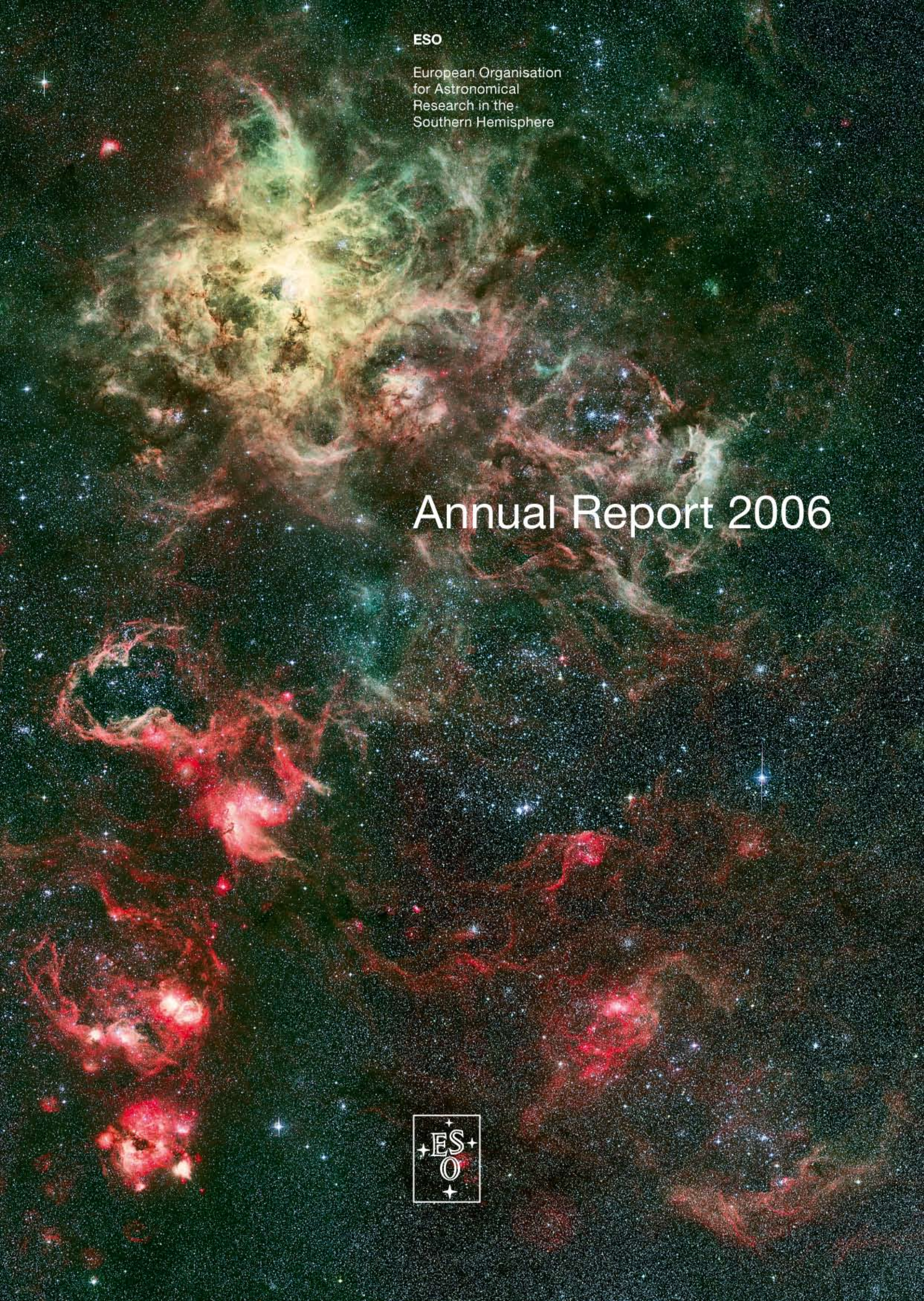
ESO

European Organisation
for Astronomical
Research in the
Southern Hemisphere

Annual Report 2006



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presented to the Council by the
Director General
Dr. Catherine Cesarsky

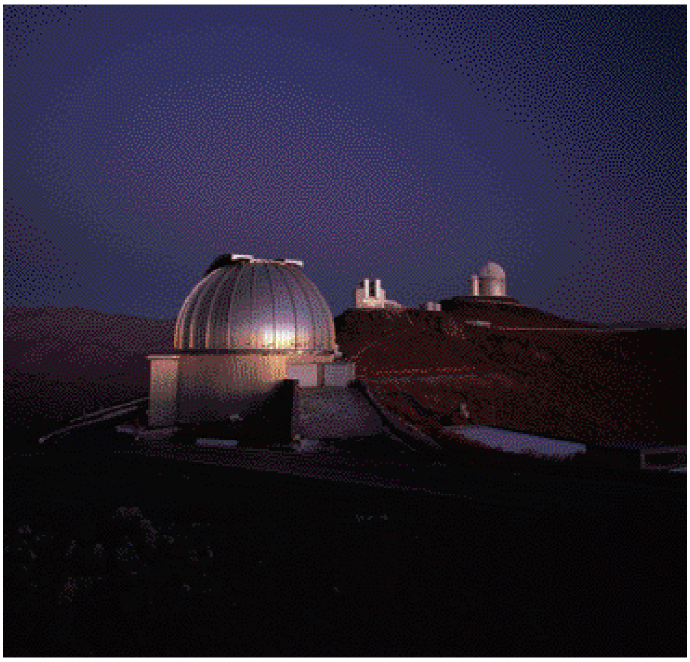
About ESO

ESO is the foremost intergovernmental European Science and Technology organisation in the field of ground-based astrophysics. It is supported by 12 countries: Belgium, Denmark, France, Finland, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom. The Czech Republic is currently in the process of joining ESO (Status as of 31.12.2006). Further countries have expressed interest in membership.

Created in 1962, ESO provides state-of-the-art research facilities to European astronomers and astrophysicists. In pursuit of this task, ESO's activities cover a wide spectrum including the design and construction of world-class ground-based observational facilities for the member-state scientists, large telescope projects, design of innovative scientific instruments, developing new and advanced technologies, furthering European cooperation and carrying out European educational programmes.

ESO operates the La Silla Paranal Observatory at several sites in the Atacama Desert region of Chile. The first site is at La Silla, a 2 400 m high mountain 600 km north of Santiago de Chile. It is equipped with several optical telescopes with mirror diameters of up to 3.6 metres. The 3.5-m New Technology Telescope (NTT) was the first in the world to have a computer-controlled main mirror.

Whilst La Silla remains one of the scientifically most productive observing sites in the world, the 2 600 m high Paranal site with the Very Large Telescope array (VLT) is the flagship facility of European astronomy. Paranal is situated about 130 km south of Antofagasta in Chile, 12 km inland from the Pacific Coast in what is probably the driest area in the world. Scientific operations began in 1999 and have resulted in a high number of extremely successful research programmes. The VLT is a most unusual telescope, based on the latest technology. It is not just one, but an array of four telescopes, each with a main mirror of 8.2-m diameter. With one such telescope, images of celestial objects as faint as magnitude 30 have been obtained in a one-hour exposure. This corresponds to seeing objects that are four billion times fainter than what can be seen with the naked eye.



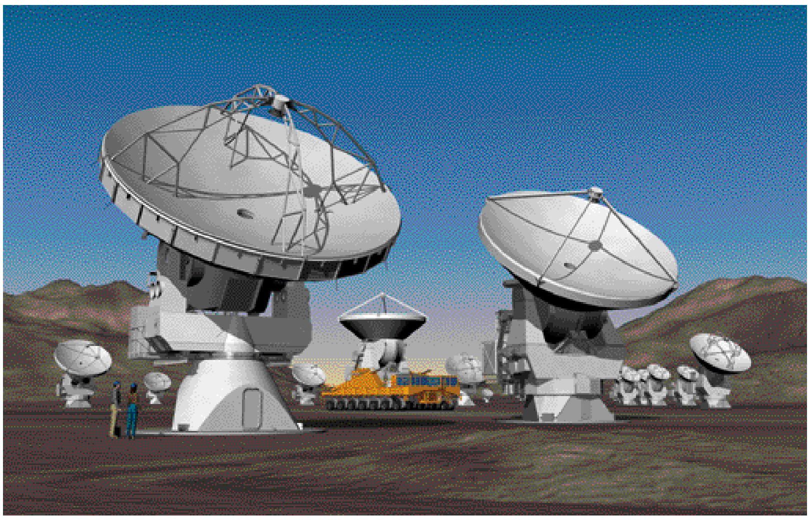
The 2.2-m, the 3.5-m NTT and the 3.6-m telescopes at La Silla.

One of the most exciting features of the VLT is the possibility to use it as a giant optical interferometer (VLT Interferometer or VLTI). This is done by combining the light from several of the telescopes, including one or more of four 1.8-m moveable Auxiliary Telescopes. In the interferometric mode, one can reach the resolution on the sky that would be obtained with a telescope of the size of the separation between the most distant of the combined mirrors.

In 2006, over 1700 proposals were made for the use of ESO telescopes. They have resulted in a large number of peer-reviewed publications. In 2006, 630 refereed papers based on data from ESO telescopes were published.

ESO is also a major partner in the Atacama Large Millimeter/Submillimeter Array (ALMA), one of the largest ground-based astronomy projects of the next decade.

Artist's impression of a part of ALMA on Chajnantor.

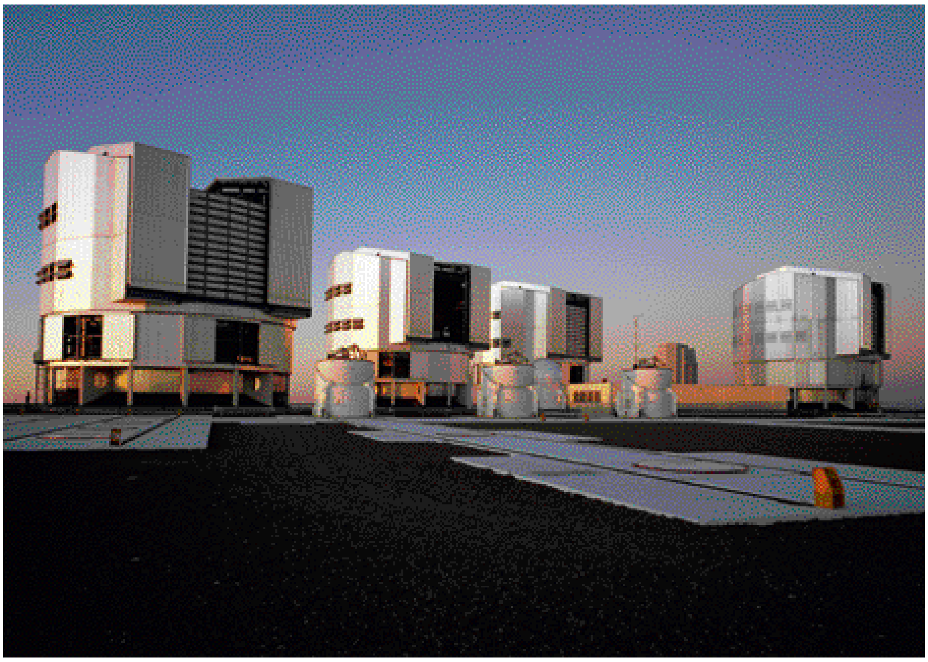


ALMA will be comprised of a main array of fifty 12-m submillimetre quality antennas, with baselines of several kilometres. An additional compact array of four 12-m and twelve 7-m antennas complements the main array. Construction of ALMA started in 2003 and will be completed in 2012; it will become incrementally operational from 2010 on. ALMA is located on the high-altitude Llano de Chajnantor (5 000 m elevation), east of the village of San Pedro de Atacama in Chile. The ALMA project is a partnership between Europe, Japan and North America in cooperation with the Republic of Chile. ALMA is funded in Europe by ESO, in Japan by the National Institutes of Natural Sciences in cooperation with the Academia Sinica in Taiwan and in North America by the U.S. National Science Foundation in cooperation with the National Research Council of Canada. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of Japan by the National Astronomical Observatory of Japan and on behalf of North America by the National Radio Astronomy Observatory, which is managed by Associated Universities, Inc.

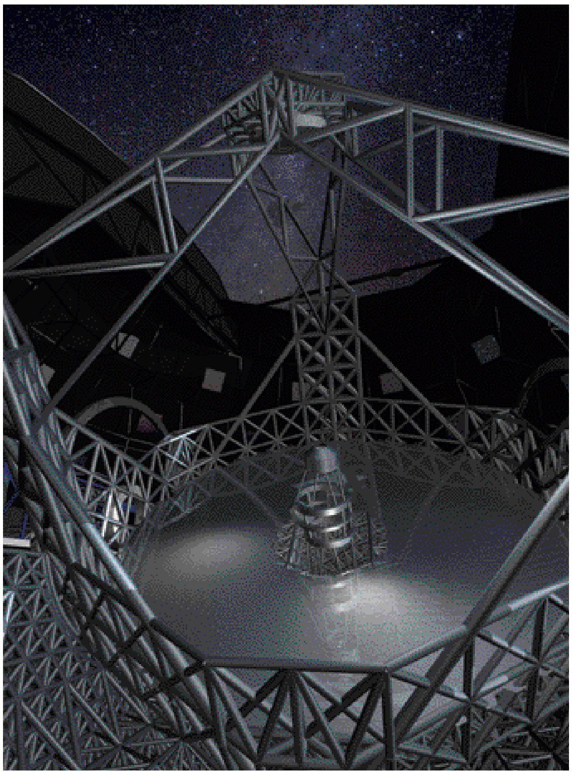
The Chajnantor site is also home of the 12-m APEX submillimetre/millimetre-wavelength telescope, operated by ESO on behalf of the Onsala Space Observatory, the Max-Planck Institute for Radio Astronomy and ESO itself.

ESO has built up considerable expertise in developing, integrating and operating large astronomical telescopes at remote sites. Together with the ideas developed in the framework of the OWL Conceptual Study and the EC co-funded Extremely Large Telescope Design Study, this expertise forms the backbone of the effort to develop a next-generation extremely large ground-based optical/infrared telescope for Europe's astronomers. For this project, currently known as the European Extremely Large Telescope (E-ELT), ESO has developed a basic reference design for a 42-m telescope with a novel five-mirror optical concept. The current detailed design phase is scheduled to be completed by the end of 2009.

The ESO headquarters are located in Garching, near Munich, Germany. This is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the observatories with the most advanced instruments. It is also home for the Space Telescope – European Coordinating Facility (ST-ECF), operated jointly by ESO and the European Space Agency (ESA).



The VLT Array at Paranal.



Artist's impression of the E-ELT.

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Foreword

It would be evident even to the most casual observer that ESO is as vibrant and dynamic as ever with a strong track record of excellence and ambitious projects. Some of these projects are now operational facilities, some are under construction and others are in the design phase. The task of Council is to provide the overall strategy and a framework for the further evolution of the organisation and it is this forward-looking task that makes the work of Council members so rewarding.

Arguably, the most important issue regarding the future that Council had to address in 2006 was the decision to endorse the proposal to embark on the detailed design study for a European Extremely Large Telescope (E-ELT). The study, scheduled to last for three years, will lead to a proposal for construction for Council to consider in due course. Council was able to take this decision not least because of the impressive preparatory work by ESO and the various working groups with strong involvement by the scientific community across Europe. In taking this important step Council recognised that the E-ELT is crucial to the further development of European astronomy and its ability to retain a competitive edge on a global stage.

Building the E-ELT is as big a challenge to all of us as any of the preceding projects in ESO's already impressive project portfolio. We can succeed only if we manage to harness the necessary resources – financial, technological and human. It is therefore gratifying that more potential member countries continue to express interest in joining. I was delighted that the entry of Spain as the 12th member state of ESO was becoming a reality at the end of the year, with just the final formalities pending. Spain plays an important role in European astronomy and its membership of ESO is a very welcome. At its December meeting Council also approved the entry of the Czech Republic, the first of the Central European countries to join.

The expansion of ESO's membership base is clearly important in the context of the E-ELT. It also strengthens ESO as the focal point for Europe's astronomers and thus reinforces the significance of the organisation as an important actor in the European Research Area.

ESO's overall role in the European research landscape is an important question that warrants serious consideration. At the June meeting of Council, the Science Strategy Working Group presented several scenarios that are now subject to further debate.

Entrusting the management of the organisation to the most competent leader is clearly most important to all of us. With the term of the current Director General coming to its end by September 2007, Council set up a search committee for the next DG, leading to the selection of Prof. Tim de Zeeuw as successor to Dr. Catherine Cesarsky. With this decision, Council has provided the base for a smooth transition of the management of ESO.

In conclusion I am pleased to note that by the end of the year, Council, working with the Executive, had acted to set ESO on a track towards a very exciting future and I wish to express my sincere thanks to all involved in this important endeavour.

Richard Wade
President of the ESO Council

Introduction

Photo: Volker Steger

In my introduction to the 2005 Annual Report, I described that year as a pivotal year for ESO. This was not least on the basis of the progress regarding the ALMA project. Looking at 2006, however, it is impossible not to use similar vocabulary again. Shortly before Christmas 2005 I had launched a very ambitious plan aiming to move quickly and decisively towards the realisation of the European Extremely Large Telescope (E-ELT). The task was daunting: the plan foresaw the establishment of five mixed Community-ESO topical Working Groups within the shortest space of time to lay the groundwork for a set of extremely intense activities to be conducted within a 'core' Working Group, the ELT Science and Engineering Working Group, supplemented by an ELT Standing Advisory Committee. Before the end of 2006, and with broad involvement of the scientific community, we wanted to be able to present a basic reference design and ask Council for approval of a Phase B for the project.

The way the scientific community and the ESO staff embraced the plan was truly encouraging, with 85 out of 88 invitees enthusiastically agreeing to board the 'ELT-train'. Now, 12 months later, the train has arrived – precisely on schedule. At the 27 November–1 December conference in Marseille, which was attended by more than 250 scientists, the results were presented to and discussed by the scientific community. Only a week later, Council gave the green light to embark on Phase B, a three-year long detailed design study that should allow us to present a proposal for construction to the ESO Council in the 2009–2010 time frame. The basis for the design study is a 42-m telescope with a unique five-mirror design. It constitutes an innovative design solution that takes account of all the concerns raised with previous design proposals. Yet, while pursuing the detailed studies, we retain the option of the classical Gregorian telescope as a fallback possibility.

These twelve months have seen a remarkable coming together of people, ideas, policy decisions and much hard work. The outcome is a tribute to the ability of Europe's astronomers to set ambitious goals but also to forge tenable compromises – to set their sights on the sky, while keeping their feet on the ground.

Aside from the impressive mobilisation of the scientific community, two other elements in the jigsaw puzzle should be mentioned: the inclusion of the ELT in the so-called ESFRI-list of large future research infrastructures deemed to be of European interest, and the setting up at ESO of a dedicated E-ELT project office with cross-divisional parts in a matrix structure. The former embeds the E-ELT decision process in the wider European science policy scene, a necessary step in the age of the European Research Area. The latter is part of preparing ESO for the challenges arising from the fact that we have become a multi-project organisation. A new step in the matrix structure foreseen to cope with this new situation is the creation of the Software Development Division, encompassing software developers from the previous Data Management Division, the Technological Division, and ALMA. Meanwhile, the new Data Management Operations division serves the VLT/VLTI and the ALMA ARC, ensuring continued attention to our running operations.

At Paranal, we introduced in January the Laser Guide Star (LGS) system on Yepun. At ESO, as elsewhere, success requires hard work, and indeed it became evident that the LGS launch-telescope needed modifications in order to perform as required. However, with the improvements carried out, the LGS commissioning could resume by October, and the facility will be fully used in scientific observations early in 2007.

Also this year, the fourth Auxiliary Telescope saw First Light, completing the suite of ATs for the Very Large Telescope Interferometer (VLTI) and we thank the Belgians, the Swiss and the Italians for providing the additional resources needed for this significant improvement.

Progress was also achieved with respect to VISTA, the 4-m survey telescope that forms a part of the UK entrance fee to ESO. In May 2006 most of the structural parts were shipped to Chile. The telescope enclosure was accepted in Chile, while the camera was ready to leave the UK for Chile at the end of the year. The coating plant that comes with VISTA was also being installed. This facility will prove a useful resource as it will allow mirrors to be silver rather than aluminium coated. Public Surveys for VISTA have been selected and I am glad to see that there were so many proposals, with the result that a very good set of surveys have been chosen.

The other survey telescope, the 2.5-m VST, remains on the other hand a matter of concern due to serious, continued delay. Nonetheless, following a visit by ESO engineers to Naples, plans were made for shipping of the telescope structure early in 2007. The 32-CCD-mosaic OmegaCAM wide-field optical camera for the VST, which was developed by ESO, was, however, finished. The primary mirror of the telescope is also now ready, in Moscow.

In June the VLT cryogenic high-resolution infrared echelle spectrograph CRIRES was commissioned at the Nasmyth focus of Antu, marking the completion of the first-generation VLT instrumentation. First steps of Science Verification also took place during the year and work was progressing very well on developing a dedicated pipeline for the CRIRES data reduction.

At the same time, the near-infrared imager HAWK-I, often described as a VLT 'generation 1.5' instrument, was in an advanced stage, undergoing Assembly and Integration at ESO Garching, paving the way for a shipment to Chile in 2007.

Important progress was also achieved with respect to the second-generation instrumentation. In September, an agreement was signed with an extended consortium led by LAOG in Grenoble to develop SPHERE. The revised design fulfils all the requirements set by the ESO Scientific Technical Committee (STC) for the planet-finder instrument.

Meanwhile, the multi-conjugate adaptive optics demonstrator (MAD) was successfully tested in the laboratory in Garching, passing its PAE (Preliminary Acceptance Europe) in December and thus being ready to go to Chile.

All of these instruments constitute technological marvels; we are thrilled by their ingenious design and capabilities, for they allow us to do science at the cutting-edge. This is undoubtedly also the case for AMBER, the interferometric beam combiner for the VLTI, which was offered to the scientific community from P 76, and it is gratifying to see a string of truly impressive scientific results, scheduled to appear in a special issue of A&A in March 2007.

AMBER is not the only facility to have this honour, as in July 2006 the submillimetric telescope APEX was also the topic of a special A&A issue, with no fewer than 26 articles based on early science being published.

Although some of the great scientific achievements made with ESO's telescopes are published in the Research Highlights, I cannot resist mentioning a few. In January, the discovery of the smallest exoplanet found so far, a five-Earth-mass planet, was announced. The planet was discovered by microlensing, with the help of a worldwide network of telescopes, among which the 1.5-m Danish telescope at La Silla was the one that could pick up the signal due to the planet. This discovery heralds a new era in the search for exoplanets. The identification, also at La Silla but with the 3.6-m telescope this time, of a planetary system containing three Neptune-mass planets and an asteroid belt, is also of crucial importance in this very hot research area.

With the VLT, astronomers have found possible proofs of stellar vampirism in the globular cluster 47 Tucanae. Indeed, some hot, bright, and apparently young stars in the cluster present less carbon and oxygen than the majority of their sisters, indicating that these few stars likely formed by taking their material from another star. Farther away, the combination of adaptive optics techniques with the new SINFONI integral-field spectrograph allowed astronomers to study a very distant galaxy with a record-breaking resolution of a mere 0.15 arcseconds, giving an unprecedented detailed view of the anatomy of such a distant proto-disc galaxy. The observations imply that large disc galaxies akin to our Milky Way must have formed on a rapid timescale, only three billion years after the Big Bang.

With the VISIR instrument, astronomers have mapped the disc around a star more massive than the Sun. The very extended and flared disc most likely contains enough gas and dust to spawn planets. It appears as a precursor of debris discs such as those around Vega-like stars and thus provides the rare opportunity to witness the conditions prevailing prior to or during planet formation. The huge gain in resolving power offered by the VLTI also made a difference. VINCI and MIDI were used to discover envelopes around three Cepheids, massive pulsating stars that play a crucial role in cosmology, being one of the first steps on the cosmic distance ladder.

Of course, these are but a few examples of the science that is based on observations with ESO telescopes. In fact, on average, our user community produces close to two papers with ESO data a day all year round, more than any other ground-based observatory in the world.

ESO telescopes generate a large quantity of data, which are kept for reuse in the Science Archive. With the coming online of VISTA, and later of the VST, the flow of data will considerably increase, reaching 100 TB of data per year. To anticipate this, ESO is preparing a Petabyte-class archive that will be ready next year.

In July, the first data release of the UKIRT Infrared Deep Sky Survey (UKIDSS) was available, providing a year of data to the ESO community of users. The full survey is expected to take seven years. But this first set of observations already shows how powerful the full survey will be at finding rare objects that hold vital clues to how stars and galaxies in our Universe formed. Indeed, the new data on young galaxies is already challenging current thinking on galaxy formation, revealing galaxies that are massive at a much earlier stage of development than anticipated.

In 2005, the ALMA project was set on track with major industrial contracts being awarded. The year 2006 was a year of construction: the road from the highway to the high site, the AOS, was completed at its full width, and construction of the buildings at the OSF, at 2 900 m altitude, began at full speed. The road and the OSF buildings are deliverables for which ESO is responsible.

In Europe, the first cryostats and receivers for two frequency bands were delivered. By now, prototypes are available for all four ALMA frequencies (0.6, 0.9, 1.3 and 3 mm), fulfilling specifications. For the cryostats, a first series of eight was manufactured and delivered. The first cartridge for Band 7 exceeded the specifications, being much more sensitive than initially planned. This, in effect, is equivalent to having many more antennas. First tests on the SMA on Mauna Kea of the water vapour radiometers proved the technology to be highly successful. It was thus decided to implement these in ALMA, thereby further increasing the output of this unique facility.

Another important milestone for the ALMA project was reached in June with the signing of the agreement with Japan (and Taiwan), bringing a Compact Array and other wavebands to the project. According to the agreement, the ALMA array will thus initially comprise 66 antennas, 54 of them with 12-m diameter and 12 7-m antennas.

ALMA is the first quasi-global project in ground-based astronomy, and it is fitting that ESO, with its international orientation, plays its part in it. That ESO plays an important role on the international scene was also visible during the 2006 SPIE conference, with a large involvement in the organisation and numerous presentations by ESO staff. The SPIE meeting also allowed for starting most fruitful discussions with other ELT groups, especially the TMT, that have since been ongoing.

Equally, in November, a top-level meeting on exoplanets took place in Washington D.C. between ESO, ESA, NSF and NASA.

Back in Europe, the IAU General Assembly was held in Prague. These triennial events always provide a unique opportunity to experience first-hand the progress across the entire range of astronomy, as well as to meet friends and colleagues from one's own and other sub-fields, and this General Assembly certainly lived up to expectation. Some 2800 participants from around the world attended the event. Again, ESO was well presented, in the various sessions and also with a major information stand – fitting in the context of our ongoing talks with the Czech Republic.

We continued our collaboration with ESA, with the publication of two joint reports on Herschel/ALMA synergies and fundamental cosmology, respectively, as visible signs of the coordination efforts in this field on our continent.

In June, with our Chilean colleagues we celebrated the 10th anniversary of the supplementary agreement with Chile, which not only paved the way for ESO's operations in Chile in the VLT era, but also provided strong impulses to Chilean astronomy. Some of the results are described in the book "10 Years Exploring the Universe" that was published on this occasion. We are pleased that our relations with Chile, its scientific community and its people, remain strong and positive.

Moving from international relations in general to the issue of new member states, we were happy when, in February, Spain took a decisive step towards full membership with the signing in Madrid of a statement aiming at accession to the ESO Convention effective from 1 July. As it turned out, the ratification process needed more time and the last steps remained to be completed by the end of the year. Nonetheless, we were assured by the Spanish authorities of the intent to respect the accession date, as set out in the February statement.

In parallel, negotiations with the Czech Republic progressed rapidly. At the December meeting, Council approved the agreement, which foresaw Czech membership as of 1 January 2007. A few days later, the agreement was also approved by the Czech Government, and on 22 December the agreement was signed at a ceremony in Prague. As in the case of Spain, however, the parliamentary approval and the subsequent deposition of the instrument of ratification remained to be completed.

ESO is a high-tech research organisation with a global perspective. As such it must meet the challenges of the dynamic, international labour market, competing for the best and most talented staff. With the opening of the IPP/ESO crèche for our staff in Garching, we have taken further steps to create a working climate that is also amenable to family needs. In Chile, we entered collective bargaining, concluding collective arrangements valid for three years.

Having physical surroundings that foster human and intellectual exchange is another important element. It is therefore good that the long-awaited expansion of our Headquarters building moved closer as, with the help of the German authorities, we made progress towards securing the land to the south of the existing premises.

In its 45th year, ESO remains a strong and dynamic organisation, not just full of ideas and initiatives but with a clear will to harness these into projects that can serve our users. An important tool in this process is the Medium Range Implementation Plan, which was endorsed by Council at its December meeting. This plan provides a clear path for ESO's development over the next four years; now it is for us to turn it into reality.

Catherine Cesarsky
Director General, ESO

Research Highlights

In 2006 ESO again proved that it has the telescopes and instruments to maintain its lead position in the quest for exoplanets, that is, planets that orbit a star other than the Sun. Using a variety of telescopes, at La Silla and Paranal, astronomers were able to find the smallest exoplanet yet discovered — a five-Earth-mass icy world — as well as a complete planetary system composed of 3 Neptune-mass planets. Also noteworthy is the study of free-floating planets that appear to harbour discs and even form as twins, thereby sharing many properties of stars.

Talking about discs, the VISIR instrument allowed astronomers to map a disc around a very young star, possibly witnessing the precursor of a planetary system.

But it is not all about stars and planets. In 2006, astronomers provided unique insights into two classes of important objects in cosmology, Cepheids and Type Ia supernovae.

They also have revealed several cases of stellar vampirism, including one on a very big scale. In other studies, they have provided important clues on the past of our own Galaxy. Looking farther away, SINFONI on the VLT made a record observation of a very young galaxy, showing that it formed very quickly, contrarily to previous beliefs. The VLT also helped discover a 'blob' twice as large as the Milky Way and emitting as much as several billion suns, yet it is invisible in normal light! In another bout of magic, the VLT also studied an invisible galaxy, from the imprint it leaves on the spectrum of a distant quasar acting as a beacon.

One cannot doubt that the Universe has still many surprises in store but it seems also evident from the few Research Highlights presented here that ESO telescopes are revealing more and more of them every day!

The Comet With a Broken Heart

On the night of 23/24 April, ESO's Very Large Telescope observed fragment B of the comet Schwassmann-Wachmann 3 that had split a few days earlier. To their great surprise, the ESO astronomers discovered that the piece just ejected by fragment B was splitting again! Five other mini-comets are also visible on the image. The comet seems thus doomed to disintegrate but the question remains in how much time.

Comet 73P/Schwassmann-Wachmann 3 (SW 3) is a body with a very tormented past. This comet revolves around the Sun in about 5.4 years, in a very elongated orbit that brings it from inwards of the Earth's orbit to the neighbourhood of giant planet Jupiter. In 1995, when it was coming 'close' to the Earth, it underwent a dramatic and completely unexpected, thousandfold brightening. Observations in 1996, with ESO's New Technology Telescope and 3.6-m telescope, at La Silla, showed that this was due to the fact that the comet had split into three distinct pieces. Later, in December 1996, two more fragments were discovered. At the last comeback, in 2001, of these five fragments only three were still seen, the fragments C (the largest one), B and E. No new fragmentations happened during this approach, apparently.
Things were different this time, when the comet moved again towards its closest approach to the Sun – and to the Earth. Early in March, seven fragments were observed, the brightest (fragment C) being of magnitude 12, i.e. 250 times fainter than what the unaided eye can see, while fragment B was 10 times fainter still. In the course of March, 6 new fragments were seen.

Early in April, fragment B went into outburst, brightening by a factor 10 and on 7 April, six new fragments were discovered, confirming the high degree of fragmentation of the comet. On 12 April, fragment B was as bright as the main fragment C, with a magnitude around 9 (16 times fainter than what a keen observer can see with unaided eyes). Fragment B seems to have fragmented again, bringing the total of fragments close to 40, some being most probably very small, boulder-sized objects with irregular and short-lived activity.

The new observations reveal that this new small fragment has split again! The image clearly reveals that below the main B fragment, there is a small fragment that is divided into two and a careful analysis reveals five more tiny fragments almost aligned. Thus, this image alone shows at least 7 fragments. The comet has thus produced a whole set of mini-comets!

Mini-comets coming off comet SW 3.

An Icy 5 Earth-mass Exoplanet

Driven by the need for increasing efficiency to address current frontline research topics, astronomy is moving more and more in the direction of huge international teams working together, not unlike what has been the rule for many years in particle physics. Nothing can better illustrate this trend than the discovery of the smallest exoplanet. This incredible result is a joint effort of three independent campaigns: PLANET/RoboNet, OGLE, and MOA, involving a total of 73 collaborators affiliated with 32 institutions in 12 countries.

Designated by the unglamorous identifier of OGLE-2005-BLG-390Lb, the alien world is a five Earth-mass object located 20 000 lightyears away, not far from the centre of our Milky Way galaxy.

Contrary to most of the more than 200 exoplanets discovered until now, OGLE-2005-BLG-390Lb was found using the 'microlensing' technique. This method is based on the fact that the gravity of a dim, intervening star can act as a giant natural telescope, magnifying a more distant star, which then temporarily looks brighter. A small 'glitch' in the brightening reveals the existence of a planet around the lens star. Neither the planet nor the star that it is orbiting can be seen, only the effect of their gravity. Such an intervening star causes a characteristic brightening that lasts about a month. Any planets orbiting this star can produce an additional signal, lasting from days for giant planets down to hours for Earth-mass planets.

In order to be able to catch and characterise these planets, nearly-continuous round-the-clock high-precision monitoring of ongoing microlensing events is required. This is the goal of the PLANET network of 1-m-class telescopes consisting of the ESO 1.54-m Danish at La Silla (Chile), the Canopus Observatory 1.0-m (Hobart, Tasmania, Australia), the Perth 0.6-m (Bickley, Western Australia), the Boyden 1.5-m (South Africa), and the SAAO 1.0-m (Sutherland, South Africa). Since 2005, PLANET has operated a common campaign with RoboNet, a UK-operated network of 2-m fully robotic telescopes currently comprising the Liverpool Telescope (Roque de Los Muchachos, La Palma, Spain) and the Faulkes Telescope North (Haleakala, Hawaii, USA).

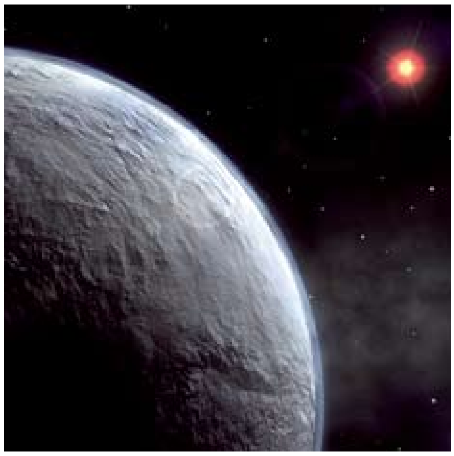
The OGLE (Optical Gravitational Lensing Experiment) search team discovered the event OGLE-2005-BLG-390 on 11 July 2005, triggering the PLANET telescopes to start taking data. A light curve consistent with a single lens star peaking at an amplification of about 3 on 31 July 2005 was observed, until 10 August when a PLANET member, observing at the Danish 1.54-m at ESO La Silla, noticed a planetary deviation. An OGLE point from the same night showed the same trend, while the last half of the planetary deviation, lasting about a day, had been covered by images from Perth Observatory. The MOA (Microlensing Observations in Astrophysics) collaboration was later able to identify the source star on its images and confirmed the deviation.

The new planet orbits a red star five times less massive than the Sun in about 10 years. It is the least massive exoplanet around an ordinary star detected so far, and also the coolest: its relatively cool parent star and large orbit implies that the likely surface temperature of the planet is 220 degrees Celsius below zero, too cold for liquid water. It is likely to have a thin atmosphere, like the Earth, but its rocky surface is probably deeply buried beneath frozen oceans. It may therefore more closely resemble a more massive version of Pluto, rather than the rocky inner planets like Earth and Venus.

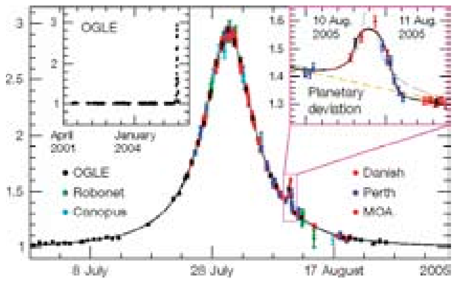
Astronomers claim that this planet is actually the first and only planet that has been discovered so far that is in agreement with the theories for how our Solar System formed. The favoured theoretical explanation for the formation of planetary systems proposes that solid 'planetesimals' accumulate to build up planetary cores, which then accrete nebular gas – to form giant planets – if they are sufficiently massive. Around red dwarfs, the most common stars of our Galaxy, this model favours the formation of Earth- to Neptunemass planets being between 1 and 10 times the Earth-Sun distance away from their host. OGLE-2005-BLG-390Lb is only the third extrasolar planet discovered so far through microlensing searches. While the other two microlensing planets have masses of a few times that of Jupiter, the discovery of a 5 Earth-mass planet – despite being much harder to detect than more massive ones – is a strong hint that these lower-mass objects are very common. In particular, astronomers now think that such frozen worlds are much more common than their larger, Jupiter-like brethren, as otherwise the microlensing method should have found dozens of them by now.

There is no doubt that the discovery of this planet marks a groundbreaking result in the search for planets that support life.

J.-P. Beaulieu, D. P. Bennett, P. Fouqué, A. Williams, M. Dominik, U. G. Jørgensen, D. Kubas et al., Nature, 26 January 2006.



Artist's Impression of the Icy Exoplanet.



Light Curve of OGLE-2005-BLG-390.

Trio of Neptunes and their Belt

A most unusual planetary system has been found, in which a nearby star is hosting three Neptune-mass planets. The innermost planet is most probably rocky, while the outermost is the first known Neptune-mass planet to reside in the habitable zone. This unique system is likely further enriched by an asteroid belt.


Impression of the planetary system around HD 69830.

A planet in orbit around a star will manifest its presence by pulling the star in different directions, thereby changing its measured velocity by very small amounts. Astronomers therefore measure the velocity of a star with very high precision to detect the signature of one or more planets. Certainly the best instrument to do this kind of work is the High Accuracy Radial velocity Planet Searcher (HARPS) at the ESO La Silla 3.6-m telescope, a fibre-fed high-resolution echelle spectrograph that has demonstrated a long-term precision of about 1 m/s.

During more than two years, a team of astronomers used HARPS to monitor the velocity of HD 69830, a rather inconspicuous nearby star slightly less massive than the Sun. Located 41 light-years away towards the constellation of Puppis (the Stern), it is, with a visual magnitude of 5.95, just visible with the unaided eye. Precise measurements allowed the astronomers to discover the presence of three tiny companions orbiting their parent star in 8.67, 31.6 and 197 days.

The detected velocity variations are between 2 and 3 metres per second, corresponding to about 9 km/h! That's the speed of a person walking briskly. Such tiny signals could not have been distinguished from 'simple noise' by most of today's available spectrographs.

The newly found planets have minimum masses between 10 and 18 times the mass of the Earth. Extensive the oretical simulations favour an essentially rocky composition for the inner planet, and a rocky/gas structure for the middle one. The outer planet has probably accreted some ice during its formation, and is likely to be made of a rocky/icy core surrounded by a quite massive envelope. Further calculations have also shown that the system is in a dynamically stable configuration.

The outer planet also appears to be located near the inner edge of the habitable zone, where liquid water can exist at the surface of rocky/icy bodies. Although this planet is probably not Earth-like due to its heavy mass, its discovery opens the way to exciting possibilities.

This alone would make this system already exceptional. But the recent discovery by the Spitzer Space Telescope that the star most likely hosts an asteroid belt adds the cherry to the cake. With three roughly equal-mass planets, one being in the habitable zone, and an asteroid belt, this planetary system shares many properties with our own Solar System. The planetary system around HD 69830 clearly represents a 'Rosetta stone' for our understanding of how planets form. No doubt it will help us better understand the huge diversity we have observed since the first extrasolar planet was found in 1995.

Christophe Lovis et al., Nature, 18 May 2006.

Increasing the Odds of the Sweep

The VLT has confirmed the extrasolar planet status of two of the 16 candidates discovered by the NASA/ESA Hubble Space Telescope.

The 16 candidates were uncovered during an international HST survey, called the 'Sagittarius Window Eclipsing Extrasolar Planet Search', or SWEEPS.

HST couldn't see the 16 newly found planet candidates directly. Instead, astronomers used HST to search for planets by measuring the slight dimming of a star due to the passage of a planet in front of it. This event is called a transit. The planet would have to be about the size of Jupiter to block enough starlight, about 1 to 10 per cent, to be measurable by HST. These objects are called planetary 'candidates' because astronomers cannot be sure of their mass, and hence of their status, without further spectroscopic measurements.

For two of the stars, the SWEEPS team could use the UVES and FLAMES instruments on the VLT to make an independent confirmation of a planet's presence by spectroscopically measuring a slight wobble in the star's motion due to the gravitational pull of an unseen companion. One of the planetary candidates has a mass below 3.8 Jupiter masses. It orbits its host star, which is 25% more massive than the Sun, in 4.2 days. The other candidate's mass is 9.7 Jupiter masses.

These are the faintest stars with planets that have been confirmed by radial velocities so far. To confirm the other planet candidates one would need a much bigger telescope on Earth, such as the European Extremely Large Telescope.

Kailash Sahu et al., Nature, 5 October 2006.

Do ‘Planemos’ Have Progeny?

Two new studies show that objects only a few times more massive than Jupiter are born with discs of dust and gas, the raw material for planet-making. This suggests that miniature versions of the Solar System may circle objects that are some 100 times less massive than our Sun. What’s more, such objects appear also to be able to form as twins: an approximately seven-Jupiter-mass companion was found orbiting an object that is itself only twice as hefty. The existence of such a double system puts strong constraints on formation theories of free-floating planetary-mass objects.

Since a few years ago, it has been known that many young brown dwarfs — ‘failed stars’ that weigh less than 8 per cent the mass of the Sun — are surrounded by a disc of material. This may indicate these objects form in the same way as our Sun. The new findings confirm that the same appears to be true for their even punier cousins, sometimes called free-floating planetary mass objects or ‘planemos’. These objects have masses similar to those of extrasolar planets, but they are not in orbit around stars – instead, they float freely.

In a way, the new discoveries are not too surprising – after all, Jupiter must have been born with its own disc, out of which its bigger moons formed. Still they may lead to a revision of our understanding of planetary formation as, unlike Jupiter, these planemos are not circling stars.

The first study used two of ESO’s telescopes – Antu, the 8.2-metre Unit Telescope no. 1 of the Very Large Telescope, and the 3.5-metre New Technology Telescope – to obtain optical spectra of six candidates identified recently by researchers at the University of Texas at Austin. Two of the six turned out to have masses between five and 10 times that of Jupiter while two others are a tad heftier, at 10 to 15 times Jupiter’s mass. All four of these objects are ‘newborns’, just a few million years old, and are located in star-forming regions about 450 light years from Earth. The planemos show infrared emission from dusty discs that may evolve into miniature planetary systems over time.

The other study also used the Very Large Telescope, but this time with its adaptive optics system and infrared camera NACO, to obtain images and spectra of a planetary-mass companion discovered two years ago at ESO around a young brown dwarf that is itself about 25 times the mass of Jupiter.
This planetary-mass companion is the first-ever exoplanet to have been imaged. The brown dwarf, dubbed 2M1207 for short and located 170 light years from Earth, was known to be surrounded by a disc. Now, evidence has been found for a disc around the eight-Jupiter-mass companion as well.

The pair probably formed together, like a petite stellar binary, instead of the companion forming in the disc around the brown dwarf like a star-planet system.
It is also possible that smaller planets or asteroids could now form in the disc around each one.

Astronomers have in fact found a double system composed of even smaller objects. Oph 162225-240515, or Oph 1622 for short, is the first planemo found to be a double. Researchers discovered the companion candidate in an optical image taken with the NTT, then took optical spectra and infrared images of the pair with the VLT to make sure that it is a true companion, instead of a foreground or background star that happens to be in the same line of sight. These follow-up observations indeed confirmed that both objects are young, at the same distance, and much too cool to be stars. This suggests the two are physically associated.

By comparing to widely used theoretical models, the astronomers estimate that the companion is about seven times the mass of Jupiter, while the more massive object comes in at about 14 times Jupiter’s mass. The newborn pair, barely a million years old, is separated by about six times the distance between the Sun and Pluto, and is located in the Ophiuchus star-forming region approximately 400 light years away.

Planets are thought to form out of discs of gas and dust that surround stars, brown dwarfs, and even some free-floating planetary mass objects, as described above. But, it is likely that these planemo twins formed together out of a contracting gas cloud that fragmented, like a miniature stellar binary.

Oph 1622B is only the second or third directly-imaged planetary-mass companion to be confirmed spectroscopically, and the first one around a primary that is itself a planetary-mass object. Its existence poses a challenge to a popular theoretical scenario, which suggests that brown dwarfs and free-floating planetary-mass objects are embryos ejected from multiple protostar systems.
Since the two objects in Oph1622 are so far apart, and only weakly bound to each other by gravity, they would not have survived such a chaotic birth.

Recent discoveries have revealed an amazing diversity of worlds out there. Still, the Oph1622 pair stands out as one of the most intriguing. Now, the astronomers are curious to find out whether such pairs are common or rare. The answer could shed light on how free-floating planetary-mass objects form.

Ray Jayawardhana & Valentin Ivanov, American Astronomical Society, June 2006, Calgary, Canada.
Ray Jayawardhana & Valentin D. Ivanov, Science, 3 August 2006.
Subhanjoy Mohanty et al., American Astronomical Society, June 2006, Calgary, Canada.

Spectra of candidate ‘planemos’.

Watching How Planets Form

The disc around a star more massive than the Sun has been mapped, revealing a very extended and flared disc that most likely contains enough gas and dust to spawn planets. It appears as a precursor of debris discs such as the one around Vega-like stars and so provides the rare opportunity to witness the conditions prevailing prior to or during planet formation.

Planets form in massive, gaseous and dusty protoplanetary discs that surround nascent stars. This process must be rather ubiquitous given the many exoplanets already known. However, very little is known about these discs, especially those around stars more massive than the Sun. Such stars are much more luminous and could have a large influence on their disc, possibly quickly destroying the inner part.

Astronomers used the VISIR instrument on the VLT to map the disc surrounding the young star HD 97048 in the infrared. HD97048 has an age of a few million years – a blink of an eye compared to the age of the Sun (4.6 billion years) – and belongs to the Chameleon I dark cloud, a stellar nursery 600 lightyears away.

Sketch of a flared proto-planetary disc such as the one around the young star HD 97048.

The star is 40 times more luminous than our Sun and is 2.5 times as massive. The astronomers could only have achieved such a detailed view due to the high angular resolution offered by an 8-metre-size telescope in the infrared, reaching a resolution of 0.33 arcsecond. They discovered a very large disc, at least 12 times more extended than the or-bit of the farthest planet in the Solar System, Neptune. The observations suggest that the disc is flared, the first time such a structure, predicted by some theoretical models, has been imaged around a massive star.

Such geometry can only be explained if the disc contains a large amount of gas, in this case, at least as much as 10 times the mass of Jupiter. It should also contain more than 50 Earth masses in dust.

The dust mass derived here is more than thousand times larger than what is observed in debris discs and Kuiper-belt-like structures found around older, 'Vega-like' stars, such as Beta Pictoris, Vega, Fomalhaut and HR 4796, and which is thought to be produced by collisions of larger bodies.

The dust mass observed around HD 97048 is similar to the mass invoked for the (undetected) parent bodies in the more evolved systems. HD 97048's disc is thus most likely a precursor of debris discs observed around older stars.

From the structure of the disc, the astronomers gather that planetary embryos may be present in the inner part of the disc. Follow-up observations at higher angular resolution with the VLT interferometer (VLTI) should allow them to probe these regions.

Pierre-Olivier Lagage et al., Science, 28 September 2006.

A Substellar Jonah

Astronomers have discovered a rather unusual system, in which two planet-size stars, of different colours, orbit each other. One is a rather hot white dwarf, weighing a little bit less than half as much as the Sun. The other is a much cooler, 55 Jupiter-masses brown dwarf.

The low-mass companion to the white dwarf (named WD0137-349) was found using spectra taken with EMMI at the New Technology Telescope at La Silla. The astronomers then used the UVES spectrograph on the VLT to record 20 spectra and so measure the period and the mass ratio.

The two objects, separated by less than 2/3 of the radius of the Sun, or only a few thousandths of the distance between the Earth and the Sun, rotate around each other in about 2 hours. The brown dwarf moves on its orbit at the amazing speed of 800 000 km/h!

The two stars were not so close in their past. Only when the solar-like star that has now become a white dwarf was a red giant did the separation between the two objects diminish drastically. During this fleeting moment, the giant engulfed its companion. The latter, feeling a large drag similar to trying to swim in a bath full of oil, spiralled in towards the core of the giant. The envelope of the giant was finally ejected, leaving a binary system in which the companion is in a close orbit around a white dwarf.

The existence of the system proves that the brown dwarf came out almost unaltered from an episode in which it was swallowed by a red giant. Models show that had the companion been less than 20 Jupiter masses, it would have evaporated during this phase. The brown dwarf shouldn't rejoice too quickly to have escaped this doom, however. Einstein's General Theory of Relativity predicts that the separation between the two stars will slowly decrease. In about 1.4 billion years, the orbital period will have decreased to slightly more than one hour. At that stage, the two objects will be so close that the white dwarf will work as a giant 'vacuum cleaner', drawing gas off its companion, in a cosmic cannibal act.

Pierre Maxted et al., Nature, 3 August 2006.

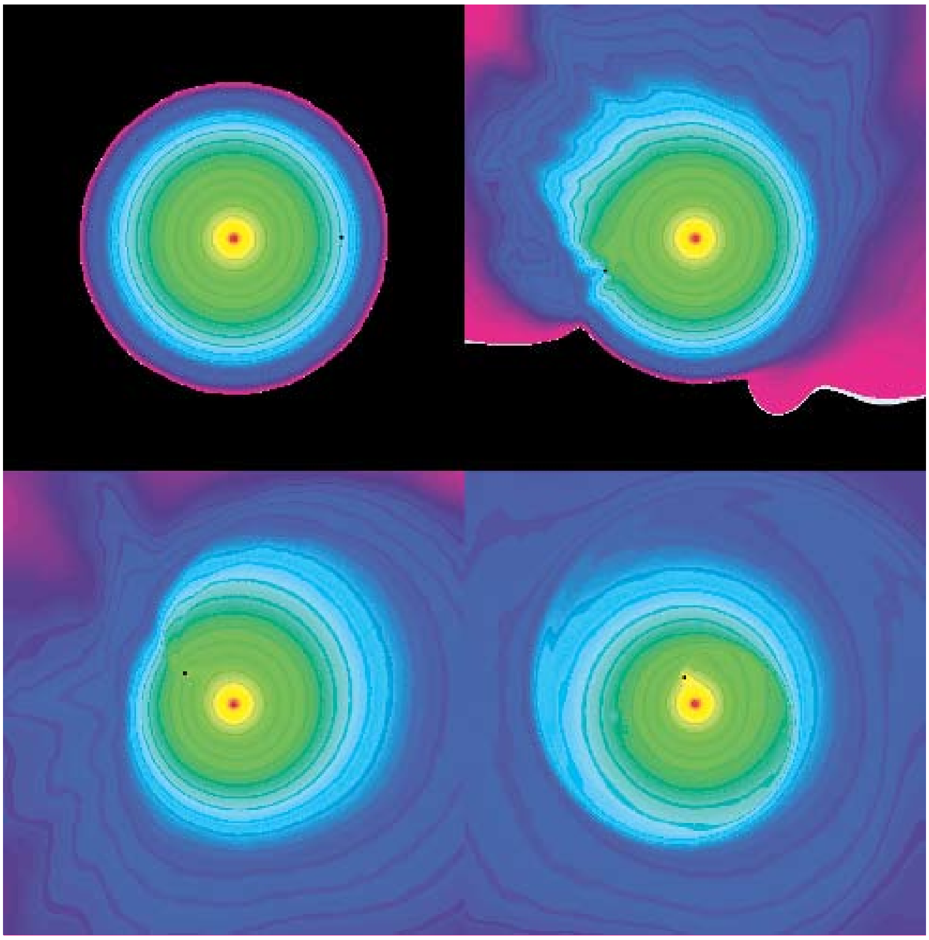


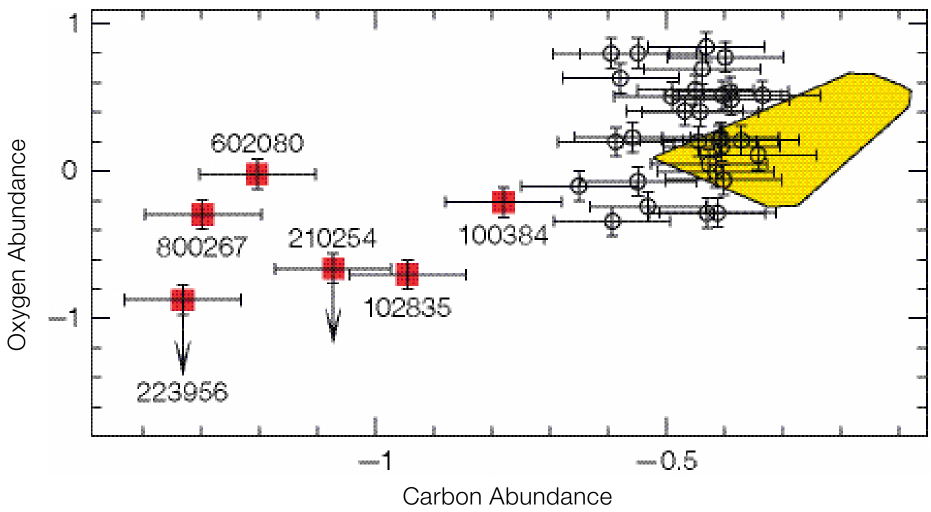
Image: Los Alamos National Laboratory

Numerical simulations of a brown dwarf being swallowed by a red giant.

Stellar Vampires Unmasked

Some hot, bright, and apparently young stars – known as 'blue stragglers' – in the globular cluster 47 Tucanae contain less carbon and oxygen than the majority of their sisters. This indicates that these few stars likely formed by taking their material from another star, acting as stellar vampires.

Blue stragglers are unexpectedly young-looking stars found in stellar aggregates, such as globular clusters, which are known to be made up of old stars. These enigmatic objects are thought to be created in either direct stellar collisions or through the evolution and coalescence of a binary star system in which one star 'sucks' material off the other, rejuvenating itself. As such, they provide interesting constraints on both binary stellar evolution and star-cluster dynamics. To date, the unambiguous signatures of either stellar traffic accidents or stellar vampirism have not been observed, and the formation mechanisms of blue stragglers are still a mystery.



Abundances in blue straggler stars.

The VLT was used to measure the abundance of chemical elements at the surface of 43 blue straggler stars in the globular cluster 47 Tucanae, an impressive globular cluster that has a total mass of about 1 million times the mass of the Sun and is 120 light years across. Measurements of so many faint stars are only possible since the advent of 8-m-class telescopes equipped with spectrographs which have multiplexing capability. In this case, the astronomers used the FLAMES/GIRAFFE instrument, that allows the simultaneous observation of up to 130 targets at a time, making it ideally suited for surveying individual stars in closely populated fields.

Six of these blue straggler stars were found to contain less carbon and oxygen than the majority of these peculiar objects. Such an anomaly indicates that the material at the surface of the blue stragglers comes from the deep interiors of a parent star. Such deep material can reach the surface of the blue straggler only during the mass transfer process occurring between two stars in a binary system. Numerical simulations indeed show that the coalescence of stars should not result in anomalous abundances.

In the core of a globular cluster, stars are packed extremely close to each other: more than 4 000 stars are found in the innermost lightyear-sized cube of 47 Tucanae. Thus, stellar collisions are thought to be very frequent and the collision channel for the formation of blue stragglers should be extremely efficient. The chemical signature detected by these observations demonstrates that the binary mass-transfer scenario is also fully active, even in a high-density cluster like 47 Tucanae.

This is the first detection of a chemical signature clearly pointing to a specific scenario to form blue straggler stars and therefore a fundamental step toward the solution of the long-standing mystery of blue-straggler formation in globular clusters.

Francesco R. Ferraro et al. 2006, Astrophys. Journal Lett., 647, L53.

Cepheids and their ‘Cocoons’

Combining data from the Very Large Telescope Interferometer (VLTI) and the CHARA Interferometer at Mount Wilson, California, astronomers have discovered envelopes around three Cepheids, including the Pole Star. This is the first time that matter has been found surrounding members of this important class of rare and very luminous stars whose luminosity varies in a very regular way.

Cepheids are commonly used as distance indicators, thanks to the existence of a basic relation between their intrinsic brightness and their pulsation period. By measuring the period of a Cepheid star, its intrinsic brightness can be deduced, and from the observed apparent brightness the distance may then be calculated. As they are intrinsically very bright stars, and can be observed in distant galaxies, this remarkable property has turned these yellow supergiant stars into primary ‘standard candles’ for extragalactic distance estimations. Cepheids thus play a crucial role in cosmology, being one of the first ‘steps’ on the cosmic distance ladder.

The southern Cepheid L Carinae was observed with the VINCI and MIDI instrument at the VLTI, while Polaris (the Pole Star) and Delta Cephei were scrutinised with FLUOR on CHARA, located on the other side of the equator. FLUOR is the prototype instrument of VINCI, both being built by the Paris Observatory (France). L Carinae is the brightest Cepheid in the sky, and also the one that presents the largest apparent angular diameter. It is a massive supergiant star, having about 10 times the mass of the Sun and approximately 180 times its radius. Polaris is a peculiar star located very close to the north celestial pole (hence its name). It is classified as a Cepheid, but it shows very weak pulsations compared to the other stars of its class. Delta Cephei is the prototype of the Cepheids. It was discovered to be a variable star in the 18th century by the English amateur John Goodricke, and it is still one of the brightest members of the Cepheid class. Its short period is characteristic of a relatively small supergiant, with a radius of ‘only’ 43 times that of the Sun.

Although such stars are thus rather large, they are so far away that they cannot be resolved by single telescopes. Indeed, even the largest Cepheids in the sky subtend an angle of only 0.003 arc second. To resolve this would be similar to viewing a two-storey house on the Moon.

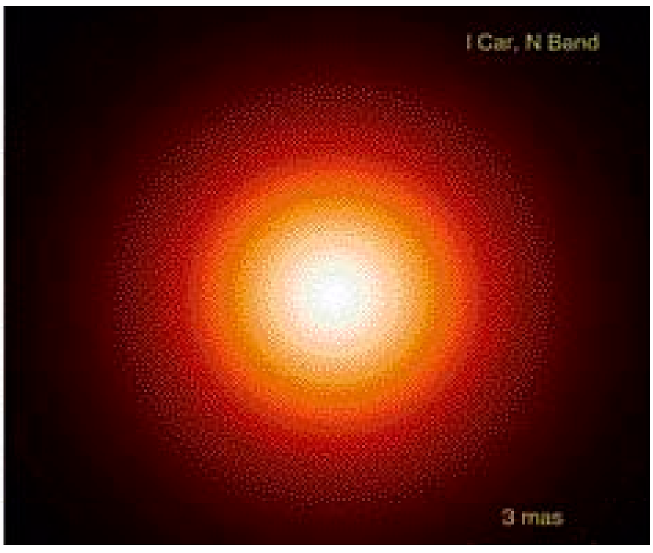
Astronomers therefore have to rely on the interferometric technique, which combines the light of two or more distant telescopes, providing the angular resolution of a single telescope as large as the separation between them. With the VLTI, it is possible to achieve a resolution of 0.001 arcsecond or less.

For most stars, the observations made with interferometers follow the theoretical stellar models very closely. However, for these three stars a tiny deviation was detected, revealing the presence of an envelope. The envelopes were found to be 2 to 3 times as large as the star itself.

The fact that such deviations were found for all three stars, which have very different properties, seems to imply that envelopes surrounding Cepheids are a widespread phenomenon. The physical processes that have created these envelopes are still uncertain, but, in analogy to what happens around other classes of stars, it is most probable that the environments were created by matter ejected by the star itself. Cepheids pulsate with periods of a few days. As a consequence, the star goes regularly through large-amplitude oscillations that create very rapid motions of its apparent surface (the photosphere) with velocities up to 30 km/s, or 108 000 km/h! While this remains to be established, there could be a link between the pulsation, the mass loss and the formation of the envelopes.

P. Kervella et al. 2006, Astronomy and Astrophysics, 448, 623.
Antoine Mérand et al. 2006, Astronomy and Astrophysics, 453, 155.

Model image of the Cepheid L Carinae.



To Be or Not to Be: Is It All About Spinning?

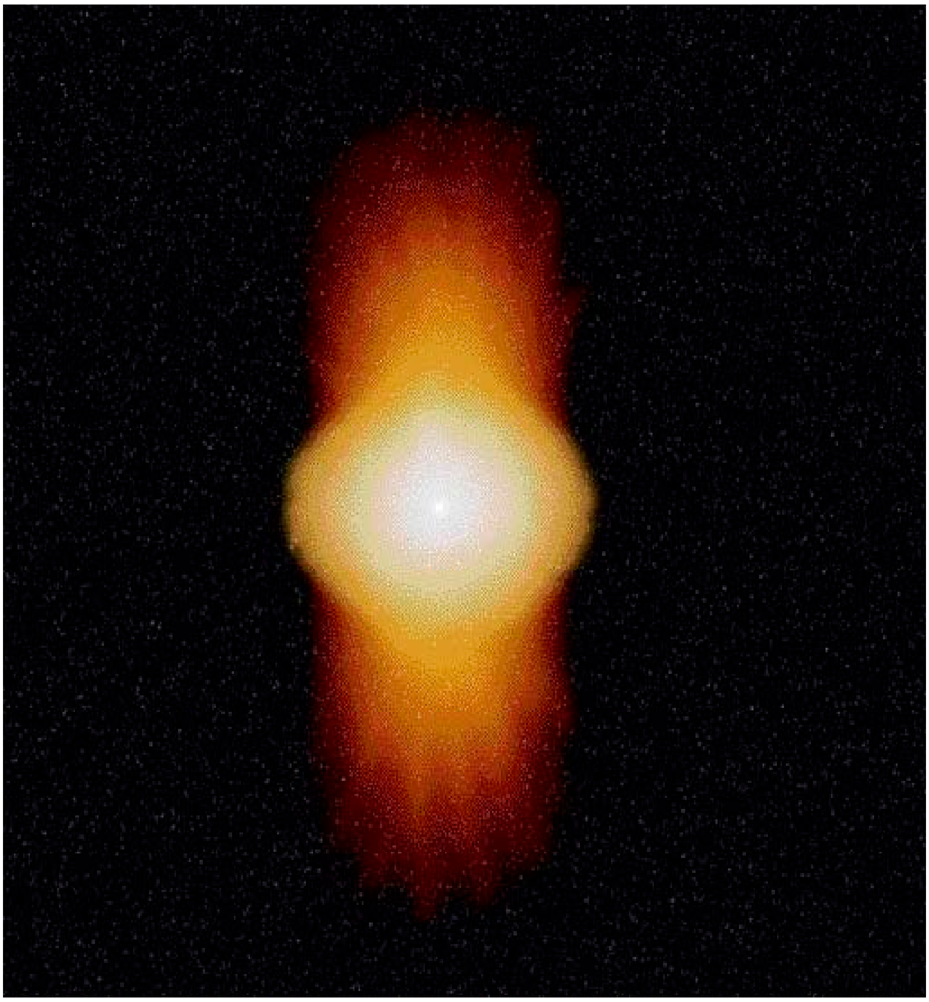
A study of the active hot star Alpha Arae solves a 140-year-old mystery.

Lying about 300 light years away from the Sun, Alpha Arae is the closest member of the class of active stars known as ‘Be stars’. Be stars are very luminous, massive and hot stars that rotate rapidly. They are losing mass along the poles through a strong stellar wind and are surrounded at the equator by a disc of matter. Alpha Arae has ten times the mass of the Sun, is three times hotter and 6 000 times as luminous.

With AMBER on the VLTI, the team of astronomers were able to examine the structure of the disc surrounding Alpha Arae in detail. Moreover, because AMBER also provides spectra, the astronomers could study the motion of the gas in the disc and so understand how it rotates. The disc surrounding Alpha Arae was found to be in ‘Keplerian rotation’, that is, obeying the same rules as discovered by Johannes Kepler for the planets circling the Sun: the velocity of the material decreases with the square root of the distance from the star. The new result rules out the possibility of the disc rotating with a uniform velocity, as would be the case if a strong magnetic field were present which forced the matter to spin at the same rate as the star.

Combining the new data with previous studies, the astronomers also show that the star Alpha Arae rotates 50 times faster than our Sun. In fact, with a speed at the equator of 470 km/s, it is spinning so quickly that it is near its break-up velocity. Matter having such a critical velocity would be able to freely escape from the star, in the same way that we would be ejected from a merry-go-round that has gone out of control. This could be the clue to the ‘Be phenomenon’.

A. Meilland et al., 2007, Astronomy and Astrophysics, 464, 549.



Artist’s rendering of the Be star Alpha Arae.

Asymmetric Ashes

Astronomers are reporting remarkable new findings that shed light on a decade-long debate about one type of the supernova explosions that mark a star's final demise: does the star die in a slow burn or with a fast bang? From their observations, the scientists find that the matter ejected by the explosion shows significant peripheral asymmetry but a nearly spherical interior, most likely implying that the explosion finally propagates at supersonic speed.

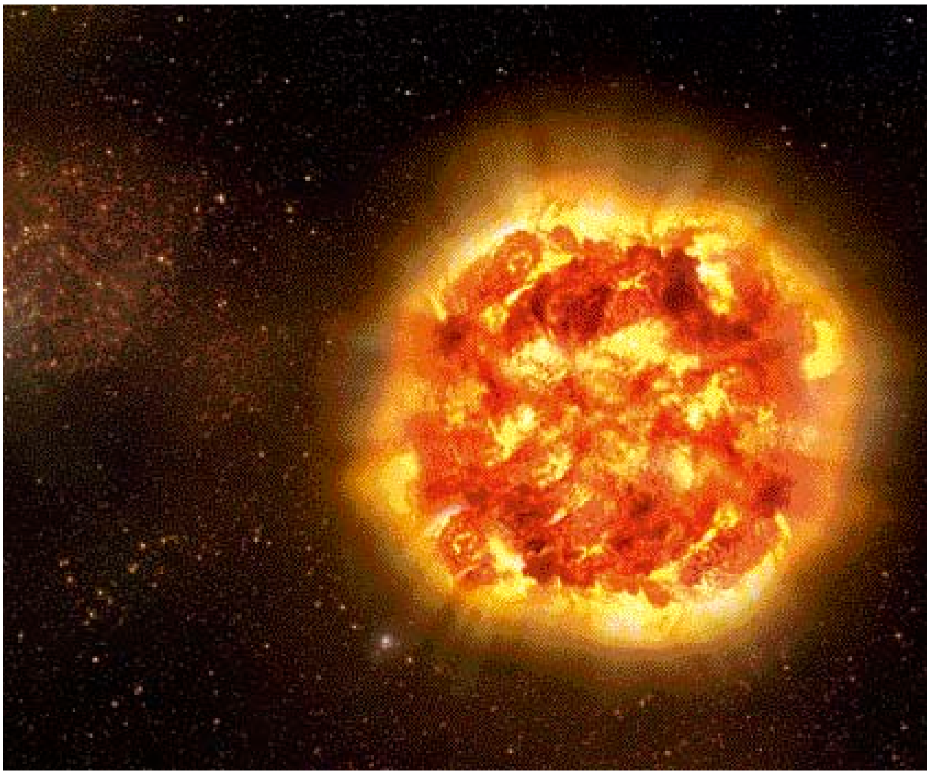
Using observations of 17 supernovae made over more than 10 years with the VLT for one part and the McDonald Observatory's Otto Struve Telescope for another, astronomers inferred the shape and structure of the debris cloud thrown out from Type Ia supernovae. Such supernovae are thought to be the result of the explosion of a small and dense star – a white dwarf – inside a binary system. As its companion continuously spills matter onto the white dwarf, the white dwarf reaches a critical mass, leading to a fatal instability and the supernova. But what sparks the initial explosion, and how the blast travels through the star have long been thorny issues.

The supernovae that were observed occurred in distant galaxies, and because of the vast cosmic distances could not be studied in detail using conventional imaging techniques, including interferometry. Instead, the team of researchers determined the shape of the exploding cocoons by recording the polarisation of the light from the dying stars.

Polarimetry relies on the fact that light is composed of electromagnetic waves that oscillate in certain directions. Reflection or scattering of light favours certain orientations of the electric and magnetic fields over others. This is why polarising sunglasses can filter out the glint of sunlight reflected off a pond. When light scatters through the expanding debris of a supernova, it retains information about the orientation of the scattering layers. If the supernova is spherically symmetric, all orientations will be present equally and will average out, so there will be no net polarisation. If, however, the gas shell is not round, a slight net polarisation will be imprinted on the light.

This is what broadband polarimetry can accomplish. If additional spectral information is available ('spectropolarimetry'), one can determine whether the asymmetry is in the continuum light or in some spectral lines. In the case of the Type Ia supernovae, the astronomers found that the continuum polarisation is very small, implying that the overall shape of the explosion is crudely spherical. But the much larger polarisation in strongly blue-shifted spectral lines shows the presence, in the outer regions, of fast-moving clumps with peculiar chemical composition.

Artist's impression of a clumpy SN Ia explosion.



The study reveals that explosions of Type Ia supernovae are truly three-dimensional phenomena. The outer regions of the blast cloud are asymmetric, with different materials found in 'clumps', while the inner regions are smooth.

The research team first spotted this asymmetry in 2003, as part of the same observational campaign. The new, more extensive results show that the degree of polarisation, and hence the asphericity, correlates with the intrinsic brightness of the explosion. The brighter the supernova, the smoother, or less clumpy, it is.

This has some impact on the use of Type Ia supernovae as standard candles. This kind of supernovae is used to measure the rate of acceleration of the expansion of the Universe, assuming these objects behave in a uniform way. But asymmetries can introduce dispersions in the quantities observed.

The discovery also puts strong constraints on any successful models of thermonuclear supernova explosions. Models have suggested that the clumpiness is caused by a slow-burn process, called 'deflagration', and leaves an irregular trail of ashes. The smoothness of the inner regions of the exploding star implies that at a given stage, the deflagration gives way to a more violent process, a 'detonation', which travels at supersonic speeds – so fast that it erases all the asymmetries in the ashes left behind by the slower burning of the first stage, resulting in a smoother, more homogeneous residue.

Lifan Wang, Dietrich Baade and Ferdinando Patat, Science Express, 30 November 2006.

How to Steal a Million Stars?

In another bout of stellar vampirism, but on a grand scale, astronomers found that the stellar cluster Messier 12 must have lost close to one million low-mass stars to the rest of the Milky Way galaxy.

The astronomers measured the brightness and colours of more than 16 000 stars within the globular cluster Messier 12 with the FORS1 multimode instrument attached to one of the Unit Telescopes of ESO's VLT at Cerro Paranal (Chile). The astronomers could study stars that are 40 million times fainter than what the unaided eye can see.

Messier 12 is one of about 200 globular clusters known in our Galaxy. These are large groupings of from 10 000 to more than a million stars that were formed together in the youth of the Milky Way, about 12 to 13 billion years ago. Globular clusters are a key tool for astronomers, because all the stars in a globular cluster share a common history. They were all born together, at the same time and place, and only differ from one another in their mass. By accurately measuring the brightness of the stars, astronomers can determine their relative sizes and stage of evolution precisely. Globular clusters are thus very helpful for testing theories of how stars evolve.

The Central Part of Messier 12.

Located at a distance of 23 000 light years in the constellation Ophiuchus (The Serpent-holder), Messier 12 got its name by being the 12th entry in the catalogue of nebulous objects compiled in 1774 by French astronomer and comet chaser Charles Messier. It is also known to astronomers as NGC 6218 and contains about 200 000 stars, most of them having a mass between 20 and 80 per cent of the mass of the Sun.

It is however clear that Messier 12 is surprisingly devoid of low-mass stars. For each solar-like star, we would expect roughly four times as many stars with half that mass. The VLT observations only show an equal number of stars of different masses.

In the solar neighbourhood and in most stellar clusters, the least massive stars are by far the most common. The new observations show this is not the case for Messier 12.

Globular clusters move in extended elliptical orbits that periodically take them through the densely populated plane of our Galaxy, then high above and below, in the 'halo'. When venturing too close to the innermost and denser 'bulge' of the Milky Way a globular cluster can be perturbed, with the smallest stars being ripped away.

The astronomers estimate that Messier 12 lost four times as many stars as it still has. That is, roughly one million stars must have been ejected into the halo of our Milky Way.

The total remaining lifetime of Messier 12 is predicted to be about 4.5 billion years, i.e. about a third of its present age. This is very short compared to the typical expected globular cluster's lifetime, which is about 20 billion years.

The scientists now hope to discover and study many more clusters like this, since catching clusters while they are being disrupted should clarify the dynamics of the process that shaped the halo of our home galaxy, the Milky Way.

Guido de Marchi, Luigi Pulone, and Francesco Paresce, 2006, Astronomy and Astrophysics, 449, 161.

A 'Genetic Study' of the Galaxy

Looking in detail at the composition of stars with the VLT, astronomers are providing a fresh look at the history of the Milky Way. They reveal that the central part of our Galaxy formed not only very quickly but also independently of the rest.

For the first time, it has been possible to clearly establish a 'genetic difference' between stars in the disc and the bulge of our Galaxy. From this one can infer that the bulge must have formed more rapidly than the disc, probably in less than a billion years and when the Universe was still very young.

The Milky Way is a spiral galaxy, having a pinwheel shape with arms of gas, dust, and stars lying in a flattened disc, and extending directly out from a spherical nucleus of stars in the central region, the bulge. While the disc of our Galaxy is made up of stars of all ages, the bulge contains old stars dating from the time the galaxy formed, more than 10 billion years ago. Thus, studying the bulge allows astronomers to know more about how our Galaxy formed.

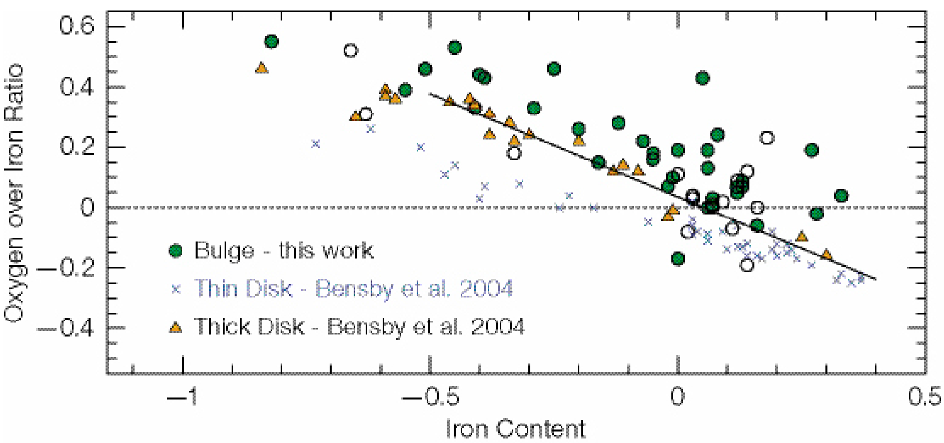
To do this, an international team of astronomers analysed in detail the chemical composition of 50 giant stars in four different areas of the sky towards the Galactic bulge. They made use of the FLAMES/UVES spectrograph on the VLT to obtain high-resolution spectra.

The chemical composition of stars carries the signature of the enrichment processes undergone by the interstellar matter up to the moment of their formation.
It depends on the previous history of star formation and can thus be used to infer whether there is a 'genetic link' between different stellar groups. In particular, comparison between the abundance of oxygen and iron in stars is very illustrative. Oxygen is predominantly produced in the explosion of massive, short-lived stars (so-called Type II supernovae), while iron instead originates mostly in Type Ia supernovae, which can take much longer to develop. Comparing oxygen with iron abundances therefore gives insight into the star-birth rate in the Milky Way's past.

The larger size and iron-content coverage of the new sample allowed the astronomers to draw much more robust conclusions than were possible until then.
They clearly established that, for a given iron content, stars in the bulge possess more oxygen than their disc counterparts. This highlights a systematic, hereditary difference between bulge and disc stars.

In other words, bulge stars did not originate in the disc and then migrate inward to build up the bulge but rather formed independently of the disc. Moreover, the chemical enrichment of the bulge, and hence its formation timescale, was faster than that of the disc. Comparisons with theoretical models indicate that the Galactic bulge must have formed in less than a billion years, most likely through a series of starbursts when the Universe was still very young.

Manuela Zoccali et al. 2006, Astronomy and Astrophysics, 457, L1.



The Oxygen abundance in the bulge of our Galaxy.

Cut from Different Cloth

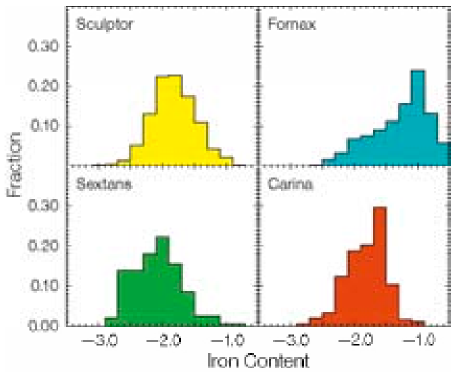
A large survey has shed light on our Galaxy's ancestry. After determining the chemical composition of over 2 000 stars in four of the nearest dwarf galaxies to our own, astronomers have demonstrated fundamental differences in their make-up, casting doubt on the theory that these diminutive galaxies could ever have formed the building blocks of our Milky Way Galaxy.

Our Milky Way Galaxy is surrounded by a number of dwarf satellite galaxies, which because of their loosely rounded shape are referred to as 'dwarf spheroidal' galaxies. Faint and diffuse, these dwarf galaxies are a thousand times fainter than the Milky Way itself, making them the least luminous galaxies known.

Modern cosmological models predict that small galaxies form first, and later assemble into larger systems like our Galaxy. Since the Universe initially only contained hydrogen and helium (most of all other chemical elements being synthesized inside stars), dwarf galaxies should have the lowest heavy element content. Not so, reveal the observations.

As part of a large observational programme, called the Dwarf galaxies Abundances and Radial-velocities Team (DART), astronomers from institutes in 9 different countries used FLAMES on the VLT to measure the amount of iron in over 2000 individual giant stars in the Fornax, Sculptor, Sextans and Carina dwarf spheroidals.

Their data unearthed fundamental differences in the dwarf galaxy stars' chemical composition compared with those in our galactic halo, calling into question the merger theory as the origin of large galaxies' haloes. Whilst the average abundances of elements in the dwarf spheroidals is comparable with that seen



Chemical abundance in several dwarf galaxies.

in the Galactic halo, the former are lacking the very metal-poor stars that are seen in the Milky Way – the two types of systems, contrary to theoretical predictions, are essentially of different descent.

Amina Helmi et al. 2006, Astrophysical Journal Letters, 651, L121-L124.

The Topsy-Turvy Galaxy

This FORS image of the central parts of NGC 1313 shows a stunning natural beauty. The galaxy bears some resemblance to some of the Milky Way's closest neighbours, the Magellanic Clouds. NGC 1313 has a barred spiral shape, with the arms emanating outwards in a loose twist from the ends of the bar. The galaxy lies just 15 million light years away from the Milky Way – a mere skip on cosmological scales. The spiral arms are a hotbed of star-forming activity, with numerous young clusters of hot stars being born continuously at a staggering rate out of the dense clouds of gas and dust. Their light blasts through the surrounding gas, creating an intricately beautiful pattern of light and dark nebulosity.

NGC 1313's appearance suggests it has seen troubled times: its spiral arms look lop-sided and gas globules are spread out widely around them. Moreover, observations with ESO's 3.6-m telescope at La Silla have revealed that its 'real' centre, around which it rotates, does not coincide with the central bar. Its rotation is therefore also out of kilter. Strangely enough, NGC 1313 seems to be an isolated galaxy. It is not part of a group and has no neighbour, and it is not clear whether it may have swallowed a small companion in its past. So what caused its asymmetry and stellar baby boom?

The Topsy-Turvy Galaxy NGC 1313.

Long-lasting but Dim Brethren of Cosmic Flashes

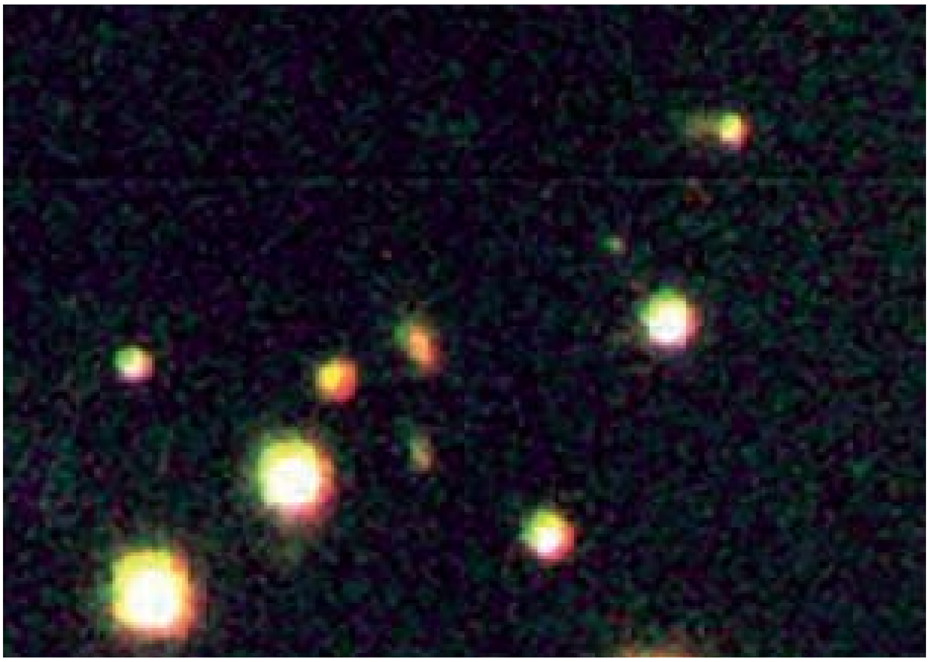
For the first time, it has been possible to make the link between an X-ray flash and a supernova. Such flashes are the little siblings of gamma-ray bursts (GRB) and this discovery suggests the existence of a population of events less luminous than 'classical' GRBs, but possibly much more numerous. This also implies a common origin for these two classes of events.

The event began on 18 February 2006: the NASA/PPARC/ASI Swift satellite detected an unusual gamma-ray burst, about 25 times closer and 100 times longer than the typical gamma-ray burst. GRBs release in a few seconds more energy than that of the Sun during its entire lifetime of more than 10 000 million years. The GRBs are thus the most powerful events known in the Universe since the Big Bang.

The explosion, called GRB 060218 after the date it was discovered, originated in a star-forming galaxy about 440 million light years away toward the constellation Aries. This is the second-closest gamma-ray burst ever detected. Moreover, the burst of gamma rays lasted for nearly 2 000 seconds; most bursts last a few milliseconds to tens of seconds. The explosion was surprisingly dim, however.

Using several telescopes, among them the VLT, the scientists watched the afterglow of this burst grow brighter in optical light. This brightening, along with other telltale spectral characteristics in the light, strongly suggests that a supernova was unfolding. Within days, the supernova became apparent.

The observations with the VLT started on 21 February 2006, just three days after the discovery. Spectroscopy was then performed nearly daily for seventeen days, providing the astronomers with a large data set to document this new class of events.



The field around SN2006aj.

The astronomers could finally confirm that the event was tied to a supernova called SN 2006aj which was observed a few days later. The newly discovered supernova is dimmer by about a factor of two than the hypernovae associated with normal long gamma-ray bursts, but it is still a factor of 2-3 times more luminous than regular core-collapse supernovae. All together, these facts point to a substantial diversity between supernovae associated with GRBs and supernovae associated with X-ray flashes. This diversity may be related to the masses of the exploding stars.

Whereas gamma-ray bursts probably mark the birth of a black hole, X-ray flashes appear to signal the type of star explosion that leaves behind a neutron star. Based on the VLT data, another team of astronomers postulate that the 18 February event might have led to a highly magnetic type of neutron star called a magnetar.

They find indeed that the star that exploded had an initial mass of 'only' 20 times the mass of the Sun. This is smaller, by about a factor of two at least, than those estimated for the typical GRB-supernovae.

The properties of GRB 060218 suggest the existence of a population of events less luminous than 'classical' GRBs, but possibly much more numerous. Indeed, these events may be the most abundant form of X- or gamma-ray bursts in the Universe, but instrumental limits allow us to detect them only locally. The astronomers find that the number of such events could be about 100 times more numerous than typical gamma-ray bursts.

Elena Pian et al., Nature, 31 August 2006.
Paolo Mazzali et al., Nature, 31 August 2006.

Faraway Galaxy Under the Microscope

Some large-disc galaxies akin to our Milky Way have formed on a rapid timescale, only 3 billion years after the Big Bang, reveals a study made with the new SINFONI spectrograph on VLT.

Over the past decade astronomers have established an overall model of how galaxies formed and evolved when the Universe was only a few billion years old. Gas made of ordinary matter cooled and collected in concentrations of the mysterious 'dark' matter (so-called dark-matter halos). Since that time, and up to the present epoch, collisions and mergers of galaxies subsequently led to the hierarchical build-up of galaxy mass. This general picture leaves open, however, on what timescales galaxies were assembled and when and how bulges and discs, the primary components of present-day galaxies, were formed.

A major study of distant, luminous star-forming galaxies at the VLT, the 'SINS' (Spectroscopic Imaging survey in the Near-infrared with SINFONI) survey, has now resulted in a major breakthrough on these questions. This study exploited SINFONI, a novel infrared 'integral-field spectrometer' that simultaneously delivers sharp images, with adaptive optics, and highly resolved spectra of an object on the sky.

In one case, studying the galaxy BzK155043 at cosmological redshift of 2.4, the SINFONI observations achieved an angular resolution of 0.15 arcsecond, a mere 4 000 light years at the distance of this high-redshift galaxy. With this superior angular resolution the data reveal the physical and dynamical properties in unprecedented detail. Surprisingly, instead of showing mostly irregular and perhaps even chaotic motions caused by the frequent merger activity in the young Universe, the observations reveal a large and massive rotating protodisc that is channelling gas toward a growing central stellar bulge. The high gas surface densities, the large star-formation rate and the moderately young stellar ages derived from these observations suggest that the system was assembled rapidly, by fragmentation and star formation in an initially very gas rich protodisc. SINS observations of several other massive, high-redshift galaxies give similar results.

The fact that these galaxies are so large and rotate rapidly indicates that the gas has a similar amount of rotation as the dark matter halo from which it cooled, thus empirically solving an important question of galaxy formation.

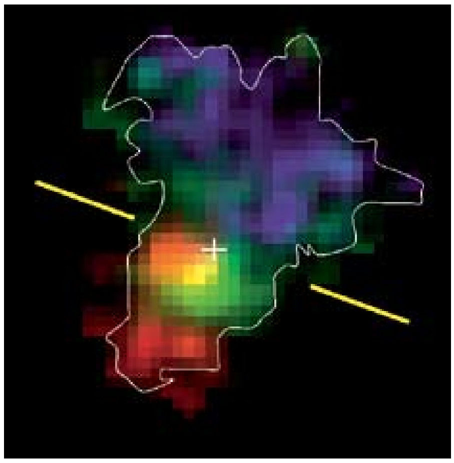
The SINFONI data suggest that the proto-discs may have eventually been transformed to dense elliptical galaxies, either by internal processes, such as the spectacular gas inflows observed in BzK-15504, or by collisions and mergers with other galaxies, which were frequent in the dense environments in which the high-redshift luminous star-forming galaxies appear to reside.

Another important aspect of the work is the deduction of very high star-formation rates for many of the luminous star-forming high-redshift galaxies, about one hundred times greater than in the present-day Milky Way.

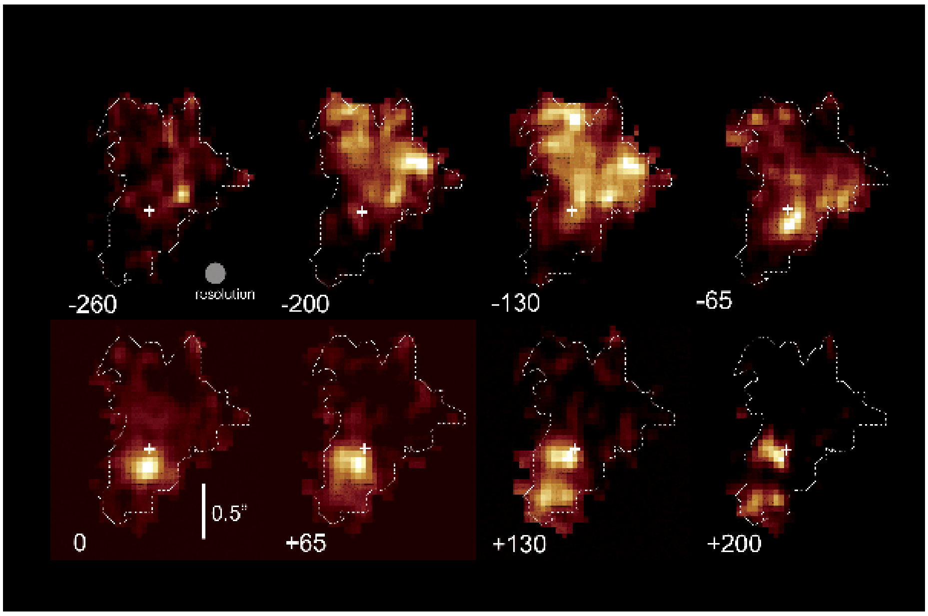
Astronomers have a growing body of evidence that massive galaxies formed much more rapidly in the redshift range 2-3 than originally anticipated. The new SINFONI data give us a first glimpse of what processes might be involved.

In fact, the SINS programme on the VLT is a stunning demonstration of what is going to be possible in the next few years with the combination of integral-field spec-troscopy and adaptive optics.

N.M. Förster Schreiber et al. 2006, Astrophys. Journal 645, 1062.
R. Genzel et al., Nature, 17 August 2006.
X. Kong et al. 2006, Astrophys.J. 638, 72.



Emission of the galaxy BzK-15504.



SINFONI maps of emission in BzK-15504.

The Invisible Galaxies That Could Not Hide

Astronomers have found a metal-rich hydrogen cloud in the distant universe. The result may help to solve the missing metal problem and provides insight on how galaxies form. This discovery shows that significant quantities of metals are to be found in very remote galaxies that are too faint to be directly seen.

Metal shouldn't however be taken too literally as, for astronomers, metals are all chemical elements heavier than helium. The Sun, for example, is made mostly of hydrogen (73%) and helium (25%), and 2% of 'metals'.

Almost all of the elements present in the Universe were formed in stars, which themselves are members of galaxies. By estimating how many stars formed over the history of the Universe, it is possible to estimate how much of the metals should have been produced. However, this apparently straightforward reasoning has been confronted for several years with an apparent contradiction: adding up the amount of metals observable today in distant astronomical objects falls short of the predicted value. When the contribution of galaxies now observed at cosmological distances is added to that of the intergalactic medium, the total amounts for no more than a tenth of the metals expected.

Studying distant galaxies is however a difficult task. The further a galaxy, the fainter it is, and the smallest or intrinsically faintest ones will not be observed. This may introduce severe biases in the observations as only the largest and most active galaxies are picked up.

Astronomers therefore came up with other ways to study distant galaxies: they use quasars, most probably the brightest distant objects known, as beacons in the Universe.

Interstellar clouds of gas in galaxies, located between the quasars and us on the same line of sight, absorb parts of the light emitted by the quasars. The resulting spectrum consequently presents dark 'valleys' that can be attributed to well-known elements. Thus, astronomers can measure the amount of metals present in these galaxies – that are otherwise invisible – at various epochs.

This can best be done by high-resolution spectrographs on the largest telescopes, such as UVES on the VLT.

Astronomers thus studied, with the UVES spectrograph on the VLT, the light emitted by the quasar SDSS J1323-0021. Located 9 billion light years away, its light is partially absorbed by an otherwise invisible galaxy sitting 6.3 billion light years away along the line of sight.

The analysis of the spectrum shows that this galaxy has four times more metals than the Sun. This is the first time one finds such a large amount of 'metals' in a very distant object, giving encouragement to astronomers. If a large number of such 'invisible' galaxies with high metal content were to be discovered, they might well alleviate the missing metals problem considerably.

C. Péroux et al., 2006, Astronomy and Astrophysics, 450, 53.

Falling Onto the Dark

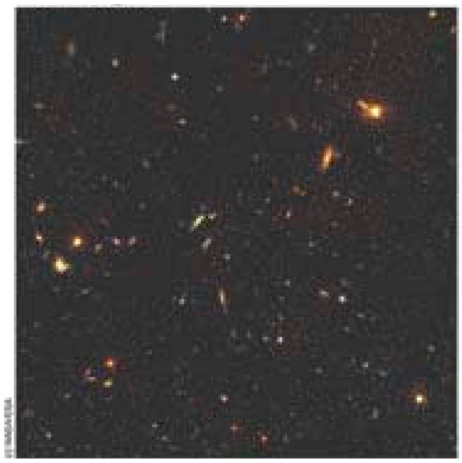
Using the FORS1 instrument on the VLT, an international team of astronomers have discovered a new 'blob' located at a distance of 11.6 billion light years (redshift 3.16). It is thus seen as it was when the Universe was only 2 billion years old, or less than 15% its present age. The newly discovered object is located in the well-studied GOODS South field.

With a diameter of 200 000 light years, the blob is twice as big as our Milky Way and the total energy emitted is equivalent to that of about 2 billion suns. Despite this, the object is invisible in images taken with various telescopes observing from the infrared to the X-ray wavebands, making it a very peculiar object indeed. This is because the object emits most of its light in the Lyman-alpha hydrogen line, while its continuum emission is too low to be detected. It is also the only such object found by the astronomers in their survey.

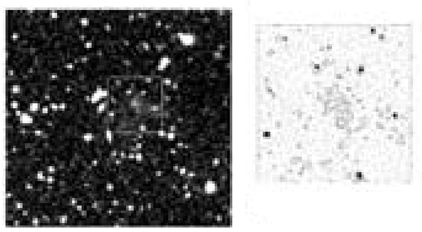
Trying to explain this blob by invoking a powerful galaxy as the cause for the object to emit so much radiation proved impossible. The astronomers are instead led to the conclusion that the observed hydrogen emission comes from primordial gas falling onto a clump of dark matter. They could thus be literally seeing the building up of a massive galaxy, like our own, the Milky Way.

K.K. Nilsson et al. 2006, Astronomy and Astrophysics, 452, 23.

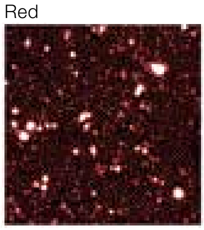
HST Image



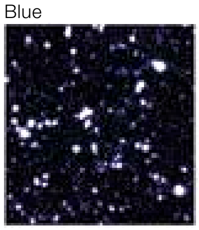
Narrow-band



Red



Blue



A Rare Blob.

A 1.8-m Auxiliary Telescope at Paranal.

Venus and the Moon setting over Paranal.

La Silla Paranal Observatory

In 2006 the La Silla Paranal Observatory has been routinely operating a total of 10 telescopes with 19 optical, near-infrared and mid-infrared instruments. On Paranal these are nine VLT instruments at the four 8.2-m Unit Telescopes (UTs). There are also two instruments at the VLT Interferometer (VLTI), which coherently combine the light of the UTs or the 1.8-m Auxiliary Telescopes (ATs). On La Silla, a total of eight instruments are operated on the 3.5-m NTT, the 3.6-m, and the MPG/ESO 2.2-m telescopes.

The observatory has also supported the operation of the Atacama Pathfinder Experiment (APEX). The 12-m APEX antenna is located on the high plateau of Chajnantor at an altitude of 5100 m. APEX and its two workhorse instruments, APEX2a and FLASH, have been operated from the base camp in the village of Sequitor near San Pedro de Atacama. During this first year of regular operation about 210 nights of mostly Service Mode observations were carried out at APEX with an average observing time of 13 hours per night.

In 2006 more than 630 peer-reviewed articles and papers were published in scientific journals in which the authors have made use of astronomical data collected with telescopes and instruments available at the three sites of the La Silla Paranal Observatory. This number translates into an impressive publication rate of nearly two refereed papers for every day of the year. APEX alone in its very first year of routine operations has produced the respectable number of 21 publications – all contained in a special edition of the *Astronomy & Astrophysics* journal.

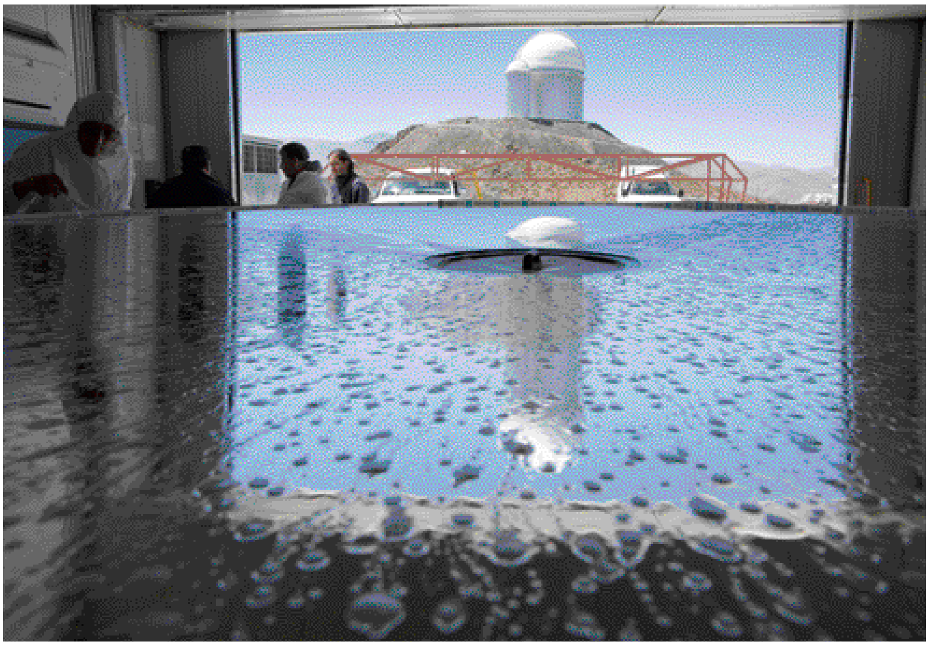
One of the important ingredients for such a high productivity of the observatory is the high availability of its telescopes and instruments to carry out scientific observations. In this respect the observatory had another excellent year, with a total of 2410 nights scheduled for scientific observations with the four UTs at the VLT and with the three major telescopes at La Silla. In addition, the VLTI was operated for about 140 nights, executing scientific observations with its MIDI and AMBER instruments. This total number of nights scheduled for scientific observations is equivalent to about 90% of the theoretically available total time.

The remaining 10% were scheduled for planned engineering and maintenance activities to guarantee the continuous performance of the telescopes and instruments. Technical time further includes the time slots required to commission the new instruments and facilities, which keep arriving in particular on Paranal for the VLT.

Of the available science time on Paranal, only 2.3% was lost due to technical problems and about 6% due to bad weather. On La Silla bad weather accounted for a loss of about 11%, and technical problems for 5.4%. This comparatively high figure for the technical downtime in La Silla was solely due to a major problem of the aged dome rotation system of the 3.6-m telescope, which required extended periods of corrective maintenance during which no operation of the telescope was possible. Otherwise, the downtime figure would have been reduced to an excellent 2.6%.

One of the great technical achievements of the year has been the first-ever recoating of a secondary mirror (M2) of the VLT with a few-nanometre-thick layer of fresh aluminium (Al). The M2 of the VLT is a lightweight 1.2-m hyperbolic mirror, made of beryllium in order to minimise its mass to allow precise and fast tilt motions ('field stabilisation') and chopping with frequencies of up to several hertz. The optical surface of the M2 is protected by a thin layer of nickel (Ni) onto which the reflective layer of Al is superimposed. The challenges are first to develop and define the M2 recoating procedure, then to actually remove the old Al layer without affecting the Ni layer, and finally to recoat the surface with fresh Al. The engineering department mastered these challenges for the M2 of Antu (UT1), in May 2006. Recoating of the secondary mirrors of the UTs has now become part of the regular maintenance of the VLT to ensure the optimal long-term performance of the telescope optics. The scheduled recoating of the primary and tertiary mirrors of Kueyen (UT2) and Yepun (UT4) were also successfully performed.

Cleaning a mirror at La Silla.



New Instruments and Facilities

With the installation and commissioning of the CRIRES instrument on the Nasmyth A focus of Antu (UT1) a major milestone of the VLT programme was reached this year: the completion of the first generation of VLT instruments. CRIRES is a cryogenic high-resolution infrared échelle spectrograph, that provides a resolving power of up to 10^5 in the spectral range from 1 to 5 μm when used with a narrow slit of 0.2 arcseconds. After its successful commissioning in 2006, CRIRES was offered for the first time to the astronomical community for Period 79, which starts in April 2007.

The sixth ESO standard adaptive optics system, Multi-Applications Curvature Adaptive Optics (MACAO), was deployed on Paranal to feed the narrow CRIRES slit, and to optimise the achievable signal-to-noise ratio and spatial resolution. Four MACAO systems were already installed in the Coudé feeds to VLTI, and a similar system has been installed in the Cassegrain focus of UT4 feeding the SINFONI instrument.

Maximum concentration during the CRIRES Commissioning.

The Laser Guide Star Facility (LGSF) achieved its 'First Light' in early 2006 and created the first artificial star in the Paranal sky. The LGSF provides the adaptive optics (AO) systems of instruments like SINFONI and NACO with bright reference stars in regions of the sky where sufficiently bright natural stars cannot be found close enough to the scientific targets for the AO system to perform. The path from having seen the first artificial laser star to regular operations turned out to be longer and harder than expected after the initial success. Several modifications and improvements of the LGSF were required over the course of the year until the facility was successfully commissioned by the end of the year. The very first observations with SINFONI and NACO in the new LGS mode immediately gave a taste of the exciting new possibilities this facility will provide to the observatory in early 2007 when the LGSF will be fully commissioned together with the AO instruments.

The VLT welcomed its second Visitor Instrument, DAZLE (Dark Age 'Z' Lyman-alpha Explorer). DAZLE is an innovative narrowband imaging instrument, specifically developed by the Institute of Astronomy (Cambridge, UK) and the Anglo-Australian Observatory for use on the Visitor focus of UT3 (Melipal) in order to detect the most distant objects in the Universe. Nine nights of data were taken with the VLT and first results from this ambitious search project are eagerly expected.

On La Silla the mid-infrared instrument TIMMI2 was decommissioned after the corresponding mid-infrared instrument VISIR at the VLT had begun full operation.

A new telescope has joined the suite of gamma-ray burst (GRB) hunters on La Silla: the very fast moving and robotic TAROT-S telescope has been installed by a consortium led by *Observatoire de Haute-Provence* to follow-up GRBs within seconds of their detection by dedicated satellites in the Earth's orbit. The new telescope delivered first results on newly-detected GRBs only a few days after its installation.

The 2.2-m telescope on La Silla was prepared over the year to receive the GRB follow-up instrument GROND, which is being built by the *Max-Planck-Institut für Extraterrestrische Physik* and will be commissioned in early 2007.

GRBs also triggered several fast follow-up observations with the VLT using the novel Rapid-Response Mode (RRM), which allows authorised VLT users to interrupt ongoing observations and to point the UTs to a transient target of interest. On 7 June 2006, the Rapid-Response Mode triggered UVES observations of the quickly fading afterglow of a distant gamma-ray source. Integrations with the high-resolution spectrograph started a mere 7.5 minutes after the detection of the GRB by the SWIFT satellite – to date, still a record for the spectroscopic follow-up of any GRB.

APEX is expecting its final suite of facility instruments, including new heterodyne receivers from the Onsala Space Observatory to cover all atmospheric windows from 200 to 1000 GHz, and the Large

APEX Bolometer Camera (LABOCA) developed by the *Max-Planck-Institut für Radioastronomie*. LABOCA, a detector array with 295 pixels operating at a wavelength of 870 µm, has been extensively tested during the year at Chajnantor. We expect regular science operation for all new instruments to start in 2007.

In addition to these workhorse instruments, several experimental receivers covering selected windows above 1 THz are under development. This frequency regime has so far been considered to be only accessible from space. However, the exceptional site of Chajnantor at an altitude of 5100 m, and the excellent quality of the APEX antenna, will allow us soon to explore the sky at the shortest radio wavelengths from the ground.

The VLT Interferometer

In 2006 the VLT Interferometer (VLTI) executed about 140 nights of scientific observations with MIDI and AMBER using both UT and AT baselines. The other nights were used for intensive engineering and commissioning activities to complete and improve the interferometer infrastructure and to fully exploit the capabilities of the VLTI Sub-Array (VISA). The VISA feeds the VLTI infrastructure and instruments with the light from the 1.8-m Auxiliary Telescopes (AT) when the individual UTs are used for stand-alone VLT observations. By the end of 2006, VISA was completed with the arrival of the fourth AT and has become integral part of the VLTI science operation. Because it is now possible to choose between any six baselines and switch from one to another during the same night, AT4 provides the VLTI operations with ad-ditional flexibility in the selection of different and complementary AT baselines without having to physically reconfigure the array of telescopes. This capability, in combination with AMBER phase-closure on three telescopes, is an important step toward imaging with the VLTI.

The AMBER instrument allows the interferometric combination of up to three beams, and could be offered to the community for the first time with three ATs starting in Period 79 after first fringes were obtained on 23 August 2006. The VLTI infrastructure was prepared accordingly and the three delay lines numbered 4, 5 and 6 were equipped with Variable Curvature Mirrors (VCM) to control the longitudinal position of the pupil of the individual interferometric beams. The delay lines themselves were put under an intensive preventive maintenance plan in order to keep them literally in the best possible shape.

These were all necessary steps towards the VLTI team's ambitious goal of offering AMBER on three ATs with FINITO fringe-tracking for the call for proposals for Period 80, and to eventually bring AMBER close to the expected sensitivities in its different spectroscopic modes. A major milestone in this direction was reached when, for the first time, FINITO fringe-tracking with AMBER and three ATs was achieved on 1 December 2006 on the bright star [illegible] Ceti.

The investigation and improvement of the stability of the interferometric beams, and in particular of the vibration-induced variations in the optical path differences (OPD) of the interferometric beams delivered by the 8.2-m UTs, continued in parallel to the implementation of new VLTI observing modes with the VISA and the ATs.

Working on APEX.

Beam instabilities and vibrations of the UTs transmitted to the VLTI were identified as the primary reasons that prevented fringe-tracking with the UTs in the past. While the beam stability was recently improved dramatically through the introduction of fast beam control with the VLTI Infrared Image Sensor IRIS, the elimination of vibrations or their compensation remained the primary goal of the VLTI team during 2006. Active suppression of the OPD variations as introduced by the vibrating optical surfaces of the Unit Telescopes was achieved through a novel Vibration Tracking (VTK) system. The performance of this vibration-suppression system was further enhanced by the installation of accelerometers close to the vibrating optical surfaces of the UTs.

User Support

The User Support Department (USD) of the ESO Data Management and Operations Division, based in Garching, represents the primary link between the ESO community and the Observatory and its operation groups. It provides support primarily to Service Mode users of ESO facilities and to the operations teams of the La Silla Paranal Observatory. In 2006, Service Mode continued to be the most requested observing mode at the VLT (a factor of 2.5 higher than the time requested for Visitor Mode during Period 77 and 78). This clearly shows that the community has recognised the advantages of this observing mode for many different types of projects. Period 77 also marked the beginning of Service Mode observing at the APEX facility, the ESO Project Scientist of which is a member of the User Support Department. A total of 1054 Service Mode runs were supported by USD at the VLT, VLTI, and MPG/ESO 2.2-m telescope during 2006, which includes all runs approved during Period 77 and 78, including those that were granted telescope time via the Director's Discretionary Time channel.

Data Processing and Quality Control

Ensuring that data taken on Paranal are of certified and predictable quality, and continuously monitoring the 'health' of the instruments, are cornerstone concepts in the ESO end-to-end data flow model. The DFO Quality Control (QC) group is responsible primarily for the monitoring and reporting of basic instrument performance for all VLT/VLTI instruments as well as the creation of various calibration and science data products for these instruments. Raw calibration data are processed into master calibration products that are used not only to monitor instrument performance but also to process science data. These master calibration products are stored in the ESO archive and are available to the scientific community at large.

For Service Mode users, the QC group provides two additional services. First, Service Mode science data are processed into science products using standard pipelines which, by now, cover virtually 100 % of the Paranal data stream. Second, QC creates data packages that include all raw data, resultant products, and associated information for each and every Service Mode observing run. These packages are burned onto DVDs and shipped to users by the DFO SAO group.

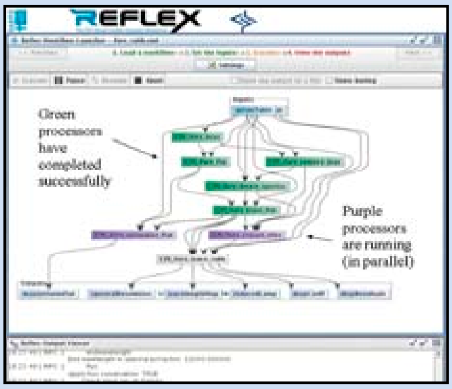
During 2006 QC processed 5 TB of raw data in 156 500 processing jobs to create 1 014 service mode packages – an increase of 13 % compared to 2005 – which were distributed to their respective Principal Investigators on 2 100 DVDs. The quality control processing of the expected 150 TB/year of VISTA/VIRCAM data will certainly be challenging. New concepts and tools were developed and tested in 2006 both to cope with the computing challenges posed by the high data rate itself and to efficiently monitor the quality of a large number of images.

The Data Flow System

The Data Flow System Department is responsible for the design, the implementation and the maintenance of the Data Flow System software components, that are critical for the end-to-end operation of the VLT, VLTI, VST, VISTA and some of the La Silla telescopes.

The Data Flow System consists of two kinds of modules or tools. Some of them (e.g. P2PP) are generic and provide a uniform interface to all instruments, while others, e.g. pipelines, are instrument specific. The department delivers its tools to a variety of customers: the astronomical community (e.g. P2PP, Exposure Time Calculators, Archive Interface), VISAS and OPC, User Support Department (P2PP, Observing Tool), and Science Operations and Data Flow Operation (Instrument Pipelines, data packing tools). The Data Flow System Department is also responsible for the installation and the commissioning of its software modules on-site.

The front-end and back-end teams continued to concentrate their efforts on the design and implementation of software components required to support survey facilities. This includes an upgrade of the Observation Preparation Tools to introduce new scheduling concepts such as groups and links of Observation Blocks. The development of the User Portal, which will provide the user community with one registration system for all services provided by the Observatory, is progressing well. The pipeline team released three instrument pipelines to the community: the ISAAC, VISIR and GIRAFFE packages, based on the Common Pipeline Library. At the same time, the CRIRES pipeline was verified and validated during the commissioning phases of the instrument. The pipeline team developed an innovative algorithm based on pattern-matching for the wavelength calibration of spectroscopic data. This algorithm was implemented in the new FORS pipeline, which is now fully operational and will become publicly available in the first quarter of 2007. During 2006 the SAMPO work has focused on addressing the requirements within the ESO community for more flexible access to the ESO reduction pipeline recipes. Following a review of the available options an open source graphical workflow system (Taverna) was selected and extensively extended to interface to ESO software components. This workflow system has been named ESO Reflex (ESO Recipe Flexible Execution Workbench). The FORS spectroscopy and AMBER recipes have been integrated in a beta-test version of Reflex.



The Reflex scientific workflow allows users to run instrument recipes as a sequence of reduction steps while inspecting intermediate products and calling external applications.

The accelerometers enable the feeding of direct measurements of the actual vibration signals to the VTK system. Through this effort the original residual OPD variations of 480 nm were reduced by the end of the year to 230 nm. The VLTI team is confident that, with a robust implementation of these new vibration-suppression techniques and further elimination of the major vibration sources, fringe-tracking with three UTs and AMBER can be delivered to science operations by the end of 2007 – just in time for the observatory to receive PRIMA, the next VLTI facility, which is expected to further push the sensitivity of the VLTI and provide relative astrometric measurements of the highest precision.

VST and VISTA Survey Telescopes

The construction, integration and testing of the 2.4-m optical VLT Survey Telescope (VST) and its subsystems continued in Naples during 2006 by the *Osservatorio di Capodimonte*. The disassembly of the main telescope structure started in collaboration with ESO at the end of the year, to prepare for the shipment to Paranal where the reintegration of the telescope is planned during the second half of 2007.

The primary mirror cell and the secondary mirror unit, however, remain in Naples for their completion. The VST secondary mirror optics were completed and shipped to Paranal early this year while the 2.4-m primary mirror remained at the manufacturer's premises for its completion.

The 4.2-m infrared survey telescope VISTA is currently under construction by the VISTA project office on its own peak about 1500 m from the Paranal summit.

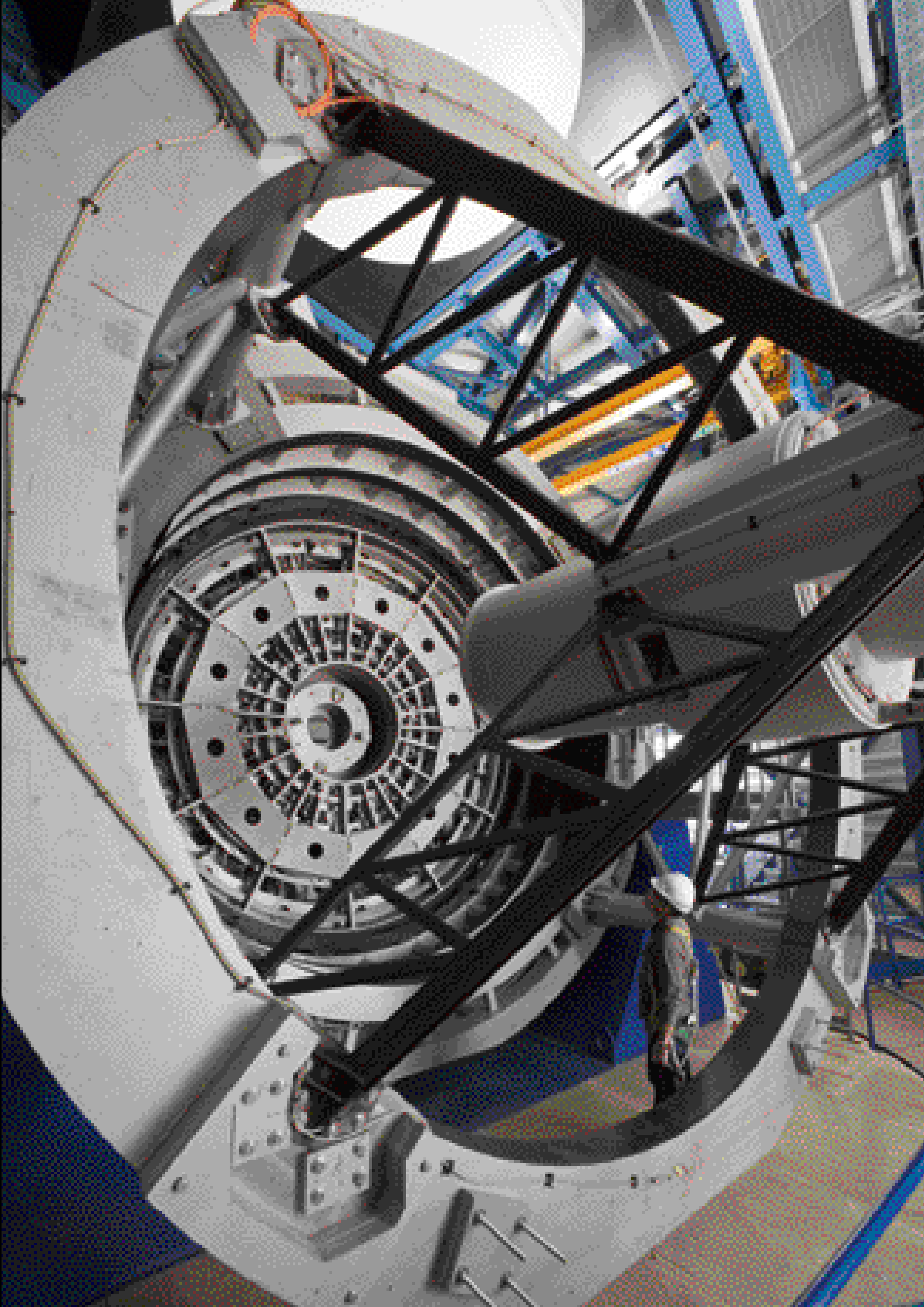
The enclosure was essentially completed and accepted before the telescope structure arrived on 11 May 2006. Since then, the telescope assembly progressed rapidly and the VISTA telescope had entered a phase of intensive testing and tuning by the end of the year. At the same time, the VISTA facility was integrated into the power and computer networks of the Paranal site to prepare for its future operation. VISTA – as all telescopes on Paranal – will eventually be operated from the same common control room as the VLT and the VLTI.

A dedicated coating unit arrived in September and was successfully commissioned in the following months. The VISTA coating unit is the only facility on Paranal that allows the coating of mirror surfaces with a layer of silver (instead of aluminium as used for the VLT mirrors) to provide highest reflectivity of the optical surfaces in the near-infrared wavelengths where VISTA is going to survey the sky.

The VISTA telescope is now awaiting the arrival of its optics and its instrument. The primary and secondary mirrors are still in the phase of final polishing in Europe, and are now only expected to arrive on Paranal in the second quarter of 2007. Commissioning of the telescope and the formal handover to ESO are planned to take place in the second half of 2007. In December, the IR Camera that was developed at the Rutherford Appleton Laboratory in the UK was also shipped to Paranal for arrival in mid-January 2007.

VISTA enclosure.

The VISTA telescope.



Llano de Chajnantor

Atacama Large Millimeter/submillimeter Array

The Atacama Large Millimeter/submillimeter Array (ALMA) is a very sensitive, high-resolution aperture-synthesis array telescope, which will work at millimetre and submillimetre wavelengths. It is an international facility, constructed and operated as a partnership between Europe (through ESO), North America (through the National Radio Astronomy Observatory, NRAO) and Japan (through the National Astronomical Observatory of Japan, NAOJ), in cooperation with the Republic of Chile.

The initial plan was to install and operate 64 antennas of 12 metres diameter, but detailed design studies and prototype research showed that this project could not be realised with the funds foreseen by the agreement between the North American and European partners. During 2005, in-depth studies were made to redefine the ALMA baseline project with acceptable cost, while still maintaining the prime scientific objectives. By the middle of 2006, the North American partners received approval from their Funding Agency (the US National Science Foundation, NSF) for the rebaselined ALMA project, which had already been approved by ESO Council towards the end of 2005.

In parallel, Japanese scientists, through the NAOJ, continued to define their participation in the ALMA project. The European and North American partners in ALMA spent a considerable amount of time with their Japanese partners in identifying the Japanese participation and reviewed various subsystems, in particular the correlator, receivers and antennas. Details of the partnerships were defined and a trilateral agreement between ESO, the NSF, and the National Institute for Natural Sciences (NINS, Japan) was signed in summer 2006. In addition to the equipment that NAOJ will provide for the bilateral ALMA configuration of 50 antennas, NAOJ will provide four antennas of 12 metre diameter, twelve antennas of 7 metre diameter, and two receiver bands for all 66 antennas of ALMA. Approval of funds required for the Japanese participation in ALMA is expected by spring 2007. With the inclusion of the Japanese partners, ALMA becomes a truly global astronomy facility, involving scientists from four different continents.

Construction Work

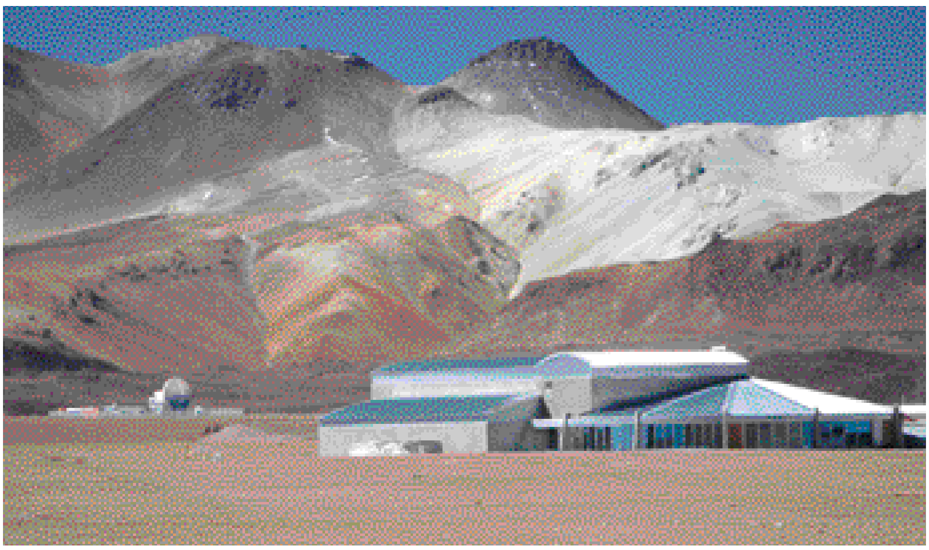
The ALMA Array Operations Site (AOS) will be located at a truly unique and unusual place: the Altiplano de Chajnantor, a plateau at an altitude of 5 000 metres above sea level, in the Atacama Desert in Chile. This location was selected for scientific reasons, particularly dryness and altitude. Considering these aspects, the ALMA Observatory will not only be unique because of its ambitious scientific goals and the unprecedented technical requirements. It will also be unique because of the harsh environment and living conditions in which the array has to operate with high efficiency and accuracy.

A second site, the ALMA Operations Support Facilities (OSF), will be the base camp for the day-to-day operation of the observatory. It is located at an altitude of about 2 900 metres, quite high compared to standard living conditions, but still acceptable for scientific projects in astronomy of similar scope. However, the OSF will not only serve as the location for operating the ALMA Observatory: it will also be the site for Assembly, Integration and Verification (AIV) of all the high-technology equipment before this is moved to the Array Operations Site.

Both the AOS and OSF are remote locations. The 2 900-metre OSF site is about 15 kilometres away from the closest public road, the Chilean highway No. 23. The AOS is another 28 kilometres away from the OSF site. Thus, one of the first ALMA projects was to construct an access road not only to the OSF but also to the AOS. This road, 43 kilometres long and at high altitude, with sufficient width for the regular transport of many large radio telescopes with diameters of 12 metres, was completed in the course of 2006.

The OSF is in many ways the centre of activities of the ALMA project, and will remain so in the future. The focus there will, however, change as ALMA moves through the different phases of construction and operations.

Presently, the OSF site is the area where all ALMA Site contractors and their staff are accommodated – the base camp for work on the OSF and AOS infrastructure. Local contractors' staff live there and start their work either at the OSF, the road construction (between the Chilean Highway No. 23 and the AOS) or at the AOS itself. Work is organised in 20 days working/10 days rest periods. Special facilities for board and lodging have had to be organised for such a large activity. Camps have been erected and by now can accommodate the maximum required capacity of 500 workers.



The AOS Technical Building.

Construction of the OSF Technical Buildings.

The construction of the multi-purpose OSF, intended to serve over the lifetime of the observatory, is a challenging task. It requires taking into account many aspects of the functionality of these facilities over a period of 30 years. During the years 2005 and 2006 the Technical Specifications and Statements of Work for the OSF construction were defined, refined and adapted to the requirements and resources of ALMA. ESO signed a very important contract for the construction of the OSF Technical Facilities in August 2006. Construction work has started, and during the first five months of this unique endeavour no major problems or delays occurred. As specified in the construction schedule, foundations have been prepared and the erection of the first walls started in November 2006. Provisional Acceptance of all facilities is foreseen for the first quarter of 2008. The construction of the AOS Technical Building, a project to be delivered by the North American partner in ALMA, started in October 2005 and the outer shell was completed by mid-2006. After this date installation of the interior infrastructure started.

Antennas

The four antennas of 12 metre diameter to be provided by Japan have been ordered from Mitsubishi Electrical Company by NAOJ. The twelve remaining antennas of 7 metre diameter will be ordered during the year 2007.

The Preliminary Production Design Review for antennas to be produced by Vertex SRL was held in September 2006. The corresponding review for the AEM antennas contracted by ESO is scheduled for the end of January 2007.

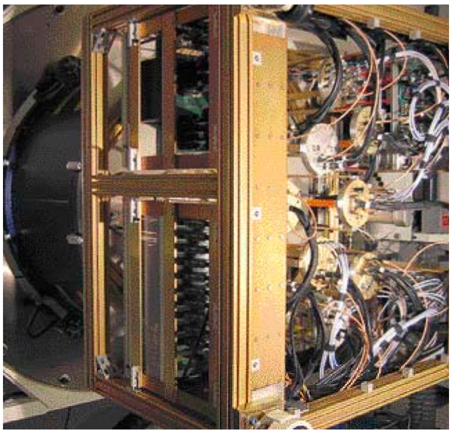
The design of the antenna transporter vehicle has progressed well. Some delays, due to long delivery time for materials, have arisen. The first transporter is expected to be delivered to the OSF in October 2007, about three months later than originally foreseen.

Front End

The ALMA Front End system is the first element in a complex chain of signal reception, conversion, processing and recording. The Front End is designed to receive signals in ten different frequency bands. In the initial phase of operation the antennas will be equipped with six bands. These are Bands 3, 4, 6, 7, 8 and 9. ESO is in charge of providing Bands 7 and 9. It is planned to equip the antennas with the missing bands at a later stage of ALMA operation.

The ALMA Front Ends are superior to almost all existing systems. Indeed, development work for the ALMA prototypes has also led to improved receivers for existing millimetre and submillimetre observatories.

The Front End units are comprised of numerous elements, produced at different locations in Europe, North America and East Asia. In the initial phase of construction after the prototyping and developing stage, it was decided to build a set of eight pre-production units before moving to mass production. This initial phase started in the years 2002 and 2003. The pre-production phase has advanced well and 2006 was an especially important year, because it marked the start of the transition from this pre-production to the final series production phase.



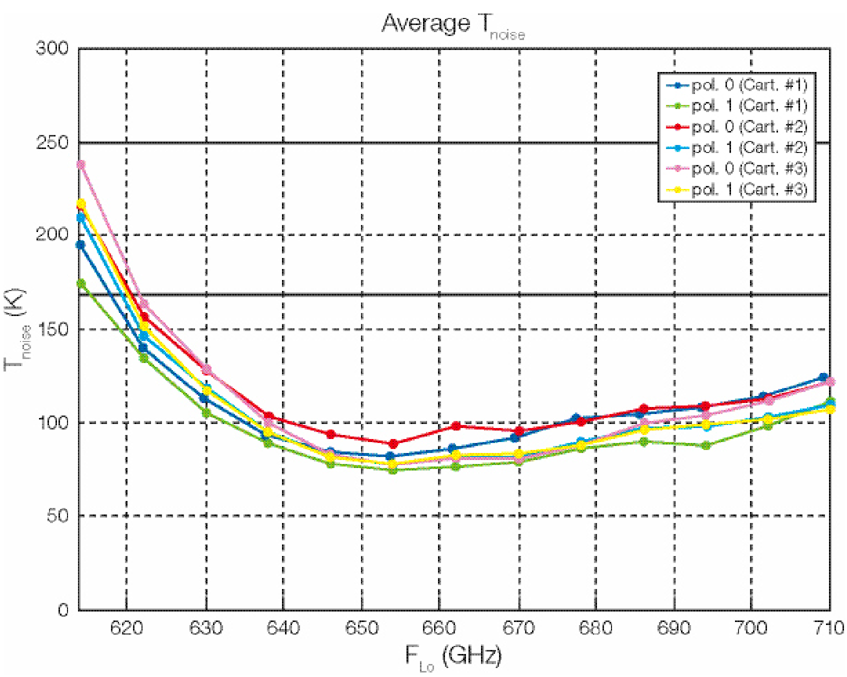
ALMA FE No. 1 rear view (chassis covers removed) with receiver cartridges for Bands 3, 6, 7 and 9 installed.

In 2006, the European groups made essential contributions to the integration of the first ALMA front end. In early 2006, the Band 7 Cartridge delivered by IRAM (Grenoble, France) was the first of all the cartridges to be accepted by the North American Front End Integration Centre (NAFEIC), which is based at NRAO (Charlottesville, Virginia, USA). The first Band 9 Cartridge, manufactured by NOVA (Groningen, the Netherlands), was successfully delivered and accepted by the NAFEIC at the end of 2006.

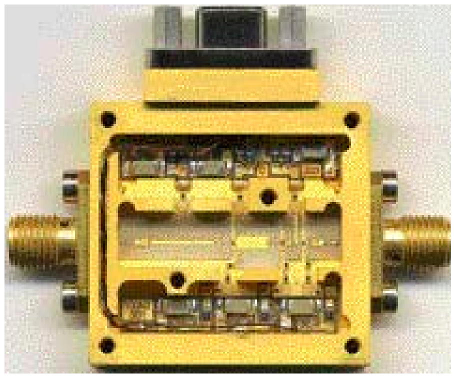
In 2003, ESO and the Rutherford Appleton Laboratory (RAL, UK) launched a development and pre-production programme for the manufacture of eight operational cryostats. By the end of 2006, six cryostats had been fully assembled. The remaining two units are in manufacture and will be completed in early 2007.

With the end of the pre-production phase of these cryostats in sight, efforts were made to prepare the final series production phase. This resulted in the approval by ESO Finance Committee at its November 2006 meeting of a proposal to place a contract for 45 production units to cover the needs of the ALMA Baseline.

With the ongoing production of ALMA receiver cartridges, more insight was also obtained into the repeatability of their performance. Collecting this information was one of the main goals of the pre-production phase, and is essential for increasing the accuracy of the series production schedule. The graph below shows the receiver noise performance for three Band 9 Cartridges, each having two independent polarisation channels. Besides the exceptionally good noise performance for reach of the cartridges – well within the specified project requirements – the repeatability is very good.



Receiver noise performance for three Band 9 Cartridge (pre-production) units.



Pre-production 4-8 GHz cryogenic low-noise amplifier.

In the framework of an EC FP6 programme, ESO is leading a group of European institutes to develop and build six Band-5 receiver cartridges and to develop associated software. This project, "Enhancement of ALMA Early Science", was approved by the European Commission at the end of 2005 and actual work started in January 2006. The Band 5 receiver design is being developed by the Onsala Space Observatory (OSO, Sweden). By the end of 2006, most of the receiver design concept had been finalised.

Discussions have been initiated between ESO, OSO, and RAL to provide the local oscillator as needed in this Band 5 receiver. An initial plan for this activity has been provided by RAL and it is planned to include them as a participant in the FP6 programme.

The pre-production phase of the cryogenic low-noise amplifiers used in the IF of the Band 7, 4-8 GHz bandwidth, and Band 9, 4-12 GHz bandwidth receivers has been successfully completed by *Centro Astronómico de Yebes* (CAY, Spain). Amplifier production for the Band 7 cartridges (198 units) by industry will commence in early 2007. A proposal was received and approved by the ESO Finance Committee at its meeting in November 2006.

Production of the more complex 4-12 GHz cryogenic amplifiers will remain at CAY. It is planned to start this series production phase in early 2007.

Water Vapour Radiometers (WVRs) operating at 183 GHz are essential for ALMA to improve the fidelity of high-resolution radio maps when using baselines longer than 300 metres. These radiometers provide a correction of the signal phase due to atmospheric water vapour fluctuations. The development of two prototype WVRs, a joint undertaking by the University of Cambridge and OSO, has been completed and they are undergoing intensive tests at the Submillimeter Array (SMA) on Mauna Kea (Hawaii). This field test of the WVRs has shown that it is feasible to do this correction of the atmospheric phase fluctuations with the necessary accuracy. The performance of both prototypes meets the requirements, and a simpler, more cost-effective, single-channel Dicke switched radiometer design has been adopted as the baseline for production. By the end of 2006 a Call for Tender had been prepared for the final detailed design phase and production phase of 53 units. This Call will be issued to industry in early 2007.

Back End

The ALMA Back End systems deliver signals generated by Front End units installed in each antenna to the central Correlator at the AOS Technical Building. At any time, 8 GHz of signal bandwidth in each of two orthogonal linear polarisations can be processed and recorded. Analogue data, produced by the Front End electronics, are processed and digitised before entering first the data encoder, and then the optical transmitter units and multiplexers. All these elements are installed in the receiver cabins of each antenna. Optical signals are then transmitted by fibres to the AOS Technical Building. The total distance in the most extended antenna configuration is about 15 kilometres. At the AOS Technical Building the incoming optical signals are de-multiplexed and de-formatted before entering the Correlator.

Pre-production ALMA cryostat lined up for delivery at the Rutherford Appleton Laboratory.

The European deliverables in the ALMA Back End project are various components, which are produced by several European institutes, working closely with ESO and NRAO. These deliverables are:

- digitiser chip production
- digitiser chip assembly,
- digitiser clock and assembly,
- optical data transmission system design,
- fibre patch panel,
- optical multiplexers (MUX), amplifiers (EDFA), and de-multiplexers (De-MUX), and
- photonic local oscillator photomixers.

Development and pre-production of these components has either been successfully completed or is so far advanced that completion will happen in the first few months of 2007. The components will be integrated at the Back End Integration Center at Socorro (New Mexico) and installed in the European and North American prototype antennas for tests at the ALMA Test Facility.

Correlator

The ALMA Correlator, to be installed in the AOS Technical Building, is the last component in the receiving end of the data transmission. It takes as input the digitised signals from the individual antennas, and outputs amplitude and phase on all of the interferometer baselines in each of a large number of spectral channels. It is a very large data-processing system, composed of four quadrants, each of which can process data coming from up to 16 different antennas. The complete correlator will have 2 912 printed circuit boards, 5 200 interface cables, and more than 20 million solder joints. The first quadrant was completed at NRAO in the third quarter of 2006. Work on the second quadrant is progressing on schedule. Integral parts of the Correlator are Tunable Filter Bank (TFB) cards, which allow a major increase in the flexibility by subdividing the frequency range into 32 independently configurable sub-channels. The layout is such that four TFB cards are needed for the data coming from a single antenna. The TFB cards have been developed and optimised by the University of Bordeaux over the last few years. Prototypes and pre-production units have been extensively tested and their performance was critically reviewed in the first half of 2006. In the meantime, series production has started and the first batch of 36 cards has been produced.

Software Development

The ALMA software is planned from the beginning as an end-to-end software system, which goes from proposal preparation to data reduction, including all the necessary control software for antennas and correlator. The computing work in Europe is organised through ESO. Many developments are done directly by ESO; others are done in collaboration with European institutes in Spain, France, Italy, Germany and the United Kingdom.

In 2006, the ALMA software was tested end-to-end in different observing modes, starting from proposals consisting of Scheduling Blocks up to reducing data obtained with the ALMA prototype antennas at the ALMA Test Facility (ATF) located at the site o the Very Large Array (VLA) in Socorro. ESO and its associated institutes not only provided their software for this, but also actively participated in the testing campaigns.

The next goal is to perform interferometry tests with the two prototype antennas at the ATF, while preparing to support integration and tests of the first European ALMA antenna to be delivered to Chile in the second part of 2007.

System Engineering (SE)

Substantial progress was achieved on project-wide requirements and Interface Control Document (ICD) completion, which are now 93% and 80% completed, respectively. The ALMA system requirement version B was released, and is now consistent with the refined science requirements document and much more complete. Progress was also made on the Front End and Back End requirements and these will be formally released at the beginning of 2007. The requirements database DOORS was updated and enhanced, and more requirements were added.

The 3-dimensional models of the AEM and Vertex Antenna receiver cabins with their interiors have been developed and documented. The Antenna cabling designs for these antennas were done and released. Support was given to all Integrated Project Teams (IPTs) for their technical activities, e.g. for the ridges procurement and for the design and manufacturing of the ridges alignment tool. The mechanical tolerance budget was refined. Master Frequency Standard specification was prepared and the procurement process was initiated. ALMA system block diagrams have been updated, refined and distributed. The sensitivity budget was further refined and used for system design trade-offs and analysis tasks.

System Engineering participated in several review meetings, such as maser laser review, and organised and chaired the Antenna Transporter PDR, Band 7 Cartridge CDR, 1st Local Oscillator CDR, System Requirement review, Vertex antenna Pre-production review (PPDR), and the ACA correlator CDR.

The ALMA optical analysis led by SE started. The goal is to perform a detailed analysis of the antenna optical performance including polarisation, sidelobe patterns, and subreflector scattering cone under load conditions to predict antenna performance and the science case of polarisation mosaicing.

A new ALMA Product Assurance (PA) manager was hired in mid-2006. His main task was to organise PA to be ready for the production contracts. This was achieved through close cooperation and meeting with all IPTs. Also, Statements of Work, verification plans and PA plans were reviewed and updated.

System prototyping in the laboratory continued until November. A lot of detailed technical work was done to finally achieve continuity of the signal chain in the laboratory. Millimetre-wavelength cross-correlation was achieved in the lab using both the AEM and Vertex antenna racks. For this a signal at 86 GHz was injected into each leg of the RF simulator. Then, system level testing, leading to phase tracking and delay switching interferometry, was achieved in the lab.
After that the Back End antenna racks were removed from the lab in November, moved onto the antennas, and installed. The Evaluation Front Ends were also installed on both antennas, on which the signal path through the Front End to the Correlator is functional; the evaluation Front Ends were cooled down; and monitoring and control is functional via control software. The Central Local Oscillator racks and Correlator were installed, populated, powered up, and monitoring and control was established. First on-the-sky fringes are expected in the first quarter of 2007.
Other activities of PSI staff were the support of the holography system at the ATF and the support of the photogrammetry mission.

System integration planning in Chile progressed well. Discussions with all IPTs about deliveries and acceptance of equipment for Chilean Assembly, Integration and Verification (AIV) were held and documented. The Japanese AIV involvement, deliverable and schedule were agreed. The interface between the IPTs delivering the equipment and the commissioning team receiving the system from AIVS was agreed and documented. The AIV Interim Lab construction, needed because the OSF technical building will only be ready at the beginning of 2008, was completed. The Holography Tower construction was completed. In total 11 AIV engineers have been employed. All are posted at the executives (Socorro, Charlottesville, Garching) for training.

ALMA Back End engineers at work.

Science Activities

One of the main roles of the Science IPT is to define the top-level science requirements for ALMA and, in close collaboration with the System Engineering team, to ensure that they can be met by the hardware and software. The year 2006 saw the completion of a comprehensive System Requirements Review, covering all aspects of the specification. The major conclusion was that the current design would indeed meet (and in several areas such as receiver sensitivity even exceed) the demanding specification.

The calibration of ALMA is a challenging problem. The Science IPT has produced a comprehensive series of examples which demonstrate how key quantities such as amplitude, phase, antenna location and instrumental polarisation can be calibrated in practice. Even on the excellent Chajnantor site, water vapour in the atmosphere both absorbs and refracts millimetre waves from astronomical sources. To correct the fast fluctuations of phase which would otherwise limit imaging, ALMA will use a combination of two methods: fast switching between the object of interest and a nearby point calibrator, and water vapour radiometry. The latter technique measures emission from the 183-GHz atmospheric water line, using receivers mounted on each antenna and infers the resulting phase differences on all baselines.

ALMA Regional Centre

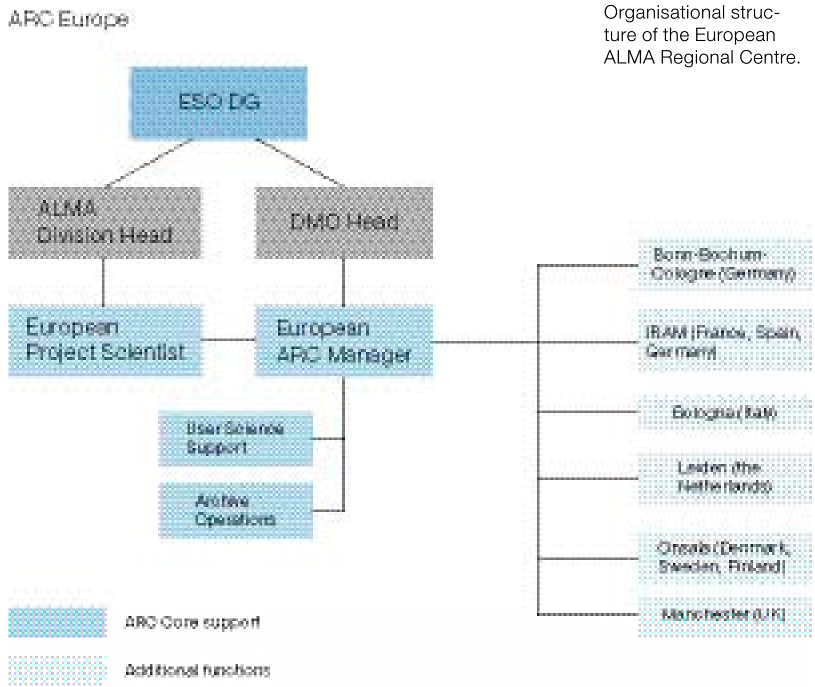
The European ALMA Regional Centre (ARC) is part of ESO's Data Management Operations Division and started its activities on 1 June 2006. The ARC's mission is to provide the science and technical support services necessary for the European user community to exploit ALMA to its full scientific potential. The ARC will form the interface between the ALMA Observatory in Chile and the European user community. Similar ARCs are currently being established in North America and East Asia, ESO's partners in the trilateral ALMA project. For European users, the ARC is being set up as a cluster of nodes located throughout Europe, with the main coordinating centre at the ESO Headquarters in Garching. In this distributed network, user support and operations experience at ESO can be mixed with millimetre-wave astronomy experience that exists in the community to create optimal science support services.

The European ARC will be the point of contact for European ALMA users from the moment of proposal submission to the actual distribution of calibrated data and consequent analysis. The core of the ARC activities will consist of running a help desk for the proposal submission and submission of observing programmes, the delivery of data to principal investigators, the maintenance and refinement of the ALMA data archive, and the feedback to the data reduction pipeline and the off-line reduction software systems that surround it.

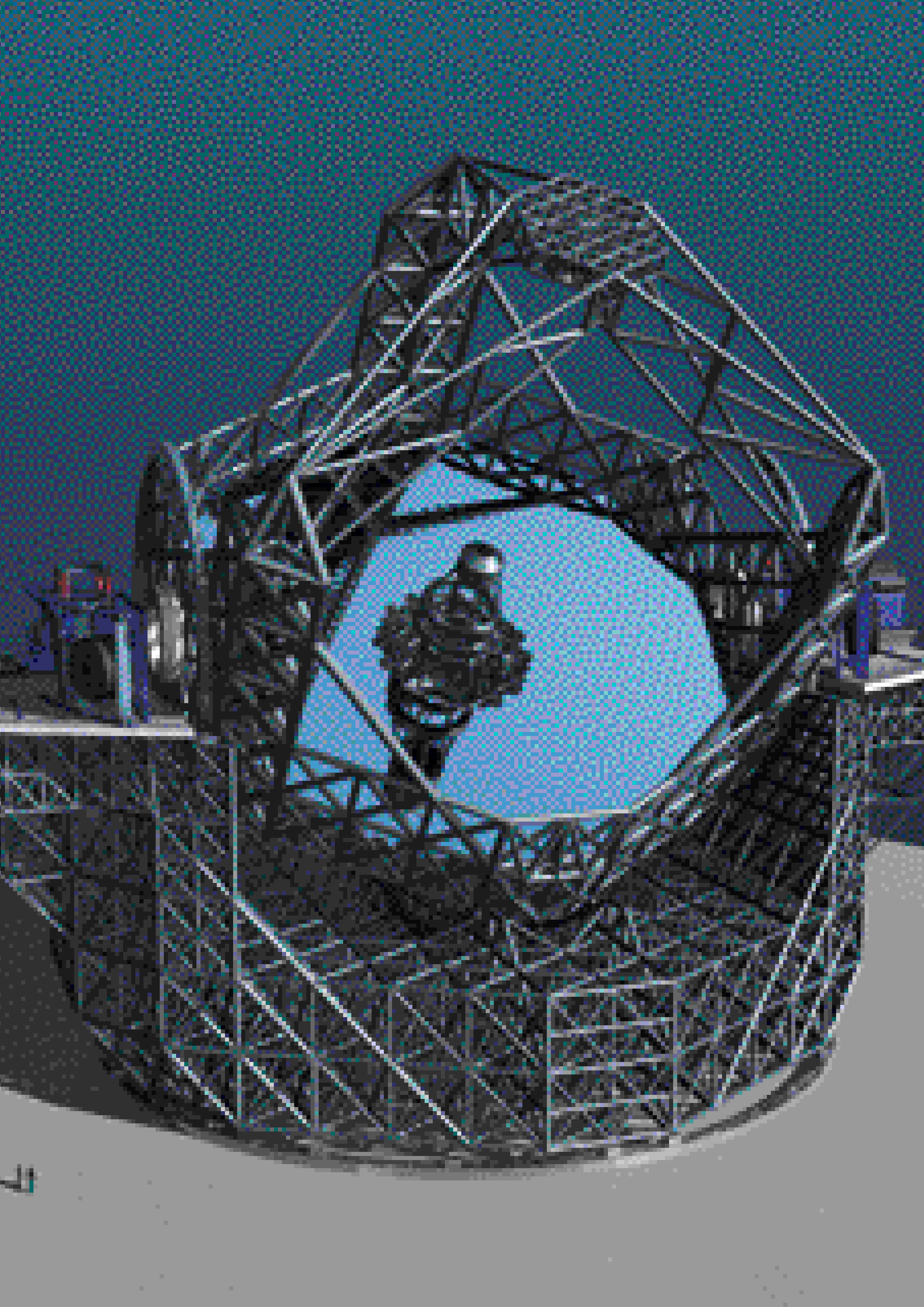
Among the tasks of the ARC Manager is the contribution to the preparation of the ALMA Operations Plan (AOP), which describes both the science operations and the technical services provided by the technical staff when ALMA becomes operational, and its implementation within ESO.

Fundamental to ALMA's success in Europe are the enhanced services provided by the network of ARC nodes. These are required to fully realise the potential of ALMA and to maximise the scientific return for the European community. Fostering community development and guiding the future evolution of ALMA's use are among the primary tasks for the nodes. The nodes will provide face-to-face help and additional support, beyond what are called the ARC core functions. This help includes, for example, advanced user support for special projects, and refinement in the data reduction process. To achieve these goals, the nodes will conduct fellowship, user grant, student and postdoctoral programmes, as well as promote the organisation of workshops, schools, and any other support facilities for users.

The ARC Manager coordinates this network of nodes. Activities have been started with a face-to-face meeting with representatives of the ARC nodes, held at ESO on 9 August. Most of these activities are described on the ARC web page (*www.eso.org/projects/alma/ARC*), whereas internal information is shared and exchanged via a 'wiki'.



Organisational structure of the European ALMA Regional Centre.



The European Extremely Large Telescope

Extremely Large Telescopes – telescopes with a diameter of 30 m or more – are seen worldwide as one of the highest priorities in ground-based astronomy. They will vastly advance astrophysical knowledge, allowing detailed studies of, *inter alia*, planets around other stars, the first objects in the Universe, supermassive black holes, and the nature and distribution of the dark matter and dark energy which dominate the Universe. The European Extremely Large Telescope project will maintain and reinforce Europe's position at the forefront of astrophysical research and, as such, it is no surprise that it was included in the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap in October 2006. This European Roadmap, defined at the request of the European Union Council, identifies new Research Infrastructures of pan-European interest corresponding to the long-term needs of the European research communities which are likely to be realised in the next 10 to 20 years, covering all scientific areas and regardless of possible location.

The European Extremely Large Telescope (E-ELT) project made large strides in 2006. In the first half of the year, five working groups composed of over 100 scientists and engineers from ESO and its community of users elaborated a new vision for the project. These ELT Science and Engineering (ESE) working groups focused on the scientific case, telescope design, site, adaptive optics and instrumentation. Chaired by members of the community, the working groups produced their reports, which were collected into a 'tool box' to guide the further design activities.

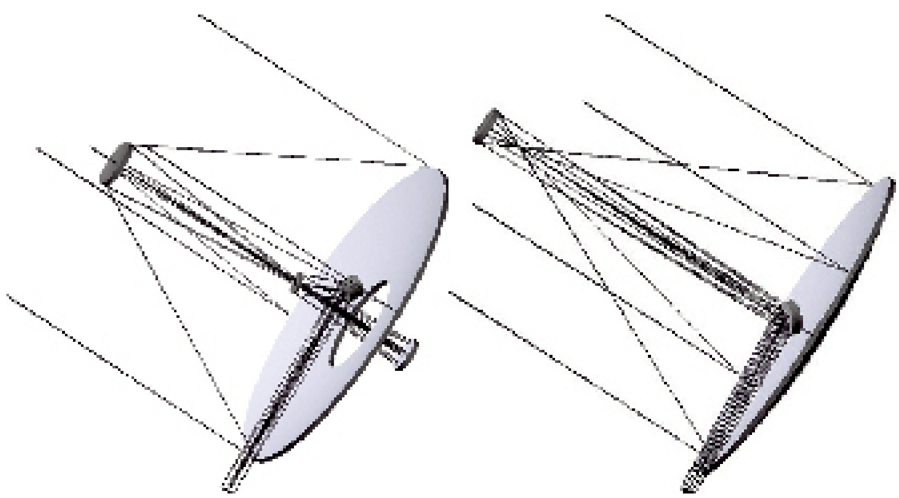
The chairs of the working groups, augmented by members of the ESO Scientific Technical Committee (STC), formed a subcommittee of the STC naturally named ESE to monitor the project and advise both the STC and ESO on the work. In parallel to this community-wide consultation, the ESO Council established an ELT Standing Review Committee (ESRC) composed of external experts to advise on a broad variety of aspects to do with the project.

With the tool box in place, ESO formed a telescope project office in the middle of the year and tasked it with absorbing the recommendations of the ESE working groups and developing a coherent proposal for a telescope – a baseline reference design – and associated instrumentation to be elaborated upon in the coming years. The ESO ELT programme is in fact split into three parallel activities on telescope, instrumentation and operations, each with its own office within the respective divisions at ESO: Telescope Systems, Instrumentation, and Data Management and Operations.

Innovative Design

The baseline reference design of the telescope is to have adaptive optics as an integral part of the system, to provide instrumentation with gravity-invariant foci, to have an instrumentation-friendly focal plane and to avoid the areas considered high-risk by the OWL review undertaken in late 2005. The telescope design working group activities focused on establishing the viability and relative merits of the two front-runners in the designs that could address these basic requirements. The first design was a classical Gregorian telescope and the second a novel five-mirror design. The activities at ESO focused on establishing the viability of a mechanical structure to support a mirror diameter of 42 metres and the rest of the optics required to relay the beam back to a focal station. Sophisticated finite-element modelling and analysis, as well as preliminary control engineering work, were used to develop a mechanical structure that could host either of the two designs with comparable performance. The size of 42 metres was considered by the ESE as a good compromise between ambition and technical feasibility.

In parallel, ESO contracted European industrial firms to develop conceptual designs for the adaptive optics systems that are going to be built into the telescope. External consultants worked on developing concepts for the dome to house the telescope and within ESO a great deal of attention has been placed on the interfaces of the telescope and its infrastructure with instrumentation. Industrial firms were contacted to establish a first top-down cost estimate for the telescope.



The two optical designs considered during the Basic Reference Design development: five-mirror (left) and Gregorian (right).

The activities within the EU FP6-supported ELT Design Studies programme, led by ESO but largely executed in industry and academia outside the organisation, are aligned with the activities of the E-ELT programme and in all areas much progress is being made. Actuator prototypes, edge sensors, phasing techniques, wind evaluation systems, dome designs, site testing and many other such activities are all contributing to the knowledge we require to advance the project into the next phase. Integral to this planning is the membership of Spain in ESO and the expertise that the Spanish community will bring. Spain has just completed the segmented 10.4-m Gran Telescopio Canarias (GTC) telescope and, with Spain's membership, ESO engineers will gain technical access to that system.

The baseline reference design selected and approved by the ESO Council to move into the Phase B of the project is the five-mirror design. While the Gregorian design had advantages in a better theoretical performance in adaptive optics, a smaller mirror count and smaller central obstruction, the five-mirror design was considered to have advantages in the image quality across the focal plane, the control of the wavefront using laser guide stars, the flexibility of the focal stations, the deployment of atmospheric dispersion compensators, the smaller dome and the relative ease with which it could be upgraded to follow the development of technology in the future. Most critically however, the five-mirror design was considered to have much lower risk in the area of adaptive optics by virtue of the separation of the field-stabilisation and adaptive-optics functions, a key recommendation of the OWL review.

Into Phase B

The results of this burst of activity came together during November 2006 in preparation for a series of presentations of the Project Office conclusions to ESE, ESRC, STC, to 250 astronomers at the Marseilles meeting on the E-ELT and, finally, to the ESO Council. The endorsement of the Project Office proposal by this broad spectrum of the community and decision makers reflects not only the good progress ESO made during 2006 in the elaboration of the design but also the clear scientific need to advance rapidly and effectively in the area of E-ELTs and the commitment of the user community.

Participants to the E-ELT conference in Marseille.

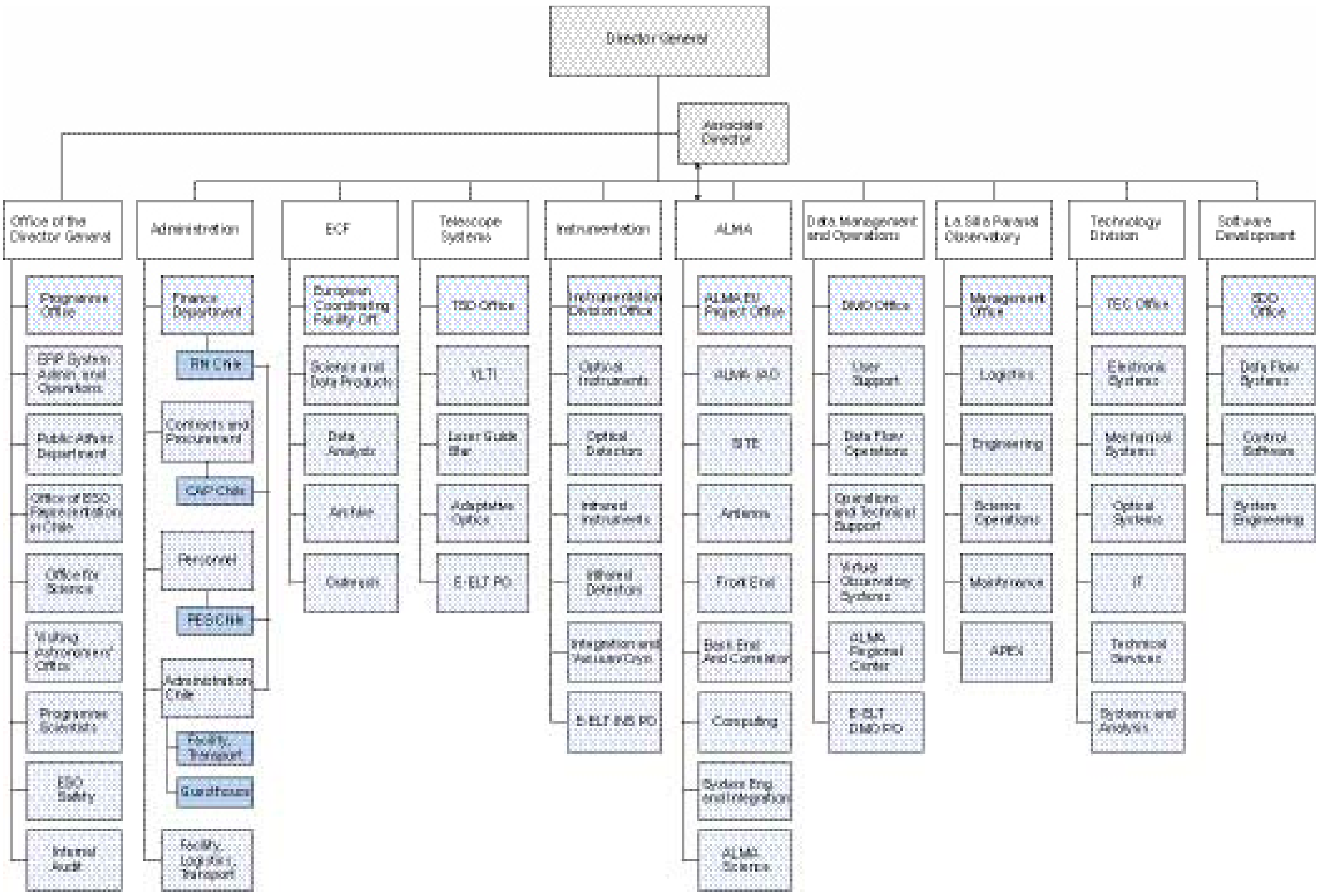
The baseline reference design selected and approved by the ESO Council to move into the Phase B of the project is the five-mirror design. While the Gregorian design had advantages in a better theoretical performance in adaptive optics, a smaller mirror count and smaller central obstruction, the five-mirror design was considered to have advantages in the image quality across the focal plane, the control of the wavefront using laser guide stars, the flexibility of the focal stations, the deployment of atmospheric dispersion compensators, the smaller dome and the relative ease with which it could be upgraded to follow the development of technology in the future. Most critically however, the five-mirror design was considered to have much lower risk in the area of adaptive optics by virtue of the separation of the field-stabilisation and adaptive optics functions, a key recommendation of the OWL review.

The E-ELT is now in Phase B, a period during which the design will be elaborated further. Together with academic and industrial partners, and with continuous consultation with its user community, ESO expects that a proposal for the construction of this ambitious project can be ready by the end of this decade.

A Revolutionary Concept

The present concept features as a base-line a 42-m diameter mirror telescope, and is revolutionary. The primary mirror is composed of 906 segments, each 1.45 m wide, while the secondary mirror is as large as 6 m in diameter. In order to overcome the fuzziness of stellar images due to atmospheric turbulence the telescope needs to incorporate adaptive mirrors into its optics, and a tertiary mirror, 4.2 m in diameter, relays the light to the adaptive optics system, composed of two mirrors: a 2.5-m mirror supported by 5 000 or more actuators so as to be able to distort its own shape a thousand times per second, and one 2.7 m in diameter that allows for the final image corrections. This five-mirror approach results in an exceptional image quality, with no significant aberrations in the field of view.

Organisation and Personnel



The main organisational and managerial units of ESO are the Divisions which currently include: the Office of the Director-General, the Administration, the Space Telescope/European Coordinating Facility, the La Silla Paranal Observatory, and the Instrumentation, Telescope Systems, Technology, Data Management and Operations, Software Development, and ALMA Divisions. Most divisions are organised in Departments, some of which consist of two or more Groups.

List of Personnel

Office of the Director General[1]

Catherine Cesarsky

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Stefan Vehoff
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Elisabeth Völk
Rein Warmels
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Thomas Wilson
Gabriele Zech

[1] Including all the Fellows and Students under the Studentship programme.

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Pierre Haguenauer
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Seconded Staff Members

Joint ALMA Office

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Alejandra Araya
Ann Edmunds
Jacques Lassalle
Russell Smeback

Personnel Services

The 'Five-Yearly Review' of the conditions of employment for International Staff Members was completed, in close interaction with CERN. The results of the study led to further reviews and amendments, in particular regarding: the definition of family, now recognising same-sex marriages and same-sex or opposite-sex partnerships; maternity leave, parental leave and further options to facilitate and increase the harmonisation of family and professional career; education grants and expatriation allowances.

The Personnel Department in Garching and Vitacura prepared and concluded the collective bargaining with the representatives of the Unions of La Silla and Paranal as well as with the representatives of the Administration in Santiago. The new Collective Contracts are effective as of 1 December 2006 for a period of three years.

The process of the creation and implementation of the Software Development Division and reorganisation of the Data Management and Operations Division was accomplished. Personnel also participated in the review and restructuring of the Administration Division, all the related decisions being implemented by 1 July 2006.

Personnel Services was greatly involved in matters regarding the ALMA project. We participated in the recruitment of key positions of the Joint ALMA Observatory, in the foundation of the ALMA Human Resource Advisory Group, and in the completion of the Internal Regulations as well as the Compensation and Benefits for ALMA Local Staff.

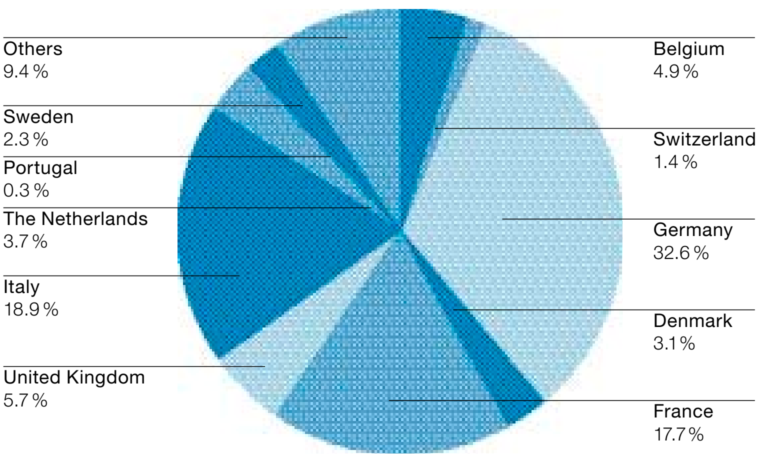
The 'leave module' was implemented for Garching on 1 July 2006 in the ERP system. To make this process smooth, training was provided for all the Staff.

To make new staff members in Garching more used to all the aspects of the organisation, from an overview of its different activities to very practical questions, an induction day was established with support from all Divisions at ESO. Conditions in Garching have also been improved for young parents with the opening of the IPP/ESO Crèche on 1 April 2006.

Other activities included participating in the recruitment of key management positions in Garching and Chile, making regular visits to the sites in Chile in order to keep close contact with the International and Local Staff Members and their representatives, organising common training in 'managing people' for about 25 team leaders of the La Silla Paranal Observatory during the month of November 2006, and providing short-term and long-term office accommodation in Garching.

The employment conditions and further guidelines for International Staff Members and Local Staff in Chile were revised, particularly with respect to:
- The calculation and adjustment of the Cost of Living for International Staff Members in Chile;
- Contract Policy for International Staff Members;
- Regular medical examinations for Staff in Chile and Garching;
- Equal Opportunity Statement;
- Recruitment Policy Statement and its guidelines;
- The application of the Social Activity Day;
- Limitation of claims;
- Home leave regulation;
- The application of official holidays during duty travels.

In the course of the year, 9 Local Staff and 34 International Staff Members were recruited. In addition, 101 Students, Fellows, and Paid and Unpaid Associates joined ESO. The diagramme below shows the International Staff Members of ESO, by nationality, as of December 2006.



Distribution of International Staff Members by Nationality as of 31 December 2006.

Instrumentation

Highlights of the year were the installation and commissioning on Antu (UT1) of the Cryogenic Infrared Spectrometer (CRIRES), the last of the first-generation VLT instruments, and the successful commissioning of the laser guide-star facility on Yepun (UT4), which will substantially increase the sky coverage achievable with the adaptive optics assisted instruments NACO and SINFONI. The OmegaCAM camera was completed in advance of the VLT Survey Telescope for which it has been built; integration of the HAWK-I infrared camera for the VLT started in Garching; work on PRIMA continued; the approved second-generation VLT instruments X-Shooter, KMOS, MUSE and SPHERE, plus the Adaptive Optics Facil-ity (AOF) and the new NGC detector con-troller all progressed well, and Phase A studies were launched of three potential second-generation VLT interferometric instruments to eventually replace MIDI and AMBER. In addition, work ramped up on defining the ELT instrument interfaces and the design of possble instruments both within the ESO E-ELT Instrument Project Office and the FP6 ELT Design Study.

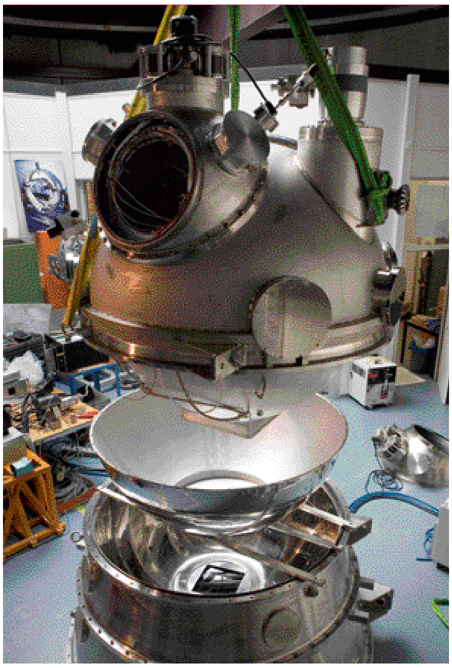
The leadership and know-how in astronomical instrumentation of ESO and its partners was very visible at the 2006 SPIE Astronomical Telescopes and Instrumentation Symposium that took place in Orlando, Florida, bringing together 1700 astronomy, technology, and engineering experts from all over the world. ESO staff played a key role in the numerous meetings, either as organisers or speakers, and many ESO projects were discussed.

CRIRES, the infrared (1–5 μm), high resolution ($R = 10^5$), adaptive optics assisted spectrograph built for the VLT by ESO was integrated, extensively tested and formally passed its Preliminary Acceptance Europe (PAE) review in Garching on 13 April. In order to optimise the installation and commissioning process the adaptive optics part was reviewed first, and released for shipment to Chile by the end of February. First light was achieved with an infrared test camera on 6 April when the adaptive optics control loop was closed on the star Muscae. Although packing of the cryogenic spectrograph only started on 25 April, first astronomical spectra were already obtained together with the adaptive optics feed on 4 June. We believe that this constitutes a record time for such a complex installation. By year's end, commissioning was almost complete and the first scientific results had already been obtained through a highly successful set of science verification observations conducted to test the end-to-end system including the proposal preparation, instrument operation, and data handling and analysis tools and procedures. Following final commissioning and calibration in early 2007, CRIRES will officially enter full science operations at the start of Period 79 on 1 April.

The Laser Guide Star Facility (LGSF) had first light on 28 January. During the first commissioning a degradation of the image quality of the projected artificial star was detected. This was found to be due to the deformation of the flange at the interface between the launch telescope and the secondary mirror of UT4. The flange was redesigned and replaced in April. This solved much of the image quality problem although a second problem appeared: at low temperatures the supports of the launch telescope's primary mirror caused an aberration that also affected the image quality of the artificial star. The launch telescope was dismounted, tested and shipped back to Garching for repairs. A task force was created to manage the recovery actions. A new mirror support was designed and mounted in the launch telescope. A more advanced focusing mechanism was also developed and mounted. A comprehensive set of realistic tests was then performed in a controlled environment to check the quality of the refurbishment before sending the launch telescope back to Paranal in October. All recovery activities were done in collaboration with the telescope provider. The LGSF went back 'on sky' in October, and commissioning resumed together with the NACO and SINFONI instruments. Although not yet fully within specifications, the LGSF was starting to produce scientific results at the end of the year.

The OmegaCAM wide-field optical camera for the VST was finished and passed its PAE. The camera itself has been built by a German/Dutch/Italian consortium and the detector system, comprising a mosaic of 32 CCDs, by ESO. The instrument is now being stored in Garching, awaiting the installation and commissioning on Paranal in 2007 of the 2.6-m VST, being supplied by INAF in Italy.

Manufacturing and procurement of essentially all the components of the HAWK-I infrared camera for the VLT proceeded well. In particular, all four of its 2k × 2k Hawaii 2RG infrared detectors were delivered and fully tested with excellent results. They were mounted together to form a mosaic similar to that planned for the James Webb Space Telescope. The radiation shield was installed in the vacuum vessel in Garching, resulting in a rather large camera system. The reflecting optics were also mounted and found to exhibit excellent optical quality at room temperature. The first cool-down and test of the complete system at cryogenic temperatures is expected in January 2007 and, if all goes well in the following few months, HAWK-I will be commissioned in the period June–September 2007 at one of the Nasmyth foci of Yepun (UT4). After around three years use for direct imaging it is planned to install four wavefront sensors to exploit the possibility of ground layer adaptive optics correction with the AOF.



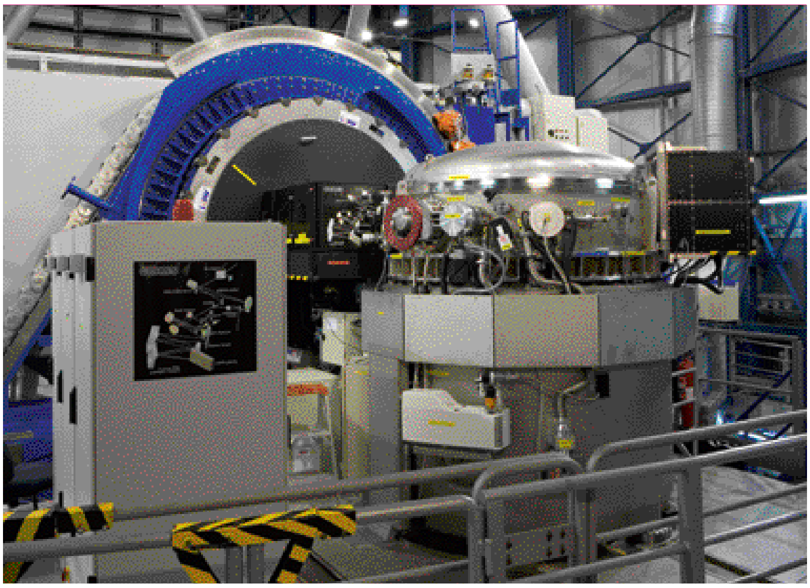
Installation of the radiation shield in the HAWK-I vacuum vessel in Garching.

The Adaptive Optics Facility

The AOF is a project to upgrade one of the VLT 8.2-m telescopes, Yepun (UT4), with an adaptive secondary mirror, multiple Laser Guide Stars and two adaptive optics modules: GRAAL for HAWK-I and GALACSI for MUSE. The aim is to provide both instruments with 'enhanced seeing' performance in a large field of view and to achieve diffraction-limited performance in a small field of view for MUSE. An optical test-bench, ASSIST, built by a Dutch partner, will be used to test the complete system in Europe before sending it to the observatory.

Substantial progress was achieved in the design of the various subsystems during the year. The Deformable Secondary Mirror (DSM) preliminary design has advanced well and major design difficulties – such as procedures for safe handling of the thin mirror shell, design of a stiff hexapod structure with sophisticated flexible joints, manufacture of a light-weight reference body – have been solved. The end of the year has been used to write the documentation for the DSM Preliminary Design Review (PDR) planned for early 2007. A complete design for GRAAL has been produced, including the large bearing which allows rotation of the wavefront sensors. Preliminary inquiries have taken place for specifications and cost-estimate of such a device, opening the way for the GRAAL PDR in early 2007. GALACSI and 4LGSF preliminary designs are in line for reviews planned in autumn 2007. The synergy between GRAAL and GALACSI (e.g. their similar real-time computer and wavefront sensor) allows GALACSI to benefit from the GRAAL progress. Moreover, the results and lessons learned from the LGSF commissioning in Paranal are retrofitted to the actual 4LGSF design. The ASSIST test-bench has undergone Optical PDR in October 2006 and a reliable optical design is on hand for the 'DSM main tower'. The mirror blank for the Thin Shell prototype has been prepared by a contractor and is ready to undergo aspherical polishing.

Concerning the Very Large Telescope Interferometer (VLTI), several parts of the PRIMA (Phase-Referenced Imaging and Micro-arcsecond Astrometry facility)



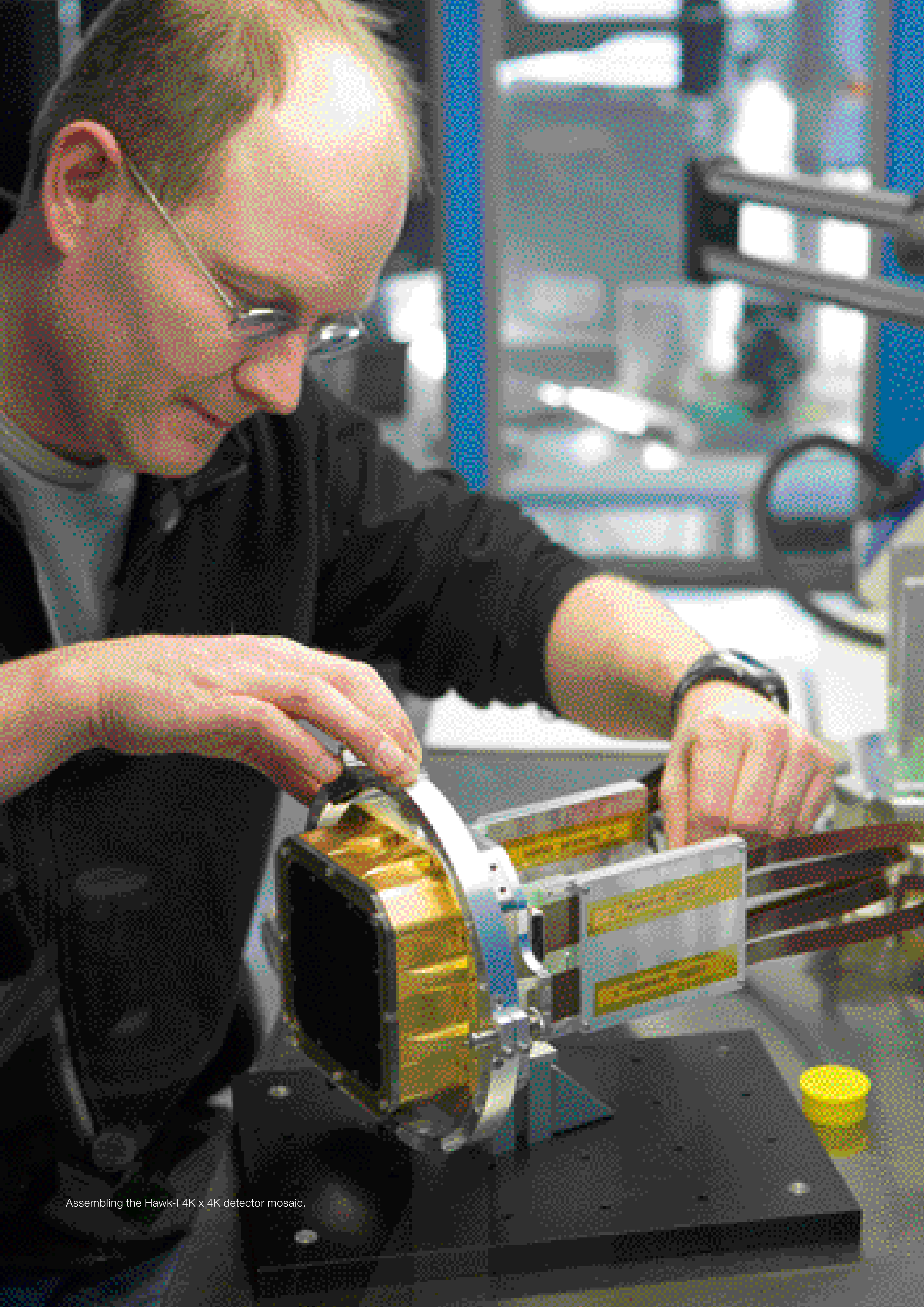
CRIRES installed at a Nasmyth focus of Antu. The large vacuum vessel houses the cryogenically cooled, high-resolution infrared spectrometer, and the enclosure between it and the telescope contains adaptive optics and calibration systems.

hardware have been delivered and are undergoing intensive tests in the Garching laboratories. The PRIMA facility is a sys-tem designed to enable simultaneous interferometric observations of two objects – each with size of at most 2 arcseconds – that are separated by up to 1 arcminute. PRIMA can be used to increase the sensitivity of the VLTI, to image faint objects with a high angular resolution and to perform high-precision astrometry, mainly for planet detection. The principal components of PRIMA are: a Star Separator per telescope, a system of laser metrology, two Fringe-Sensor Units, and four Differential Delay Lines.

One Star Separator for the Auxiliary Telescopes and one for the Unit Telescopes have been delivered within specifications. The second of each type will be delivered in early 2007. Two additional Star Separators for the Unit Telescopes are under manufacturing and should be delivered in 2008. The Fringe Sensor Units (FSU) are under intensive tests at a laboratory in the *Max-Planck-Institut für Extraterrestrische Physik*. Some specifications are not yet met but several solutions are being worked out and implemented in collaboration with the contractor. The laser metrology, the system measuring the phase and delay that is at the basis of the PRIMA concept, is regularly used in the testing of the FSU. Its interface with the Star Separators has also been proven adequate. Continuous improvement of this essential device is ongoing as the lessons learned from the Interferometric Task Force in Paranal are taken into account and used to improve the PRIMA reliability. The Differential Delay Lines are under manufacturing and currently no problem has been encountered. Finally, the PRIMA Astrometric Software, a detailed data analysis software and calibration package needed to reach the ambitious 10 micro-arcsecond accuracy, is under development. A first version of the software will be available for the integration and commissioning of PRIMA during 2008.

Second-generation Instruments

Design work advanced well on the four approved second-generation VLT instruments. X-Shooter, the wideband UV-IR spectrograph being developed by a Danish/Dutch/French/Italian consortium led by ESO, is the most advanced. It passed its Final Design Review (FDR) in June 2006 and its optical CCDs and infrared array detector have already been successfully tested. KMOS, the multiple, deployable integral-field infrared spectrometer being developed by a UK/German consortium (with ESO providing the detector system) passed its PDR in Sep-



Assembling the Hawk-I 4K x 4K detector mosaic.

tember following successful tests of a prototype cryogenic pick-off arm – one of 24 to be installed in the final instrument – and of diamond machined optical components representative of those needed for its image slicer systems. The agreement between ESO and the French/Swiss/German MUSE consortium was signed and the instrument itself continued in its preliminary design phase. MUSE is an integral-field optical spectrograph – actually 24 spectrographs – with ESO again responsible for the design and procurement of the detector systems. An important milestone in 2006 was the optical PDR, which paved the way for the production of a prototype of one of the 24 spectrographs. MUSE is also designed to be used together with the AOF described above in order to enhance the delivered image quality and hence sensitivity and resolution.

The aim of SPHERE is to directly detect extrasolar planets, possibly down to Jupiter masses, achieving a contrast of at least 1/100 000 at 0.1 arcsecond from a bright central star. This will be made possible by an 'extreme' adaptive optics system to correct atmospheric turbulence effects, by suppression of the diffraction pattern using state-of-the-art coronagraphs, and by advanced differential techniques aimed at reducing the speckle noise. The corrected beam will feed three scientific instruments which will work at optical and near-infrared wavelengths.

The SPHERE consortium comprises partners from France, Germany, Switzerland, Italy, and the Netherlands. ESO is a full partner in the project, which also includes significant support by the OPTICON FP6 network. During 2006, the preliminary design of systems and subsystems has advanced well at the various institutes. The PDR of the Optics is planned for March 2007, with the overall PDR planned for July 2007. The development of the extreme AO deformable mirror, its drive electronics and the digital detectors necessary to analyse the wavefront is proceeding. The delivery of these critical components is expected in autumn 2007. The High Order Test-bench (HOT), supported by OPTICON and dedicated to the verification of high-contrast imaging concepts, has been set up at ESO and first closure of the AO loop has been achieved.

A formal call for second-generation VLT interferometric instruments yielded three Proposals in January: for GRAVITY, MATISSE and VSI (down from nine possible concepts at the start of the selection process in 2005). Following a recommendation of the STC committee, Phase A study contracts were let for all of them with final study reports being due in summer 2007.

In addition to specific instrumentation projects, detector and other development work was undertaken to ensure that ESO remains at the forefront in this critical area. Most visibly, development of the Next General detector Controller (NGC) continued to advance. The NGC is designed to meet the needs of all foreseeable visible and infrared detector systems for the coming years – both to achieve the noise, speed and other performance requirements and also to provide the maintenance benefits of a single type of system at the La Silla Paranal Observatory. Furthermore, detector developments and characterisation together with industry continued in various areas aimed at improving the quantum efficiency, noise, speed and other properties of both visible and infrared detectors. In addition to the science detectors themselves, new drivers for these improvements have come from the requirements for adaptive optics wavefront sensors and fringe-tracking systems needed for interferometric applications.

MAD, the Multi-Conjugate Adaptive Optics Demonstrator, is a bench instrument to demonstrate and study, both in the Laboratory and on-sky, many of the new AO approaches proposed in the last years, which are needed for some second-generation VLT instruments and which are crucial for the future European Extremely Large Telescope. The most important approaches to be demonstrated by MAD are the Multi-Conjugate AO and the Ground Layer AO, both aiming at enlarging the field of view of the correction, which is typically very small in traditional AO systems. During the year MAD completed its test and characterisation phase in the laboratory for both the 'classical' wavefront-sensing mode developed at ESO and the layer-oriented mode developed by an Italian consortium.

The laboratory results have shown that Multi-Conjugate AO has diffraction-limited capabilities and good correction uniformity across a field of view up to 2 arcminutes, under Paranal median seeing conditions. Ground Layer AO has shown its great potential in increasing the energy concentration on similar fields of view. On-sky demonstration will be extremely helpful in understanding how the two correction approaches will perform under real atmospheric conditions. MAD achieved Preliminary Acceptance in Europe (PAE) in December. The infrared camera produced by the Portuguese partner also achieved PAE, in September. MAD has been sent to Paranal to be reintegrated and should perform first on-sky runs in March/April 2007.

Technical Developments

The Technology Division provided engineering support to over 150 different ESO projects and workpackages in 2006 – a 50 % increase over 2005. The increase has been largely due to the start of the production phases of major on-going projects like ALMA, second-generation VLT instrumentation, and VLTI instruments, as well as the demands of new workpackages related to the E-ELT and FP6. Support for VLT operations at Paranal also continues as an important background activity for the Division.

Electronic Engineering

The introduction of the EU RoHS Directive (Restriction on the use of Hazardous Substances) has had an impact not only on internal electronic developments at ESO but also on the availability of many commercial electronic units. This relates, in particular, to the requirement for lead-free soldering. In some cases compatible alternative commercial units that conform to RoHS are available, but others, like the ESO-standard Maccon motor control units that are used within all VLT instruments, are now no longer available. The Electronics Department has therefore ordered a sufficient stock of these and other operations-critical modules to provide for long-term maintenance support for the VLT and its instrumentation.

A new standard motor-control suite for instrumentation based on the CAN-bus standard has been developed and, in 2006, a pre-production series of the DC motor controllers and prototypes of the stepper motor controllers were produced and tested in Garching. These will complement the existing Maccon boards and will be particularly suitable for new applications where distributed motors are to be controlled.

In order to be able to assure reliable operation of electronic systems over the entire range of operational temperatures, the Electronics Department has acquired a new climatically controlled enclosure to allow thermal stress-testing all new electronics designs as well as commercially bought equipment. Although electronic reliability has not been a serious problem in the past, the new equipment will contribute to our goal of improving quality assurance procedures throughout the organisation.

Systems Engineering

Computer modelling of opto-mechanical systems is an important aspect of ESO's systems engineering work. To enable increasingly complex systems such as the E-ELT to be modelled, the analysis tools used at ESO have to be continually extended to keep pace with project requirements. A particular example in 2006 is the Structural Modelling Interface (SMI) tool developed jointly at ESO and the Technical University in Munich. The SMI can reduce the complexity of large FEM models produced in ANSYS to levels that permit control simulations using Matlab/Simulink to be carried out, but without significant losses in model fidelity. Another analysis tool that has been developed over a number of years at ESO, together with Astrium, is Beam Warrior. A limitation of classical optical design tools like Code-V and Zemax is that they produce optical models but these are not linked to the mechanical and other perturbations of the complete system. By combining optical design parameters from these programs with flexure information obtained from a FE Analysis, Beam Warrior can calculate parameters like the point-spread functions or Zernike coefficients for a variety of telescope orientations and load conditions. It allows optical models to be integrated into control-loop simulations and can also handle segmented-mirror telescopes. Beam Warrior will thus be an important element of the E-ELT integrated model.

Systems Engineering is an important discipline for all complex projects, and for major projects like ALMA and the E-ELT it is indispensable. Keeping track of the continually evolving projects requirements throughout the development cycle is a challenging task and is an area where a Requirement Management Tool can be very useful. DOORS is such a tool that has been successfully used within the Software Department for several years for the ALMA software documentation and requirement management. Requirement Management promotes a formal approach to the definition of project requirements at different levels (stakeholder requirements, systems requirements, operational requirements, etc.), and links these to subsystems requirements, design documentation, verification procedures, and so on. It allows transparent requirement traceability for change control and helps with the early identification of errors that can be expensive to correct later on in the project.

In 2006, a pilot project has been started to apply DOORS to the E-ELT project. The Level 1 project requirements have been identified and integrated into the DOORS requirements management process framework, and linking has started.

Test chassis with multiple units of the ESO-developed CAN-bus DC motor drive module.

Opto-Mechanics

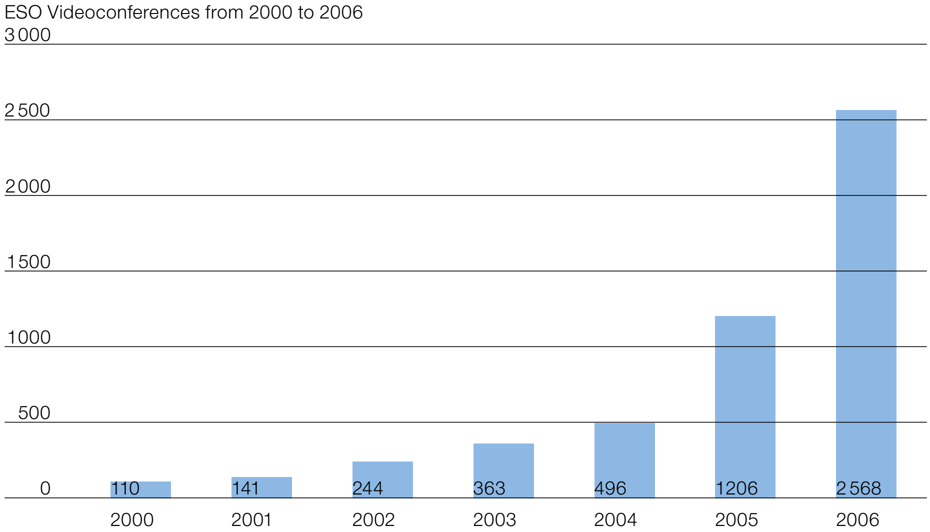
During 2006, several background developments have been pursued in technologies that could be of potential interest for future ESO projects. One area of key importance for an ELT project is fine mirror-shape control and, with this in mind, two parallel development projects have been undertaken to evaluate piezoelectric actuators. The first project used piezo fibres attached to a bar. The test results obtained showed bending that was in good agreement with a FE analysis and, in particular, showed no significant hysteresis. The second development, which is still ongoing, uses piezo stack actuators attached to a dummy mirror blank. Both these techniques show good potential for a precise and economic means of mirror deformation control.

A design challenge for any large exposed structure like the ELT is wind buffeting control. Although wind tunnel testing and CFD (Computational Fluid Dynamics) models are both valuable techniques, there always remains a problem of validating these models, both in terms of scaling and understanding the correct disturbance spectra to apply. In order to obtain realistic test data for an extremely large telescope, an experiment has been undertaken with the support of the University of Manchester to attach some 200 pressure sensors on the surface of the Jodrell Bank 70-m Lovell radio telescope in the UK. These allow not only the absolute pressure variations to be determined over a period of one year, but also enable us to gain a good understanding of the pressure correlations across the reflector surface, that have an important impact on the overall telescope design. During the course of 2006, the sensors and their readout electronics were installed on the telescope by ESO's partner firm GBF, and analysis of the initial data is already underway.

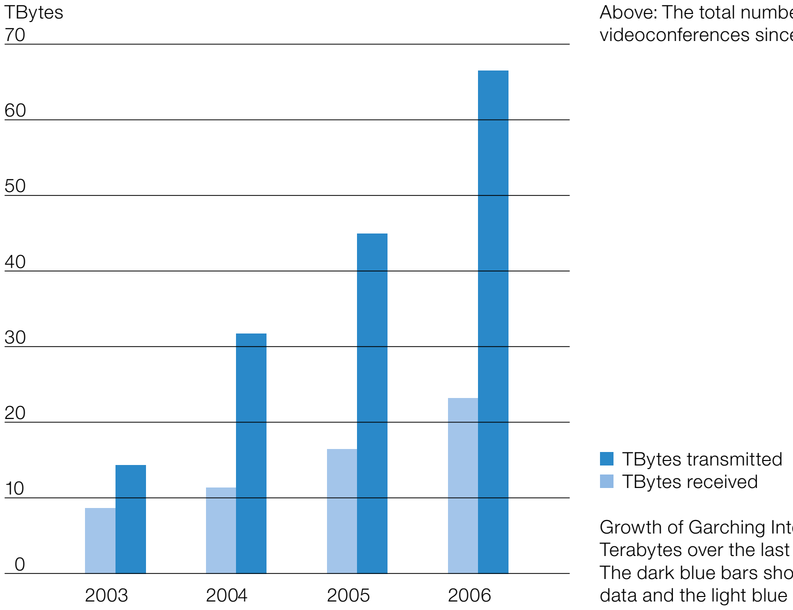
Software Engineering

The 15th release of the VLT Software, i.e. the January 2006 release, was the last to support HP-UX and Sun Solaris operating systems. The next planned release, in February 2007, will support Linux only. This change will considerably reduce the amount of software testing to be carried out and contribute to improved reliability.

Software updates are needed primarily to meet the specific requirements of new VLT instruments as well to cater for various hardware configuration changes. For real-time control environments, ESO has now moved from WindRiver VxWorks release 5.5 to release 6.0. This step was necessary, not only to be able to use the latest real-time processor boards, but also because release 6, unlike its predecessors, supports Linux as a development platform.



Above: The total number of yearly ESO videoconferences since the year 2000.



Growth of Garching Internet traffic in Terabytes over the last four years. The dark blue bars show outgoing data and the light blue incoming data.

In December 2006, an internal reorganisation in Garching led to the transfer of staff of the Software Department from the Technology Division to the newly formed Software Development Division. There they join software engineers who were previously in the software development group of the former Data Management Division. This move is intended to consolidate software developers within the organisation and provide improved synergy.

IT Services

A major event for IT services was the change of outsource service provider in April 2006. The new contractor has taken over responsibility for providing IT support not only in Garching but also in Santiago, La Silla and Paranal. Previously, three separate contractors were responsible for providing IT support in Garching, Paranal and Santiago respectively, with La Silla being supported by ESO staff. This change will greatly assist inter-site coordination and the rationalisation of IT services.

The use of ESO communications systems continues to rise rapidly. Since videoconference systems were first introduced at ESO in 2000, their usage has increased dramatically. Today, videoconferencing is an indispensable part of ESO's activities, not only for internal ESO meetings between Europe and Chile, but also for regular contacts with our project partners in Europe and beyond. Videoconferences not only facilitate closer contact between staff in Europe and Chile but also lead to reduced travel costs. In 2006, an average of 10 videoconferences took place each working day.

Similarly, network traffic has also increased steadily over the last few years, fuelled by higher available bandwidths and cheaper access costs. In 2006, the total incoming and outgoing traffic through the Garching Internet portal was about 90 Terabyte/year.

The Spiral Galaxy NGC 3190 (FORS/ESO).

Science Archive Operation

The Science Archive Operation (SAO) group is responsible for receiving, storing and redistributing ESO and Hubble Space Telescope (HST) data, as well as providing front-line archive user support. The current total archive holding is 53.2 terabytes (TB) of ESO data and in excess of 2 TB of HST data. Roughly 13 TB of new data were archived during 2006, a 10 % increase over 2005. While the volume of HST data is rather small compared to that of ESO data, the number of files archived for the two observatories is comparable: 6 million ESO files and 4 million from HST, for a grand total holding in excess of 10 million files hosted in the ESO Archive. Users around the world can access the ESO archive via a web-based data request submission system. In addition to the general archive web interface, all current VLT instruments, the VLTI MIDI instrument, the HARPS instrument on La Silla, and APEX on Chajnantor have dedicated instrument-specific forms to query the data. More than 16 600 unique archive requests were served in 2006, totalling 24 TB of data (a 4 % increase with respect to 2005). Of those requests, 14 900 were for ESO data, while the remaining 1 700 were for HST data. In addition we have prepared 1 211 data packages that were delivered to Principal Investigators on 2 733 CDs or DVDs. Finally, 140 calibrated pre-imaging data sets from the two FORS instruments, VIMOS, VISIR and, as of the third quarter of 2006, ISAAC, NACO and SINFONI were delivered automatically within 48 hours of acquisition at the telescope. Raw data from the UKIRT Infrared Deep Sky Survey (UKIDSS) executed with the WFCAM instrument at the UK Infrared Telescope (UKIRT) have kept flowing into the ESO archive. During 2006 we have received 2.5 TB worth of UKIDSS data, mostly concentrated in the first part of the year.

The year 2006 marked the beginning of operations of the APEX submillimetre antenna on the Llano de Chajnantor. The data belonging to two out of the three APEX partners – ESO itself and the Onsala Space Observatory in Sweden – are stored in the ESO archive. As with any other ESO data, APEX files will also be made public to the community at large, once the usual proprietary period has expired. The ESO archive currently holds 75 GB of APEX data, as produced by the Science Verification runs and the first round of ESO and Onsala General Observer programmes.

A major milestone for 2007 will be the archiving of data from VISTA/VIRCAM, the new wide-field infrared imager scheduled to start operating in the course of the year. With an expected data rate of 150 TB a year, this instrument alone will produce a tenfold increase of data volume compared to all other instruments combined!

In order to cope with this massive flow of data, the way data themselves are transferred from Paranal to Garching was overhauled in 2006. In fact, the traditional way of transferring data on CDs and DVDs, which has faithfully served VLT operations since the beginning, was discontinued. As of December 2006, VLT data are transferred to Garching in a novel and very efficient way, i.e. directly on NGAS (Next Generation Archiving System) discs, a technology developed at ESO and the foundation of the ESO archive itself.

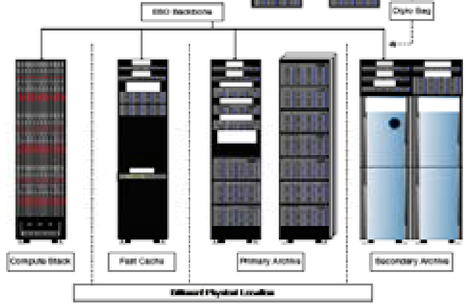
Fundamentally, archive operations rely on a large number of hardware servers to store science data and their associated metadata in a reliable manner. We estimate that the archive data volume will exceed the petabyte limit by 2011. Therefore, a petabyte-class archive has been designed to deal with the challenge of huge astronomical data volumes. This petabyte-class archive consists of ESO's Primary and Secondary Archive, the Compute Stack and the Fast Cache.

The Primary Archive is based on hard-disc technology, currently distributed on 25 Linux servers with a storage capacity of 6.4 TB each, whereas the Secondary Archive is based on a petabyte tape library, currently equipped with over 300 tapes, each with a storage capacity of 0.5 TB. The Secondary Archive will store a second copy of the entire ESO archive contents at another physical location. The Compute Stack consists of blade systems with a maximum capacity of 132 CPUs. The Fast Cache provides 9 TB of extendable Fibre Channel disc-based storage. For the safe installation of the Primary Archive at different physical locations, ESO approved the plan to build an ESO Data, Computing and Operations Centre, to be completed in 2007.

Archive Database Content Management

The ESO science archive contains two kinds of information: the actual science data generated by various ESO telescopes as well as the HST, and metadata which describe these science data, e.g. what objects were observed, when they were observed, and how they were observed. These important descriptions are necessary to allow users to find and retrieve science data and data products from the Archive. The DFO Database Content Management (DBCM) group has responsibility for maintaining these metadata. This is not an easy task, with the landmark of two billion database entries being reached and surpassed in 2006!

In particular, DBCM implements metadata changes and updates following requests from various ESO operations groups or upon identification of erroneous entries. In addition, the DBCM group works closely with the DMO Virtual Observatory Systems (VOS) department to interface VOS services with the operational archive.



Structure of the ESO archive and its main components. Scheme by R. Höllmüller.

SN 2006X in the spiral galaxy M 100.

The European Virtual Observatory

The Virtual Observatory (VO) aims to allow users easy and seamless access to the huge amount of astronomical data currently available, to facilitate its exploitation and foster new science. The VO initiative is a global collaboration of the world's astronomical communities under the auspices of the International Virtual Observatory Alliance (IVOA). From the start, ESO has been very active in the VO arena, creating on 1 November 2004 a Virtual Observatory Systems (VOS) Department in the ESO Data Management and Operations Division. VOS' role is also to make the Science Archive Facility (SAF) a powerful scientific resource for the ESO community, and thereby ensure that ESO also plays a major role in the VO as a data provider.

ESO is a founding member of the EURO-VO project, whose aim is to deploy an operational VO in Europe. Besides ESO, initial partners include the European Space Agency (ESA), and six national funding agencies, with their respective VO nodes: *Istituto Nazionale di Astrofisica* (INAF, Italy), *Institut National des Sciences de l'Univers* (INSU, France), *Instituto Nacional de Técnica Aeroespacial* (INTA, Spain), *Nederlandse Onderzoeksschool voor Astronomie* (NOVA, Netherlands), the Particle Physics and Astronomy Research Council (PPARC, UK), and *Rat Deutscher Sternwarten* (RDS, Germany). EURO-VO has established three interlinked structures:

– the Data Centre Alliance (DCA), an alliance of European data centres which will populate the EURO-VO with data, provide the physical storage and computational fabric and which will publish data, metadata and services to the EURO-VO using VO technologies;
– the Facility Centre (VOFC), an organisation that provides the EURO-VO with a centralised registry for resources, standards and certification mechanisms as well as community support for VO technology take-up and dissemination and scientific programme support using VO technologies and resources; the VOFC is located at ESO and is managed by ESO and ESA;
– the Technology Centre (VOTC), a distributed organisation that coordinates a set of research and development projects on the advancement of VO technology, systems, and tools in response to scientific and community requirements.

The EURO-VO Science Advisory Committee (SAC) was put together in March 2006 to provide overall scientific input to the project. Two SAC meetings were held in 2006, the first on 27–28 April at ESO, the second on 22 November at ESRIN in Frascati, Italy. SAC members were introduced to the different aspects of the EURO-VO through various presentations and were updated on the latest EURO-VO developments and on the goals of the three EURO-VO substructures. The SAC then discussed some EURO-VO tools and a call for proposals to carry out astronomical research projects using VO tools.

New EURO-VO Web pages (*http://www.euro-vo.org*) were presented to the SAC at its first meeting, and opened to the public a week or so later. They contain, among other things, concrete examples for astronomers of what the VO can and cannot do for them at present, and links to VO software applications.

VOS was in charge of the organisation of the IVOA booth at the XXVIth General Assembly of the International Astronomical Union in Prague, on 14–25 August. VOS also coordinated the EURO-VO presence and demonstration and the work on the EURO-VO flier.

The first meeting of the board of the EURO-VO Data Centre Alliance (DCA) project, which has received funding of 1.5 M€ from the Sixth Framework Programme (FP6; Coordination Actions) of the European Community, took place on 2–3 October in Strasbourg. The DCA, which is made up of eight European astronomical organisations including ESO, is vital for the EURO-VO goal of making the VO a reality in Europe. The DCA project is currently funded for two years, with expected completion by September 2008. ESO's main role in the DCA is to organise, in collaboration with ESA, dedicated workshops to ensure the dissemination of technical knowledge necessary to implement VO-endorsed standards.

The VOTech project is a design study, which aims to complete the technical preparation for the construction of the EURO-VO. The project is funded at the 6.6 M€ level by FP6 and by the partners, which include ESO, the Universities of Edinburgh, Leicester, and Cambridge (UK), CNRS and Université Louis Pasteur (France), and INAF (Italy). The duration of the project is three years, with expected completion by the end of 2008. ESO has a strong role in the VOTech project as leader of the Design Study 4 on New User Tools, which aims to provide European astronomers with research tools integrated in, and fully compliant with, the VO. The project works in six-month cycles. Two planning meetings were held: on 6–9 March in Sorrento, Italy, and on 4–7 September in Strasbourg, France.

VOS maintains the Euro-VO project web site, which in 2006 served 77 GB of content resulting from 210 000 user sessions. VOS is also in charge of the IVOA project web site, which served 62 GB of web content resulting from 330 000 user sessions.

ST-ECF

ESO and the European Space Agency continued their successful collaboration through the Space Telescope European Coordinating Facility (ST-ECF).

The Hubble Space Telescope (HST) is currently in observing cycle 15, routinely achieving observing efficiencies between 45 and 50 per cent. It is performing nominally in two-gyro mode. As a precautionary measure, plans have been designed to test the HST in one-gyro mode. Science highlights include the mapping of dark energy in space and time, the observation of the earliest galaxies in the Universe, and the discovery of many planets around nearby stars. European participation continued to be well above the nominal 15 %.

Following directives from the ESA executive the ST-ECF reached a stable staffing level: seven ESA-funded positions and seven ESO-funded positions, corresponding exactly to the initial agreements between the two organisations, except that two of the staff members are now allocated to public outreach. The primary consequence of this staff rampdown was the discontinuation of the Advanced Calibration Project. It was possible to salvage some of the products of the group through an early partial delivery to the STScI. Moreover, two staff members of the former ST-ECF Advanced Calibration Group are now working for ESO, continuing this very successful effort, which, while initially developed for the HST spectrographs, works exceedingly well for the ESO ground-based instruments. In October, ESO and ESA decided to terminate the ST-ECF when the current Hubble ESA/NASA MoU expires at the end of 2010. The tasks of the group remain those agreed at the 2006 Annual Review.

The focus of the ST-ECF efforts was on Advanced Science Data Products: both the ACS and the NICMOS instruments on HST have integral-field spectroscopic capabilities. The data produced in these modes are complex to analyse and require techniques unfamiliar to most astronomers. ST-ECF has therefore begun to extract the spectra from the data frames and to calibrate them, with the aim of making them available to the community. This capability is also applicable to Wide Field Camera 3, one of the two new scientific instruments that will be installed on the HST during Servicing Mission 4.

The proposed mode of operation for the other instrument to be installed, the Cosmic Origins Spectrograph, will put a higher demand on the usage of the wavelength calibration lamps. The ST-ECF coordinated a NASA/ESA funded project that involved ESO, NIST, STScI and the COS team to evaluate the spectral characteristics and the life expectancy under these operating conditions.

The European HST Archive was migrated to the new ESO Archive infrastructure. The total holdings are now 547 000 data sets. During 2006, 41 426 data sets (2.9 TB) were distributed to 402 users. ST-ECF staff also assisted the STScI in the final reprocessing of the FOC and GHRS archives. In collaboration with the STScI and the CADC the Hubble Legacy Archive was initiated. The goal is to collect and generate selected High Level Science Data Products and make them available to the community.

User support continued through the Newsletter, the HST email hotline, and the production of technical documents. ST-ECF staff also monitored the TAC process and continued to support the ESO SAMPO Project. More recently, the editorship of the ESO Messenger was taken over by ST-ECF staff.
For the ST-ECF's task to disseminate the discoveries from Hubble to the public, 2006 has been the most successful year so far. Nineteen news and photo releases were produced (up 20 % from 2005). The European Hubble website had 2.8 million visitors (up 90 %) and distributed 36 TB of multimedia materials (up 65 %).

The ESA/ESO/NASA Photoshop FITS Liberator 2.1 was released. Several exhibitions were produced together with external organisations – perhaps most noteworthy was a part of the permanent exhibition in Armagh Planetarium. The Astronomy Visualisation Metadata standard (co-authored with Robert Hurt) was endorsed by the International Virtual Observatory Alliance.

The third ESA-ESO Bilateral meeting took place in Garching at the end of Octo ber. The third working group report – on Fundamental Cosmology by Peacock, Schneider *et al.* – was finished and distributed. The meeting addressed the recommendations of all three working groups and decided to continue both the bilateral meetings, which are essential for the coordination of science planning, and the series of topical working groups.

The former Instrument Advanced Calibration Group was selected by NASA to receive the "Group Achievement Award" for its work on high-fidelity calibration. The award, given at a ceremony at NASA Headquarters on 21 July to Paul Bristow, Florian Kerber and Michel Rosa, is shared with a three-member team from the US National Institute of Standards.

Artist's view of Servicing Mission 4 to Hubble. This Servicing Mission will not only ensure that Hubble can function for perhaps as much as another ten years, it will also increase its capabilities significantly in key areas. As part of the upgrade, two new scientific instruments will be installed: the Cosmic Origins Spectrograph and the Wide Field Camera 3.

ESA/Hubble

Open House at the ESO Headquarters on 15 October 2006.

Public Outreach

On all accounts, the year 2006 marked a record year in terms of Public Outreach activities by ESO. This growth is motivated by several factors, including
– the increase in the number of member states of ESO;
– the current and planned project portfolio, which foresees investments in the range of several hundreds of millions of Euros;
– the increased focus on the need to secure an adequate recruitment base, not just in the time to come, but also in today's labour market, which is characterised by stiff competition for the best people.

Furthermore the increased competition for public visibility and communication in general in today's society places strong demands on the quality of the communication efforts, not just in terms of contents but also with respect to delivery mechanisms. Other aspects such as timing and timeliness are of course of crucial importance in today's fast moving media world.

This has led us to pursue a particular strategy, which builds on technical autonomy, short communication lines within the organisation and an elaborate system of partnerships. For example, ESO has established a Science Outreach Network with representatives in all ESO member states. These 'ambassadors' perform an important interface function between the national media and ESO.

Of course, as in the previous years, many press releases are done in collaboration with national organisations (e.g. PPARC, MPE, CNRS, INAF), universities, the leading research journal *Astronomy & Astrophysics*, and other partners.

Obviously, the Public Affairs Department (PAD) works in close consultation and coordination with ESO's Santiago Representation, which conducts targeted outreach activities for Chile and provides logistical support to European media and high-level visitors.

PAD also works with ESO's sister organisation ESA, including the Hubble Europe Information Centre, sited in adjacent rooms to PAD. The cooperation involves sharing of information and technical facilities, wherever possible.

In the field of education, the European Association for Astronomy Education (EAAE) is a long-standing partner of ESO. The EAAE members help by spreading information about ESO in the schools, while at the same time they often provide didactic advice to PAD as it formulates and prepares its education activities.

The European Commission has become a major partner as well, not least in funding educational activities, which have come to be seen as representing substantial added value for Europe's societies and therefore enjoy significant political attention and goodwill.

Finally, the major education activities, such as *Science on Stage* and *Science in School*, are carried out within the framework of the EIROforum, the partnership of Europe's seven intergovernmental research organisations. The partnership enables a very successful pooling of resources and expertise and allows undertaking activities on a scale that would have been impossible for the individual organisations alone.

Media

In 2006, ESO issued a total number of 51 releases to the media, or roughly one release per week.

This number can be broken down into 39 'standard' press releases, including 26 about scientific results from observations with ESO telescopes, and 13 press photos. The press photos enjoy great popularity among the media and ensure a much increased visibility of ESO. Seven ESO images were selected as the Astronomy Picture of the Day in 2006 by the NASA website. This number is indicative of our potential for creating world-class astronomical images – a potential that with increased resources could be expanded significantly. The most appreciated image was certainly the new, stunning mosaic of the Tarantula Nebula (ESO Press Photo 50a/06), a 256 million pixel image obtained with the Wide-Field Imager on the 2.2-m telescope at La Silla. The image was voted amongst the ten best of 2006 by a very popular web site. Other successes were encountered particularly with images of galaxies, such as the topsy-turvy one (ESO Press Photo 43a/06) or the gigantic dusty potato crisp (ESO Press Photo 17/06), as well as those of the broken comet (ESO Press Photo 15a/06).

Among the most successful press releases, the prize goes without any doubt to the discovery through microlensing of a five-Earth-mass planet, a press release (ESO Science Release 03/06) that

Press conference on exoplanets at ESOF, Munich.

generated huge media attention worldwide. Other excellent results were obtained with the press releases on the VLT being equipped with a laser guide star (ESO Instrument Release 07/06), the discovery of a trio of Neptune-mass planets (ESO Science Release 18/06), the SINFONI observations of a very remote galaxy (ESO Science Release 31/06) and ESO's Council decision to go ahead with a design study for the European Extremely Large Telescope (ESO Organisation Release 46/06).

Other features which have been very much welcomed by the media are the increased use of captivating artistic imagery as an alternative way of explaining physical phenomena, and the provision of video footage that is directly linked to ESO press releases.

ESO stand in Paris, France.

With respect to broadcast support and video production, in 2006 we delivered an average of 11 minutes/day of footage to TV Channels worldwide, produced 1.5 seconds/day of high-end 3D animations on technical and scientific topics and 90 minutes of videos, including six video newsreels – the equivalent of a 15-minute full film production every two months. This resulted in some 75 registered broadcasts about ESO. The real number is likely to be significantly higher, since the use of ESO footage is often not reported to us.

Provision of high-quality material is clearly a prerequisite for winning the daily battle for visibility in the public sphere, but it is not enough. Exploiting a variety of diffusion channels and new communication tools are crucially important. Not surprisingly, much of this is linked to the world-wide web. For example, we now make broadcast material electronically available for download by TV channels, giving them the option of almost instant access to ESO news reels. Another aspect is the web-based public sphere. This has arguably emerged as one of the most important ways to reach young people in particular – beyond the classic media such as broadsheet newspapers and conventional TV. These new media include traditional web pages, blogs, pod-casts, vodcasts, and other emerging technologies sometimes described as 'Web 2.0'. PAD is taking steps to gain a foothold in this virtual world. A first experiment was done for the press release about the discovery of a five-Earth-mass exoplanet, when a podcast and a vodcast was provided. Vodcasts are also done in connection with Video newsreels, whenever possible.

The growing importance of the web and the speed with which it evolves, both technically and conceptually, creates new demands on web sites to remain up to date. Of course, ESO cannot turn its back on this development. Hence, a major effort has been undertaken during the year by PAD, in collaboration with other departments, to develop a new website for our organisation. This web site, which will serve as the point of entry into ESO for thousands of users every day will feature a much more attractive appearance, easier navigation and a major overhaul of the content. It is the intention to launch the new web site in the course of 2007.

The web is, of course, not just a diffusion channel, but also provides an important source of information regarding the public awareness of and interest in ESO's activities. Hence, the increased visibility of ESO in media is mirrored by the growth in traffic on the ESO Outreach site, which in 2006 has reached a mean number of almost 10 000 visitors/day, a factor of 2.3 increase from three years ago.

Exhibitions and Events

In spite of the undisputed importance of new distribution methods and tools, face-to-face communication of course remains of crucial value, particularly from the perspective of a coordinated communication effort. Exhibitions and events clearly provide excellent forums for exchange and communication with key target groups, such as scientists, media, industry and policymakers. In 2006, PAD organised or participated in more than 20 events, involving exhibitions, briefings and VIP visits – in other words roughly an event every 2 ½ weeks. This constitutes a significant increase over the previous years, both illustrating the growing importance and visibility of ESO, but also the necessity to enlist wide support for ESO's ambitious future projects. For example, on 2 February, PAD in collaboration with PPARC organised a very successful press event in London in connection with this year's AstroFest at Kensington Town Hall. The event was a briefing about ESO in general and also served as a 'primer' to a subsequent visit to ESO's sites in Chile by a group of UK journalists. About 15 journalists attended this meeting. Just 11 days hence, a major press event took place in Madrid on the occasion of the signing of the agreement aimed at bringing Spain into ESO. Only 10 days later, we took part at the AAAS meeting in Saint Louis, Missouri. The AAAS is the world's largest forum for science and media contacts, and our presence at such an event not only supports ESO's visibility in the USA but also in Europe, since the meetings attract large numbers of European journalists. The AAAS exhibition stand was subsequently transferred to and assembled at the SPIE conference in Orlando, Florida, in May. ESO was very strongly represented at this meeting, illustrating that our organisation has become a global actor in the field of astronomy.

Back in Europe, we had a major information stand at the year's *Salon de la Recherche et de l'Innovation* in Paris in June and, in the context of the EIROforum partnership, at the ESOF 2006 Conference in Munich. At ESOF we also held a press event about exoplanet research. In August, at the XXVIth General Assembly of the International Astronomical Union in Prague, PAD set up a 60 square metre exhibition for ESO and a somewhat smaller one, on behalf of ALMA.

The last press event of the year took place in connection with the ELT conference in Marseille in late November. The event was co-organised by PAD and INSU, and resulted in many media reports, including ones in all major French newspapers – *Libération* devoting three full pages to the story – and also, for example, on German radio.

The last exhibition took place in Dublin at the beginning of December. ESO participated as the 'guest of honour' at the Astro-Expo 2006 event, organised at the Dublin City University (DCU) by the Irish *Astronomy and Space* magazine.

Education

One of ESO's major education activities for pupils is the popular *Catch a Star!* contest, carried out in close collaboration with the EAAE. Students work in teams or individually, learning about an astronomical topic and writing a report. During 2006 we saw the conclusion of the fourth iteration of the competition. The contest is evolving, with its division into three categories. As an important aim is simply to encourage an interest in astronomy, and because we wish to avoid a sense of elitism, some of the winning projects were decided by lottery. Nevertheless, to cater for particularly talented students who may be budding astronomers, there were also major prizes to be won. These prizes, including a trip to the VLT on Paranal, were awarded by an international jury. Furthermore, a drawing competition category was introduced, following the success of a similar competition as part of the Venus Transit 2004 activities. For the first time, the contest was also opened to countries beyond Europe and Chile. We received a total of 134 written projects and 60 pieces of artwork from 24 countries across Europe and beyond, with about 400 students and teachers taking part.

In November 2006 *Catch a Star! 2007*, was launched (so named because this competition will conclude in 2007). Building on lessons learned in the previous competition, its structure was streamlined to make it easier to enter, and the web-based infrastructure for administering it at ESO was greatly improved. The differentiation in categories has been retained with *Catch a Star! Artists*, *Catch a Star! Adventurers* and *Catch a Star! Researchers*.

Over the years, ESO has supported the EAAE summer schools for astronomy teachers in a number of ways, e.g. by providing speakers and taking care of proceedings. This was also the case in 2006, where the summer school took place on the island of La Palma. Next year, however, the summer school will change format and scope, and will be hosted by ESO. The intention is to foster a stronger interaction between teachers and active scientists and to bring real science into the classrooms. Towards the end of the year, preparations for this event were underway.

Similar thoughts underpin the wider, targeted effort to stimulate original, attractive high-quality science teaching in Europe's secondary schools, known as the EIROforum European Science Teachers' Initiative (ESTI), in which ESO is an active partner. With its twin pillars, *Science on Stage* and *Science in School*, ESTI is a unique activity in the world. In the teaching world it constitutes a completely innovative approach with a focus on excellence, market mechanisms, interdisciplinarity combined with direct links between teachers and active scientists and, finally, cross-border collaboration on a big scale. The most recent *Science on Stage* Festival, with about 500 participants from more than 25 countries, took place at CERN in November 2005; the next one is scheduled for Easter 2007.

Throughout 2006, staff members of the EIROforum organisations, including those at ESO, supported and participated in the many national events that took place in 29 countries to select the participants to the European festival. In March 2006 the first issue of *Science in School* was launched. *Science in School* is a new European science education journal for teachers, scientists, and others. Issues include teaching material, articles about cutting-edge science, interviews, and reviews. ESO is strongly involved with the journal, contributing astronomy-related articles and participating in the editorial board.

Videoconference with Paranal on the main square of Munich, *Marienplatz*, Germany, during the annual German *Wissenschaftssommer*.

ESO Press Releases

ESO Press Photo 01/06 (3 January): ESO PR Highlights in 2005
ESO 02/06 Science Release (4 January): Measuring the Size of a Small, Frost World
ESO Science Release 03/06 (25 January): It's Far, It's Small, It's Cool: It's an Icy Exoplanet!
ESO Press Photo 04/06 (7 February): How to Steal a Million Stars?
ESO Organisation News 05/06 (13 February): Spain to Join ESO
ESO Science Release 06/06 (15 February): The Invisible Galaxies That Could Not Hide
ESO Instrument Release 07/06 (23 February): Man-made Star Shines in the Southern Sky
ESO Press Photo 08/06 (23 February): A Blast To Chase
ESO Science release 09/06 (28 February): Cepheids and their 'Cocoons'
ESO Science release 10/06 (15 March): The Cosmic Dance of Distant Galaxies
ESO Science release 11/06 (22 March): The Sun's New Exotic Neighbour
ESO EIROforum release 12/06 (28 March): Bringing Science out of the Lab into the Classroom
ESO Press Photo 13/06 (7 April): Cosmic Spider is Good Mother
ESO Press Photo 14/06 (14 April): The Great Easter Egg Hunt: The Void's Incredible Richness
ESO Press Photo 15/06 (25 April): The Comet With a Broken Heart
ESO Science Release 16/06 (8 May): Physics in Universe's Youth
ESO Press Photo 17/06 (11 May): Twin Explosions In Gigantic Dusty Potato Crisp
ESO Science Release 18/06 (18 May): Trio of Neptunes and their Belt
ESO Science Release 19/06 (6 June): Do 'Planemos' Have Progeny?
ESO Press Photo 20/06 (8 June): The Toucan's Diamond
ESO Organisation News 21/06 (19 June): ESO and Chile: 10 Years of Productive Scientific Collaboration
ESO Press Photo 22/06 (28 June): The Hooked Galaxy
ESO Science Release 23/06 (3 July): Falling Onto the Dark
ESO Instrument Release 24/06 (13 July): Sub-millimetre Astronomy in Full Swing on Southern Skies
ESO Organisation Release 25/06 (18 July): Towards a European Extremely Large Telescope
ESO Science Release 26/06 (21 July): Looking Deep with Infrared Eyes
ESO Press Photo 27/06 (26 July): Island Universes with a Twist
ESO Science Release 28/06 (3 August): A Sub-Stellar Jonah
ESO Science Release 29/06 (4 August): The 'Planemo' Twins
ESO Science Release 30/06 (10 August): Stars Too Old to be Trusted?
ESO Science Release 31/06 (17 August): Far Away Galaxy Under The Microscope
ESO Organisation Release 32/06 (24 August): Catherine Cesarsky elected President of the International Astronomical Union and Ian Corbett elected Assistant General Secretary
ESO Science Release 33/06 (31 August): Long-lasting but Dim Brethren of Cosmic Flashes
ESO Science Release 34/06 (12 September): A "Genetic Study" of the Galaxy
ESO Science Release 35/06 (20 September): To Be or Not to Be: Is It All About Spinning?
ESO Science Release 36/06 (28 September): Watching How Planets Form
ESO Science Release 37/06 (2 October): Stellar Vampires Unmasked
ESO Science Release 38/06 (4 October): Increasing the Odds of the Sweep
ESO Science Release 39/06 (19 October): The Star, the Dwarf and the Planet
ESO 40/06 (22 October) - Organisation News: Extremely Large Telescope Project Selected in ESFRI Roadmap
ESO Science Release 41/06 (7 November): Cut from Different Cloth
ESO Organisation News 42/06 (12 November): Catch a Star!
ESO Press Photo 43/06 (11 November): The Topsy-Turvy Galaxy
ESO Science Release 44/06 (30 November): Asymmetric Ashes
ESO Science Release 45/06 (6 December): Do Galaxies Follow Darwinian Evolution?
ESO Organisation Release 46/06 (11 December): The Rise of a Giant
ESO EIROforum Release 47/06 (14 December): Magna Carta for Researchers
ESO Press Photo 48/06 (20 December): It Is Too Early To Be Santa's Sleigh, Isn't It?
ESO Science Release 49/06 (20 December): The Dark Side of Nature: the Crime was Almost Perfect
ESO Press Photo 50/06 (21 December): Portrait of a Dramatic Stellar Crib
ESO Press Photo 51/06 (22 December): Little Brother Joins the Large Family
ESO Organisation Release 52/06 (22 December): Czech Republic to Become Member of ESO
ESO Press Photo 53/06 (24 December): Season's Greetings!

The starburst galaxy NGC 908 (FORS/VLT).

Relations with Chile

The year 2006 marked an important anniversary: a decade of the Supplementary Agreement between the Republic of Chile and ESO, which has allowed the successful installation of the VLT at Paranal and strengthened the cooperative relations between ESO and the Chilean scientific and local communities. To celebrate this, rectors of Chilean universities and representatives of the Chilean Ministry of Foreign Affairs gathered at the ESO offices in Santiago to launch a commemorative book, "10 Years Exploring the Universe". This publication presented an external, independent overview of the broad impact of the ESO–Government of Chile Joint Committee, an annual fund for the development of astrophysics and scientific culture in the country, which was established by the Supplementary Agreement.

In January 2006, Dr. Michelle Bachelet became the first woman in the history of Chile to be elected President of the Republic. One of the first international events in which the new government participated was the opening of the 2006 International Air and Space Fair, held in Santiago in March. There, more than 150 000 people visited the Space & Astronomy Pavilion, which presented realistic scale models of the VLT, ALMA and the E-ELT as well as a collection of most impressive astronomical pictures. The exhibition in the Pavilion was organised by ESO Santiago and the *Planetario USACH*.

As a step forward in the well-established ESO astronomical outreach programmes in Chile, a new strategic partnership was launched with the Chilean Ministry of Education to improve the teaching of astronomy in primary schools, within the framework of a national programme called "Science Education Based on Research". ESO staff astronomers worked in collaboration with education specialists to design a learning module on basic astronomy, which is currently being tested by the Ministry of Education in pilot schools in Santiago and cities close to the observatory sites.

Another new initiative promoted by ESO, in a joint effort with the French Embassy in Chile, was the organisation of the first *Cafés Scientifiques*, in which adults and youngsters could freely ask questions of specialists while enjoying an informal café atmosphere. Inspirational issues like exoplanets and the possibility of life in the Universe attracted the interest of many in Santiago and Antofagasta.

The *Universidad Católica del Norte* Astronomy Institute, in partnership with ESO Vitacura, continued an extensive programme of public lectures and star parties in Antofagasta, Taltal and San Pedro de Atacama, the closest neighbours to Paranal and the ALMA site. Also in Chile's Region II, ESO supported partial scholarships of 170 undergraduates studying at regional universities, in a joint programme with the Municipality of Taltal. Near La Silla, the educational agreement with the Municipality of La Higuera entered its second year of cooperative work to support local schools.

ESO also played an active role in the Chilean National Science and Technology week, in partnership with the "Explora" Programme of CONICYT. Enthusiastic young students and teachers visited the ESO stand at the recently opened Biblioteca de Santiago, and more than 300 schools received copies of a new documentary produced in-house about recent science highlights obtained at La Silla and Paranal.

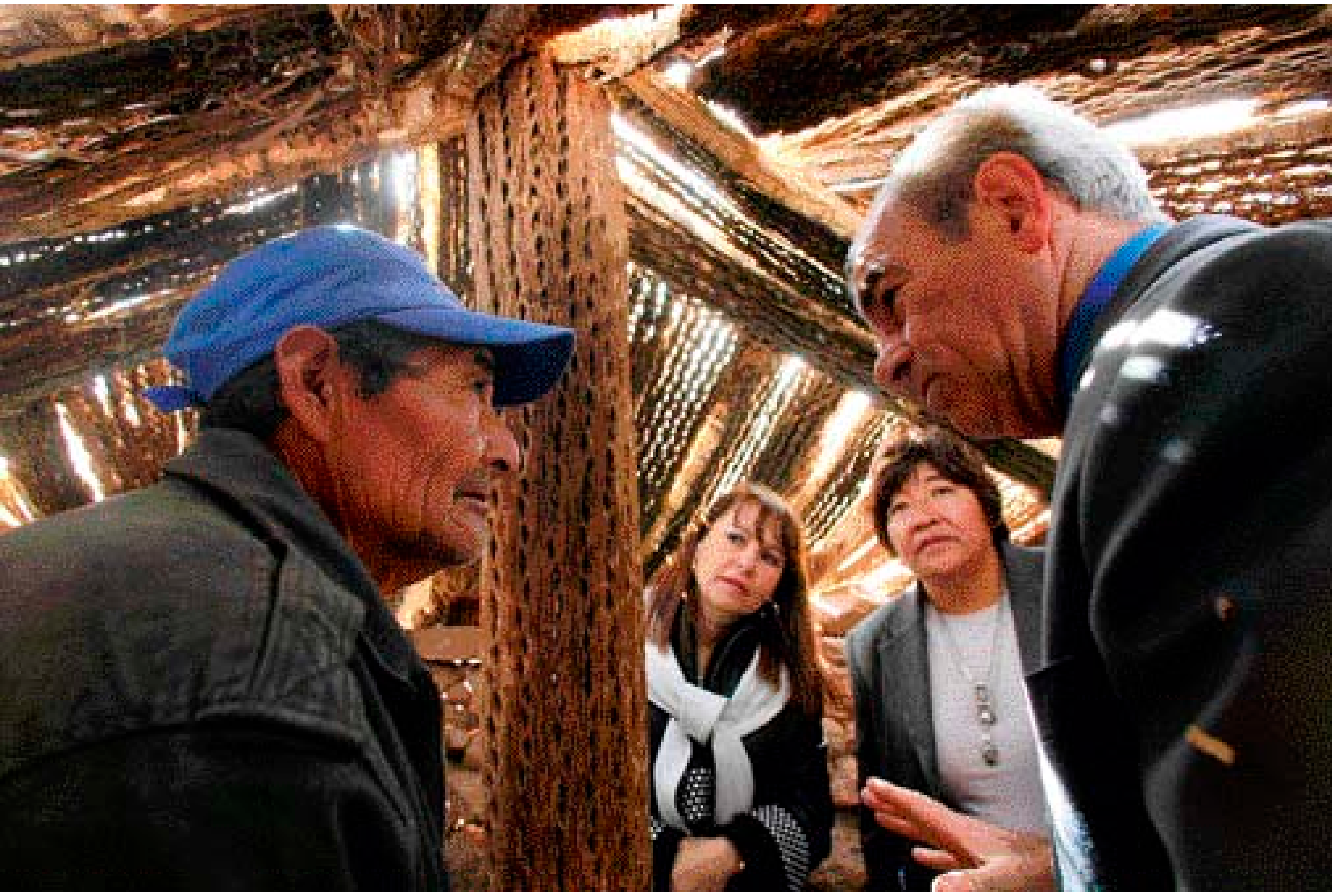
In the framework of ALMA, the regional fund financed by ESO, AUI and NAOJ supported several social and educational projects in San Pedro de Atacama and Toconao in 2006. The only primary school in the village of San Pedro de Atacama has, in particular, increased its regular staff of teachers thanks to this fund.

Besides this, ALMA is contributing to other areas of education and culture. A site museum located near the ALMA road was inaugurated in 2006, in the presence of the *Intendenta* of Region II, the Mayor of San Pedro de Atacama, and members of the local communities. The site museum – in the form of a reconstruction of an abandoned *estancia* – provides physical evidence of the way of life of shepherds from the ancient *Likan Antai* culture. In order to support the understanding and protection of the archaeological heritage in the area, a book edited by ESO, "Footprints in the Desert", was published and distributed among all schools of Region II, teachers, and regional authorities.

In partnership with ESO and ALMA, the University of Antofagasta and University of Chile, in collaboration with the University of Copenhagen, launched a joint research programme on high-altitude medicine, taking advantage of the operations on the Chajnantor plateau at 5 050 metres above sea level. For the very first time, scientists will have systematic, detailed statistics on the long-term reaction of the human body to regular commuting between sea level and high sites. This information will help to solve some intriguing, open questions of human physiology and high-altitude illness.

Continuing our promotion of scientific interaction with the Chilean community, ESO held joint open houses with the Astronomy Department at the *Pontificia Universidad Católica* and *Universidad de Chile* with the participation of about 60 young researchers in each of the events. ESO Santiago also sponsored the international conference on Globular Clusters organised by Universidad de Concepción in March, and the Fourth Advanced Chilean School of Astrophysics organised by the Pontificia Universidad Católica de Chile in December.

Several delegations from Europe and all over the world were hosted in Santiago and the observatories, in particular three delegations from China, including that of the Vice-President of the Academy of Sciences. All scientific delegations gave informative seminars on science and technology in their countries.



Inaugurating the ALMA site museum.

Launch of the "10 Years Exploring the Universe" book.

ESO at the 2006 International Air and Space Fair.

European Affairs

European Affairs at ESO is coordinated by the Public Affairs Department, but frequently involves several other departments within the organisation as well as external partners, notably the EIROforum. European Affairs focuses on EU-related policy aspects of relevance to ESO. These can manifest themselves in many ways, which has increased the scope of ESO's EU-related activities in recent years. This development is in line with the overall changes in Europe as European integration progresses. Hence, our activities are not necessarily limited to direct interaction with the primary institutions of the European Union, such as the European Commission and the European Parliament. The main conceptual frame within which this development follows is the European Research Area.

The end of 2006 marked the termination of the EU Sixth R&D Framework Programme (FP6) and the new Seventh Framework Programme (FP7) was launched at the beginning of 2007.

ESO's FP6 participation can be judged as very positive and successful, both because it has allowed us to carry out projects that could not have been funded otherwise, and as a vehicle for a more general interaction with the EU at a time when the Union is emerging as a new, but potentially important actor in the field of setting European science policy. In this sense, the activities deserve continuation in the context of FP7. Currently ESO still has 11 running FP6 projects, most of which will terminate in 2008. From the running FP6 projects the E-ELT preparatory-phase, the ESTI project and the VO project are already aiming for continuation in FP7.

Obviously, the preparation of the Seventh Framework Programme played an important role in 2006. From ESO's perspective, the challenge has been to be able to deal with the first FP7 calls, which were launched by the Commission in December 2006. The complications of this were linked to the preceding legislative process, which meant that many important details still remained unclear by the end of the year. Other issues were not subject to the direct political process, but nonetheless remained important. This was the case for the E-ELT project, which became included in the so-called ESFRI-list that was published by the European Strategy Forum for Research Infrastructures (ESFRI) in October 2006. The ESFRI-list is a 'road-map' describing 35 major research infrastructure projects that are deemed to be "Research Infrastructures of European interest" (from the Competitiveness Council Conclusions, 25–26 November 2004), and thus pre-qualify for potential co-funding, however limited, from the Seventh Framework Programme. Furthermore, EU member states were encouraged to develop national roadmaps that are aligned with the ESFRI-list, in order to determine funding priorities.

ESFRI was tasked with developing a long-term European view of the development of Research Infrastructures of pan-European interest, covering a wide range of sciences. In the meantime, another activity took place, focusing on Astronomy and Space Sciences. This occurred under the auspices of ASTRONET (*http://www.astronet-eu.org/*), a network comprising national funding agencies and ESO (with ESA as an observer), which was set up under the FP6 ERA-net scheme. ESO's main responsibility in the ASTRO-NET programme is to coordinate the development of a common Science Vision for European Astronomy in the next 20 years, with NWO in charge of collating the scientific content from the community. To prepare for this development and the follow-up construction in 2007–2008 of a prioritised Infrastructure Roadmap under the responsibility of PPARC, a web-based census tool has been developed by ESO. It currently contains all available European national prospectives and a comprehensive list of existing and planned medium- to large-scale infrastructures. The activity picked up much momentum in the autumn of 2006 with the preparation for a dedicated symposium scheduled to take place towards the end of January 2007 in Poitiers to discuss and refine the draft Science Vision released by NWO by mid-December 2006.

ESO Council member Jean-Pierre Swings at the Walloon Space Days.

As mentioned, ESO's European Affairs activities are linked to basic policy changes in Europe that have a bearing on many parts of society. Since these changes are a result of constant negotiation between stakeholders at the European and national levels, our activities must also be of a broad nature and involve contacts with decision-takers beyond the EU system.

Thus, on 15 March, ESO was pleased to host the Education Committee of the Finnish Parliament, an event which created a fine opportunity for dialogue between ESO and national policy-makers as well as a chance to present ESO's future plans. Further visits by diplomatic representatives of the UK and Switzerland occurred in the spring. On 28–29 March, ESO played a major role in the First Walloon Space Days, organised by the Walloon Space Cluster and intended to become a recurring event focusing on technologies for astronomy and space sciences, including R&D policy issues. The event coincided with the delivery of the fourth Auxiliary Telescope for the VLTI and provided a forum for European companies to meet with ESO experts.

Visit by the Education Committee of the Finnish Parliament.

In November, we welcomed to Paranal a high-ranking delegation from the Academy of Sciences of the Czech Republic (CAS), led by its President, Václav Pačes, and Jan Palouš, responsible for international relations of the CAS. The visit was related to the negotiations regarding the Czech Republic's membership of ESO. In December these negotiations were successfully concluded with the approval both of the ESO Council and the Czech government, paving the way for the signing of the agreement on 22 December and enabling the parliamentary ratification procedure to be initiated. Whilst a Czech accession to the ESO Convention is not in itself of formal institutional EU relevance, it may open possibilities with respect to EU funding for national Czech activities that follow in the wake of the membership – illustrating the complexities, but also the importance, of ESO's European Affairs activities.

Finally, within the EIROforum partnership, three events deserve particular mention. On 15 November, a brainstorming session was organised between the EIROforum Directors General and key Commission officials to discuss long-term perspectives for the European Research Area.

On 22 November, EIROforum organised a 'Breakfast Event' at the European Parliament on the topic "Fostering Scientific Understanding Among Young People – Reinforcing scientific education initiatives in Europe". The event was hosted by Prof. Jerzy Buzek MEP, and attended by more than 10 MEPs and a further 20 people from the European Parliament.

On 13 December, a get-together was organised between senior staff from the EIROforum partner organisations and research attachés of the permanent representations of the EU member states. The topic for discussion was how to achieve synergies between the activities of the intergovernmental research organisations and the EU-based actions as conducted through the Framework Programme.

In 2006, the Research Directorate General of the Commission established a dedicated unit to facilitate contacts with the European Intergovernmental Research Organisations. This is clearly an expression of the intensification of the interactions between the EC and the EIROforum in relation to both project funding and policy-related interactions.

Delegation from the Czech Academy of Science visits Paranal.

The ESO Council in session on 6 December 2006.

Council

The Council is ESO's ruling body, which delegates day-to-day responsibility to the Executive under ESO's Director General. In 2006, Council held two ordinary meetings, both in Garching. Committee of Council met three times, in February in Berne, Switzerland, in September in Santiago, Chile, and in October in Munich. The President of Council, Prof. Richard Wade, chaired all the meetings.

In 2006, Council approved the extension of the agreement for APEX until 2012, the agreements for the instrument SPHERE, and the agreement for a fourth star-separator for the VLT, including the proposed guaranteed observing time, in accordance with the standing rules.

Council received the usual VLT/VLTI, Instrumentation and ALMA biannual reports, and the reports from the Chairs of the Finance Committee, the Scientific Technical Committee, and Observing Programmes Committee. Council also endorsed the document "ESO Medium Range Implementation Plan, 2006–2010" and examined the document "ESO Future Perspectives, 2006–2032".

In December, Council adopted a resolution authorising the move of the E-ELT project, based on the innovative five-mirror design, to Phase B (detailed design) and requested the Executive to provide a detailed work plan by early 2007.

Council had been kept informed about the developments in the negotiations with the Czech Republic, and at its meeting in December adopted the necessary resolutions on the accession of the Czech Republic to ESO as the 13th member state from 1 January 2007.

The issue of a new Headquarters building in Garching was still of concern. However, progress in obtaining the necessary land could be reported, and Council agreed to give the Executive freedom to pursue the most cost-effective solution, including the option of purchasing the land.

Council dealt with various other issues and approved the schedule and terms of reference for the visiting committee. The visiting committee will come to the sites in Chile and the Headquarters in Garching in early 2007. New terms of reference for the Finance Committee were also approved and the working group which had been chaired by Dr. Finn Karlsson was discharged. Council agreed on a new remit and membership of the Scientific Strategy Working Group. The Working Group will meet again in early 2007.

At the meeting in December, Prof. Richard Wade was re-elected President of Council for 2007 and Dr. Monnik Desmeth was re-elected Vice-President. Ms. Rowena Sirey was re-appointed Chair of the Finance Committee for 2007. Dr. Simon Morris was appointed Chair of the Observing Programmes Committee for 2007 and Dr. Svetlana Berdyugina was appointed Vice-Chair.

Dr. Monnik Desmeth was appointed Assessor to the ALMA Board for 2007. The President of Council and the Director General are members ex officio.

Council set up an ELT Standing Review Committee and appointed Prof. Roger Davies as its Chair. This Committee met twice in 2006 and subsequently reported to Council.

The Scientific Strategy Working Group met twice during 2006. In January it met with three representatives of the European Square Kilometre Array (SKA) Consortium and the initial findings were reported on at the meeting of Committee of Council in February. The working group met again in April and presented an interim report to the Council at its meeting in June. Council requested the working group to elaborate on some of the scenarios included in the interim report and to look into related European Union issues. In addition, it was decided to organise a meeting of the Council members representing the funding agencies.

Council and Committee of Council 2006

President	Richard Wade
Belgium	Monnik Desmeth Jean-Pierre Swings
Denmark	Jens Viggo Clausen Henrik Grage
Finland	Kalevi Mattila Pentti Pulkkinen
France	Philippe Barré (until November 2006) Julien Galabru (as of November 2006) Laurent Vigroux
Germany	Ralf Bender Andreas Drechsler
Italy	Vicenzo Dovì Bruno Marano
The Netherlands	P. Tim De Zeeuw (until September 2006) Piet C. van der Kruit (as of September 2006) Jan A. C. van de Donk
Portugal	Fernando Bello Teresa Lago
Sweden	Claes Fransson Finn Karlsson
Switzerland	Michel Mayor Martin Steinacher
United Kingdom	Gerry Gilmore Rowena Sirey

The ESO Tripartite Group, chaired by Dr. Ugo Sessi, met in Garching in April and in October. The issue of the CERN Pension Fund continued to be a very important topic. Among the other discussion points were the changes to the regulations regarding cost-of-living adjustment, expatriation allowance, and regarding family/spouse and related leave. The Tripartite Group received information concerning the and the collective bargaining for local staff in Chile.

The Scientific Technical Committee

The Scientific Technical Committee 2006

José Afonso (P)
Willy Benz (CH)
Joris Blommaert (B)
Jean-Gabriel Cuby (F)
Raffaele Gratton (I)
Lauri Haikala (FIN)
Thomas Michael Herbst (D)
Richard Hills (UK)
Hans Kjeldsen (DK)
Yannick Mellier (F)
Dante Minniti (RCH)
Goran Olofsson (SE)
Patrick Roche (UK)
(Chair for first meeting in 2006)
Linda Tacconi (D)
(Chair as of second meeting in 2006)
Leonardo Testi (I)
Huib Jan van Langevelde (NL)

Dr. Artemio Herrero participated in the meetings as the representative of Spain, first as an observer, and then as the interim Spanish member of the committee. Due to personal reasons, Dr. Ikka Tuominen resigned from the committee and in the interim was replaced by Dr. Juhani Huovelin.

2006 was an extremely busy year for the Scientific Technical Committee (STC), in particular in relation to the European Extremely Large Telescope (E-ELT). In addition to the two regular meetings (62nd and 64th) in April and October, STC met for two extra one-day sessions in May and November. In order to cope with the wide range of technical projects currently going on at ESO, STC appointed two additional sub-panels which, in addition to members of the committee, incorporate experts from the community. These are the ELT Science and Engineering (ESE) sub-panel and the Very Large Telescope Interferometer (VLTI) sub-panel. Together with the ALMA European Science Advisory Committee (ESAC), these three panels advise STC in all matters related to these important components of the ESO programme.

STC 62nd Meeting

At its 61st meeting, STC had encouraged ESO to explore ways of achieving the goal of a large, deep, multi-colour survey, which would be substantially deeper than the multipurpose Sloan Digital Sky Survey whilst also tackling the nature of dark energy. A detailed report about achieving this goal with the two VLT survey telescopes (VST and VISTA) was presented at the 62nd meeting that took place on 6 and 7 April. Recognising that VST and VISTA have the potential to play a leading role in investigating some of the major current astronomical questions such as the nature of dark energy, STC encouraged the Director General to find ways of maximising the fraction of time that these telescopes will dedicate to public surveys. In particular, STC suggested that the OPC should award only up to 15 % of the available ESO time with these telescopes to PI projects (down from the 25 % foreseen originally), and that this fraction should be considered in scientific competition with the public surveys such that any unallocated time should be returned to public surveys.

A full report by the Director of the La Silla Paranal Observatory on the activities of the Interferometry Task Force (ITF) was presented at the meeting. STC was "enormously impressed by the heroic efforts" of the ITF that found solutions to many of the issues which were limiting the performance of the VLTI. STC congratulated ITF and Paranal for these achievements, and in particular for demonstrating fringe tracking with FINITO and the Auxiliary Telescopes.

Following the recommendations at the 60th meeting of STC, proposals for Phase A studies for three second-generation VLTI instruments were presented to the committee: MATISSE, VSI (a merging of VITRUV and BOBCAT), and GRAVITY. Reassured by the progress in understanding the performance of the VLTI infrastructure reported at the meeting, STC made the following recommendations regarding second-generation VLTI instruments:

1. The three consortia should proceed with Phase A studies for second-generation instruments.
2. ESO should issue a draft Interface Control Document (ICD) reflecting the current state of knowledge of the VLTI system, which should be updated during these Phase A studies as ITF further defines the VLTI performance.
3. Phase A studies should proceed on timescales consistent with the ITF investigations. At the end of these studies, and following the review of the Phase A instrument studies, a new definition of the VLTI mission and a new ICD will be put in place.

Extraordinary STC 63rd meeting

Another STC meeting took place on 11 May. The need for this extraordinary meeting was dictated by the fast pace of the E-ELT project established by Council in December 2005. Extensive reports by the five ELT working groups and by the Core ELT Science and Engineering (Core-ESE) working group were presented at the meeting. STC welcomed these reports and congratulated the committees for the "admirable job of investigating potential telescope design and adaptive optics solutions". STC recommended to develop an operational model for the E-ELT, which will inform telescope and instrument design options. The committee also recommended that the highest priority of the ESE should be to define, together with ESO and the community, "the key science and technology that Europe will want to pursue". STC emphasised that the combination of the E-ELT and the VLT will be unparalleled in the world, and recommended ESO to devote a significant effort to identify the science cases that would uniquely utilise both the E-ELT and the VLT.

A very important item of the agenda was the nomination of the ESE committee that would take over from the Core-ESE as a sub-panel advising STC in all matters related to the E-ELT project. The STC endorsed ESO's proposal that the members of the Core-ESE continue to serve in the ESE, and thus formally nominated Daniel Enard (France), Roland Gredel (Germany), Colin Cunningham (UK), Gerard Rousset (France), Marijn Franx (the Netherlands), and Isobel Hook

(UK) as members of the ESE. As STC members of the ESE, STC nominated Jean-Gabriel Cuby (France), Raffaele Gratton (Italy), Thomas Herbst (Germany), and Göran Olofsson (Sweden). To complete the committee, STC proposed names of experienced astronomers from the community at large. STC also appointed Daniel Enard as Chair and Thomas Herbst as co-Chair.

STC 64th meeting

ESO received a partnership offer to participate in the Large Synoptic Survey Telescope (LSST) project, which was presented to STC for advice at its 64th meeting on 23 and 24 October. While STC recognised the enormous scientific potential of LSST, it also recognised that the financial impact of such partnership would stress ESO, given the on-going developments for the E-ELT, ALMA, VLTI, and the VLT. Therefore STC recommended the creation of a small working group of ESO and STC members to further explore and identify viable options for an ESO LSST collaboration, and indicated the terms of reference for this group. STC proposed Yannick Mellier and Artemio Herrero as members of the group with Dante Minniti as an alternative. For ESO the members are Bruno Leibundgut and Paolo Padovani.

Following a presentation of the status of the APEX project, and the request of the partners to extend the APEX agreement until the end of 2012, STC, encouraged by the recent progress on commissioning APEX instruments, and recognising the potential unique nature of this facility in the Southern Hemisphere, unanimously agreed that ESO should extend the APEX agreement as proposed. STC also strongly supported the development and expansion of APEX/ALMA synergies, and in particular, the development of surveys using the APEX instruments to provide targets for ALMA (as well as for the VLT and even the E-ELT).

The STC endorsed the ESAC recommendations concerning the enhanced capabilities for Early Science operations of ALMA, and the optimisation of the time allocation process by having a single international Time Allocation Committee. The ESAC also recommended names to replace two of its members whose terms expire at the end of 2006 and early 2007. STC also recommended that, given their expertise in sub-millimetric systems, the ESAC should also be the forum where APEX matters could be discussed.

Concerning the E-ELT development, STC fully endorsed the recommendations of the ESE concerning the importance of retaining nine science cases for the Design Reference Mission (DRM) and that three demonstrator science cases be selected in the early evaluation by ESO. The ESE also made a number of technical and organisational recommendations including a request for a detailed plan for instrument development and selection, and an organisation chart of the E-ELT effort within ESO. The ESE lauded the efforts of the E-ELT Project Office in rapidly advancing in the study of both the five-mirror and the Gregorian optical designs, and recommended that the project office continue contacts to understand the potential of segmented secondaries.

The VLTI sub-committee met for the first time in September 2006. While recognising the progress made in some areas, especially by the ITF, and that the resources required for VLTI are both adequate and necessary, the sub-panel recommended that the ITF be maintained and even strengthened with the addition of one or two persons. The sub-panel considered that the development of an AMBER data reduction package within the framework of the SAMPO project in the Data Management Division (DMD) is an asset to the VLTI that should be extended to all VLTI instruments. The members of the sub-committee were impressed by the progress on PRIMA and, while recognising that PRIMA is well on track, recommended that the project establishes contacts with the VLBI community since they have experience in solving similar technical problems. These and other technical recommendations made by the sub-panel were endorsed by STC, especially the recommendation of maintaining the ITF effort.

Extraordinary STC 65th meeting

Developments of the E-ELT and their related impact on ESO's Medium Range Implementation Plan (MRIP) prompted a special meeting of the STC, on 23 November, to discuss these developments and make related recommendations prior to the December meeting of Council.

Noting that the highest priority components of the ESO programme, and especially the Phase B of the E-ELT project, are included in the document, STC endorsed the MRIP presented by ESO. It took note of the fact that the MRIP does not include initiatives for a next-generation deep-sky survey. STC also discussed the document on Long Term Perspectives (LTP) and noted that it does not include funding for the La Silla Observatory beyond 2010, indicating that the scientific impact of this will be evaluated in 2007. STC emphasised the requirement to deliver the E-ELT on a competitive timescale, and encouraged Council to seek extra funds to make this a reality. STC reaffirmed that the scientific importance of the VLT and ALMA will not wane in the era of the E-ELT, and stressed that it will be critical to maintain these facilities as world-class even then.

At the meeting, the E-ELT Project Office presented STC with comprehensive information on the E-ELT Basic Reference Design, including a detailed analysis of the pros and cons of the Gregorian and five-mirror designs. On the basis of the evidence acquired from within ESO and from industry so far, STC was convinced that there are no showstoppers for the five-mirror option, which they considered would be the most ambitious project that ESO had thus far endeavoured to undertake.

The ESE held a special meeting after the E-ELT conference in Marseille, France, during which it essentially confirmed the statements made by STC. In particular, the ESE considered that a 42-m aperture is a good balance between very ambitious scientific goals, risks, cost, and schedule, and recommended to adopt the nominal 42-m aperture for the E-ELT.

Considering that the Gregorian design bears as a single high-risk item the large secondary mirror, for which there is no mitigation, the ESE recommended that ESO and its governing bodies adopt the 42-m five-mirror concept as the E-ELT project baseline and that the project proceeds to Phase B as soon as possible. STC fully endorsed the recommendations of the ESE.

A report on the status of the VST was presented at the meeting. Gianpaolo Vettolani, representing INAF, assured STC that INAF was working together with ESO to enable as quickly as possible the start of scientific operations of VST on Paranal. STC recommended that ESO engage fully in the critical design review of the primary and secondary mirror supports that will take place in early 2007, and requested that STC be represented at the review. Noting that the delay in VST is impacting key components of ESO's scientific programme, and that completion of the project is very urgent, STC urged ESO to start immediately a study of alternative plans or possible back-up solutions.

Finally, STC endorsed the recommendation of ESAC concerning the implementation of a sub-reflector tilt capability for the European ALMA antennas, noting this enhancement is a cost-effective means to regain some of the sensitivity lost by descoping the project to 50 antennas.

NGC 5917, the 'Hooked' Galaxy and its companion (FORS/VLT).

Finance Committee

Finance Committee 2006	
Chair	Rowena Sirey
Belgium	Alain Heyen
Denmark	Cecilie Tornøe
Finland	Jaana Aalto
France	Patricia Laplaud
Germany	Marlene Lohkamp-Himmighofen
Italy	Ugo Sessi
The Netherlands	Coen J. van Riel
Portugal	Fernando Bello
Sweden	Sofie Björling
Switzerland	Jean-Pierre Ruder
United Kingdom	Colin Vincent

In 2006 the Finance Committee held two ordinary meetings. It met in addition twice in extraordinary sessions. All the meetings were chaired by Ms. Rowena Sirey and took place in Garching.

The committee dealt with various financial issues (annual accounts, budget, cash-flow situation, financial projections, member state contributions) and with personnel issues concerning international as well as local staff. These subjects were discussed in detail and recommendations were made to Council.

Finance Committee approved the awarding of 15 contracts exceeding 300 000 € and 31 single-source procurements exceeding 150 000 €. Conditions governing forthcoming ALMA production contracts were also approved and information was received concerning procurement statistics, forthcoming calls for tenders and price inquiries.

A major item was the approval of a contract for the construction of the technical facilities at the Operation Support Facility (OSF) site of the ALMA Observatory in Chile.

The committee received regular progress reports on the implementation of the ERP system, and appreciated the outcome of the external ERP review.

The Users' Committee

The Users' Committee 2006	
Belgium	Griet Van de Steene
Denmark	Uffe Gråe Jørgensen
Finland	Merja Tornikoski
France	Pascale Jablonka (Chairwoman)
Germany	Jochen Heidt
Italy	Bianca Maria Poggianti
The Netherlands	Walter Jaffe
Portugal	Nuno Cardoso Santos
Sweden	Sofia Feltzing Vice-Chairwoman)
Switzerland	Fréderic Courbin
United Kingdom	Malcolm Bremer
Chile	Wolfgang Gieren

The Users' Committee (UC) held its annual meeting on 3 and 4 April. The meeting was chaired by Pascale Jablonka.

Representatives from ESO gave presentations to the Committee about the La Silla Paranal Observatory, ALMA, the proposal submission and time allocation processes and the revised OPC procedures, the forthcoming User Portal, and the SAMPO project for data reduction. The UC in turn provided feedback from the users on the usage of ESO facilities, based in part on the outcome of a survey designed and distributed by the Committee. The level of satisfaction of the users with respect to observations carried out both at the La Silla and Paranal sites is in general high. Most of the expressed concerns are related to the diffusion of information from ESO to its community, in particular about the current and future status of available instrumentation, and to the transparency of the OPC processes. This is reflected in a number of action items and recommendations assigned by the UC to ESO following the open and constructive discussion of these topics. The number of such action items and recommendations from 2005 that could be closed at the 2006 meeting, or on which significant progress had been achieved following corresponding action by ESO, is a testimony to efficiency of the UC process for improvement of ESO's service to its user community in the direction expected by the latter.

As usual, half a day was devoted to a 'special topic', this time the VLT second-generation instruments. Given the nature of this topic, exceptionally, no frequent users were invited to contribute. Instead, presentations were given by ESO representatives, starting with an overview of the instrumentation under development, followed by specific talks on the individual instruments HAWK-I, X-Shooter, KMOS, MUSE and SPHERE. The subsequent discussion featured a first exchange of views about possible additional candidates for developments to start around 2010. Finally, ESO presented a report on the status of the E-ELT project.

The globular cluster 47Tuc (FORS/VLT).

The Observing Programmes Committee

The Observing Programmes Committee 2006

Xavier Barcons
Svetlana Berdyugina (Period 79)
Eric F. Bell
Hermann Böhnhardt
Sven de Rijcke
Hans de Ruiter
Gösta Gahm (Period 79)
Martin Groenewegen (Period78)
Michiel Hogerheijde
Jari Kotilainen
Donald W. Kurtz (Period 79)
Rafael Rebolo Lopez (Period 78)
André Moitinho de Almeida (Vice-chairman)
Simon Morris
Tom Richtler
Daniel Rouan (Period 78)
María Teresa Ruíz (Period 78)
Monica Tosi
Lutz Wisotzki (Chairman)
Sebastian Wolf (Period 79)

In 2006, the Observing Programmes Committee (OPC) held its two annual meetings in May/June and in November. While the number of proposals received for Observing Period 78 (P78: 1 October 2006 to 31 March 2007), at 827, was somewhat lower than in recent periods, a new all-time record was hit for Observing Period 79 (P79: 1 April to 30 September 2007), with the submission of 913 proposals. This corresponds primarily to an increased demand in the 'Galactic' scientific areas: interstellar medium, star formation and planetary systems (OPC category C), and stellar evolution (OPC category D). Indeed, since the introduction of the current OPC categories for Period 66 (starting in October 2000), the number of proposals submitted in categories C and D has nearly doubled, while this number has remained approximately constant for the 'extragalactic' proposals of categories A (cosmology) and B (galaxies and galactic nuclei).

In Period 78, the ratio between the requested time and the available time (the 'pressure factor') has risen above 6 on some of the Unit Telescopes (Antu and Kueyen) for the first time since the start of science operations of the VLT in April 1999, while demand for the La Silla telescopes has decreased by about 10 % from 2005 to 2006. The workhorse instrument FORS2, which has been in operation since early 2000, remains extremely popular: the amount of time that is requested on it is considerably higher than on any other VLT instruments. Most of the latter experience similar demand, within about 20 % of one another. The only exception is VISIR: the significantly lower demand on this instrument can be attributed to the specific nature of the science for which it is designed. The last first-generation VLT instrument, CRIRES, which was offered to the community for the first time in Period 79, was immediately on a par with more established instruments in terms of the amount of requested time. Visitor Instruments were also scheduled at the VLT in both P78 (DAZLE on Melipal) and P79 (ULTRACAM on Melipal and DAZLE on Yepun).

As in P75 and P77, joint telescope time applications for coordinated observations with the VLT and with the XMM-Newton X-ray observatory have been invited in P79. These proposals fall within the framework of an agreement between ESO and ESA for a joint telescope time application scheme, which aims to take full advantage of the complementary nature of ground-based and space-borne observing facilities. Of the four joint applications evaluated by ESO's OPC in P79, one was allocated time on both the VLT and XMM-Newton telescopes; one of the nine proposals evaluated by the XMM Time Allocation Committee was also successful.

In 2006, the field of gamma-ray bursts (GRBs) continued to account for about half of the successful Target of Opportunity (ToO) proposals. A large fraction of the GRB proposals make use of the Rapid Response Mode (RRM) of the VLT, with which observation of a transient event can be automatically started within minutes of its triggering. The unique performance of the VLT in this mode, combined with ESO's policy to allow it to override both Visitor and Service Mode observations, have positioned the VLT and the GRB community of the ESO member states at the forefront of this field of research. We further support the optimisation of the scientific return of the GRB programmes carried out at its observatory sites by inviting the Principal Investigators (PIs) of the successful GRB proposals to observational strategy meetings in Garching twice a year.

Large Programmes

Large Programmes (LPs) are projects requiring more than 100 hours of observing time per year over no more than two years, and that have the potential to lead to a major advance or breakthrough in the considered field of study. In P78, the OPC evaluated 20 LP proposals, and recommended five of them for implementation. A sixth proposal, submitted as a preliminary step towards the construction of a Visitor Instrument for the NTT, was also supported. In P79, four of the 15 LP proposals that had been submitted were approved. In total, between the start of VLT science operations in 1999 and 2006 (P79), 72 LP proposals that received favourable evaluation from the OPC were allocated time on the La Silla Paranal Observatory telescopes. They cover almost all current astronomical topics, from the Solar System to cosmological studies.

Public Surveys

Surveys provide large, homogeneous data sets covering a variety of combinations in the parameter space of wavelength, depth and sky area. Often surveys span longer time intervals and have a broader scope than LPs. From their databases, large uniformly-treated products can be generated, which can be used for a variety of scientific purposes.

For optimal exploitation of the wide-field telescopes VST and VISTA, ESO, recognising that it does not have the resources to conduct public surveys on behalf of its user community, has put in place in 2005 a new scheme for the implementation of such surveys, allowing them to be treated as a separate category of LPs. Within this framework, a Public Survey is understood to be an observing programme in which the investigators commit to produce and to make publicly available, within a defined time, a fully reduced and scientifically usable data set that is likely to be of general use to a broader community of astronomers. Following recommendations by the STC and the OPC, 75 % of the ESO time on both VST and VISTA will be devoted to Public Surveys.

For evaluation of Public Survey proposals, ESO established a Public Survey Panel (PSP), comprising scientists with expertise in a broad range of current astronomical research, with particular emphasis on the areas that can profit from Public Surveys. The PSP prime mandate is to review the proposals and to elaborate a scientifically and observationally well-coordinated set of Public Surveys.

Similarly to what had been done in 2004 for the VST, a call for VISTA Public Survey proposals was issued at the beginning of 2006. In response to this call, 15 proposals were received. The PSP held a first meeting in Garching on 2–3 May, at which it identified those proposals that indeed qualified as scientifically valid public surveys. A second meeting took place in Edinburgh in June, with participation of the PIs of the selected projects. At this meeting, possible revisions of these proposals and the merging of some of them with the aim of enhancement of the scientific value of the coordinated set were discussed, and corresponding recommendations were issued. This resulted in the submission of six revised proposals by the P79 OPC deadline. Following their evaluation by the PSP at a final meeting in Garching on 31 October, and formal endorsement of the conclusions of the PSP by the OPC at its November meeting, these six programmes were recommended for execution.

OPC procedures

Starting with P78, the revised OPC procedures that had been worked out in 2005 were implemented. The most significant changes took place in the areas of the nomination of the members of the OPC and of its Panels, and of the duration of their terms of service. As a result, as of P78, OPC members are no longer proposed by the member states. Instead, members of the OPC and of its panels are selected on scientific excellence. They are appointed by ESO's Director General based on the recomendations of the Nominating Committee for the OPC. This Nominating Committee, which was constituted and held its first two meetings in 2006, comprises three astronomers from the community and two ESO astronomers. In order to reduce the burden of the commitment required from astronomers who serve on the OPC or on its panels, and to allow a greater fraction of the community to participate more actively in the selection of the observing programmes, and hence in the definition of the orientation of European astronomy, the term of service was reduced to two years for OPC members (compared to four years previously) and to one year for panel members (from two years).

On the other hand, in order to face the increasing number of proposals in scientific categories C and D, new subpanels were created for each of these categories. Thus as of P78, the OPC consisted of a total of 10 sub-panels: two for each of categories A and B (unchanged) and three for each of categories C and D (instead of two until P77). The beneficial effect of this change on the workload of the referees of categories C and D was already offset by P79, where due to the unexpectedly steep increase in the numbers of proposals submitted in these categories, the amount of work of the members of the corresponding subpanels was back to its P77 level. Further steps to be taken to address this extremely fast evolution were discussed at the P79 OPC meeting, for implementation in 2007.

Summary of Use of Telescopes by Discipline

The scientific categories referred to in the following tables correspond to the OPC classifications given below:

OPC Categories and Sub-Categories

A: Cosmology
- A1 Surveys of AGNs and high-z galaxies
- A2 Identification studies of extragalactic surveys
- A3 Large-scale structure and evolution
- A4 Distance scale
- A5 Groups and clusters of galaxies
- A6 Gravitational lensing
- A7 Intervening absorption-line systems
- A8 High-redshift galaxies (star formation and ISM)

B: Galaxies and Galactic Nuclei
- B1 Morphology and galactic structure
- B2 Stellar populations
- B3 Chemical evolution
- B4 Galaxy dynamics
- B5 Peculiar/interacting galaxies
- B6 Non-thermal processes in galactic nuclei (incl. QSRs, QSOs, blazars, Seyfert galaxies, BALs, radio galaxies, and LINERS)
- B7 Thermal processes in galactic nuclei and starburst galaxies (incl. ultra-luminous IR galaxies, outflows, emission lines, and spectral energy distributions)
- B8 Central supermassive objects
- B9 AGN host galaxies

C: Interstellar Medium, Star Formation and Planetary Systems
- C1 Gas and dust, giant molecular clouds, cool and hot gas, diffuse and translucent clouds
- C2 Chemical processes in the interstellar medium
- C3 Star-forming regions, globules, protostars, H II regions
- C4 Pre-main-sequence stars (massive PMS stars, Herbig Ae/Be stars and T Tauri stars)
- C5 Outflows, stellar jets, HH objects
- C6 Main-sequence stars with circumstellar matter, early evolution
- C7 Young binaries, brown dwarfs, exosolar planet searches
- C8 Solar system (planets, comets, small bodies)

D: Stellar Evolution
- D1 Main-sequence stars
- D2 Post-main-sequence stars, giants, supergiants, AGB stars, post-AGB stars
- D3 Pulsating stars and stellar activity
- D4 Mass loss and winds
- D5 Supernovae, pulsars
- D6 Planetary nebulae, nova remnants and supernova remnants
- D7 Pre-white dwarfs and white dwarfs, neutron stars
- D8 Evolved binaries, black-hole candidates, novae, X-ray binaries, CVs
- D9 Gamma-ray and X-ray bursters
- D10 OB associations, open and globular clusters, extragalactic star clusters
- D11 Individual stars in external galaxies

Percentage of scheduled observing time/telescope/instrument/discipline

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
2.2-m	FEROS	4	3	14	45	66
	WFI	20	5	6	3	34
Total		24	8	20	48	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
3.6-m	EFOSC2	12	7	1	6	26
	HARPS	0	0	51	12	63
	Special3.6	0	0	1	0	1
	TIMMI2	0	2	7	1	10
Total		12	9	60	19	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
NTT	EMMI	17	8	9	12	46
	SOFI	5	5	24	9	43
	SUSI2	0	5	2	1	8
	SpecialNTT	0	0	2	1	3
Total		22	18	37	23	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
APEX	APEX-2A	2	12	35	14	63
	FLASH	0	2	22	13	37
Total		2	14	57	27	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT1	FORS2	30	17	3	14	64
	ISAAC	8	5	11	12	36
Total		38	22	14	26	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT2	FLAMES	0	8	10	7	25
	FORS1	16	5	5	15	41
	UVES	7	5	5	17	34
Total		23	18	20	39	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT3	DAZLE	4	0	0	0	4
	VIMOS	38	22	4	4	68
	VISIR	0	5	19	4	28
Total		42	27	23	8	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT4	NACO	0	11	22	12	45
	SINFONI	21	21	9	4	55
Total		21	32	31	16	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
VLTI	AMBER	0	0	10	11	21
	MIDI	0	1	13	65	79
Total		0	1	23	76	100

Publications

Publications in refereed journals based on ESO data

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Financial Statement

Financial Statements 2006
(in € 1000)

Balance Sheet	31.12.2006	31.12.2005
Assets		
Cash and short-term deposits	89 222	76 880
Claims, advances, refundable taxes and other assets	60 402	4 958
Total assets	149 624	81 838
Liabilities and equity		
Dues	6 803	18 438
Advance payments received and other liabilities	20 616	16 725
Total liabilities	27 419	35 163
Cumulated result previous years	46 675	12 977
Annual result	75 530	33 698
Total equity	122 205	46 675
Total liabilities and equity	149 624	81 838

Statement of Income and Expenditure	01.01.2006–31.12.2006
Income	
Contributions from member states	179 089
Contributions from third parties and partners	5 200
Income from sales and other income	4 623
Total income	188 912
Expenditure	
Expenditure for staff	49 734
Operating and other expenditure	63 648
Total expenditure	113 382
2006 Result	75 530

Statement of Cash flow	01.01.2006–31.12.2006
Cash flow from operating activities	
Receipts	
Income	188 912
Net movements on accounts receivable	–55 443
Total	133 469
Payments	
Expenditure	–113 382
Net movements on accounts payable	–14 140
Total	–127 522
Net cash flow from operating activities	5 947
Cash flow from financing activities	
Net cash flow from financing activities	6 395
Net cash flow = Net increase/decrease in cash and short-term deposits	12 342

Budget for 2007
(in € 1000)

Income budget	2007
Contributions from member states	117 732
Other income from member states	4 388
Income from third parties	12 014
Various income	4 000
Total income budget	138 134

Payment budget	2007
Personnel cost	51 170
Other cost	149 728
Total payment budget	200 898

Commitment budget	2007
Personnel cost	51 170
Projects commitments without personnel	158 209
Operations commitments without personnel	37 261
Total commitment budget	246 640

Since 2003, the ESO annual accounts have shown a positive cash flow development, which is reflected in the amount of cash and short-term deposits at end of year. In 2006, the positive cash flow amounted to 12,3 M€ and the cash and short-term deposits as of 31 December 2006 amounted to 89,2 M€.

The net result of the statement of income and expenditure for 2006 was + 75,5 M€. The high income figure of 188,9 M€ included in particular the amount of the entrance fee due by Spain following the country's accession as a new ESO member state as of 1 July 2006.

The budget for 2007 was approved by the ESO Council in December 2006. The budget comprises three sections: the income budget, the payment budget and the commitment budget.

With 200,9 M€, the 2007 payment budget is driven by the payment profile of the ALMA project. It also includes a provision for the detail design phase of the European ELT. In total, it is expected to be significantly higher than the 2007 income budget, which amounts to 138,1 M€.

The commitment budget for 2007 is 246,6 M€.

Four Seasons at a Glance

January

First Light for the Laser Guide Star on UT4 of the VLT.

Astronomers find 5 Earth-mass exoplanet with microlensing technique, using a worldwide network of telescopes, including the 1.5-m telescope at La Silla.

Meeting of the Scientific Strategy Working Group.

15th release of the VLT Software.

Workshop on ALMA (From Z-Machines to ALMA: (Sub)millimeter Spectroscopy of Galaxies), NRAO Charlottesville.

ALMA European Science Advisory Committee meeting, Garching.

ALMA Science Advisory Committee meets in Washington, US.

February

Signing of the agreement between Spain and ESO about membership.

Committee of Council meets in Berne, Switzerland.

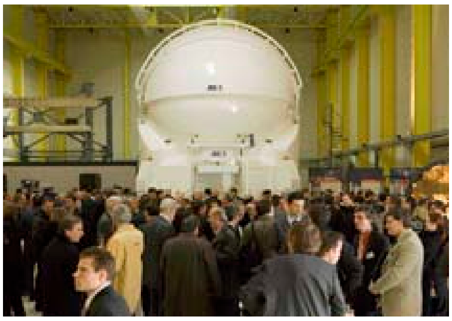
Breakfast press briefing for the UK media in connection with the yearly Astrofest in London, organised by ESO and PPARC. ESO is also present at the Astrofest with a scale model of the VLT and display panels.

ESO is present at the annual AAAS meeting in St. Louis, Missouri.

Yearly ESO Status Overwiew held in Garching.

March

Visit to the ESO HQ by the Education Committee of the Finnish Parliament.



Walloon Space Days in Liège and delivery ceremony for the 4th VLT Auxiliary Telescope at AMOS, Belgium.

Launch of the first international, multidisciplinary journal for innovative science teaching, “Science in School”, by EIROforum at EMBL in Heidelberg.

Joint ESO-FONDAP Workshop on Globular Clusters, Concepción, Chile.

European ALMA Board meets in Garching.

ALMA Board meeting, Kyoto, Japan.

Extraordinary Finance Committee in Garching.

Danish Minister of Education, Bertel Haarder, visits Paranel.

April

Preliminary Acceptance Europe review of CRIRES.

827 proposals are received in answer to the Call for Proposals for observing in Period 78.

CRIRES AO system (MACAO) installed and commissioned at UT1.

An image made of about 300 million pixels is released by ESO, based on more than 64 hours of observations with the Wide-Field Imager on the 2.2-m telescope at La Silla.

VLT observes fragment B of the comet Schwassmann-Wachmann 3, that had split a few days earlier.

Meeting of the Scientific Strategy Working Group.

62nd Meeting of the Scientific Technical Committee.

The Users’ Committee meets in Garching.

Meeting of the ESO Tripartite Group.

Opening of the IPP/ESO Crèche.

May

HARPS helps discover a nearby star hosting three Neptune-mass planets.

Strong ESO participation at the SPIE Astronomical Telescopes and Instrumentation Symposium in Orlando, Florida.

First recoating of M2 of UT1 successfully completed.

114th Finance Committee Meeting in Garching.

Extraordinary 63rd meeting of the Scientific Technical Committee.

European ALMA Board meeting, Garching.

Public Survey Panel meets in Garching.

Workshop on “Complex Molecules in Space: Present status and prospects with ALMA”, Fuglsøcentret, Denmark.

June

First spectra on-sky obtained by CRIRES on the VLT.

ESO establishes a dedicated E-ELT Project Office.

X-shooter passes Final Design Review in Europe.

The ESO Council meets in Garching.

ALMA Board meeting, Santiago, Chile.

Signing of the ALMA agreement with Japan.

Observing Programmes Committee meeting in Garching.

ESO and the Government of Chile launch the book “10 Years Exploring the Universe”, written by the beneficiaries of the ESO-Government of Chile Joint Committee.

Public Survey Panel meets in Edinburgh, UK.

ESO participates with a major information stand at the 2nd *Salon Européen de la Recherche & de l’Innovation* in Paris, France.

EuroSummer School, Observation and data reduction with the Very Large Telescope Interferometer, Château de Goutelas, France.

Conference “Library and Information Services in Astronomy V: Common Challenges, Uncommon Solutions”, Cambridge, Mass., USA.

July

26 articles based on early science with APEX are published in the research journal Astronomy & Astrophysics.

The first of seven years of data of the UKIRT Infrared Deep Sky Survey (UKIDSS) enters ESO’s archive.

The Fifth NEON Observing School, Observatoire de Haute-Provence, France.

EIROforum takes part in the Euroscience Open Forum 2006 Conference in Munich with a major information stand, press conferences and a reception.
ESO is also visible in the German Science Festival with an on-stage show at Munich’s *Marienplatz*, involving a live videoconference with Paranal.

August

The new SINFONI spectrograph scrutinises a distant protodisc galaxy with a record-breaking resolution of a mere 0.15 arcseconds.

Provisional Design Review for the ALMA Transporter.

“Heating vs. Cooling in Galaxies and Clusters of Galaxies”, MPA/ESO/MPE/USM Joint Astronomy Conference, Garching, Germany.

The Second NEON Archive Observing School takes place at ESO.

ESO is present at the IAU XXVIth General Assembly in Prague with presentations and information stands. ESO’s Director General Catherine Cesarsky is elected President of the International Astronomical Union while ESO’s Deputy Director General Ian Corbett is elected Assistant General Secretary

September

Thomas Wilson is appointed as ESO’s Associate Director.

Committee of Council meets in Santiago, Chile.

ALMA European Science Advisory Committee meeting, Garching.

ALMA Science Advisory Committee meets in Florence, Italy.

Joint ESO-Lisbon-Aveiro University Conference on Precision Spectroscopy in Astrophysics, Aveiro, Portugal.

October

KMOS passes Preliminary Design Review.

913 proposals are received in answer to the Call for Proposals for observing in Period 79, a new all-time record.

DAZLE visitor instrument successfully commissioned on UT3.

UT4 recoating of M1/M3 completed.

Visit to the ESO Headquarters by a group of university rectors from Chile.

Committee of Council meets in Munich.

ESO exhibition at major astronomy festival in Vaulx-en-Velin, France.

ESO exhibition in Montpellier, France.

64th Meeting of the Scientific Technical Committee.

Extraordinary Finance Committee in Garching.

Public Survey Panel meets in Garching.

ALMA Commissioning meeting.

Meeting of the ESO Tripartite Group.

UNAWE Workshop in Leiden, the Netherlands.

Almost 3000 people visit the ESO HQ at the Open House. On that occasion ESO together with other institutes on the Garching campus, receives the "Deutschland – Land der Ideen" Trophy for its public communication activities.

ESO releases its 2007 Calendar.

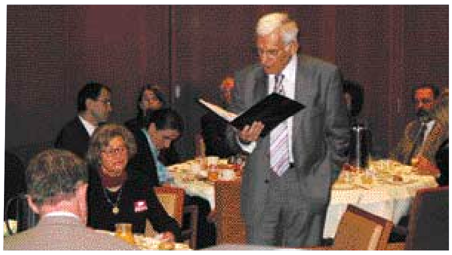
November

Visit to Paranal by a delegation from the Academy of Sciences of the Czech Republic.

More than 250 European astronomers gather at the 'Towards the European ELT' conference in Marseille, France.

International ALMA Conference on "Science with ALMA: a new era for Astrophysics", held in Madrid, Spain.

European Extremely Large Telescope is selected in the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap.



EIROforum breakfast meeting at the European Parliament discusses science education issues in Europe.

ESO and the European Association for Astronomy Education launch the 2007 edition of 'Catch a Star!', their international astronomy competition for school students.

The Finance Committee (116th) meets in Garching.

ALMA board meets in Madrid, Spain.

Extraordinary 65th meeting of the Scientific Technical Committee.

Observing Programmes Committee meeting in Garching.

EIROforum Assembly in Grenoble, France.

A top-level meeting on exoplanets takes place in Washington D.C. between ESO, ESA and NASA.

December

ESO participates at major astronomy and space exhibition, Astro-expo, in Dublin, Ireland.

The ESO Council meets in Garching. Council decides to proceed with Phase B studies for the European Extremely Large Telescope. Council also approves the Agreement with the Czech Republic about membership.

Fourth and last-to-be-installed VLTI Auxiliary Telescope (AT4) obtains its 'First Light'.

EIROforum issues statement of support for the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers.

ESO releases 256 million pixel image of 30 Doradus.

UT2 recoating of M1/M3 completed.

Laser Guide Star Facility on VLT successfully commissioned.

The Multi-conjugate Adaptive optics Demonstrator (MAD) passes its PAE (Preliminary Acceptance Europe).

Fourth Advanced Chilean School of Astrophysics (co-sponsored by ESO), "Interferometry in the Epoch of ALMA and VLTI", *P. Universidad Católica de Chile*, Santiago, Chile.

Signing Ceremony in Prague of the Agreement between ESO and the Czech Republic regarding Czech membership of ESO.

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Glossary of Frequently Used Acronyms

4LGSF	Four-Laser Guide Star Facility
AAAS	American Association for the Advancement of Science
A&A	Journal "Astronomy & Astrophysics"
ACS	Advanced Camera for Surveys (HST)
ACS	ALMA Common Software
ADP	Advanced Data Products (VOS)
AEM	Alcatel Alenia Space France, Alcatel Alenia Space Italy, European Industrial Engineering s.r.L., MT Aerospace Consortium (ALMA)
ALMA	Atacama Large Millimeter/Submillimeter Array
ALMA ARC	ALMA Regional Centre
AMBER	Astronomical Multi-BEam combineR (VLTI Instrument)
ANSYS	ANSYS Multiphysics, general-purpose finite element analysis software
AO	Adaptive Optics
AOF	Adaptive Optics Facility
AOS	Array Operations Site
APEX	Atacama Pathfinder Experiment
ASAC	ALMA Science Advisory Committee
ASI	Italian Space Agency (*Agenzia Spaziale Italiana*)
ASSIST	Adaptive Secondary Setup and Instrument Simulator
AT	Auxiliary Telescope for the VLTI
AVO	Astrophysical Virtual Observatory
BMBF	German Federal Ministry for Education and Research
CADC	Canadian Astronomy Data Centre
CAS	Academy of Sciences of the Czech Republic
CCD	Charge-Coupled Device
CES	Coudé Echelle Spectrometer (3.6-m)
CERN	European Organisation for Nuclear Research (*Conseil Européen pour la Recherche Nucléaire*, Switzerland)
CDR	Conceptual Design Review
CFD	Computational Fluid Dynamics
CI	corporate identity
CMMS	computerised maintenance management system
CNRS	Centre National de la Recherche Scientifique (France)
CRIRES	Cryogenic InfraRed Echelle Spectrometer (VLT)
CSIC	Spanish National Research Council (*Consejo Superior de Investigaciones Científicas*)
darkCAM	dark energy camera for VISTA
DAZLE	Dark Age 'Z' Lyman-alpha Explorer
DBCM	Database Content Management
DCA	EURO-VO Data Centre Alliance
DCU	Dublin City University
DFO	Data Flow Operations
DMD	Data Management Division
DMO	Data Management and Operations Division
DRM	Design Reference Mission
DSM	Deformable Secondary Mirror
EAAE	European Association for Astronomy Education
EFOSC	ESO Faint Object Spectrograph and Camera (3.6-m)
EIS	ESO Imaging Survey
ELT	Extremely Large Telescope
E-ELT	European Extremely Large Telescope
EMC	Electromagnetic Compatibility
EMMI	ESO Multi-Mode Instrument (NTT)
ERA-net	European Research Area Network
ESA	European Space Agency
ESAC	European Science Advisory Committee (for ALMA)
ESE	ELT Science and Engineering
ESFRI	European Strategy Forum on/for Research Infrastructures
ESRC	ELT Standing Review Committee
ESRIN	ESA Centre for Earth Observations
ESTI	EIROforum European Science Teachers' Initiative
EURO-VO	European Virtual Observatory
FDR	Final Design Review
FE	Front End
FEIC	Front End Integration Centres
FEM	Finite Element Method
FEROS	Fibre-fed, Extended Range, Échelle Spectrograph (2.2-m)
FINITO	Fringe Tracking Instrument Nice Torino (VLTI)
FLAMES	Fibre Large Array Multi Element Spectrograph (VLT)
FOC	Faint Object Camera
FORS	FOcal Reducer/low dispersion Spectrograph
FP	Framework Programme
FP6	Sixth Framework Programme
FP7	Seventh Framework Programme
GALACSI	Ground Atmospheric Layer Adaptive Optics for Spectroscopic Imaging
GENIE	Ground based European Nulling Interferometer Experiment (VLTI)
GHRS	Goddard High-Resolution Spectrograph
GRAAL	GRound-layer Adaptive opctics Assisted by Lasers
GRAVITY	AO assisted, two-object, multiple-beam-combiner (VLTI)
GRB	Gamma-Ray Burst
GROND	Gamma-Ray burst Optical/Near-infrared Detector
HARPS	High Accuracy Radial Velocity Planetary Searcher (3.6-m)
HAWK-I	High Acuity Wide field *K*-band Imager (VLT)
HLA	Hubble Legacy Archive
HOT	High Order Test-bench
HST	Hubble Space Telescope
IAU	International Astronomical Union
ICD	Interface Control Document
IEM	*Instituto de Estructura de la Materia* (Madrid, Spain)
INAF	*Istituto Nazionale di Astrofisica* (Italy)
INSU	*Institut National des Sciences de l'Univers* (France)
INTA	*Instituto Nacional de Tecnica Aeroespacial* (Spain)
IPP	*Max-Planck-Institut für Plasmaphysik*
IPT	Integrated Project Team (ALMA)
IR	InfraRed
IRAM	*Institut de Radioastronomie Millimétrique* (France)
ISAAC	Infrared Spectrometer And Array Camera (VLT)
IT	Information Technology
ITF	Interferometry Task Force
ITRE	European Parliament's Committee on Industry, Research and Energy
IVOA	International Virtual Observatory Alliance
JBO	Jodrell Bank Observatory (UK)
KMOS	*K*-band multi-object spectrograph (VLT)
LABOCA	Large APEX Bolometer CAmera
LAOG	*Laboratoire d'Astrophysique de Grenoble*
LERMA	*Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique* (France)
LGS	Laser Guide Star
LGSF	Laser Guide Star Facility
LP	Large Programme
LTP	Long Term Perspectives
MACAO	Multi-Application Curvature Adaptive Optics (VLT/VLTI)
MAD	Multi-Conjugate Adaptive Optics Demonstrator
MATISSE	Multi AperTure mid-Infrared SpectroScopic Experiment (VLTI)
MEC	Minsitry of Education and Science (*Ministerio de Educación y Ciencia*, Spain)
MIDI	Mid-Infrared Interferometric Instrument (VLTI Instrument)
MoU	Memorandum of Understanding
MPE	Max Planck Institute for Extraterrestrial Physics (Germany)
MPIfR	Max Planck Institute for Radioastronomy (Germany)
MRIP	Medium Range Implementation Plan
MUSE	Multi Unit Spectroscopic Explorer (VLT)
MVM	Image processing library
NACO	NAOS-CONICA (VLT)
NAOJ	National Astronomical Observatory of Japan
NAOS	Nasmyth Adaptive Optics System (VLT)
NASA	National Air and Space Administration (US)
NGAS	Next Generation Archiving System
NGC	New General detector Controller
NICMOS	Near Infrared Camera and Multi-Object Spectrograph (HST)
NIST	National Institute of STandards
NOTSA	Nordic Optical Telescope Scientific Association
NOVA	Dutch Research School for Astronomy (*Nederlandse Onderzoekschool voor Astronomie*)
NSF	National Science Foundation
NTT	New Technology Telescope
OmegaCAM	Optical Camera for the VST
OPC	Observing Programmes Committee
OPD	Optical Path Differences
OPTICON	Optical Infrared Coordination Network for Astronomy
OSF	Operations Support Facility (ALMA)
OSO	Onsala Space Observatory
OWL	OverWhelmingly Large Telescope
P2PP	Phase 2 Preparation Tool
P75	Period 75
P76	Period 76
P77	Period 77
P78	Period 78
P79	Period 79
PAD	Public Affairs Department
PAE	Preliminary Acceptance Europe
PARSEC	Sodium line laser for VLT AO
PDM	Product Data Management
PDR	Preliminary Design Review
PI	Principal Investigator
PPARC	Particle Physics and Astronomy Research Council (UK)

PRIMA	Phase-Referenced Imaging and Micro-arcsecond Astrometry facility (VLTI)
PSP	Public Survey Panel
QC	Quality Control
R&D	Research and Development
RADIONET	Radio Astronomy Network in Europe
RDS	*Rat Deutscher Sternwarten* (Germany)
RoHS	Restriction on the use of Hazardous Substances
RRM	Rapid-Response Mode
SAC	EURO-VO Science Advisory Committee
SAF	Science Archive Facility
SAO	Science Archive Operation
SEI	System Engineering and Integration
SINFONI	Spectrograph for INtegral Field Observations in the Near Infrared
SMI	Structural Modelling Interface
SMA	SubilliMeter Array
SOCHIAS	Chilean Astronomical Society
SOFI	SOn oF Isaac (NTT)
SPHERE	Spectro-Polarimetric High-contrast Exoplanet Research instrument
SPIE	International Society for Optical Engineering
SSWG	Scientific Strategy Planning Working Group
STC	Scientific Technical Committee
ST-ECF	Space Telescope European Coordination Facility
STIS	Slit spectrograph (HST)
STScI	Space Telescope Science Institute (USA)
SUSI	SUperb Seeing Imager (NTT)
TAC	Time Allocation Committee
TB	TeraBytes
TFB	Turnable Filter Bank
TIMMI	Thermal Infrared MultiMode Instrument (3.6-m)
TMT	Thirty Meter Telescope
ToO	Target of Opportunity
UC	Users' Committee
UK	United Kingdom
UKIDSS	UKIRT Infrared Deep Sky Survey
UKIRT	UK Infrared Telescope
ULTRACAM	ULTRA-fast, triple-beam CCD CAMera
USD	User Support Department
UT1–4	VLT Unit Telescope 1–4: Antu, Kueyen, Melipal and Yepun
UVES	UV-Visual Echelle Spectrograph (VLT)
VCM	Variable Curvature Mirrors
VIMOS	VIsible MultiObject Spectrograph (VLT)
VINCI	VLT INterferometer Commissionning Instrument
VIRCAM	VISTA IR Camera
VISA	VLTI Sub-Array
VISIR	VLT Mid-Infrared Imager Spectrometer
VISTA	Visible and Infrared Survey Telescope for Astronomy
VITRUV	Near-IR spectro-imager using fibre (VLTI)
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer
VO	Virtual Observatory
VOFC	EURO-VO Facility Centre
VOS	Virtual Observatory System
VOTC	EURO-VO Technology Centre
VSI	VLTI Spectro Imager
VST	VLT Survey Telescope
VTK	Vibration Tracking
VVDS	VIMOS VLT Deep Survey
WFCAM	Wide-Field Camera (UKIDSS)
WFI	Wide Field Imager (2.2-m)
X-Shooter	Wideband UV-IR single target spectrograph (VLT)

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DVD (Mac/PC and DVD Player)

The ESO Annual Report 2006 DVD contains two parts. It should play automatically when inserted in any DVD player, featuring a set of videos made by ESO.

In addition, on a Mac or a PC, it is possible to open it to access additional content:
– All the ESO Press Releases and Press Photos having been published in 2006.
– The four Messenger issues of 2006.
– The list of all publications based on ESO telescopes that appeared in 2006.
– A gallery of photos.

To access these features, simply view the index.html file in your favourite browser.

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Back cover photo:
The Laser Guide Stars System at Paranal.