet Age' conference in June demonstrated that archival research is also well advanced and contributing significantly to the progress of astronomy. ISO continued to have a significant presence in the refereed literature also, with about 150 new publications logged in 2002.

SOHO

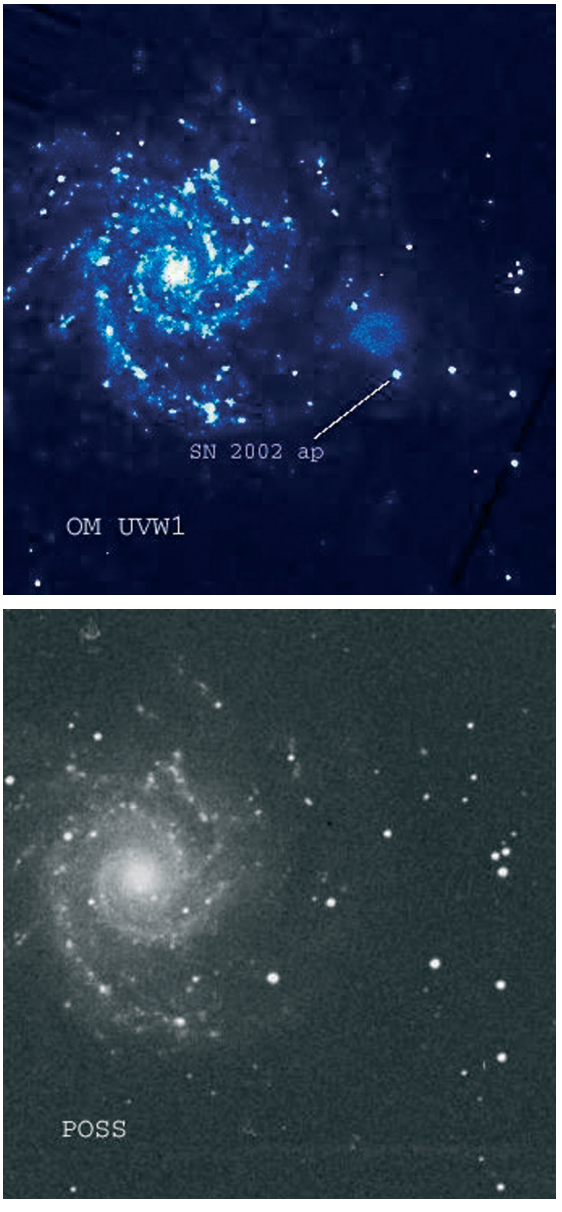
The Solar and Heliospheric Observatory, launched in December 1995, remains a busy observatory, including many coordinated observations (over 50%). During 2002, the SOHO web servers received more than 98 million requests and more than 16 terabytes of data were transferred. SOHO observations were also featured several times by major American and European news media, including CNN, CNBC, BBC, Der Spiegel, and even The Economist.

Strong oscillations in very hot loops (9–20 million degrees) above active regions of the Sun were discovered by SOHO's SUMER instrument. Whilst the nature of these oscillation modes is still unclear, this discovery has opened up the possibility of probing coronal structure by 'coronal seismology'. The apparent excess speed of solar supergranulation patterns has also puzzled solar scientists for two and a half decades. Using data from the SOHO's MDI instrument, scientists have now shown that the phenomenon is much like 'the wave' of spectators in a sports stadium.

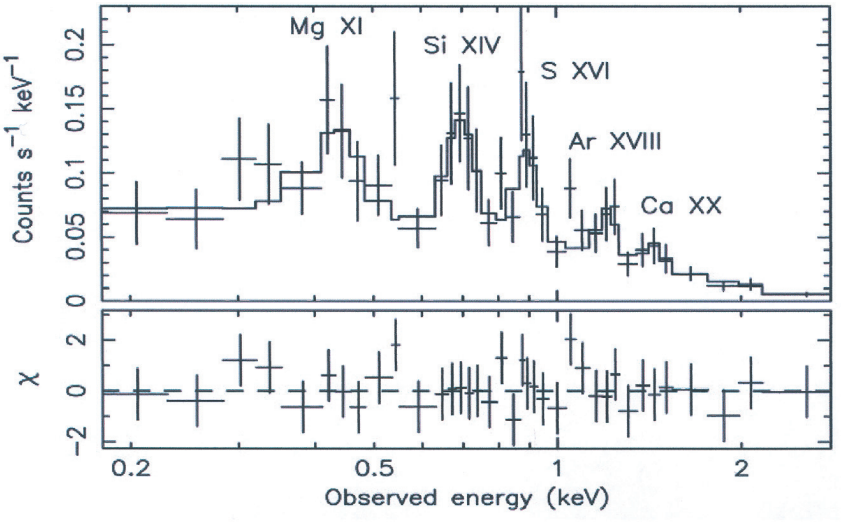
XMM-Newton

On 2 February, XMM-Newton observed the field of a newly discovered supernova named SN 2002 ap. Supernovae appear at the site of a star that has violently exploded, possibly ejecting the basic elements needed for life into the cosmos.

Gamma-ray bursts are the most powerful explosions ever detected in the Universe, but also one of the greatest mysteries of modern astronomy until now. By analysing the afterglow of the gamma-ray burst in the X-ray light, XMM-Newton provided scientists with



Comparison of an XMM-Newton Optical Monitor UV image (top) and a conventional optical Palomar Sky Survey image (centre) of SN 2002 ap and its host galaxy M74. The XMM-Newton X-ray image (bottom) provides an indication of weak X-ray emission (circled) from this supernova.



X-ray spectrum of a gamma-ray-burst afterglow, obtained by XMM-Newton. The peaks in the spectrum indicate the chemical elements present in the material emitting the X-rays.

the first evidence of the presence of chemical elements that are the unmistakable remnants of a supernova explosion that had occurred just a few days earlier.

Cassini-Huygens

The Cassini-Huygens spacecraft performed perfectly throughout the year whilst on route to Saturn. The ESA Probe will now be released from the spacecraft on 25 December 2004 and will enter Titan's atmosphere on 14 January 2005. The first composite image of Saturn and Titan was taken by the Cassini Orbiter camera in late October 2002 when the spacecraft was still 285 million kilometres from the planet.

A series of papers related to the highly scientifically rewarding six-month Jupiter flyby in late 2000/early 2001 appeared in the 28 February 2002 issue of Nature and included results obtained by Cassini, Galileo, Hubble Space Telescope, Chandra and ground-based radio observatories.

The work related to the implementation of the Huygens recovery mission (made necessary by a design flaw in the Huygens radio receiver discovered during in-flight testing in 2000) progressed according to plan. In December, the details of the new trajectory for the Probe mission were finalised with NASA/JPL and

the Probe flight-software modifications for the revised mission were designed and successfully validated at subsystem level. Two in-flight checkouts carried out during the year confirmed the excellent health of the Probe's payload and subsystems. A Probe relay test in November validated the link parameters for the revised mission trajectory.

Cluster

In February, based on its excellent scientific return, the mission was extended for an additional three years until December 2005. From June onwards, data return was doubled in order to continuously monitor the relation between the Sun and the Earth. The electric current, for example, is very important as the Sun uses it to transfer energy to the Earth. One manifestation of it are the 'northern lights' (aurorae) visible periodically in the vicinity of the Earth's North and South poles. The four Cluster spacecraft have provided a major advance in our understanding of these space currents by measuring them for the first time in three dimensions.

The process of magnetic reconnection is believed to be one of the main candidates for the production of geomagnetic substorms on the Sun and other astronomical objects. The exact location of the reconnection process could not be accurately determined with previous single-spacecraft missions, but Cluster has been able to identify it for the first time.