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European Organisation
for Astronomical
Research in the
Southern Hemisphere

Organisation Européenne
pour des Recherches
Astronomiques
dans l'Hémisphère Austral

Europäische Organisation
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Annual Report 2005

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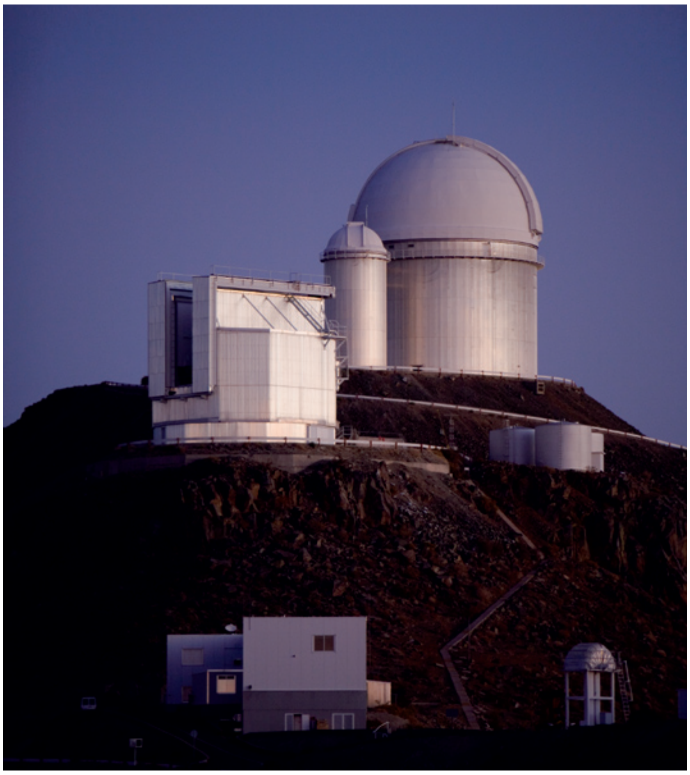
presented to the Council by the
Director General
Dr. Catherine Cesarsky

ESO is the foremost intergovernmental European Science and Technology organisation in the field of ground-based astrophysics. It is supported by eleven countries: Belgium, Denmark, France, Finland, Germany, Italy, the Netherlands, Portugal, Sweden, Switzerland and the United Kingdom. Spain is expected to join the organisation in 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 co-operation 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 2400 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 2600 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 many highly 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.



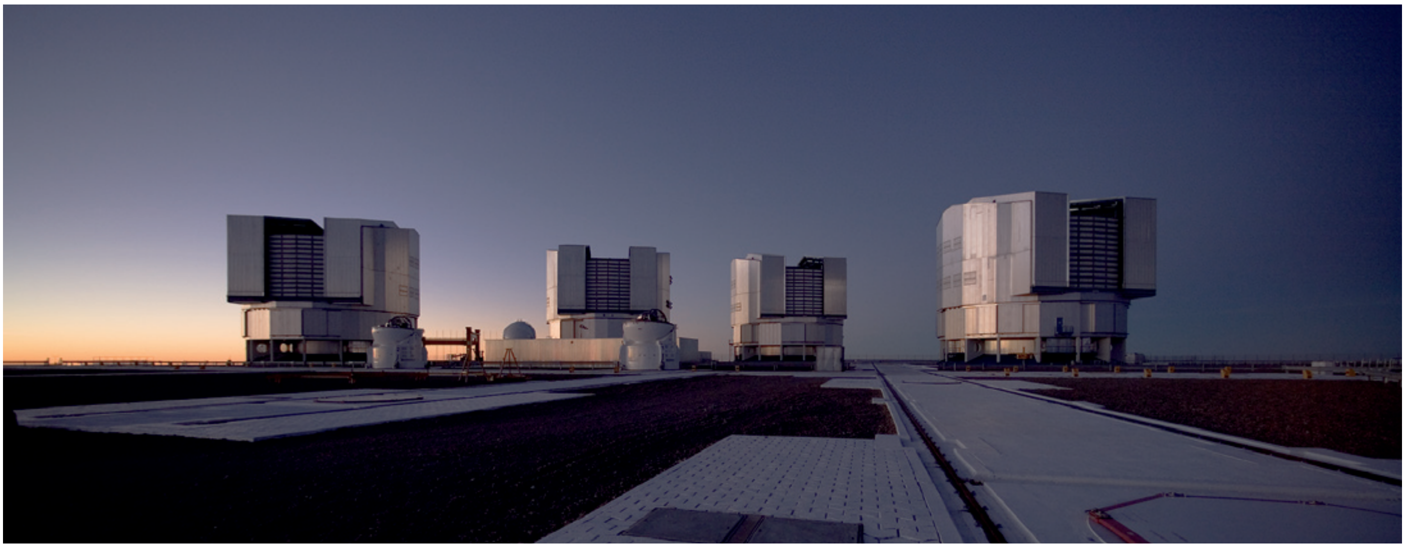
La Silla hosts medium-sized telescopes like the 3.4-m NTT and the 3.6-m telescope.

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, three of which are now in operation. 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.

Over 1700 proposals are made each year for the use of ESO telescopes. They have resulted in a large number of peer-reviewed publications. In 2005, about 600 refereed papers were published based on data from ESO telescopes.

The Atacama Large Millimetre Array (ALMA), one of the largest ground-based astronomy projects of the next decade, is a major new facility for world astronomy. ALMA will be comprised of a giant array of 12-m submillimetre quality antennas, with baselines of several kilometres. An additional, compact array of 7-m and 12-m antennas is also foreseen. 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 (5000 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 VLT and its Auxiliary Telescopes at Paranal.

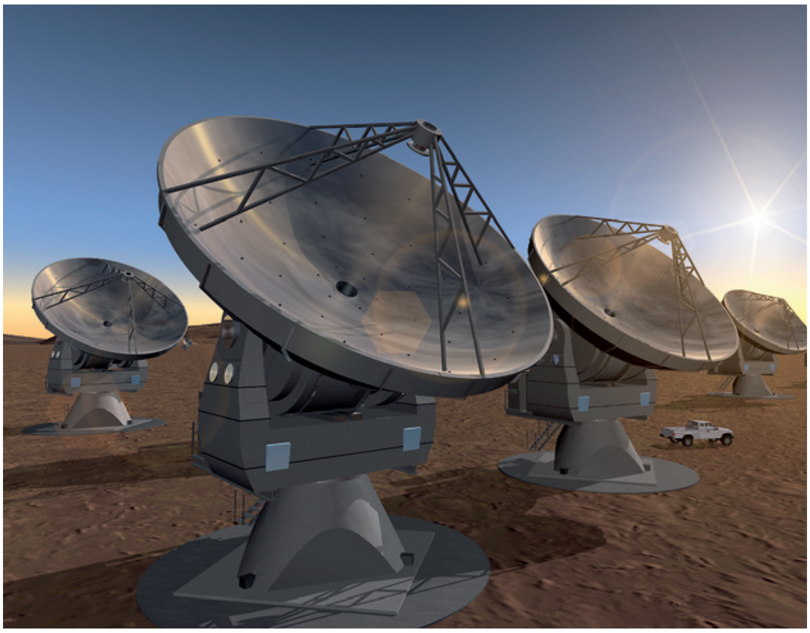


The Chajnantor site is also home for the 12-m APEX submm/mm telescope, operated by ESO on behalf of the Onsala Space Observatory, the Max Planck Institute for Radio Astronomy and ESO itself.

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 current effort to develop a next generation extremely large ground-based optical/infrared telescope for Europe's astronomers. ESO is now working towards the development of a basic reference design for such a telescope, currently known as the E-ELT.

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).

ESO employs about 570 personnel in Europe and Chile.



Artist's image of the Atacama Large Millimeter Array (ALMA).

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Foreword

I am delighted to be able to provide a few words of introduction to this Annual Report for 2005, a truly remarkable year for ESO, during which Council was called upon to decide on matters of great importance for the future of the organisation.

In 2005, two very important steps were taken to secure a bright future for the organisation, namely the successful completion of the procurement procedure for the ALMA antennas and the steps taken towards a European ELT project.

During the year the ALMA project went through an extensive and very careful process of re-baselining followed by an equally thorough four-day baseline cost review in October. Based on the recommendations of the review and a careful examination by the Executive of possible long term funding scenarios, Council agreed that a 50 % share for Europe in a 50-antenna ALMA was affordable in view of ESO's other priorities. This paved the way for the signing of the ALMA antenna contract, which as the press release states is indeed the "largest-ever European industrial contract for ground-based astronomy". Together with the similar contract signed a few months earlier in North America, this was a major milestone for ALMA and ESO.

Council discussed and agreed the recommendations of its Strategy Working Group. A key element of the strategy adopted by Council is the clear desire to move as quickly as possible to the design and development of a European ELT. Late in the year, the review of the OWL 100-m telescope Concept Study took place also with a positive outcome. This enabled ESO to enter the next phase: building on this study as well as Europe's track record in developing and implementing cutting-edge large-scale research infrastructures for astronomy, to move towards a European ELT project that will ensure that ESO member state astronomers can remain at the forefront of our science for the foreseeable future.

I wish also to mention the very promising negotiations with Spain about full membership of ESO. Along with the recent sequence of rapid accessions of Portugal, the UK and Finland, the addition of Spain as an ESO member state provides a very important step in the process to bring European astronomy together. Indeed, with Spanish membership only a few non-ESO countries remain in Western Europe, while new contacts with Central- and Eastern European states are intensifying with a view to extending ESO's coverage to that important part of the continent. Council clearly recognises that the foreseeable growth in member states must be carefully managed.

As in previous cases, Council agreed that the income from Spain should be added to the contributions from the current member states. This is clearly of great importance for ESO's ability to tackle the challenges of the ELT age in a realistic way. Also, the in-kind contributions from Spain in the form of technical and scientific access to the GranTeCan telescope at La Palma, Canary Islands, with its 10-m segmented mirror will be important for ESO and the astronomers in the member states.

These measures, together with the milestone decisions regarding the ALMA and ELT project, make it clear that ESO is doing very well indeed and can look forward to the future with confidence.

Finally, I wish to thank warmly Prof. Piet van der Kruit for his wise leadership of Council at the time of such important decisions and indeed for his unrelenting commitment to ESO and its goals.

Richard Wade
President of the ESO Council

Introduction

2005 was without any doubt a pivotal and amazing year for ESO in which the Management, together with the Council and the Committees, worked hard to ensure that ESO is on a good track towards the future as set out in the 2004 Council resolution on Scientific Strategy. Mid- and long-term plans have been developed reflecting these priorities, but also in the day-to-day operations, did we pass several crucial milestones for ESO's further development.

For the Atacama Large Millimeter Array (ALMA), the completed re-baselining and the successful cost review, in addition to the confirmation by Council that "… the estimated increase … in the cost to completion of the ESO share of the bilateral ALMA project is affordable and compatible with ESO's strategic projects", created a sound basis for the continuation of the bi-lateral project, with fifty 12-m antennas (and an option of increasing the number to sixty-four). This, in turn, allowed us to sign two major industrial contracts for ALMA, the contract with the AEM consortium for the procurement of the European antennas and another one for the ALMA transporters. The antenna contract is the largest-ever single contract awarded by ESO to industry and thus marks a significant milestone both for ESO and for the ALMA project. Furthermore, ESO signed a contract with the European Commission for the ALMA 'Enhancement' Project, enabling us to add Band 5 to our instrument suite.

Similarly, towards the end of the year, we concluded the 100-m OWL telescope Concept Study with an international review. The reviewers found that the ESO team had "demonstrated a plausible case that OWL is feasible and that a 100-m telescope can be built and operated" and that "this provides a firm technological basis for ESO to move into the next phase of an Extremely Large Telescope (ELT) project." Yet the reviewers identified a number of technical risks, which might cause serious problems in view of the need to build an ELT on a competitive timescale and with consideration to the present funding scenario. The panel therefore advised ESO to work towards an ELT with a smaller aperture, thereby minimising the risks.

With the recommendations of the reviewers as well as the huge amount of work done in the frame of the conceptual study, we are now ready to enter into the next phase towards the realisation of an Extremely Large Telescope with a primary mirror in the 30–60-m range for Europe's astronomers. We will do so in close collaboration with our user community, by putting in place a series of dedicated working groups and carefully examining the balance between science return, competitiveness and timeliness, adaptive optics performance, instrumentation, site characteristics, risks and cost. A further element is the ELT Design Study, meant to test generic design solutions, a project under FP-6 with ESO and the European Commission as the two largest individual funding bodies, but comprising 25 partners in Europe.

Obviously, ESO's true strength lies in the services it provides to the scientific community in the member-states. Therefore, much effort is being put into optimising our operations and to maintain our current facilities in a state-of-the-art manner.

The merger of La Silla and Paranal into one functional entity was an important step to streamline the operations and exploit synergies. As regards instrumentation, HARPS and VIMOS were upgraded and SINFONI and VISIR, with the corresponding pipelines, were offered to the user community. Also AMBER was offered to the community in Period 76. The year also saw the first use of the visitor focus with UltraCAM, which passed this milestone with flying colours.

For the interferometric mode of the VLT (VLTI), all four UTs are now being offered with the adaptive optics MACAO system while the first two Auxiliary Telescopes were offered to the community, and the third saw First Light. However, the need for a review of the VLTI system had arisen at the end of 2004, to ensure that the most demanding goals of the VLTI could be met. Following this review, we have embarked on a major project, called the 'Immediate Improvement Implementation Initiative', which has already yielded first results. VLTI is now firmly in the hands of the La Silla Paranal Observatory.

Meanwhile, towards the end of 2005, preparations were made for First Light of the Laser Guide System on Yepun, OmegaCam was completed and the Multi-Conjugate Adaptive Optics Demonstrator (MAD) saw closed-loop operation on the optical bench at Garching.

Following a comprehensive Conceptual Design Review, Council agreed to pursue the Adaptive Optics Facility programme, a six-year project aiming at transforming one of the four VLT Unit Telescopes into an adaptive one, with four sodium laser guide stars, a new secondary unit featuring a deformable mirror as well as wavefront sensing systems for the second-generation VLT instruments. This will also be an important pathfinder for the future Extremely Large Telescope.

The construction of VISTA continued according to plan with all subsystems in the final stage of manufacture. Regrettably the VST project has been marred by several problems and mishaps, and progress was slow.

In 2005, we also took a number of steps regarding the second-generation instruments for the VLT: HAWK-I, X-Shooter and KMOS are now in active development, MUSE was approved and the Planet Finder concept consolidated. A new general detector controller, under the acronym NGC, has been developed for both CCDs and IR detectors.

At Chajnantor, the 12-m APEX submm/mm telescope was inaugurated in September and has already yielded a flurry of interesting scientific data from which we expect many papers soon.

Of course, our user community is keen to reap the scientific 'harvest' from all these developments as it has been in the past. We now receive around 1700 proposals per year for observing time. It is gratifying to see that, in early 2005, the 1000th scientific paper based on VLT observations was published. The La Silla Paranal Observatory is now the world's scientifically most productive facility for astronomy, both in terms of refereed papers and citations.

Another indicator of ESO's standing in the scientific community is a 30 % rise in applications for fellowships.

ESO's telescopes have played several crucial roles in one of the hottest research topic, the study of gamma-ray bursts (GRBs). Observations with ISAAC and FORS2 have enabled astronomers to discover the afterglow of the farthest known ever GRB. With a measured redshift of 6.3, the light from this very remote astronomical source has taken 12 700 million years to reach us. Similarly, ESO telescopes have helped resolve a 30-year old puzzle, by observing for the first time the visible light from a short gamma-ray burst. Using the 1.5-m Danish telescope at La Silla, they showed that these short, intense bursts of gamma-ray emission most likely originate from the violent collision of two merging neutron stars. The VLT was also used to constrain the birthplace of two other short GRBs, providing further constraints on the origin of these events.

Observations with VIMOS as part of the VIMOS VLT Deep Survey (VVDS) that started early 2002 allowed astronomers to discover a large population of star-forming galaxies observed when the Universe was only 10 to 30 % its present age (redshift between 1.4 and 5). This showed that the Universe was a more fertile place soon after it was formed than has previously been suspected.

A galore of results in the field of exoplanets confirmed once more that ESO has a unique set of complementary instruments to tackle this important research area. Astrometry measures of the 2M1207 system have conclusively demonstrated that the giant planet, approximately five times the mass of Jupiter, is indeed gravitationally bound to the young brown dwarf, thereby confirming that NACO was the first ever instrument to have imaged an extra-solar planet. HARPS also found a Neptune-sized planet orbiting the red dwarf Gl 581. Although this is not the least massive planet found, the fact that its parent star is a low-mass star – the most common in our Galaxy – is important in the census of other planetary systems.

Increasingly the science archive has evolved as an important tool for our users. With 12 terabytes (TB) of data having been archived in 2005, the ESO Science Archive currently comprises 44 TB of compressed data. We are therefore undertaking considerable efforts, both to maintain the archive in its own right and in the context of the emerging Virtual Observatory (VO) paradigm. VO implies federating archives involving scientists across Europe and indeed the world. It is therefore fitting that the Euro-VO project, in which ESO is a partner, has received financial support from the European Commission. This is also significant from the perspective that the FP-6 contract involves DG Information Society underscoring the importance attributed to VO activities in a wider societal context.

ESO's role as Europe's main organisation for ground-based astronomy was strengthened further by the wish of several countries to join our organisation. To that end negotiations with Spain were conducted. Even if they could not be formally concluded before the end of the year we are optimistic about a Spanish membership in 2006. Also most fruitful initial discussions took place with the Czech Republic.

In May, we were delighted to welcome Maria van der Hoeven, Dutch Minister of Education, Culture and Science, at Paranal and in October, Bertel Haarder, Danish Minister for Education and Church Affairs, paid a visit to ESO Chile.

It is clear that more than ever ESO has become a driving force for European astronomy, which brings a number of obligations with it: it must shoulder a number of complex tasks, stemming from the demands from the current projects, especially the completion of the VLTI and of the VLT second-generation instruments, and the construction of ALMA, as well as the challenges from the ELT-era, now on the horizon, while striving to strengthen the position of European astronomy within the dynamics of the European Research Area.

This is the reason why ESO has engaged in a number of policy-driven initiatives, including the ASTRONET, a network of funding bodies working within the ERA-net scheme, to develop a strategic vision for all of European astronomy by developing a 'road-map' for our science. ESO also decided to join the ARENA network, which will explore the possibilities for astronomy in the Antarctica. ESO and ESA also continued with their working group for joint strategic initiatives in science, which produced its first report on extrasolar planet research. Further reports are forthcoming.

Another important activity for ESO is its participation in the EIROforum partnership. In April, the Directors General of the partner organisations presented a joint science policy paper outlining their common views on how science can contribute to the attainment of the Lisbon goals and the knowledge-based society.

While the number and complexity of European Interactions and Foreign Interactions continues to increase, 'back home' at Headquarters we are faced with serious problems as regards office space. I therefore welcome the decision to extend our Headquarters with a new building to alleviate this problem and to create proper working conditions for our staff and visitors.

An annual report implies stock-taking. In this context, I wish to thank the entire 'ESO community' – the entire staff, members of committees and working groups, and our users – for their dedicated support and continued contribution to our shared adventure: Providing the best tools in the world to the scientists in our member states and thus enabling them to tackle some of the biggest research questions that humankind has ever asked. I wish, however, to extend special thanks to Piet van der Kruit for his whole-hearted efforts as President of Council to pave the way for a great future for this organisation.

C. Cesarsky

Catherine Cesarsky
Director General, ESO

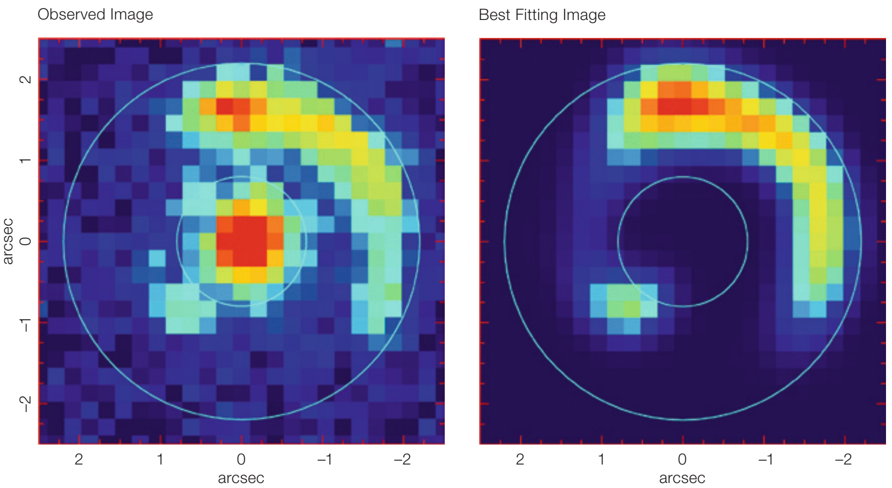
Research Highlights

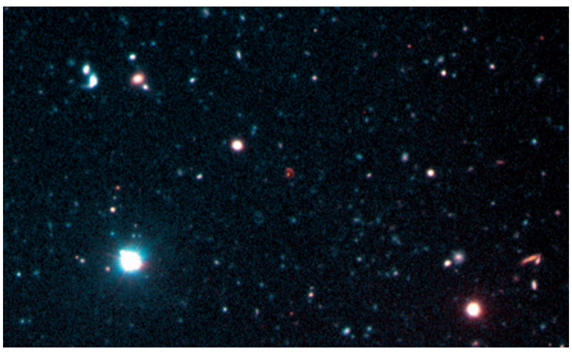
It is gratifying to see that more and more scientists are using ESO's telescopes: in 2005, about 1700 proposals for observing time were received, leading to a pressure factor (ratio of time requested over the available time) on most telescopes close to four. The success can also be seen from the outstanding science results based on ESO's telescopes and the growing number of scientific publications. In early 2005, the 1000th scientific paper based on VLT observations was published. By the end of the year 1300 publications had appeared.

In 2005, 579 papers where published using data collected with ESO's telescopes, of which eight appeared in the leading research journals *Nature* and *Science*. The VLT was used in 355 papers among which 15 are based on the interferometric mode (VLTI). The workhorses, FORS1 and FORS2, were used in 134 publications, followed by UVES (104) and ISAAC (79). Most remarkable is the large number of papers based on adaptive optics instruments (32) and on the recently installed FLAMES (17). VIMOS was used in 19 refereed publications.

As can be seen in the results highlighted below, ESO's telescopes are playing a major role in many hot topics in astrophysics, for example, exoplanets and gamma-ray bursts. For exoplanets, the La Silla Paranal Observatory is indeed well equipped with its armada of instruments: NACO for adaptive optics imaging, FLAMES and UVES on the VLT and HARPS on the 3.6-m for high resolution spectroscopy, the 1.5-m Danish and 1.2-m Swiss telescopes for long term monitoring, as well as the VLTI. Thus, ESO's telescope allowed astronomers to obtain the first image of an exoplanet, found one of the lightest exoplanets with 17 times Earth's mass orbiting a low-mass star, and showed that small stars have the same radius as large planets. In the study of gamma-ray bursts ESO's telescopes played a leading role in finding the farthest burst, having a redshift of 6.3, as well as contributing to solve the 30 year-long puzzle of the short gamma-ray bursts.

A major programme in 2005 was the study of Comet 9P/Tempel 1 that was the target of the Nasa Deep Space probe on 4 July. During almost one week centred from the time of the collision, all ESO telescopes were turning their eyes towards the comet, in a coordinated fashion and in very close collaboration with the space mission's scientific team. Among all observatories, the ESO La Silla Paranal Observatory thus provided the best coverage of this so far unique event.





Einstein Ring in Distant Universe

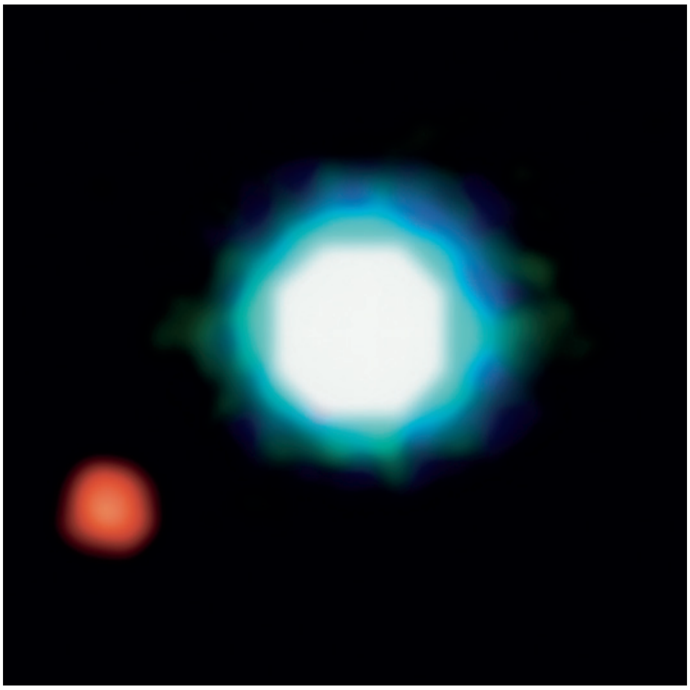
Using the VLT, astronomers discovered an amazing cosmic mirage, known to scientists as an Einstein Ring. This cosmic mirage, dubbed FOR J0332-3557, is seen towards the southern constellation Fornax (the Furnace), and is remarkable on at least two counts. First, it is a bright, almost complete Einstein ring. Second, it is the farthest ever found. The images show it to extend to almost 3/4 of a circle. The lensing galaxy is located at a distance of about 8000 million light years from us, while the source galaxy whose light is distorted is much farther away, at 12000 million light years. Thus, we see this galaxy as it was when the Universe was only 12 % of its present age. The lens magnifies the source almost 13 times. The observations reveal the galaxy acting as the lens to be a rather quiet galaxy, 40000 light years wide, with an old stellar population. The far away lensed galaxy, however, is extremely active, having recently experienced bursts of star formation. It is a compact galaxy, 7000 light years across.

Yes, it is the Image of an Exoplanet

Among the most essential quests of contemporary astronomers, taking direct images of planets outside of our Solar System is certainly near the top of the list. Obtaining such images of a so-called exoplanet would enable scientists to study the physical nature of the object in detail and, in particular, to analyse the composition of its atmosphere. The astronomers' ultimate goal is of course to perform such analysis for Earth-sized planets, in the hope of detecting a telltale signature of extraterrestrial life.

Such an ultimate objective is still at least decades in the future, as Earth-size and even Jupiter-size planets around stars as old as the Sun are too faint to be detected by present-day technology. Nevertheless, great progress can be achieved by taking images of giant planets orbiting younger objects. Because giant planets a few tens of millions of years old are hotter and brighter than their older brethren, they can be detected much more easily. Moreover, as the first tens of millions of years are considered to have been a critical period in the formation of Earth and of our own Solar System, the study of nearby young planetary systems provides astronomers with invaluable insight into our own origins, something that is difficult if not impossible to decipher from investigation of old, mature planetary systems.

Several surveys are therefore currently in progress that particularly aim at finding and taking direct images of sub-stellar companions – brown dwarfs and exoplanets – close to very young objects. Last year, an international team of astronomers reported the first image of a giant planet companion to 2MASSJ1207334-393254 (for short 2M1207). On NACO/VLT images obtained in April 2004, they detected a faint reddish speck of light in the close vicinity of this young brown dwarf member of the eight million year old TW Hydrae Association. The feeble companion, now called 2M1207b, is more than 100 times fainter than the brown dwarf, 2M1207A. The spectrum of the companion presents the strong signature of water molecules. Based on the infrared colours and the spectral data, evolutionary model calculations lead to the conclusion that 2M1207b is a five Jupiter-masses planet. Its mass can be estimated also by use of a different analysis which focuses on the strength of its gravitational field; this technique suggests that the mass might be even less than five Jupiter mass.



NACO composite image of the brown dwarf object 2M1207 (white blue in centre) and its giant planetary companion (red speck).

In April 2004, the spectroscopic and photometric analysis strongly indicated a planetary mass object close to the star. An alternative explanation, that the detected faint object was a background source unrelated to the young brown dwarf (such as an extragalactic object or a peculiar cool star with unusual infrared colours), appeared very unlikely. Observations with the Hubble Space Telescope, obtained in August 2004 (i.e. only four months later), corroborated the VLT/NACO observations, even though they were obtained too soon after the NACO ones to provide a definite answer. Additional observations at a later epoch were required to prove beyond any doubt that the two objects, 2M1207A and 2M1207b, indeed move together in the sky and are therefore gravitationally bound to each other.

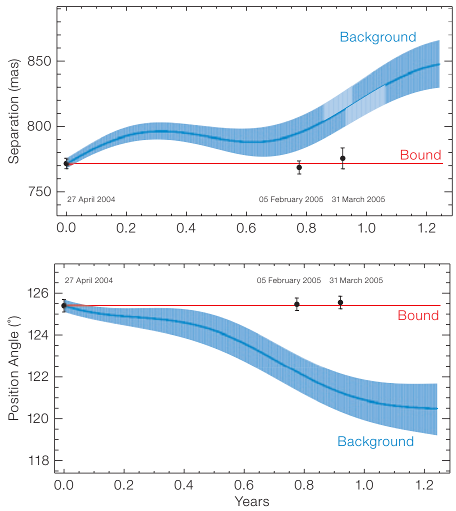
Such additional observations have been performed by the same team of European and American astronomers. Again they used NACO on Yepun, the fourth 8.2-m Unit Telescope of ESO's Very Large Telescope. The team took new images in February and March 2005 and measured the apparent motion on the sky of the young brown dwarf. For the three different epochs (April 2004, February and March 2005), they then accurately determined the relative position of the giant planet companion with respect to the brown dwarf.

These observations show, with high accuracy, that there is no change in relative position between the two objects. This is exactly what one expects over a time scale of one year if 2M1207b is gravitationally bound to its host 2M1207A. Over much longer time spans, we should be able to see the two objects orbiting around each other. This new set of NACO measurements therefore unambiguously confirms that 2M1207b is a planetary mass companion to the young brown dwarf 2M1207A. The image released last year is thus truly the first image ever taken of a planet outside of our Solar System.

According to the astronomers, given the rather unusual properties of the 2M1207 system, the giant planet most probably did not form like the planets in our Solar System. Instead it must have formed the same way the Sun formed, by a one-step gravitational collapse of a cloud of gas and dust.

In the course of the same survey, the astronomers also discovered an interesting companion to the young star AB Pictoris of the 30 million years old Tucana-Horologium Association located about 150 light years from Earth. This companion, imaged for the first time in March 2003, has a near-infrared luminosity and spectrum which point to a light and cool object.

Using the same strategy as for 2M1207b, the scientists observed the AB Pic system at different epochs over a time span of a year and a half and confirmed that the companion is not a background object. Evolutionary model calculations point to a 13 to 14 Jupiter masses object with a temperature of ~ 1700 Kelvin. As the presently accepted separation between a high mass planet and a low mass brown dwarf is at 13.6 Jupiter masses, the newly discovered companion thus may lie at the exact boundary between these two classes of sub-stellar objects. It might therefore play the role of a unique 'Rosetta stone' in the future. Remarkably, this companion is located very far from its host star – about nine times further from AB Pictoris than Neptune is from the Sun. Nothing like this situation has ever been seen before in a planetary system.



Positions of 2M1207A and of its companion as a function of time.

Celestial Blast in Bleak Reticulum

NGC 1559 is a SBc(s)-type spiral galaxy located about 50 million light years away in the Reticulum constellation. It is about seven times smaller than our Milky Way. On the night of 4 August 2005, a supernova just north of the galaxy was discovered. The supernova was of magnitude 13.8, that is only 20 times fainter than the entire host galaxy. The following night, astronomers classified the object as a somewhat unusual type Ia supernova, caught probably 10 days before it reached its maximum brightness. Such a supernova is thought to be the result of the explosion of a small and dense star – a white dwarf – inside a binary system. As its companion was continuously spilling matter onto the white dwarf, the white dwarf reached a critical mass, causing a fatal instability and the supernova. On 6 August, a team of astronomers used the FORS1 multi-mode instrument on Kueyen (UT2) of the VLT in order to study the polarization properties of this kind of supernova so as to learn more about their asphericity. This holds important clues about the detailed physics that governs this terminal catastrophe in the life of such stars. From a very first analysis of their data, the scientists found that SN 2005df resembles closely another supernova they had studied before, SN 2001el, whose explosion they showed was signifcantly asymmetric.

Is this a Brown Dwarf or an Exoplanet?

As a perfect illustration of the dynamic of this field of research, a different team of astronomers has possibly made another important breakthrough by finding a tiny companion to a young star. For several years these scientists have conducted a search for planets and low-mass objects, in particular around stars still in their formation process – so-called T-Tauri stars – using both the direct imaging and the radial velocity techniques. One of the objects on their list is GQ Lupi, a young T-Tauri star, located in the Lupus I (the Wolf) cloud, a region of star formation about 400 or 500 light years away. The star GQ Lupi is apparently a very young object still surrounded by a disc, with an age between 100 000 and two million years.

The astronomers observed GQ Lupi on 25 June 2004 with NACO. The series of NACO exposures clearly reveal the presence of the tiny companion, located in the close vicinity of the star. This newly found object has a separation of only 0.7 arcsec from its parent star, and would have been overlooked without the use of the adaptive optics capabilities of NACO.

At the distance of GQ Lupi, the separation between the star and its feeble companion is about 100 astronomical units (or 100 times the distance between the Sun and the Earth), that is, roughly 2.5 times the distance between Pluto and the Sun.

The companion, called GQ Lupi B or GQ Lupi b, is roughly 250 times fainter than GQ Lupi A. Further images obtained with NACO in August and September confirmed the presence and the position of this companion. The star had been previously observed by the Subaru telescope as well as by the Hubble Space Telescope. The older images, taken in July 2002 and April 1999, respectively, also showed the presence of the companion, giving the astronomers the possibility of precisely measuring the position of the two objects over a period of several years. This in turn allowed them to determine that the objects move together in the sky – as expected if they are gravitationally bound together.

From their measurements, the astronomers found that the separation between the two objects did not change over the five-year period covered by the observations. For the scientists this is a clear proof that both objects are moving in the same direction in the sky: If the faint object were a background object, from 1999 to 2004, the separation would have changed by 0.15 arcsec, while it seems certain that the change is a least 20 times smaller.

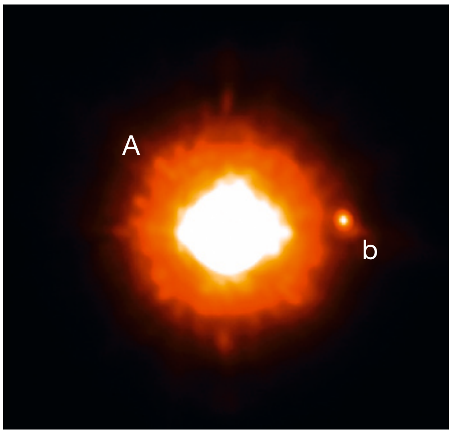
To further probe the physical nature of the newly discovered object, the astronomers used NACO on the VLT to take a series of spectra. These showed the typical signature of a very cool object, in particular the presence of water and CO bands. Taking into account the infrared colours and the spectral data available, atmospheric model calculations point to a temperature between 1600 and 2500 degrees and a radius that is twice as large as Jupiter. According to this, GQ Lupi B is thus a cold and rather small object.

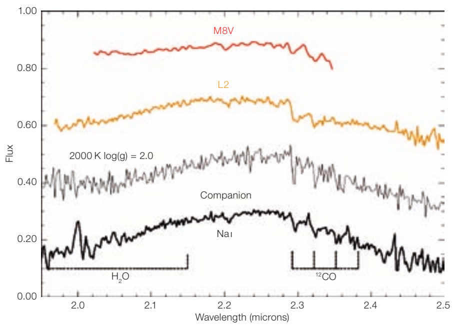
But is it a *bona-fide* exoplanet or is it a brown dwarf, those ‘failed’ stars that are not massive enough to centrally burn hydrogen? Although the borderline between the two is still a matter of debate, one way to distinguish between the two is by their mass (see above; this is also done between brown dwarfs and stars): (giant) planets are lighter than about 13.6 Jupiter-masses, the critical mass needed to ignite deuterium fusion.

Unfortunately, the new observations do not provide a direct estimate of the mass of the object. Thus the astronomers must rely on comparison with theoretical models of such objects. If, as astronomers generally accept, GQ Lupi A and B formed simultaneously, the newly found object is very young. The problem is that for such very young objects, current theoretical models are probably not applicable. If they are used, however, they provide an estimate of the mass of the object that lies somewhere between three and 42 Jupiter-masses, i.e. encompassing both the planet and the brown dwarf domains. The jury is thus still out on the exact nature of GQ Lupi B and on whether NACO and the VLT took the picture of yet another exoplanet.

The discovery of 2M1207b, AB Pic b and GQ Lup b/B, all within a short period of time, bring evidence that new, carefully designed surveys, using state-of-the-art instruments on the most advanced facilities, can provide astronomers with images of planetary companions. The first images of exoplanets have now been taken and there can be little doubt that others will follow soon. The detailed study of a growing number of exoplanets with different masses and orbital properties will provide insight on theoretical formation models and provide a unique opportunity to learn more about how the Solar System formed.

NACO image of GQ Lupi. The feeble point of light to the right of the star is the newly found cold companion.





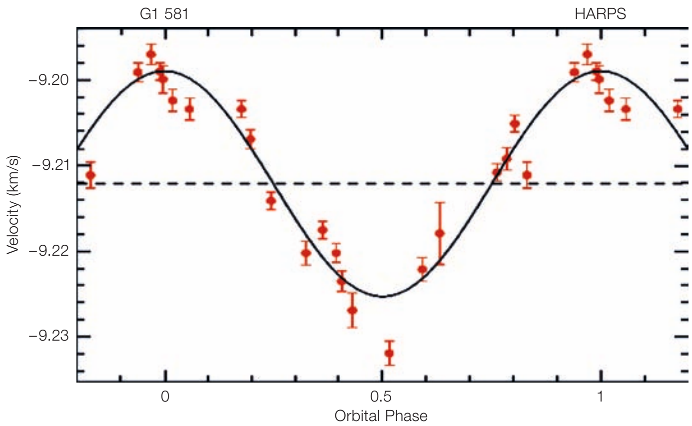
Spectrum of the Companion of GQ Lupi.

The Dwarf that Carries a World

If obtaining an image of a planet is a unique breakthrough, the main technique to find extra-solar planets is still through radial-velocity surveys, detecting the variations in the velocity of the central star due to the changing direction of the gravitational pull from an unseen exoplanet as it orbits its parent star.

In 2004 astronomers using the unequalled HARPS spectrograph at the 3.6-m telescope at La Silla, had set a new record for the discovery of the lightest exoplanet ever observed, finding a planet with fourteen times the mass of the Earth around the star μ Arae. This record was possibly the first discovery of a rocky planet. In 2005, the same team of French and Swiss astronomers discovered another small exoplanet, this time around a star that belongs to the class of red dwarfs. As these stars are very common, this discovery proves crucial in the census of other planetary systems.

The host star, Gl 581, is located 20.5 light-years away in the constellation Libra (the Scales), and has a mass of only one third the mass of the Sun. Such red dwarfs are at least 50 times fainter than the Sun and are the most common stars in our Galaxy: among the 100 closest stars to the Sun, 80 belong to this class. Being so numerous in our vicinity, it is thus fundamental to know if such stars also harbour planets. Previous surveys were rather unsuccessful: observations of about 200 red dwarfs revealed only two with planets. But previous surveys may have missed many planets due to their insufficient precision. The ultra-precise HARPS spectrograph is ideally suited to tackle this problem, with great success. HARPS is capable of measuring radial velocities with a precision better than 1 m/s, or 3.6 km/h.



Radial velocities of the red dwarf Gl 581 as a function of the orbital phase, obtained with HARPS.

The astronomers found the star to move back and forth with a maximum velocity of 13 metres/second, or a little bit less than 50 km/h, completing a full circle in only 5.4 days. The newly found planet is therefore about 17 times the Earth's mass or about the mass of Neptune. It is thus one of the smallest ever found. It is also rather close to its host star; the mean distance is about six million kilometres. By comparison, Mercury, the closest planet to the Sun, is at a distance of 58 million kilometres and completes an orbit in 88 days. Being so close, this alien world must be very hot, about 150 degrees Celsius.

Young and Exotic Stellar Zoo

The open cluster Westerlund 1 is located in the Southern constellation Ara (the Altar). This cluster is behind a huge interstellar cloud of gas and dust, which blocks most of its visible light. Astronomers studied Westerlund 1 extensively with various ESO instruments including the Wide Field Imager (WFI) attached to the 2.2-m ESO/MPG telescope. These observations have revealed a large population of very bright and massive stars. Some would fill the Solar System space within the orbit of Saturn (about 2000 times larger than the Sun!), others are as bright as a million Suns. Westerlund 1 is obviously a fantastic stellar zoo, with a most exotic population and a true astronomical bonanza. All stars identified are evolved and very massive, spanning the full range of stellar oddities from Wolf-Rayet stars, OB supergiants, Yellow Hypergiants (nearly as bright as a million Suns) and Luminous Blue Variables (similar to the exceptional Eta Carinae object). All stars so far analysed in Westerlund 1 weigh at least 30–40 times more than the Sun. Because such stars have a rather short life – astronomically speaking – Westerlund 1 must be very young. The astronomers determine an age somewhere between 3.5 and 5 million years. So, Westerlund 1 is clearly a 'newborn' cluster in our Galaxy!

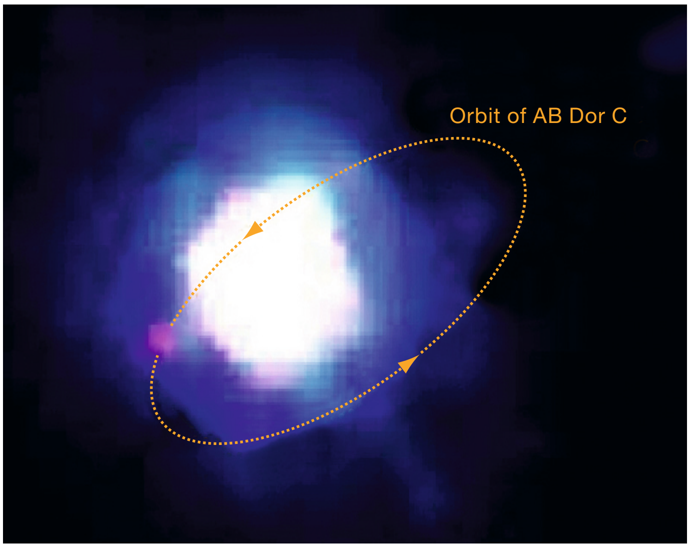
The large quantity of very massive stars implies that Westerlund 1 contains probably close to half a million stars, but most of these are not bright enough to peer through the obscuring cloud of gas and dust. This is ten times more than any other known young cluster in the Milky Way. And still more surprisingly, all these stars are packed into an amazingly small volume of space, less than six light years across. In fact, this is more or less comparable to the four light year distance to the star nearest to the Sun, Proxima Centauri! Because Westerlund 1 is at a distance of only about 10000 light years, high-resolution cameras such as NACO can resolve its individual stars. Such observations are now starting to reveal smaller stars in Westerlund 1, including some that are less massive than the Sun. Astronomers will thus soon be able to study this exotic galactic zoo in great depth.

Weighing the Smallest Stars

In their quest to find exoplanets and brown dwarfs, astronomers have to be careful not to be mistaken and make the wrong conclusions. The uncertain nature of GQ Lup B is an example of the complications at hand, where it is not always easy to distinguish between planets and brown dwarfs. Similarly, it is not always easy to distinguish the 'failed' stars that are brown dwarfs from *bona-fide* stars, these objects all having seemingly very similar sizes. Brown dwarfs are objects up to 75 times more massive than Jupiter, too small for major nuclear fusion processes to have ignited in their interior.

Because the mass is often based on theoretical models, astronomers are looking at ways to constrain them. To determine the mass of a star, astronomers generally observe the motion of stars in a binary system. They then apply the same method that allows determining the mass of the Earth, knowing the distance of the Moon and the time it takes for its satellite to complete one full orbit ('Kepler's Third Law').

Like planets, very low mass objects are brightest while they are young, before they cool off. In one particular case, an international team of astronomers studied the star AB Doradus A (AB Dor A). This star is located about 48 light years away and is 'only' 50 million years old. Because the position in the sky of AB Dor A 'wobbles', due to the gravitational pull of a star-like object, it was believed since the early 1990s that AB Dor A must have a low-mass companion. To image this companion and obtain a comprehensive set of data, the astronomers used a novel instrument mode on the high-contrast adaptive optics camera NACO. The Simultaneous Differential Imager, or NACO SDI, was specifically developed by Laird Close (University of Arizona, USA) and Rainer Lenzen (Max-Planck-Institute for Astronomy in Heidelberg, Germany) for hunting extrasolar planets. The SDI camera enhances the ability to detect faint companions that would normally be lost in the glare of the primary star.



Enhanced, false-colour near-infrared image of AB Dor A and C, taken with the new NACO SDI camera. The faint companion 'AB Dor C' – seen as the pink dot at 8 o'clock – is 120 times fainter than its primary star.

Turning this camera towards AB Dor A in February 2004, the team was able for the first time to image a companion so faint – 120 times fainter than its star – and so near its star. The Hubble Space Telescope had tried but failed to detect the companion, as it was too faint and too close to the glare of the primary star.

The tiny distance between the star and the faint companion (0.156 arcsec) is the same as the width of a one Euro coin (2.3 cm) when seen 20 km away. The companion, called AB Dor C, was seen at a distance of 2.3 times the mean distance between the Earth and the Sun. It completes a cycle around its host star in 11.75 years on a rather eccentric orbit.

Using the companion's exact location, along with the star's known 'wobble', the astronomers could then accurately determine the companion's mass. The object, more than 100 times fainter than its close primary star, has one tenth of the mass of its host star, i.e. it is 93 times more massive than Jupiter. It is thus slightly above the brown dwarf limit.

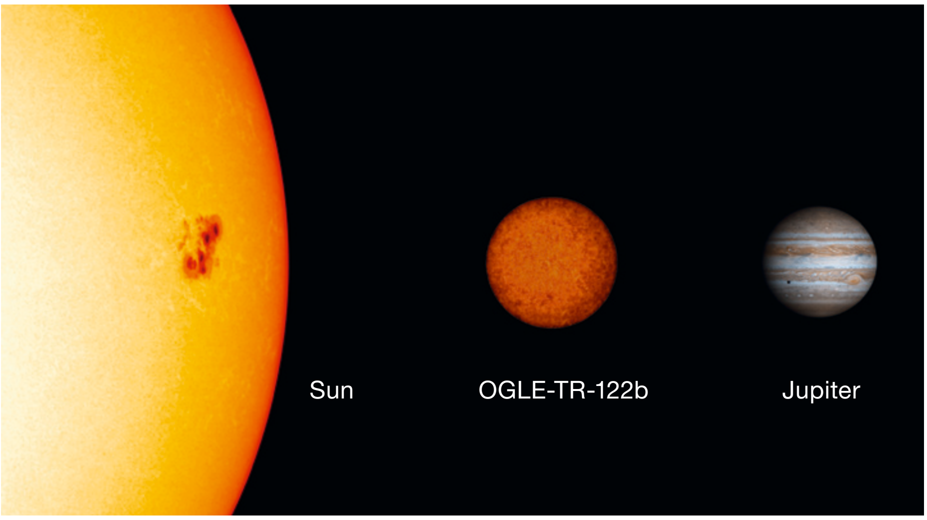
Using NACO on the VLT, the astronomers further observed AB Dor C at near infrared wavelengths to measure its temperature and luminosity. To their surprise, they found that the companion was 400 degrees Celsius cooler and 2.5 times fainter than the most recent models predict for an object of this mass and age. Theory predicts that this low-mass, cool object would be about 50 Jupiter masses. But this object is between 88 to 98 Jupiter masses. These new findings therefore challenge current ideas about the brown dwarf population and the possible existence of the widely publicised 'free-floating' extrasolar planets. Indeed, if young objects hitherto identified as brown dwarfs are twice as massive as was thought, many must rather be low-mass stars. And objects recently identified as 'free-floating' planets could be low-mass brown dwarfs.

Undercover Stars Among Exoplanet Candidates

In another series of observations, astronomers found that an object 96 times heavier than Jupiter was only 16 % larger, thereby demonstrating for the first time that stars less massive than 1/10th of the solar mass are of nearly the same size as giant planets. The observations are part of a large programme using the FLAMES multi-fibre spectrograph on the VLT and aimed at measuring accurate radial velocities for sixty stars for which a temporary brightness 'dip' has been detected during the OGLE survey.

When a planet passes in front of its parent star (as seen from the Earth), it blocks a small fraction of the star's light from our view. These 'planetary transits' are of great interest as they allow astronomers to measure in a unique way the mass and the radius of exoplanets. Several surveys are therefore underway which attempt to find these faint signatures of other worlds. One of these programmes is the Polish OGLE survey operating at the Carnegie Institution of Washington Las Campanas Observatory. It was originally devised to detect microlensing events by monitoring the brightness of a very large number of stars over extended time intervals. During the past years, it has also included a search for periodic, very shallow 'dips' in the brightness of stars, caused by the regular transit of small orbiting objects (small stars, brown dwarfs or Jupiter-size planets). The OGLE team has since announced 177 'planetary transit candidates' from their survey of several hundred thousand stars in three southern sky fields, one in the direction of the Galactic Centre, another within the Carina constellation and the third within the Centaurus/Musca constellations.

The nature of the transiting object can however only be established by subsequent radial velocity observations of the parent star. The size of the velocity variations (the amplitude) is directly related to the mass of the companion object and therefore allows discrimination between stars and planets as the cause of the observed brightness 'dip'.



Comparison between OGLE-TR-122b, Jupiter and the Sun.

Profiting from the multiplex capacity of the FLAMES/UVES facility that permits to obtain high-resolution spectra of up to eight objects simultaneously, an international team of astronomers have looked at 60 OGLE transit candidate stars, measuring their radial velocities with an accuracy of about 50 m/s. This ambitious programme has so far resulted in the discovery of five new transiting exoplanets. Most of the other transit candidates identified by OGLE have turned out to be eclipsing binaries, that is, in most cases common, small and low-mass stars passing in front of a solar-like star. This additional wealth of data on small and light stars is a real bonanza for astronomers.

Low-mass stars are exceptionally interesting objects, also because the physical conditions in their interiors have much in common with those of giant planets, like Jupiter in our Solar System. Moreover, a determination of the sizes of the smallest stars provides indirect, crucial information about the behaviour of matter under extreme conditions. Until recently, very few observations had been made and little was known about low-mass stars. At this moment, exact values of the radii are known only for four stars with masses less than one-third of the mass of the Sun and none at all for masses below one-eighth of a solar mass. This situation is now changing dramatically. Indeed, observations with the Very Large Telescope have so far led to the discovery of seven new eclipsing binaries, that harbour stars with masses below one-third the mass of the Sun. This new set of observations thus almost triples the number of low-mass stars for which precise radii and masses are known. And even better – one of these stars now turns out to be the smallest yet known!

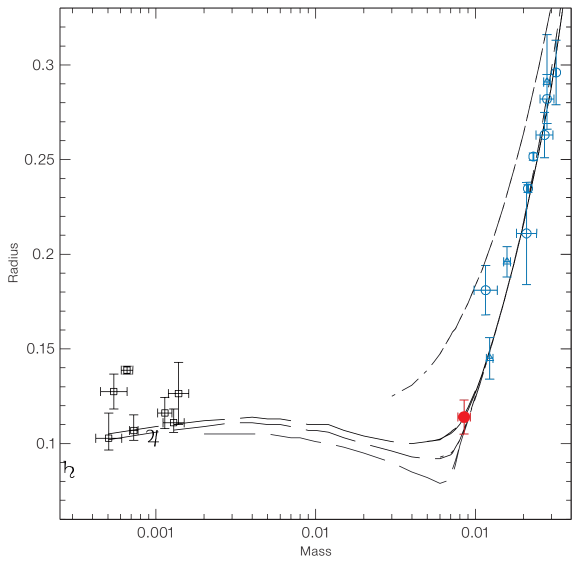
This newly found stellar gnome is the companion of OGLE-TR-122, a rather remote star in the Milky Way galaxy, seen in the direction of the southern constellation Carina. The OGLE programme revealed that OGLE-TR-122 experiences a 1.5 % brightness dip once every seven days six hours and 27 minutes, each time lasting just over three hours (about 188 min). The FLAMES/UVES measurements, made during six nights in March 2004, reveal radial velocity variations of this period with an amplitude of about 20 km/s. This is the clear signature of a very low-mass star, close to the hydrogen-burning limit, orbiting OGLE-TR-122. This companion received the name OGLE-TR-122b.

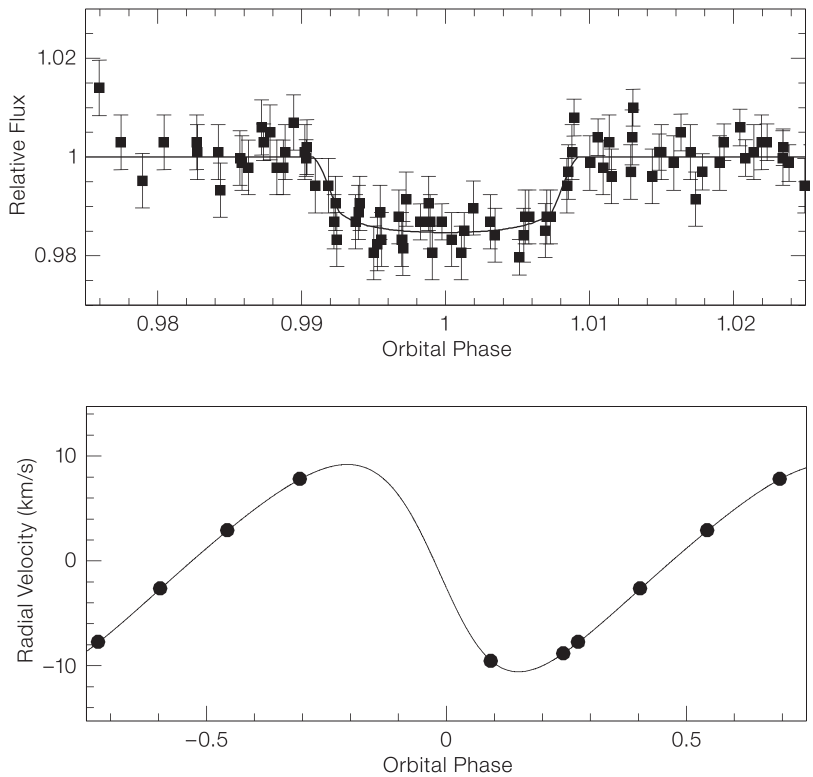
The spectroscopic data allowed the astronomers to determine the nature of the more massive star in the system, which appears to be solar-like. This information can then be used to determine the mass and radius of the much smaller companion OGLE-TR-122b. Indeed, the depth (brightness decrease) of the transit gives a direct estimate of the ratio between the radii of the two stars, and the spectroscopic orbit provides a unique value of the mass of the companion, once the mass of the larger star is known. The astronomers find that OGLE-TR-122b weighs one-eleventh of the mass of the Sun and has a diameter that is only one-eighth of the solar one. Thus, although the star is still 96 times as massive as Jupiter, it is only 16 % larger than this giant planet! The density of such a star is more than 50 times the density of the Sun.

This result shows the existence of stars that look strikingly like planets, even from close by. As all stars, OGLE-TR-122b produces energy in its interior by means of nuclear fusion. However, because of its low mass, this energy production is very small, especially compared to the energy produced by its solar-like companion star. Not less striking is the fact that exoplanets which are orbiting very close to their host star, the so-called 'hot Jupiters', have radii which may be larger than the newly found star. The radius of exoplanet HD209458b, for example, is about 30 % larger than that of Jupiter. It is thus substantially larger than OGLE-TR-122b!

This discovery also has profound implications for the ongoing search for exoplanets. These observations clearly demonstrate that some stellar objects can produce precisely the same photometric signals (brightness changes) as transiting Jupiter-like planets. What's more, the present study has shown that such stars are not rare. Stars like OGLE-TR-122b are thus masqueraders among giant exoplanets and the utmost care is required to differentiate them from their planetary cousins. Uncovering such small stars can only be done with follow-up high-resolution spectral measurements with the largest telescopes.

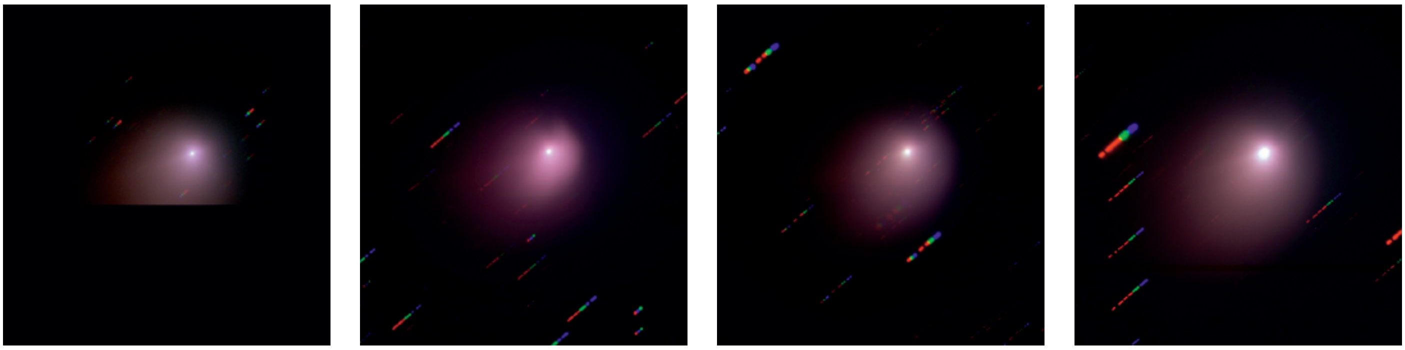
Properties of Low-Mass Stars and Planets. The newly determined, precise values of the mass and radius of OGLE-TR-122b are indicated as the red dot. The blue symbols are values for low-mass stars, while the black symbols on the left represent exoplanets.





Brightness dip of OGLE-TR-122 as measured by OGLE (top). The signal from the star is reduced by 1.5 % for a little more than three hours. The bottom panel presents the velocity variations of the star obtained with FLAMES. These measurements indicate the presence of a low-mass stellar companion to OGLE-TR-122.

A Detailed Look at a Deep Impact



Evolution of Comet 9P/Tempel 1 as observed by FORS2.

On 4 July 2005, the NASA Deep Impact spacecraft passed Comet 9P/Tempel 1 and launched a 360 kg impactor with the aim to produce a crater on the surface of the comet and a plume of gas and dust. Such an ‘attack’ was not gratuitous but constituted a unique opportunity to study the crust and the interior of a comet. As the material inside the comet’s nucleus is pristine, this experiment aimed at revealing new information on the early phases of the Solar System and providing scientists with new insight on crater physics, thereby enabling a better understanding on the crater record on comets and other bodies in the Solar System.

The scientific outcome of the experiment depended crucially on pre-impact and follow-up observations. Before the impact, it was necessary to accumulate a significant amount of data to fully characterise the comet, in terms of size, albedo (reflectivity), rotation period, etc. It was also essential to have a good set of observations before the impact to unambiguously distinguish the effects of the impact from the natural activity of the comet.

Two teams of astronomers used ESO’s telescopes over several months for pre-impact monitoring, taking images and spectra of the comet both in the visible and mid-infrared wavebands. These teams made observations typically once per month, using either the 3.6-m telescope or the 3.5-m New Technology Telescope (NTT) at La Silla.

ESO’s telescopes were also used in the post-impact observations. As soon as the comet became visible from Chile after the impact, and for almost a week afterwards, all major ESO telescopes – the four Unit Telescopes of the Very Large Telescope Array at Paranal, as well as the 3.6-m, 3.5-m NTT and the 2.2-m ESO/MPG telescopes at La Silla – observed how Comet 9P/Tempel 1 reacted to the impact. The simultaneous use of all ESO telescopes with a total of 10 instruments has an enormous potential, since it allowed for observation of the comet at different wavelengths in the visible and infrared by imaging, spectroscopy and polarimetry. Such multiplexing capabilities of the instrumentation do not exist at any other observatory in the world.

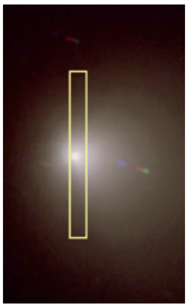
One programme was dedicated to the study of the dusty component while another looked into the gas. The “Exploring the Dust Component” programme used the Wide-Field Imager on the 2.2-m ESO/MPG telescope, the EMMI and SOFI instruments on the 3.5-m NTT, the infrared imager TIMMI2 on the 3.6-m, as well as NACO, FORS1 and VISIR on the Very Large Telescope. This observing programme studied the non-volatile components – dust and boulders – released immediately around impact time in order to characterise the structure and composition of the nucleus.

The second observing programme, “Exploring the Gas Component”, made use of the UVES, FORS2 and ISAAC instruments on the VLT to analyse the gas of the cometary coma, with the aim to study the chemical composition and isotopic ratios of the gas around the nucleus. By searching for differences between the normal coma before and after, invaluable information can be obtained on the pristine material ejected by the impact. Knowing the isotopic ratio of this more pristine material will provide important clues to trace the origins of comets.

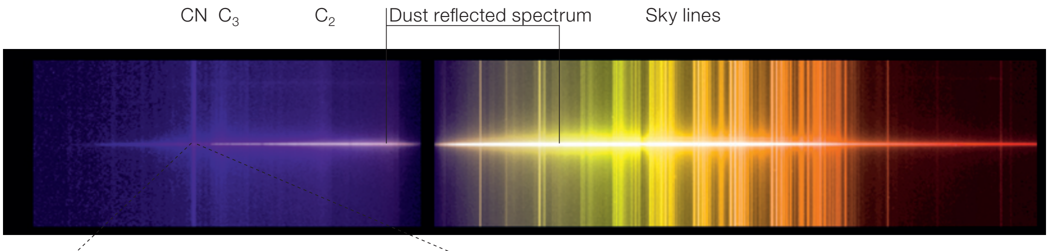
On 29 June, the astronomers met at the ESO Chilean Headquarters in Santiago to coordinate their action. Extensive discussions were held to prepare the observing sequences at the various telescopes, to arrange for fall-back solutions in case of problems, to set-up the data reduction and analysis procedures to be used and to outline the communication paths between the two teams at Paranal and La Silla as well as to the Deep Impact project and other associated teams.

The first results of this unique campaign, which proved very successful, have been published, showing that the impactor did not create a large new zone of activity and may have failed to liberate a large quantity of pristine material from beneath the surface. A more detailed presentation of the outcome of this unique campaign, together with results obtained by the spacecraft itself and other observatories in the world, is scheduled for the Summer of 2006.

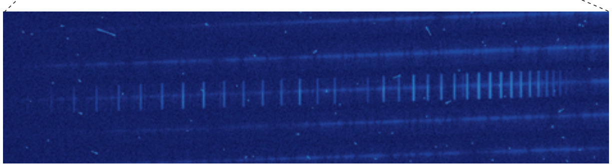
The images obtained at the VLT show that after the impact, the morphology of Comet Tempel 1 had changed, with the appearance of a new plume-like structure, produced by matter being ejected with a speed of about 700 to 1000 km/h. This structure, however, diffused away in the following days, being more and more diluted and less visible, the comet resuming again the appearance it had before the impact. Further images obtained with, among others, the adaptive optics NACO instrument, showed the same jets that were visible prior to im-



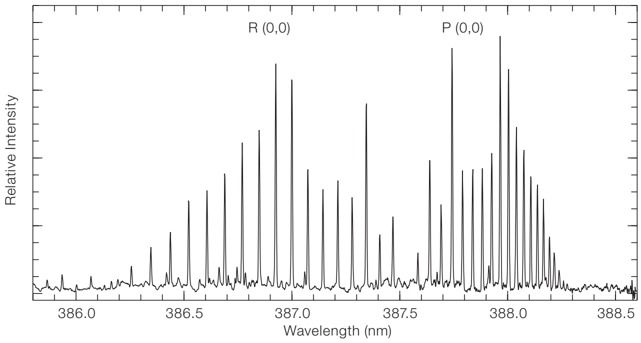
(a) Slit view image



(b) Low resolution NTT spectrum



(c) CN-band at high resolution with VLT



The low resolution spectra taken at La Silla with EMMI on the NTT during the night from 31 May to 1 June 2005 are shown in panel b. The slit was centred on the nucleus (see panel a for a schematic representation). The dust scattered spectrum (reflection of the solar light on dust grains) is well visible as the bright horizontal line in the spectrum (panel b). Several cometary emission lines belonging to different species are also visible in the blue part of the spectrum. Most of the emission lines visible in the red part are coming from the Earth's atmosphere (which is glowing) and are called 'sky lines'. The brightest gas feature (located at 387.5 nm) is due to the CN molecule; it has been observed early June in great detail with UVES (panel c). The upper part of panel c displays a very small portion of the 'raw' (two dimensional) UVES spectrum centred on this feature; the lower part is the 'extracted' (one dimensional) spectrum, now clearly displaying the individual emission lines. This spectrum represents a total of nine hours of exposure time and will be used to measure the 'isotopes' of carbon and nitrogen.

pact, demonstrating that the comet activity survived widely unaffected by the spacecraft crash.

On Melipal (UT3), VISIR took remarkable spectra of the comet before and after impact. Light from the Sun is heating the dust particles surrounding the cometary nucleus. Infrared observations measure the thermal radiation emitted by the dust grains and allow probing their temperature. In addition they offer valuable clues to study the chemical composition and the physical state of the dust in a comet. This information helps to understand how and where comets were formed in the protoplanetary cloud about 4 550 million years ago. A very preliminary analysis showed that the flux of the thermal radiation had increased by about 25 % after the impact.

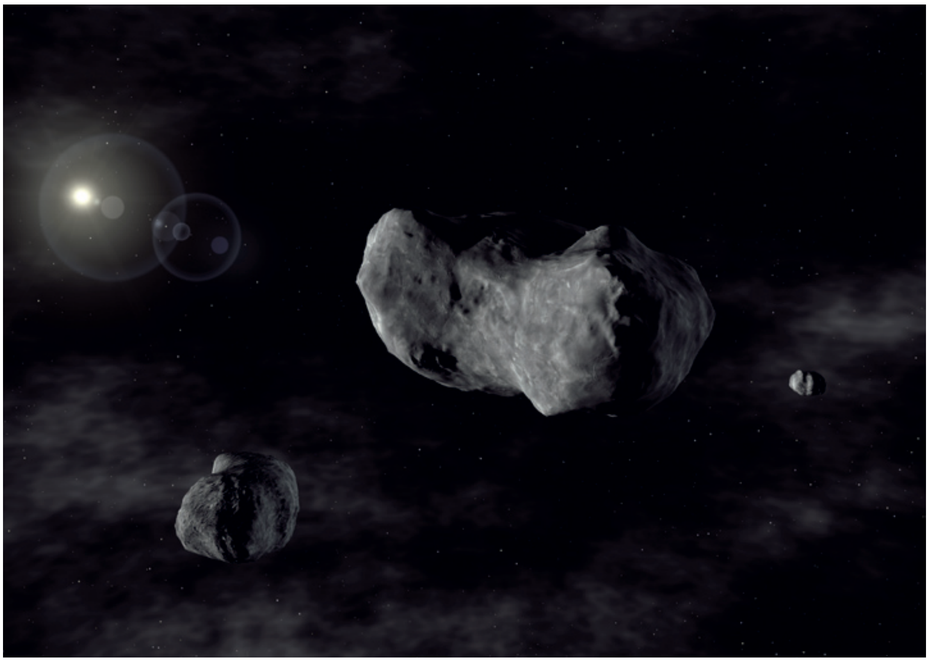
The study of the gas in Comet Tempel 1, made with UVES on Kueyen (UT2 of the VLT), also revealed a small flux increase in the first night following the impact. At that time, more than 17 hours after the impact, the ejected matter was fading away though still measurable thanks to the large light collecting power of the VLT. The data accumulated during 10 nights around the impact provided the astronomers with the best ever time series of optical spectra of a Jupiter Family comet, with a total of more than 40 hours of exposure time. This unique data set has already allowed the astronomers to characterise the normal gas activity of the comet and also to detect, to their surprise, an active region. This active region is not related to the impact as it was also detected in data collected in June. It shows up about every 41 hours, the rotation period of the comet nucleus determined by the Deep Impact spacecraft. Exciting measurements of the detailed chemical composition (such as the isotopic ratios) of the material released by the impact as well as the one coming from that source is being performed by the astronomers.

Further spectropolarimetric observations with FORS1 have confirmed the surface of the comet to be rather evolved – as expected – but more importantly, that the dust is not coming from beneath the surface. These data constitute another unique high-quality data set on comets.

Finally, observations with the UVES spectrograph found from pre-impact high-quality, high-resolution spectra, convincing evidence for the presence of water in Comet Tempel 1. The astronomers have indeed detected among many other species the light emitted at 308–316 nm by the OH molecule, the direct decay product of water.

Rubble-Pile Minor Planet Sylvia and Her Twins

Artist's impression of the triple asteroid system.



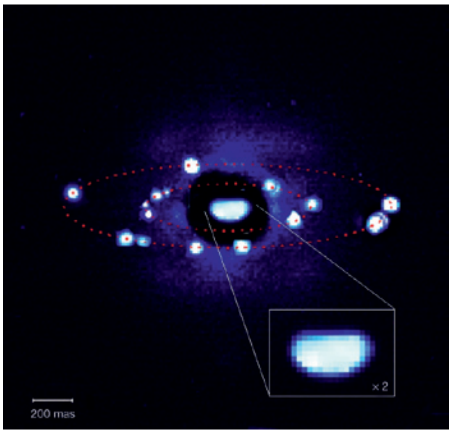
One of the thousands of minor planets orbiting the Sun has been found to have its own mini planetary system. Astronomers have discovered the first triple asteroid system – two small asteroids orbiting a larger one known since 1866 as 87 Sylvia[1].

The discovery was made with Yepun (UT4) using the NACO instrument. Via the observatory's 'Service Observing Mode', the astronomers obtained sky images of many asteroids over a six-month period without actually having to travel to Chile. One of these asteroids was 87 Sylvia, which was known to be double since 2001, from observations made with the Keck telescope. NACO was used to observe Sylvia on 27 occasions, over a two-month period. On each of the images, the known small companion was seen, allowing the scientists to precisely compute its orbit. But on 12 of the images, the astronomers also found a closer and smaller companion. 87 Sylvia is thus not double but triple!

Because 87 Sylvia was named after Rhea Sylvia, the mythical mother of the founders of Rome, the astronomers proposed naming the twin moons after her sons: Romulus and Remus. The International Astronomical Union approved the names.

[1] The 87th minor planet discovered, Sylvia was first observed from the Observatory of Madras (India) on 16 May 1866 by the Government Astronomer Norman R. Pogson. It was common in the early days to assign a name – usually feminine – from mythology to newly found asteroids. Pogson selected a name from the list furnished to him by Sir John Herschel.

Sylvia's moons are considerably smaller than Sylvia itself, orbiting in nearly circular orbits and in the same plane and direction. The closest and newly discovered moonlet, orbiting about 710 km from Sylvia, is Remus, a body only 7 km across and circling Sylvia every 33 hours. The second, Romulus, orbits at about 1360 km in 87.6 hours and measures about 18 km across.



Orbits of the twin moonlets around 87 Sylvia as observed by NACO.

The asteroid 87 Sylvia is one of the largest known from the asteroid main belt, and is located about 3.5 times further away from the Sun than the Earth, between the orbits of Mars and Jupiter. The wealth of details provided by the NACO images shows that 87 Sylvia is shaped like a lumpy potato, measuring 380 × 260 × 230 km. It is spinning at a rapid rate, once every five hours and 11 minutes.

The observations of the moonlets' orbits allow the astronomers to precisely calculate the mass and density of Sylvia. With a density only 20 % higher than the density of water, it is likely composed of water ice and rubble from a primordial asteroid. It could be up to 60 percent empty space and is therefore most probably a 'rubble-pile' asteroid. These asteroids are loose aggregations of rock, presumably the result of a collision. Two asteroids smacked into each other and were disrupted. The new rubble-pile asteroid formed later by accumulation of large fragments while the moonlets are probably debris left over from the collision that were captured by the newly formed asteroid and eventually settled into orbits around it.

Star on the Run

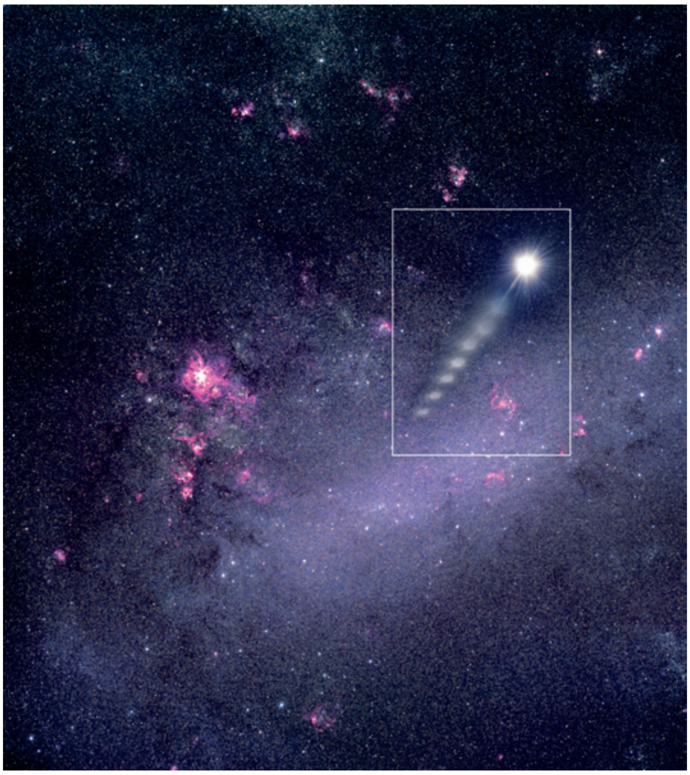
Observations with Kueyen (UT2) have led to the discovery of a short-lived massive star that is moving at a very high speed through the outer halo of the Milky Way galaxy and into intergalactic space. This finding could provide evidence for a previously unknown massive black hole in the heart of the Milky Way's closest neighbour, the Large Magellanic Cloud. The star, named HE 0437-5439, was discovered by the Hamburg/ESO sky survey, a project aimed at detecting quasars but which discovered many faint blue stars as well. A team of scientists found what is likely to be a hot massive main-sequence star, far out in the halo. This came as a great surprise. Massive stars have lifetimes of only some tens or hundreds of million years, short lived for astronomical standards, but the halo does not usually host stars as young as this. In fact, it contains the oldest stars in the Milky Way that are more than ten thousand million years old. Massive stars are usually found in or near star forming regions in the Galactic disc such as the famous Orion Nebula: HE 0437-5439 is indeed similar to the Trapezium stars that make the Orion Nebula shine.

Data were obtained with the high-resolution UVES spectrograph. This allowed the chemical composition to be measured, which turned out to be similar to that of the Sun, confirming that HE0437-5439 is a young star. Its mass is eight times larger than that of the Sun and the star is only 30 million years old. It is almost 200 000 light years away from us in the direction of the constellation Doradus (the Swordfish). Even more exciting was the fact that the data indicated the star to be receding at a velocity of 723 km/s, or 2.6 million km/h. HE0437-5439 moves so fast that the gravitational attraction of the Milky Way is too small to keep it bound to the Galaxy. Hence the hypervelocity star will escape into intergalactic space.

As the star is moving so fast, it must have been born far away from its present position and accelerated to where we observe it today. What accelerated the star to such a high speed? Calculations carried out already in the late 1980s showed that a so-called supermassive black hole (SMBH), i.e. a black hole a million times as massive as the Sun, or larger, could provide the enormous acceleration. If a binary star approaches the SMBH, one star falls towards the SMBH while its companion is ejected. The Galactic Centre of the Milky Way hosts such a black hole of about 2.5 million solar masses, and this might have accelerated HE0437-5439. But the necessary travel time was found to be more than three times the age of the star. Hence the star is too young to have travelled all the way from the Galactic centre to its present location. Either the star is older than it appears or it was born and accelerated elsewhere.

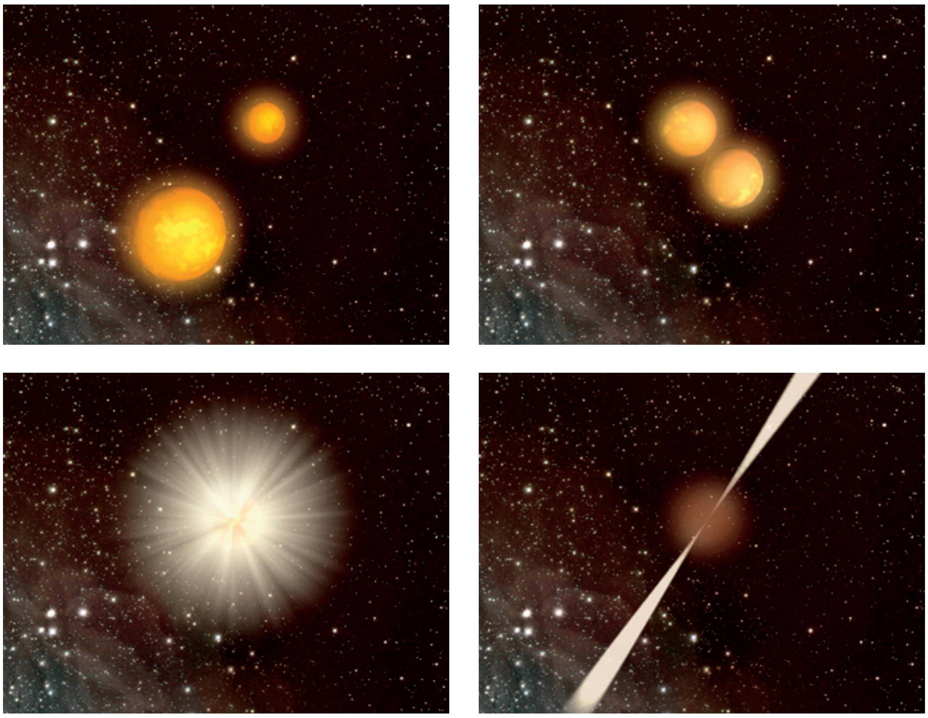
A different clue to the origin of HE0457-5439 comes from its position in the sky. HE0437-5439 is 16 degrees away from the Large Magellanic Cloud (LMC), one of the nearest neighbouring galaxies to the Milky Way. This galaxy lies at a distance of 156 000 light years. HE0457-5439 is even more distant than the LMC and is much closer to the LMC than to the Galaxy. The astronomers showed that the star could have reached its present position within its lifetime if it were ejected from the centre of the LMC. This, in turn, would provide evidence for the existence of a SMBH in the LMC. Another explanation would require the star to be the result of the merging of two stars, belonging to the so-called blue stragglers class of stars, which are older than standard evolution models predict them to be. Indeed, its age could then be as much as the lifetime of a four solar mass star which is more than six times the lifetime of an eight solar mass star.

The astronomers propose two additional observations to distinguish between the two options. The abundance of certain elements in stars belonging to the LMC is only half that of the Sun. A more precise measurement with UVES would indicate whether the star has a metal abundance appropriate to LMC stars or not. The second is to measure how much the star moves in the transverse direction on the sky, using astrometric measurements.



Star ejected from the Large Magellanic Cloud (artist's view).

Flashes Shed Light on Cosmic Clashes



The merging scenario, animation of two neutron stars orbiting each other and gradually being dragged together. The end result is a gigantic explosion where two jets are emitted. If one of the jets points toward the Earth we observe a short gamma-ray burst.

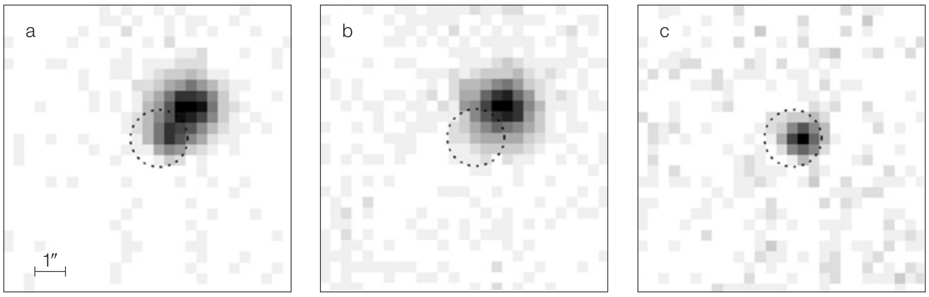
Apart from the Big Bang itself, 'Gamma-ray bursts' or GRBs are by far the most powerful explosive events that are known in the Universe.

The wealth of observations on GRBs has revealed that they come in two different flavours: the long (lasting more than two seconds) and the short ones. The difference between the two is not only in the duration: short bursts also consist of higher energy photons than the long ones. One may thus infer that the physical origins of the two are different. Over the past few years, a large international effort has convincingly shown that long gamma-ray bursts are linked with the ultimate explosion of massive stars ('hypernovae'). A key proof was provided with the help of ESO telescopes in 2003. On 29 March 2003, NASA's High Energy Transient Explorer (HETE-II) satellite detected a very bright gamma-ray burst. Following identification of the 'optical afterglow' by a 40-inch telescope at the Siding Spring Observatory (Australia), a high-dispersion spectrum obtained with the UVES spectrograph at the 8.2-m VLT Kueyen telescope allowed to measure its distance to about 2 650 million light years. This was the nearest normal GRB ever detected and, using two other powerful instruments at the ESO Very Large Telescope, the FORS1 and FORS2 multi-mode instruments, astronomers obtained, over a period of one month, spectra of the fading object. The astronomers observed the gradual 'emergence' with time of a supernova-type spectrum, revealing the extremely violent explosion of a star. With velocities well in excess of 30 000 km/s (i.e., over 10 % of the velocity of light), ejected material was moving at record speed, testifying to the enormous power of the explosion. This set of data provided irrefutable evidence of a direct connection between the GRB and the 'hypernova' explosion of a very massive, highly evolved star.

The breakthrough in our understanding of long-duration GRBs thus came from the discovery of their long-lived X-ray and optical afterglows. Short duration GRBs have however evaded optical and X-ray detection for more than 30 years. It was thus not possible to know in which environment they formed nor to study their light-curve or spectrum to characterise them. That is, until very recently.

On 29 March 2003, the NASA/ASI/PPARC Swift satellite detected a 40-millisecond duration gamma-ray burst. Further observations with the X-ray detector on board the satellite detected an X-ray afterglow of a short burst for the first time. Thanks to this, its position could be determined with an accuracy better than 10 arcsec, allowing astronomers to point ESO's Very Large Telescope towards it and to take images with FORS2. The burst, named GRB 050509B, was found to sit very close to a luminous, non-star-forming elliptical galaxy lying 2700 million light years away (redshift 0.225) and belonging to a cluster of galaxies. Based on the unlikeness of a chance alignment between GRB 050509B and such a galaxy, it is argued that this is the host galaxy of the burst. This, the astronomers explain, makes it difficult for the hypernova model to be invoked. Indeed, it is highly improbable to find a core-collapse supernova in this galaxy.

On the other hand, the other prevailing model, the merging of two neutron stars in a binary, seems more likely. Such a galaxy indeed is known to host many tight binaries with compact stars. To be sure that the hypernova model could be ruled out, the astronomers performed further observations – until three weeks after the burst – with the FORS1 and FORS2 instruments. With these observations, the astronomers are confident that even the faintest supernovae would have been detected. But none were found.



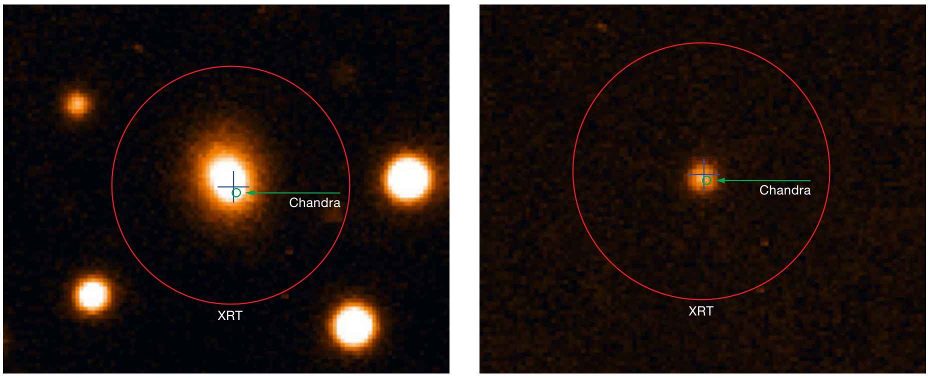
Images taken with the Danish 1.5-m telescope at La Silla of the short gamma-ray burst GRB 050709 afterglow: on July 11 (a) and on July 18 (b). Panel c shows the difference between panels a and b clearly revealing the short gamma-ray burst visible light.

And as sometime happens, a few months later, the astronomers were given the chance to study another afterglow of a short burst. And this time in the optical. In the night of 9 to 10 July 2005, the NASA HETE-2 satellite detected a 70-millisecond duration burst and was able, based on the detection of X-rays, to precisely determine its position. Thirty-three hours after, images of this region of the sky were obtained using the Danish 1.5-m telescope at La Silla. The images showed the presence of a fading source, sitting on the edge of a galaxy, most probably the host galaxy of the burst. This is thus the first optical afterglow of a short gamma-ray burst. The burst, named GRB 050709, resides 11 000 light years from the centre of a star-forming dwarf galaxy that is about 2 000 million light years away and is quite young – about 400 million years old. From the observations conducted until 20 days after the burst, the astronomers can rule out the occurrence of an energetic hypernova as found in most long GRBs. This gives further credit to the hypothesis that short GRBs are the consequence of the merging of two very compact stars.

It is striking that the two short bursts that could finally be localised appear in quite different environments. But more striking was the fact that only two weeks after, a third short gamma-ray burst afterglow was discovered, this time from a gamma-ray burst associated with a nearby elliptical galaxy. The low level of star formation in such galaxies and the detection of a second long-lasting flare indicate that this gamma-ray burst is most likely the final scream of a neutron star as it is being devoured by a black hole.

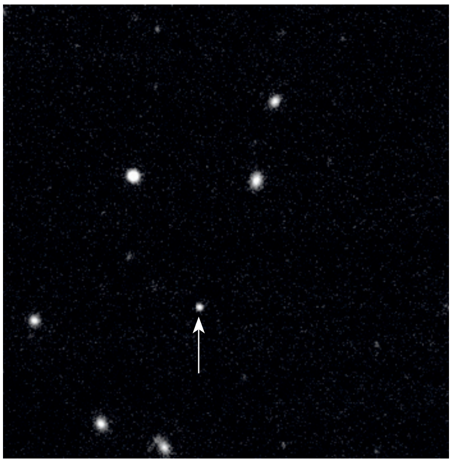
On 24 July 2005, the NASA/ASI/PPARC Swift satellite detected yet another short gamma-ray burst, GRB 050724. Subsequent observations, including some with ESO's Very Large Telescope, allowed astronomers to precisely pinpoint the position of the object, lying about 13 000 light years away from the centre of an elliptical galaxy that is located 3 000 million light years away (redshift 0.258). From its characteristics, astronomers infer that this galaxy contains only very old stars. This is similar to the host galaxy of GRB 050509B, and very different from host galaxies of long bursts. These observations thereby confirm that the parent populations and consequently the mechanisms for short and long GRBs are different in significant ways. Moreover, the observations also show this short burst has released between 100 and 1000 times less energy than typical long GRBs. The burst itself was followed after about 200–300 seconds by another, less-energetic flare. It is unlikely that this can be produced by the merger of two neutron stars. Astronomers therefore conclude that the most probable scenario for the origin of this burst is the collision of a neutron star with a black hole. Indeed, in the case of a merger between a neutron star and a black hole, the neutron star may be only partially disrupted in the initial plunge. The remainder may orbit the black hole, transferring mass at closest approach ('periastron'), until the neutron star mass is reduced to less than two tenths of the mass of the Sun, where it expands to disruption. The activity may thus extend over few tens of seconds, unlike the case of a merging between two neutron stars.

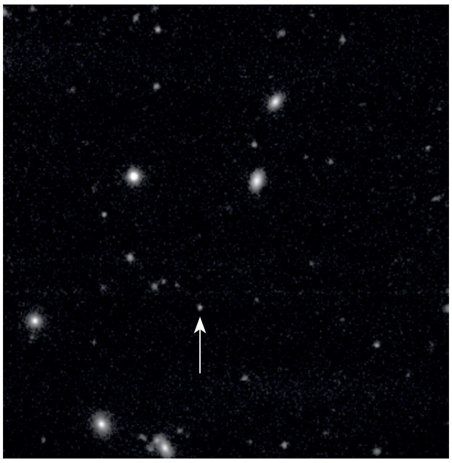
With three events having been discovered in such a short time, big steps have been made to solve the 30-year-long mystery of the short gamma-ray burst.



(Left) VLT optical image taken on 24 July, 12 hours after the burst, showing the position of the gamma-ray burst GRB 050724 as measured by the Swift X-Ray Telescope (XRT) and the Chandra X-ray satellite. The blue cross is the position of the optical afterglow. The burst positions are superimposed on a bright red galaxy at redshift $z = 0.258$. (Right) Difference between two VLT images taken on 24 and 29 July, clearly revealing the presence of the GRB.

Star Death Beacon at the Edge of the Universe





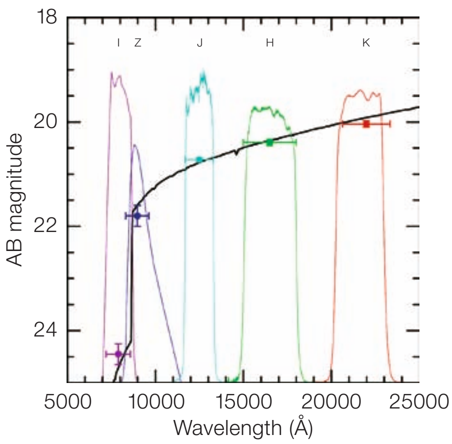
Observation with ISAAC of GRB 050904 about one day after its discovery with the Swift satellite (left), and four days after (right), in the near-infrared *J*-band.

New discoveries have also been made as far as long gamma-ray bursts are concerned. Indeed astronomers have observed the afterglow of a GRB that is the farthest known ever. With a measured redshift of 6.3, the light from this very remote astronomical source has taken 12 700 million years to reach us. It is thus seen when the Universe was less than 900 million years old, or less than seven percent its present age. This means that it is among the intrinsically most luminous GRB ever observed.

This discovery not only sets a new astronomical record, it is also fundamental to the understanding of the very young Universe. Being such powerful emitters, these GRBs serve as useful beacons, enabling the study of the physical conditions that prevailed in the early Universe. Indeed, since GRBs are so luminous, they have the potential to outshine the most distant known galaxies and may thus probe the Universe at higher redshifts than currently known. And because gamma-ray bursts are thought to be associated with the catastrophic death of very massive stars that collapse into black holes, the existence of such objects so early in the life of the Universe provide astronomers with important information to better understand its evolution.

GRB 050904 was first detected on 4 September 2005, by the NASA/ASI/PPARC Swift satellite. Immediately after this detection, astronomers in observatories worldwide tried to identify the source by searching for the afterglow in the visible and/or near-infrared, and study it. First observations by American astronomers with the Palomar Robotic 60-inch Telescope failed to find the source. This sets a very stringent limit: in the visible, the afterglow should thus be at least a million times fainter than the faintest object that can be seen with the unaided eye (magnitude 21). But observations by another team of American astronomers detected the source in the near-infrared *J*-band with a magnitude 17.5, i.e. at least 25 times brighter than in the visible. This was indicative of the fact that the object must either be very far away or hidden beyond a large quantity of obscuring dust. Further observations indicated that the latter explanation did not hold and that GRB 050904 must lie at a distance larger than 12 500 million light years. It would thus be the farthest gamma-ray burst ever detected.

Italian astronomers used Antu (UT1) to observe the object in the near-infrared with ISAAC and in the visible with FORS2. Observations were done between 24.7 and 26 hours after the burst. The afterglow was detected in all five bands in which they observed (the visible *I*- and *z*-bands, and the near-infrared *J*, *H*, and *K*-bands). By comparing the brightness of the source in the various bands, the astronomers could deduce its redshift and, hence, its distance. The value derived has since then been confirmed by spectroscopic observations made by another team using the Subaru telescope.



Magnitude of the gamma-ray burst GRB 050904 as observed with FORS2 and ISAAC in the various filters.

Black Hole in Search of a Home

Do orphan supermassive black holes exist? An international team of astronomers used two of the most powerful astronomical facilities available, the ESO Very Large Telescope and the Hubble Space Telescope, to conduct a detailed study of 20 low redshift quasars. For 19 of them, they found, as expected, that these super-massive black holes are surrounded by a host galaxy. But when they studied the bright quasar HE0450-2958, located some 5 000 million light years away, they couldn't find evidence for an encircling galaxy. This, the astronomers suggest, may indicate a rare case of a collision between a seemingly normal spiral galaxy and a much more exotic object harbouring a very massive black hole.

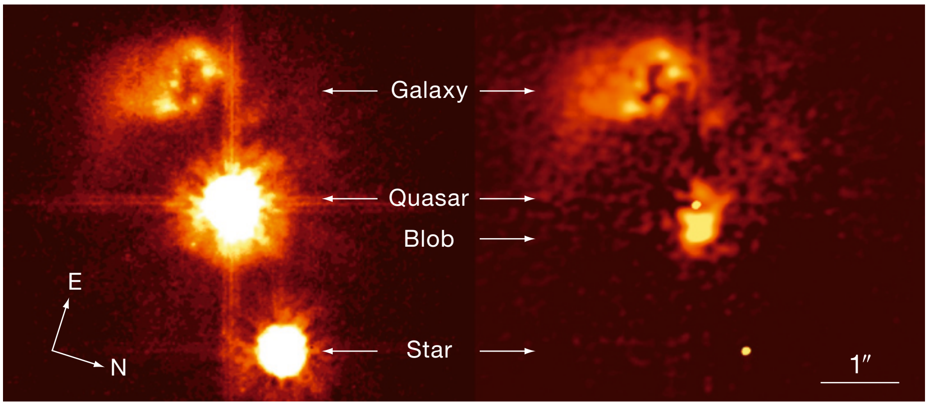
With masses up to hundreds of millions that of the Sun, 'super-massive' black holes are most tantalising. Hiding in the centre of most large galaxies, including our own Milky Way, they sometimes manifest themselves by devouring matter from their surroundings. Shining up to the largest distances, they are then called 'quasars' or 'QSOs' (for 'quasi-stellar objects'), as they had initially been confused with stars. Decades of observations of quasars have suggested that they are always associated with massive host galaxies. However, observing the host galaxy of a quasar is a challenging work, because the quasar is radiating so energetically that its host galaxy is hard to detect in the QSO's glare.

To overcome this problem, astronomers have devised a new and highly efficient strategy. Using ESO's VLT for spectroscopy and HST for imagery, they observed their quasars simultaneously with a reference star. This allowed them to measure in the best way the shape of the quasar point source on spectra and images, and further to separate the quasar light from the other contributions, i.e. from the underlying galaxy itself. This very powerful image and spectra sharpening method ('MCS deconvolution') was applied in order to detect the finest details of the host galaxy. The astronomers could detect a host galaxy for all but one of the quasars they studied. No stellar environment was found for HE0450-2958, suggesting that if any host galaxy exists, it must either have a luminosity at least six times fainter than expected *a priori* from the observed quasar luminosity, or a radius smaller than about 300 light years. Typical radii for quasar host galaxies range between 6 000 and 50 000 light years, i.e. they are at least 20 to 170 times larger. With the data the astronomers managed to secure with the VLT and the HST, they would have been able to detect a normal host galaxy. They therefore conclude that this bright quasar is not surrounded by a massive galaxy.

Instead, just next to the quasar the astronomers detected a bright cloud of about 2 500 light years in size. The VLT observations show this cloud to be composed of gas ionised by the intense radiation coming from the quasar. It is probably the gas of this cloud which is feeding the supermassive black hole, allowing it to become a quasar. A strongly perturbed galaxy, showing all signs of a recent collision, is also seen on the HST images two arcseconds away (corresponding to about 50 000 light years), with the VLT spectra showing it to be presently in a state where it forms stars at a frantic rate.

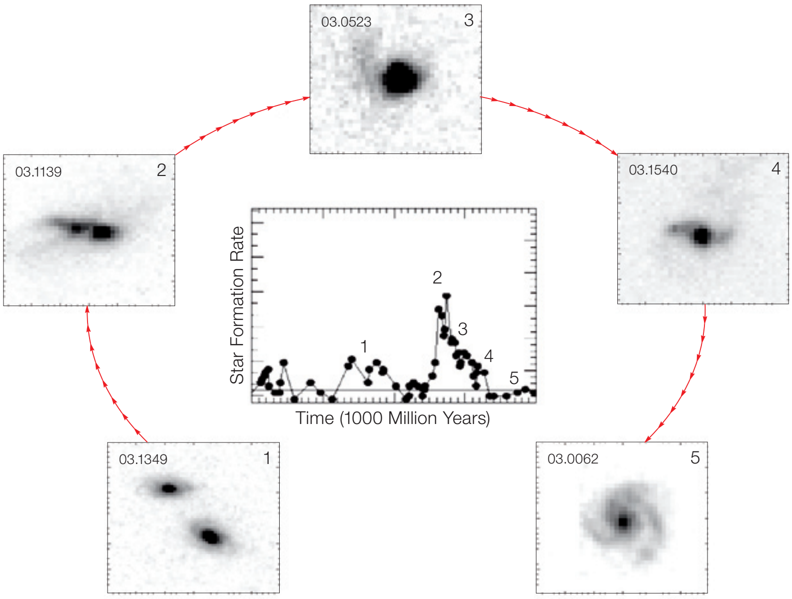
The absence of a massive host galaxy, combined with the existence of the gas cloud and the star-forming galaxy, lead the astronomers to believe that they have uncovered an exotic quasar. There is little doubt that a burst in the formation of stars in the companion galaxy and the quasar itself have been ignited by a collision that must have taken place about 100 million years ago. What happened to the putative quasar host remains unknown.

HE0450-2958 constitutes a challenging case of interpretation. The astronomers propose several possible explanations, that will need to be further investigated and confronted. Has the host galaxy been completely disrupted as a result of the collision? It is hard to imagine how that could happen. Has an isolated black hole captured gas while crossing the disc of a spiral galaxy? This would require very special conditions and would probably not have caused such a tremendous perturbation as is observed in the neighbouring galaxy. Another intriguing hypothesis is that the galaxy harbouring the black hole was almost exclusively made of dark matter. Whatever the solution of this riddle, the strong observable fact is that the quasar host galaxy, if any, is much too faint.



The quasar HE0450-2958 as seen by the HST (left) and after applying an efficient image sharpening method (right).

Rebuilding Spiral Galaxies



The spiral rebuilding scenario.

How and when did galaxies form? How and when did stars form in these island universes? These questions are still posing a considerable challenge to present-day astronomers. Front-line observational results obtained with a fleet of ground- and space-based telescopes by an international team of astronomers provide new insights into these fundamental issues.

For this, they embarked on an ambitious long-term study at various wavelengths of 195 galaxies with a redshift, that is the fraction by which the lines in the spectrum of an object are shifted towards longer wavelengths, greater than 0.4. These galaxies, thus located more than 4000 million light years away, were studied using the VLT, as well as the NASA/ESA Hubble Space Telescope, the ESA Infrared Space Observatory satellite and the NRAO Very Large Array. Observations were performed on Antu (UT1) and Kueyen (UT2) over a two-year period using the instruments FORS1 and FORS2 in the visible and ISAAC in the infrared.

From their extensive data set, the astronomers could draw a number of important conclusions. First, based on the near-infrared luminosities of the galaxies, they infer that most of the galaxies they studied contain between 30000 million and 300000 million times the mass of the Sun in the form of stars. This is roughly a factor 0.2 to 2 the amount of mass locked in stars in our own Milky Way. Second, they discovered that contrary to the local Universe where so-called Luminous Infrared Galaxies (LIRGs) are very rare objects, at a redshift from 0.4 to 1, that is, 4000 to 8000 million years ago, roughly one sixth of bright galaxies were LIRGs.

Because this peculiar class of galaxies is believed to be going through a very active phase of star formation, with a doubling of the stellar mass occurring in less than 1000 million years, the existence of such a large fraction of these LIRGs in the past Universe has important consequences on the total stellar formation rate: during the time span from roughly 8000 million to 4000 million years ago, intermediate mass galaxies converted about half of their total gas mass into stars.

A further result could be secured using the spectra obtained with the VLT: the astronomers measured the chemical abundances in several of the observed galaxies. They find that galaxies with large redshifts show oxygen abundances twice lower than present-day spirals. As it is stars which produce oxygen in a galaxy, this again gives support to the fact that these galaxies have been actively forming stars in the period between 8000 and 4000 million years ago. And because it is believed that galaxy collisions and mergers play an important role in triggering such phases of enhanced star-forming activity, these observations indicate that galaxy merging still occurred frequently less than 8000 million years ago.

The story revealed by these observations is in agreement with the so-called 'hierarchical merging of galaxies' scenario, present in the literature for about 20 years. According to this model, small galaxies merge to build larger ones. In the normal scenario, it was usually assumed that galaxy merging almost ceased 8000 million years ago. The new complete set of VLT observations show that this is far from being the case. In the following 4000 million years, galaxies still merged to form the large spirals we observe in the local Universe.

To account for all these properties, the astronomers thus devised a new galaxy formation scenario, comprising three major phases: a merger event, a compact galaxy phase and a 'growth of the disc' phase. Because of the unique aspects of this scenario, where big galaxies get first disrupted by a major collision to be born again later as a present-day spiral galaxy, the astronomers rather logically dubbed their evolutionary sequence, the 'spiral galaxy rebuilding'. Although being at odds with standard views which assert that galaxy mergers produce elliptical galaxies instead of spiral ones, the astronomers stress that their scenario is consistent with the observed fractions of the different types of galaxies and can account for all the observations. The new scenario can indeed account for the formation of about three quarters of the present-day spiral galaxies, those with a massive central bulge. It would apply for example to the Andromeda galaxy but not to our own Milky Way. It seems that our Galaxy somehow escaped major collisions in the last thousands of millions of years. Further observations, in particular with the FLAMES instrument, will show whether spiral galaxies are indeed relatively recent born-again systems created from major merger events.

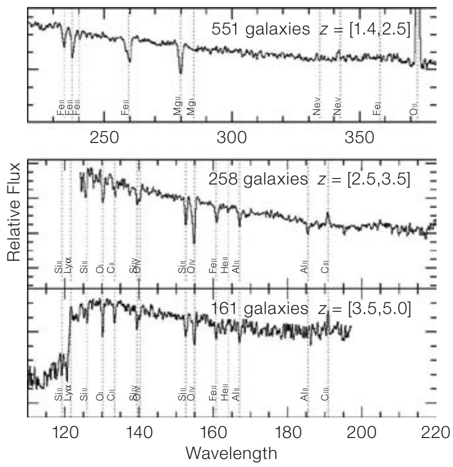
A Cosmic Baby Boom

It is one of the major goals of observational cosmology to trace the way galaxies formed and evolved and to compare it to predictions from theoretical models. It is therefore essential to know as precisely as possible how many galaxies were present in the Universe at different epochs. This is easier to say than to do. Indeed, if counting galaxies from deep astronomical images is relatively straightforward, measuring their distance – hence, the epoch in the history of the Universe where we see them – is much more difficult. This requires taking a spectrum of the galaxy and measuring its redshift. However, for the faintest galaxies – that are most likely the farthest and hence the oldest – this requires a lot of observing time on the largest telescopes. Until now, astronomers had thus to first carefully select the candidate high-redshift galaxies, in order to minimise the time spent on measuring the distance. But it seems that astronomers were too careful in doing so, and hence had a wrong picture of the population of galaxies. It would be better to ‘simply’ observe in a given patch of the sky all galaxies brighter than a given limit. But looking at one object at a time would make such a study impossible. To take up the challenge, a team of astronomers used VIMOS, which is able to observe up to 1000 (faint) objects simultaneously. In one exposure, redshifts, hence distances, of many objects can be measured. The possibility to observe two galaxies at once would be equivalent to using two VLT Unit Telescopes simultaneously. VIMOS thus effectively multiplies the efficiency of the VLT hundreds of times. This makes it possible to complete in a few hours observations that would have taken months only a few years ago. With capabilities up to ten times more productive than competing instruments, VIMOS offers the possibility for the first time to conduct an unbiased census of the distant Universe.

The VIMOS VLT Deep Survey (VVDS) aims to measure in some selected patches of the sky the redshift of all galaxies brighter than magnitude 24 in the red, that is, galaxies that are up to 16 million fainter than what the unaided eye can see. In a total sample of about 8000 galaxies selected only on the basis of their observed brightness, almost 1000 bright and vigorously star forming galaxies were discovered at an epoch 1500 to 4500 million years after the Big Bang (redshift between 1.4 and 5). To the astronomers’ surprise, this is two to six times higher than had been found previously. These galaxies had been missed because previous surveys had selected objects in a much more restrictive manner to accommodate the much lower multiplex capability of the previous generation of instruments.

While observations and models have consistently indicated that the Universe had not yet formed many stars in the first thousand million years of cosmic time, the discovery made by the scientists calls for a significant change in this picture.

The average spectrum of distant galaxies.



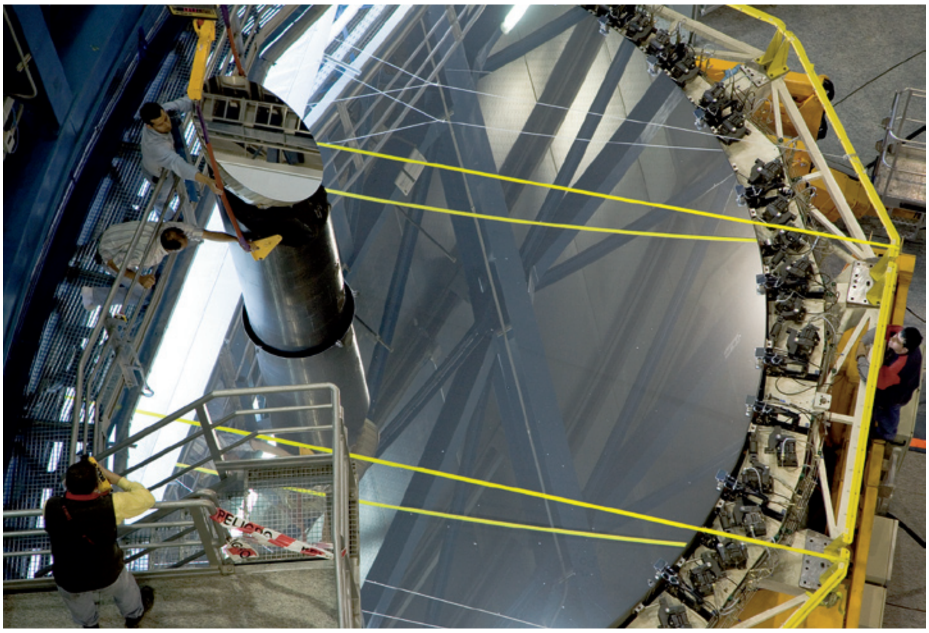
Combining the spectra of all the galaxies in a given redshift range (i.e. belonging to the same epoch), the astronomers could estimate the amount of stars formed in these galaxies. They find that the galaxies in the young Universe transform into stars between 10 and 100 times the mass of our Sun in a year. This discovery implies that galaxies formed many more stars early in the life of the Universe than had previously been thought. These observations therefore demand a profound reassessment of our theories of the formation and evolution of galaxies in a changing Universe. It now remains for astronomers to explain how one can create such a large population of galaxies, producing more stars than previously assumed, at a time when the Universe was about 10–20 % of its current age.

Feeding the Monster

Located at a distance of about 45 million light years in the southern constellation Fornax (the Furnace), NGC 1097 is a relatively bright, barred spiral galaxy seen face-on. NGC 1097 is a very moderate example of an Active Galactic Nucleus (AGN), whose emission is thought to arise from matter (gas and stars) falling into oblivion in a central black hole. However, NGC 1097 possesses a comparatively faint nucleus, and the black hole in its centre must be on a very strict ‘diet’: only a small amount of gas and stars is apparently being swallowed by the black hole at any given moment. Astronomers have been trying to understand for a long time how the matter is ‘gulped’ down towards the black hole. Watching the feeding process directly requires very high spatial resolution at the centre of galaxies. Thus, astronomers obtained images of NGC 1097 with the adaptive optics NACO instrument. These new images probe the presence and extent of material in the very proximity of the nucleus, disclosing with unprecedented detail a complex central network of filamentary structure spiralling down to the centre of the galaxy. The resolution achieved with the images is about 0.15 arcsecond, corresponding to about 30 light years across. For comparison, this is only eight times the distance between the Sun and its nearest star, Proxima Centauri.

La Silla Paranal Observatory

Recoating of the primary mirror of Antu (UT1).



The beginning of the year saw the merger of the two ESO observatories in Chile. The La Silla observatory that operated the eponymous site as well as the APEX project at Chajnantor, and the Paranal observatory hosting the VLT and VLTI were merged into a single managerial and operational entity known as the La Silla Paranal Observatory.

The merger process had been in preparation for much of 2004. In January 2005 we formalised the merger and much of the merging activity took place over the year. A single maintenance department now supports the two main sites of the observatory, and logistics and IT are also cross-site operations. Separate but closely collaborating engineering and science operations departments exist at the two main sites.

One of the achievements of the merged observatory has been the extensive recoating work undertaken during the past year. All four primary mirrors of the Unit Telescopes of the VLT as well as the primaries of the NTT, 3.6-m and 2.2-m telescopes were recoated in 2005 in an effort by a team staffed from both La Silla and Paranal.

In addition to the ESO operation of the NTT, the 3.6-m and the 2.2-m telescopes, La Silla provides the European Astronomical community with an excellent infrastructure for more specific astronomical experiments. The Swiss 1.2-m, the Danish 1.54-m and the Italian REM telescopes are all supported on La Silla and a number of visitor instrumentation programmes are ongoing.

New Instruments

On Paranal, all four 8.2-m telescopes are in routine operation with an impressive suite of instrumentation. In 2005, two new instruments, VISIR and SINFONI, were added to FORS1, ISAAC, FORS2, UVES, NACO, FLAMES, VIMOS.

SINFONI is an adaptive optics assisted integral field near-infrared spectrograph that has already been used to great effect in the study of the flaring black hole in the Centre of the Galaxy and many other studies. With the addition of SINFONI to VIMOS and FLAMES, Paranal has now integral field units deployed on three 8.2-m telescopes, covering the optical both in low and high resolution and the near-infrared in intermediate resolution.

VISIR extends the reach of the VLT to the mid-infrared (longwards of 10 microns). Exciting results from VISIR are in the pipeline but, already in 2005, VISIR observations have been able to support space-based measurements by exploiting the higher resolution delivered by the VLT optics.

End-to-End Operations

The arrival of VISIR and SINFONI brings the total number of currently operating instruments on the La Silla Paranal Observatory to 19, covering the optical, near-infrared, and mid-infrared wavelength domain: nine are at the VLT, two on VLTI, and eight in La Silla. All instruments at Paranal and some at La Silla are operated in a mixture of service and classical ('visitor') observing. In service observing mode the description of the observations is communicated to the observatory by the user via the User Support Department in Garching and the data are returned to the user after quality control is performed in the Data Flow Operations Department also at the ESO headquarters. Service Mode has continued to be the most requested observing mode at the VLT, demonstrating the appreciation by the community of the advantages that this mode has for many types of projects. The time requested in Service Mode at the VLT/VLTI exceeded that in Visitor Mode by a factor of 2.15 during 2005 (Periods 75 and 76). This led to a total of over 850 Service Mode runs being supported by the User Support Department at the VLT, VLTI, and ESO/MPG 2.2-m telescope during 2005.

All aspects of the ESO end-to-end science operations system are critically reliant on database technology. To this end, we operate several enterprise-class database servers in Germany and Chile in a coordinated fashion. During 2005, the operational databases grew by 35 %, resulting from an increase in Phase 1 and 2 information stored and an increase in the amount of data received from the La Silla Paranal Observatory. In 2005, 1165 843 header files were replicated from Paranal, that is 3194 per night, with an average size of 6.3 MBytes. In addition, two database tables have exceeded the 10 000 000 row milestone. In total, the Primary Database server has 28 tables that exceed 1000 000 rows. ESO's excellence in this area was internationally recognised by a 21st Century Achievement Award in the Science Category of the *Computerworld* Honors Program, established by this well-known US magazine.

Operationally the observatory has had an excellent year with science availability at 90 % of the total time; weather downtime (as a percentage of the science time) for Paranal was around the 10 % level and technical time for the La Silla and Paranal telescopes at or below the 3 % mark. The winter on La Silla and the observatories close to the town of La Serena was the worst on record and much observing time was lost. In spite of this, for the whole of 2005, weather downtime for La Silla was below 20 %, a number that maintains the site's status as one of the very best.

The Coming of Age of the VLTI

The year 2005 saw the completion of three important milestones in the 1.8-m Auxiliary Telescopes (AT) project. First fringes with the VINCI test instrument were achieved only a few days after aligning AT2 and several weeks before its full commissioning programme was completed. This milestone was a critical step before the ATs could be offered to the community in the call for proposals for Period 76. In fact, obtaining first fringes proved to be even simpler than acquiring a first star with a new telescope; after only a few minutes scanning with the delay lines, fringes were detected less than 2 mm from the predicted position. A few days later the exercise was successfully repeated with MIDI, which saw first AT fringes on 7 February. Thus, AT1 and AT2 have been in regular science operations from October 2005 (Period 76).

With these new additions it has been possible to start operating the VLTI Sub-Array (VISA) and take advantage of the interferometer infrastructure at times when the 8.2-m telescopes of the VLT are busy performing standalone observations. This is another milestone for the observatory, as yet another of the ambitious goals set out years ago for ESO has been reached. All 30 docking stations are fully equipped to accept the Auxiliary

At a ceremony in Washington on 6 June a team from DMD received the *Computerworld* 21st Century Achievement Award for Science on behalf of ESO. Seen here are Drs Preben Grosbøl, Michele Péron, Peter Quinn (Head of the ESO Data Management Division) and David Silva with the prestigious prize.

The Data Flow System

Tools have been developed for supporting the preparation and the execution of survey programmes. Among them is ORANG, a tool for ranking a large pool of Observations Blocks, taking into account parameters such as target visibility, priority of the observation, time constraints and all other user-provided constraints (moon distance, seeing). This application will ease operations of not only VST and VISTA but of all ESO telescopes. The User Portal project, to be deployed in 2006, will provide the user community with one registration system for all services provided by the observatory (Phase 1, Phase 2, Archive). Each user will have one or more role (PI, OPC member, USD astronomer, etc.) and will obtain access to the services through a single entry point.

Efforts have also been concentrated on the design and the implementation of the software components required to support the high data rates that will be generated by forthcoming instruments such as OmegaCAM and VISTA. This includes an upgrade of the archiving system and a system for distributing and parallelising the pipeline data reduction tasks on clusters of PCs.

The SINFONI pipeline was made available to the community. At the beginning of 2006 it will be followed by the ISAAC and GIRAFFE pipelines. The AMBER pipeline was installed at Paranal and evaluated during the commissioning run of July 2005. This version was released for the start of operations in P76. The AMBER pipeline supports the two- and three-telescope modes for AMBER *K*-Band observations. It provides measurements of the photometric flux and atmospheric piston, as well as fringe visibilities and signal-to-noise ratio over the spectral channels.

The software packages for reducing OmegaCAM and CRIRES are being prepared and a first release will be ready when those instruments go on the sky.

Telescopes which can move from one location on the deck to another 'under their own steam'.

AT3 arrived on Paranal in August and saw First Light on 1 November. It subsequently went through a successful commissioning period and was handed over to Paranal observatory in December. The performance of the three fully commissioned ATs in terms of image quality, pointing and tracking accuracy, optical path length stability, and repeatability of the telescope positioning after relocation, is truly excellent. The fourth AT is expected to be delivered in Europe in mid-2006, such that by end 2006, all four ATs should be up and running on Paranal.

Observations with the first generation VLTI instruments, MIDI and AMBER, have continued in 2005. MIDI has reached a mature level and is being routinely used in various modes and spectral dispersions both on the 8.2-m UTs and the 1.8-m ATs, although the analysis of MIDI AT data has proven to be significantly more challenging than the UT data as the Variable Curvature Mirrors (VCM) of the delay lines are still not operational. AMBER started open time observations in October 2005, albeit currently on a limited number of modes and with conservative sensitivity limits, while commissioning activities continue. These should be completed in 2006. Over 70 proposals (about 12 % of all Paranal proposals) were received for observations with MIDI and AMBER in Period 77, a very encouraging sign of interest from the community.

With the installation in early 2005 of MACAO on UT1, all four 8.2-m telescopes are now equipped with Coudé adaptive optics feeds for VLTI. This brings the total adaptive optics systems, the technology that corrects for the effects of the atmosphere on the image quality of a telescope, on Paranal to six (including NACO and SINFONI) with one more to be delivered with CRIRES in early 2006.

Looking at the Future

PRIMA, the Phase-Referenced Imaging and Micro-arcsecond Astrometry facility of the VLTI, is entering the critical phase of extensive testing in Europe for most of its sub-systems. The goal is to have PRIMA ready for installation at Paranal in the second half of 2007. PRIMA has three main scientific goals: to enhance the VLTI capabilities by increasing its limiting magnitude; to make high resolution images of the close environments of stars and extragalactic objects; and to do relative astrometry of stars with unprecedented precision. A consortium of astronomical institutes formed by the *Observatoire de Genève*, Leiden University, and the *Max-Planck-Institut für Astronomie* in Heidelberg, is currently designing the differential delay lines, necessary to track the two stars of PRIMA as the Earth rotates, as well as developing the software systems required to operate the facility and analyse the data.

In preparation for the installation of PRIMA on the VLTI we decided in early 2005 that a significant effort would be made by the observatory to conclude some outstanding commissioning activities and to stabilise the operation of the interferometer. Much work has gone into improving the maintainability of the alignment of the delay lines. A good understanding of the causes of the gradual misalignment has been developed and a procedure and toolset for managing the delay lines has been established. The first delay lines to have this system integrated into them are now under supervision and we expect the other delay lines to also be included into the same maintenance scheme in 2006. The good alignment stability has permitted the activation of the Variable Curvature Mirrors (VCM) mounted on the delay lines. The VCMs permit the delay line optics to control the position of the pupil in the longitudinal direction and as such allow the full field of view of the Auxiliary Telescopes to be sampled in the laboratory. It is expected that the VCMs will be fully operational during 2006, further improving the sensitivity of the VLTI and VISA. Quite some effort has gone into studying the beam stability within the laboratory to improve the injection of light into the interferometric instrumentation and a number of modifications were tested to good effect during 2005. The deployment in 2005 of IRIS has improved the acquisition of targets for the VLTI and, with recent modifications, also the beam stability. IRIS provides the VLTI with fast beam steering capabilities driven from the laboratory.

In the area of vibrations that introduce non-atmospheric variations in the optical path difference, significant progress has been made in identifying the sources and transmission mechanisms. In 2005 preparatory work was undertaken to isolate or eliminate the sources of vibrations


The VLT Auxiliary Telescopes 1 and 2 have been in regular science operations from October 2005.

In the VLTI control room.

but much work lies ahead. This improvement initiative on the interferometer is expected to continue in 2006 and early 2007 with the aim that the deployment of PRIMA is as rapid and effective as possible.

Although MIDI and AMBER are still in their early scientific production, preparations are already well under way for the second generation of VLTI instruments, targeted at deploying these instruments on Paranal in about five years time. A workshop partially devoted to scientific results from the VLTI and other interferometers, and partly to exploring technical concepts for new instruments, was held in Garching in April 2005. A total of nine instrumental concepts were presented of which four, MATISSE (combining four beams in the mid-infrared), VITRUV and BOBCAT (combining four to eight beams in the near-infrared), and GRAVITY (a near-infrared instrument specialised in high-sensitivity, high-accuracy narrow angle astrometry) were presented to STC in October as candidates for Phase A studies. Following recommendation by STC, formal proposals for Phase A studies were solicited from the consortia to be presented in January 2006, and completed in about one year's time. Also, a proposal by the European Space Agency was received to build a nulling-interferometer called GENIE to serve as a proof of concept for the Darwin mission.

Visitor Instrument

The installation of the Laser Guide Star Facility (LGSF) on the fourth Unit Telescope of the VLT started during 2005 and the First Light is eagerly awaited in early 2006. With a bright artificial star it is expected that adaptive optics will no longer be limited to areas of the sky close to a bright star. Both SINFONI and NACO are equipped to take advantage of the LGSF. With its infrared wavefront sensor that allows probing into obscured regions like the Galactic Centre, the VLT with NACO already had an advantage, and the LGSF will boost even further the observatory.

In addition to the diverse and powerful common user instrumentation deployed on the VLT, provision has been made for innovative visitor instrumentation to be deployed. ULTRACAM, a fast readout three-channel photometer built by a consortium of UK institutes, was the first visitor instrument to come to the VLT. Two very successful runs at Melipal (UT3) are expected to give rise to a number of exciting results and publications.

In the past years much attention has been paid to gamma-ray bursts in the astronomical community. ESO facilities have contributed much to the knowledge of these extremely energetic events.
In 2005 we put the Rapid Reaction mode of the VLT into operation, providing the ESO community with the ability to interrupt

Calibrations

To monitor and calibrate both the performance of each of the ESO La Silla Paranal Observatory instruments and the quality of the data they deliver, we execute dedicated calibration plans. These systematic and regular measurements further aid in the calibration of data from science programmes, at least to specified levels of accuracy.

The DFO Quality Control (QC) group works closely with the Paranal Science Operations (PSO) department to assure that VLT/VLTI instruments are always performing within expected and published ranges. Except for a few very specific cases, all instrument performance information generated for PSO on a daily basis is available via the QC Web pages. 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 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. 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 stored on DVDs and shipped to users by the DFO SAO group.

During 2005, QC processed 365 600 raw frames (an increase of 8.3 % relative to 2004), produced 306 000 data products (science and calibration, +29 %) and created 900 Service Mode packages (+35 %). The increase in data volume is due both to the three new Paranal instruments that came into operation during the year (SINFONI and VISIR at the VLT, and AMBER at VLTI) and to a general increase in the demand for Service Mode from the VLT/VLTI community.

ongoing observations and automatically slew the telescope to an exciting new target. This mode is offered on an ever-increasing number of instruments. On La Silla the REM 60-cm telescope is used by a consortium led by the *Osservatorio Astronomico di Brera* to provide rapid photometric and positional information of GRB candidates. In addition, the 2.2-m telescope on La Silla is being prepared for the installation of GROND, an instrument built by the *Max-Planck-Institut für extraterrestrische Physik* to follow-up gamma-ray bursts.

On La Silla work has been ongoing to commission a high efficiency fibre for the HARPS instrument on the 3.6-m telescope. HARPS is already one of the most prolific planet finding instruments and with this new facility it is expected to further improve the throughput already much enhanced in the past year with the 3.6-m secondary unit upgrade. This work has been undertaken at the excellent workshop on La Silla, which forms an integral part of the operation of the merged observatory. Another significant event in 2005 has been the deployment of the second generation of technical CCDs on La Silla, leading the way for their implementation on Paranal. Technical CCDs are used to guide the telescopes, analyse the aberrations for the active optics system, view the targets on spectrograph slits, align the acquisition bundles for FLAMES, determine the seeing at the DIMMs, and other tasks. As such, it has been critical to maintain these systems at their best performance. The La Silla workshop and detector specialists, together with staff from Paranal, supported the large technology division effort to build a backwards compatible modern system.

VST, VISTA and APEX

The two wide-field telescopes scheduled to come to Paranal in 2006 are making progress in the construction phase. The 2.6-m optical VLT Survey Telescope is under construction in Naples by the *Osservatorio di Capodimonte* where subsystem testing has started. It is eagerly awaited in its enclosure at Paranal. The VISTA project office, based at the UKATC in Edinburgh, is constructing, on behalf of PPARC, the 4.2-m infrared survey telescope VISTA that forms part of the in-kind UK entrance contribution to ESO. Work on the enclosure and support buildings at the observatory was almost completed in 2005. The telescope construction is much advanced and early training of ESO maintenance staff has started. The optics for both telescopes are in the polishing stage and it is expected that they will be delivered to Paranal in the first half of 2006.

Another milestone was reached in 2005 with the start of routine operations at the third site of the observatory. The La Silla Paranal Observatory also provides the staff and operational support for the Atacama Pathfinder Experiment (APEX). APEX is a collaborative project between ESO, the *Max-Planck-Institut für Radioastronomie* and the Onsala Space Observatory (OSO). A modified ALMA prototype antenna, equipped with Nasmyth foci in addition to the normal Cassegrain, is situated at the edge of the ALMA high site at Chajnantor. The excellent surface accuracy of the antenna permits operations in the terahertz regime. A base-camp from where the telescope can be operated via a radio-link has been constructed in the community of Sequitor (within the village of San Pedro de Atacama), in harmony with its surroundings. The facility was inaugurated in September 2005, during an event attended by representatives from all partners and the Chilean government and academia.

Science verification observations with APEX had started in the months before the official inauguration using the APEX2a receiver from OSO and the FLASH PI instrument from the *Max-Planck-Institut für Radioastronomie*. In 2006, it is expected that the bolometer array LABOCA and other receivers, as well as a wobbling secondary, will be added to the complement of instrumentation available to the scientific community. Already the first indications are that the Chajnantor site is exceptional and that, indeed, APEX will be an excellent pathfinder for ALMA.

The major telescopes at La Silla.

Right: Spiral galaxy Messier 83 seen with FORS on the VLT.

Following page: APEX started science verification observations on its 5100-m high site at Chajnantor.

Atacama Large Millimeter Array

Construction of the road to the ALMA AOS.

The year 2005 was certainly a year of critical importance to the ALMA Project – 'the' year in which the baseline project has been redefined. The birth of ALMA dates back to the end of the last century. Various ideas and concepts had been independently developed by scientists all over the world. Large array radio telescopes were studied by astronomers in Europe, North America and Japan and different possible observatories had been discussed. After thorough investigations, it became obvious that each of the ambitious projects could hardly be realised by an individual scientific community. Consequently, an agreement was signed in the year 2002 by the North American scientific community, represented through the US National Science Foundation (NSF), and the European scientific community, represented through ESO, to construct the Atacama Large Millimeter Array (ALMA). The initial ALMA project planned to install and operate 64 high-precision radio telescopes of 12-m diameter each on the *Altiplano* of Chajnantor, near San Pedro de Atacama in Chile, at an altitude of 5 000 metres.

Following years of detailed design studies and prototype research, it became evident that this project could not be realised within the available funds foreseen at the time of signing the agreement between the partners in North America and Europe. Therefore the management and scientists involved in ALMA were charged with developing a new configuration of the project within acceptable cost, while still maintaining the prime scientific objectives.

Successful prototyping of key components of the receivers over the last years was an important element in allowing a reduction of the number of antennas from 64 to 50 without compromising significantly the performance of the original baseline project. During the year 2005, in-depth studies and large efforts were made to define the 'rebaselined' ALMA project. Independent review committees, focusing on the technical performance and on the cost of the project, confirmed the scientific importance of the modified ALMA project based on the new affordable costs. By the end of 2005 the rebaselined project and the new budget were approved by the ESO Council. The North American partners are expecting approval from their funding agency (NSF) within the first half of 2006.

In parallel, Japanese scientists, through the National Astronomical Observatory Japan (NAOJ), have continued to work out details to define and formulate their participation in the ALMA project. Discussions on the partnership in the rebaselined ALMA are progressing well. The European and North American partners in ALMA spent considerable amounts of time in reviewing various subsystems, in particular correlator, receivers and antennas. Details of the partnerships are expected to be defined soon, such that an official agreement could be signed during the first half of the year 2006. With the inclusion of the Japanese partners ALMA would become a truly global astronomy facility, involving scientists from four different continents.

Also in the course of 2005 the management of ALMA and the ALMA Division at ESO has been changed with respect to several key positions. Some positions have been filled with new persons, like the European ALMA Project Manager (Hans Rykaczewski), the European ALMA Project Controller (Donald Tait), and the European ALMA Project Planner (Gareth Aspinall). Fabio Biancat Marchet from ESO has been appointed as Deputy Integrated Project Team (IPT) Leader for the ALMA Back End project.

During the year 2005 numerous open positions were filled. At the end of 2005 there were 49 persons associated with the ESO-ALMA Division; of these, 15 were delegated from other ESO divisions (DMD and TEC).

Construction Work

Work on the site has progressed considerably during this year. At the end of 2005 about 37 km of a total of 43 km of the access road between the intersection with the Chilean Highway 23, the Operations Support Facility (OSF) and the Array Operations Site (AOS) have been completed. The remaining 6 km are already open for construction traffic.

One of the most important civil engineering activities is related to the Technical Facilities at the OSF, located at an altitude of 2 900 metres. The OSF will be the central location of many activities. During the construction phase it will serve as the base for assembling the antennas, which then will be moved to the AOS at 5 000 metres altitude. During operations it will be the workplace for the operators and for the teams responsible for maintaining proper functioning of the telescopes. In the present plan, the quality of ALMA data will be assessed at the OSF. The construction of such a multi-purpose facility, intended to serve over the expected 30-year lifetime of the observatory, is a challenging task and requires taking into account many aspects of the functionality of these facilities. During the year 2005, technical specifications and statements of work were defined, refined and adapted to the requirements and resources of ALMA. The call for tenders for this large facility was submitted in December 2005. After completing the process related to place the procurement contract, we expect that construction could start by April 2006. Provisional acceptance could be in the fourth quarter of 2007.

Preparatory work for the technical facilities at the OSF includes excavation, filling and compacting activities. They were completed in September 2005. At the same time the preparation (crushing) of fill material for the road construction using the OSF excavation material was completed.

The construction of the AOS Technical Building foundations and superstructure, a project to be delivered by the North American partner in ALMA, has started in October 2005 and is progressing well. The offers for the construction of further AOS Technical Buildings were received in December 2005 and are being analysed at present. This project is on schedule.

Supplying energy for an observatory at an altitude of 5000 metres in the Chilean desert of Atacama is not at all trivial. Power Generation and Transmission Systems must be based at the OSF. In view of rapidly changing energy prices, a feasibility and total cost study is being carried out at present. It shall address the cost benefits of having energy supplied by the Chilean grid against the vulnerability of depending on an external energy supplier. Following this study, ALMA will decide on the final power supply, which is scheduled to be in operation by the end of 2009.

Although it is one of the most ambitious high-technology scientific projects, activities on the ALMA site do not only focus on building the world's most advanced and challenging astronomical observatory. Historical and environmental aspects in this unique region are of concern. The remains of a small local settlement located along the access road at km 21 have been rebuilt taking into account the advice of the last owner and in consultation with an archaeologist from San Pedro. The place serves now as a museum and an interpretive centre for the local cultures and history.

One of the ALMA *vizcachas*.

Wildlife in these altitudes is protected. Colonies of *vizcachas* (a local species of rabbit-like animals) were found along the ALMA AOS access road at 30 km. Local Chilean Authorities are carefully monitoring the movements of these colonies. The goal is that ALMA site construction does not disturb wildlife.

Antennas

The antennas are central to the ALMA project, as their quality and performance define the overall functionality of ALMA. In view of this critical issue, prototype antennas were supplied by three companies: the AEC Consortium (procured by ESO), Vertex RSL (procured by NRAO for North America) and Mitsubishi (procured by NAOJ, Japan). All three prototypes

Work on the AOS Technical Building at 5000 metres altitude.

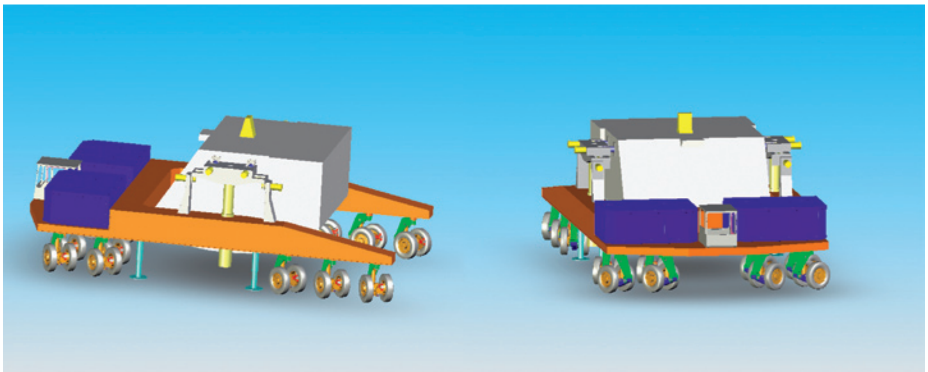
were extensively tested at the ALMA Test Facility in Socorro, New Mexico. Several groups of international experts, both internal and external to ALMA, reviewed the performance of the prototype antennas and concluded that their expected performance at the ALMA site conformed to the technical requirements.

On 11 July 2005, the North American partners of the ALMA project, through AUI, signed a contract with Vertex RSL to supply up to 25 antennas, with options to increase the contract to 32 antennas. On 6 December 2005, the ESO Director General signed a contract with the AEM (Alcatel Alenia Space France, Alcatel Alenia Space Italy, European Industrial Engineering s.r.L., MT Aerospace) Consortium for the supply of 25 ALMA antennas (as the European share of the project), also with options to increase the number of antennas to 32.

The first antenna to be supplied by Vertex SRL is expected to be ready for provisional acceptance in Chile by January 2007. The first antenna to be supplied by the AEM Consortium is expected in September 2008. ALMA expects to have six antennas available for early science verification by early 2009. Despite the later delivery of the first AEM antenna, due to a higher delivery frequency of AEM antennas, both suppliers are expected to deliver their 25th antenna by the end of 2011.

The ALMA antennas will be operating at an altitude of 5000 metres. They can be moved in order to achieve the imaging requirements. There is a compact configuration in which all antennas operate within an area of 160 × 250 metres, and there is an expanded configuration for which the maximum separation between antennas reaches 18 km. In order to move the antennas, each weighing 100 tons, at the 5 km altitude of Chajnantor, we have designed two special, dedicated transport vehicles. These transporters are truly unique. They will first move antennas from their assembly area, the OSF (2900 metres), to dedicated positions at the AOS (5000 metres). After the initial move to the high site they will move antennas around on the high site – to compact or expanded configurations – and position the antennas to an accuracy of a few millimetres. In addition, these transporters will also move antennas for extended maintenance and repair from the AOS to the OSF. The weight of the antennas, their high precision and the hostile, high altitude environment impose severe boundary conditions on these vehicles. They will have a weight of about 150 tons, and their dimensions are about 10 m × 15 m × 6 m (width × length × height). The contract for the production of these truly unique transporters was signed by the ESO Director General with Scheuerle Fahrzeugfabrik GmbH on 22 December. The first of the transporters will be delivered to the OSF by mid 2007.

The ALMA transporter (artist's impression).



Front End

A construction project like ALMA, involving several partners in four different continents, requires consensus on several organisational and managerial decisions concerning the actual execution of certain construction activities. These decisions are dominated by technical and financial considerations. One of these decisions, in fact a major one, was taken during the year 2005 for the organisation of the Front End Integration Centres (FEIC).

Four different scenarios for assembling and integrating the Front End (FE) components were extensively studied. This study revealed that a 'parallel approach', installing half of the Front End in Europe and the other half in North America with identical and parallel procedures, was the solution preferred by all partners involved. This scenario was chosen in view of logistics, organisation and programme risks. Mainly based on considerations of risk mitigation, the parallel FEIC was selected. The European FEIC shall be located at the Rutherford Appleton Laboratory (UK); the North American FEIC shall be installed at NRAO, Charlottesville (USA).

Significant progress was made concerning design of the water vapour radiometers. A review, involving Onsala Space Observatory and Cambridge Astrophysics, was carried out by ALMA personnel, as well as external reviewers. They recommended proceeding with the development of a cost effective, single polarisation Dicke-switched uncooled receiver for production. Institutions involved in the studies and this review were encouraged to collaborate for the serial production required for ALMA.

A review of the ALMA amplitude calibration device was held in August at IRAM in Grenoble (France). Various concepts and their expected performance (multi load, dual load and semi-transparent vane) were presented and compared with each other to find the most suitable solution for ALMA. The review panel recommended continuing with the detailed development of the relatively simple two-load calibration device.

European FE work packages have been shifted from development to pre-production during 2005. The cryostat work package is most advanced. By the end of 2005 four units had been delivered and successfully accepted. With this activity the FE IPT obtained very useful experience in the acceptance process. This experience and knowledge has been applied for the acceptance procedures of other deliverables, in particular for the receiver cartridges. At the end of 2005 the preparations for the delivery and acceptance of the first pre-production cartridges had advanced well and actual acceptance of these units is scheduled for early 2006.

Local Oscillator

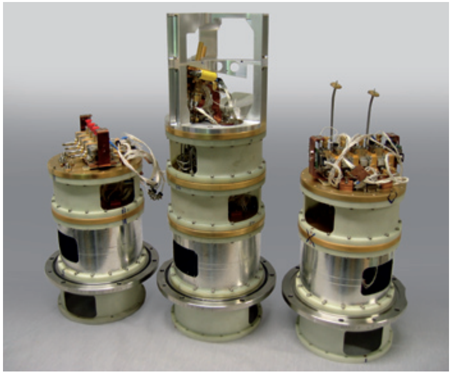
The Photonics Local Oscillator sensitivity to environmental conditions has been addressed in the design of the fibre system and of the special cable wrap to be mounted in the antenna. Successful tests demonstrated that the risks are well mitigated, although the complete end-to-end system has not yet been demonstrated in the field.

Back End

The development of the digitizer assembly with a 4 GHz, 3 bit sampler was successfully completed; the functionality has been demonstrated both in laboratory tests, as a stand alone device, and integrated within the entire Back End system. ESO is working closely with Jodrell Bank Observatory on the pre-production of optical data transmission system components for three antennas. These components are expected to be available in Spring 2006. The complete Data Transmission System has been successfully tested from the input to the output. However, the system is not yet stable and further investigations are ongoing that might lead to slight modifications to the assembly.

The two custom chips needed for the digitizer assembly have been developed in collaboration with industry. They have been shown to fulfil the requirements and have been fabricated, packaged and tested before delivery for assembly. The production covers the whole project needs.

First completed Band 7 cartridge (centre) and two partially assembled units.



The design of the fibre system to be installed at the ALMA Array Operating Site is being carried out by a UK consortium led by the Rutherford Appleton Laboratory. The design of the outdoor part is finished and the design of the part internal to the AOS Technical Building has started. Tests at the AOS site have been planned to evaluate the quality of the fibre splicing under field conditions.

Correlator

The production of the second quadrant of the correlator is almost complete at NRAO and the quadrants 3 and 4 are well on the way to completion.

The Tunable Filter Bank (TFB), developed by University of Bordeaux, Astron and *Osservatorio Astronomico di Arcetri*, provides a 32-fold improvement in frequency resolution over the original correlator design. First prototypes of this TFB have successfully undergone tests both in a dedicated test fixture and in one quadrant of the ALMA Correlator. These tests exhibited relatively high power dissipation. Therefore another prototype version of the filter card based on a more advanced generation of programmable devices has been developed and successfully tested with remarkably low power dissipation. Further prototypes are being manufactured and will be sent to NRAO for integration tests.

Computing

The European ALMA Computing Team has leading responsibility for a large number of ALMA computing subsystems. Within the software development area these are: ALMA Common Software (ACS), Archive, Executive, Observatory Preparation, Telescope Calibration and Observatory Support Software (started in 2005).

ALMA Computing in Europe is led by ESO with significant participation from IRAM, Bonn-MPIfR, JBO/University of Manchester, Edinburgh-UKATC, Paris-LERMA, and Madrid-IEM/CSIC. During 2005 four specialists were seconded by the Japanese partners in ALMA to work in Europe and two staff positions, financed by ALMA-Japan, were filled at ESO in Garching.

Software development activity focused on producing and integrating two releases in 2005 (R2.1 in March and R3.0 in September). The latter release was integrated and tested at the VLA Antenna Test Facility (ATF) by the end of December. Thus, software used for testing the antenna prototypes has transited to the final version of ALMA software. The software test at the end of 2005 was the first real test combining three software subsystems of ALMA Computing: ACS, Control and Archive. This development will continue.

System Engineering

The work of the System Engineering and Integration (SEI) IPT continued with emphasis on System Engineering activities at ESO and prototype system integration and testing at NRAO. Members of SEI supported the other ALMA IPTs in all technical aspects to ensure system integrity. The SEI team participated in or led all design review meetings.

Other important achievements were: the completion of cabling design of ALMA equipment in the antenna, receiver cabin layout, EMC analysis and testing and preparation and maintenance of a detailed ALMA performance and tolerance budget.

Support was also given to the ALMA operation planning activities with participation in the operations working group and in the procurement activities of the ALMA computerised maintenance management system (CMMS). System integration planning for activities in Chile progressed well. All equipment for prototype system integration was delivered by the different IPTs.

Science

The ALMA Science IPT performed a variety of tasks in 2005. They carried out simulations in order to define the optimum positions of the antenna pad locations out to a 4-km baseline. This was made necessary due to the ALMA rebaselining from 64 to 50 antennas. The impact of two different types of 12-m antennas in the bilateral array was assessed, and the FP-6 contract for 'ALMA Enhancement' was prepared. The contract was accepted by the European Commission at the end of 2005.

Work was also carried out within the ESA-ESO ALMA Herschel Synergy Working Group as well as for the Commissioning plan. Finally the ALMA Science IPT took part in various reviews, e.g. for the Water Vapour Radiometers and the ALMA-Japan contributions.

Night sky over Chajnantor. The Milky Way (right) and the Magellanic Clouds (left) appear in all their glory.

Following page: The 5000-m high *Llano de Chajnantor* plateau is being prepared to receive the ALMA antennas.

Extremely Large Telescope

At ESO, work is done on developing innovative technology for the ELT.

The year 2005 has been a very intense year in the area of Extremely Large Telescopes, and has marked a watershed in ESO's ELT activities with the OWL concept design review.

The first four months of 2005 saw the intense negotiations with the European Commission for the FP6-sponsored ELT Design Study contract. These were particularly complex, as the reduced funding from the EC required extensive reallocations of tasks among the consortium participants in order to maintain the original goals of the programme.

Most of the rest of the year has been devoted to the preparation of the documentation for the OWL review, which resulted in the 700-page 'OWL Blue Book' report with another 2000 pages of auxiliary documentation. This included the preliminary definition and analysis of a potential OWL instrument suite that could cover its science case, and which has been accomplished through an ESO-coordinated intense Community effort.

The Blue Book is publicly available on ESO's web pages (with the exclusion of some sections covered by confidentiality clauses with industry).

The OWL concept design review

A comprehensive review was conducted by an international panel on 2–5 November 2005. Members were: Roger Davies, Oxford University (Chair); Jean-Gabriel Cuby, LAM-Marseille; Brent Ellerbroek, Thirty-Meter Telescope Project Office; Daniel Enard, formerly VIRGO; Reinhard Genzel, MPE-Garching; Jim Oschmann, Ball Aerospace; Roberto Ragazzoni, INAF-Arcetri; Larry Ramsay, Hobby-Eberly Telescope; Stephen Shectman, Carnegie Observatories; and Larry Stepp, Thirty-Meter Telescope Project Office.

The first objective of the review was to assess whether, or to what extent, the proposed technical solutions were reasonable, i.e. judge the strengths and weaknesses of the OWL approach, analyse feasibility issues, evaluate cost and schedule estimates, and identify the main risks of the project and areas to be further explored. The second was to recommend whether and how to proceed to a next phase of the project.

The panel praised the OWL team for an extensive and largely successful feasibility study for a 100-m ELT. A strong technical point stressed by the panel was the integrated approach chosen for the OWL active/adaptive optics system, with in particular at least one large adaptive mirror as an integral part of the telescope.

Substantial technical risks were however identified, associated with OWL's double segmentation (M1 and M2), the highly aspherical M4 mirror and the telescope size that makes its Laser Guide Star 'unfriendly'. In view of these risks, but also of a consolidated cost (~ 1.2 G€) larger than the likely available ESO resources in the 2008–2020 time frame, the panel recommended to consider a smaller diameter, less complex and less risky ELT. It emphasised that most of the OWL design effort and virtually all technological developments started so far were directly useful for this new phase. In addition the panel recommended to strongly involve the ESO Community in all aspects of the project and to speed up the currently running ELT site selection programme, with additional attention given to starting government level negotiations for site access as soon as possible. The overall panel's recommendation was "that the project proceed to Phase B, and begin with a new examination of the balance between science return, competitiveness, AO performance, instrumentation, risk and final performance within an affordable cost." It noted that the time to carry out such a re-evaluation was already in the plans proposed in the Blue Book.

Towards the European ELT

Following the review, the already planned two-year consolidation phase towards the final project started in December as advocated by the review panel. We expect to develop a basic reference design for what is now the European ELT project by the end of 2006. The main goal is to define the best affordable ELT that can be built on a competitive time scale and with acceptable risks. While the project is open to international collaboration, the work is towards a baseline design that could be handled within Europe alone, should no other major partner be found.

The process of definition of the E-ELT was kick-started with mixed Community-ESO ELT Working Groups set up by ESO's Director General at the end of December, one for each of the main ELT areas, namely (a) its Science case, (b) an Instrument Suite, (c) the associated Adaptive Optics Systems, (d) the Telescope and Observatory Design and (e) potential Sites evaluation. Their respective chairpersons are: Marijn Franx, Leiden and Isobel Hook, Oxford (Science); Colin Cunningham, UKATC (Instrumentation); Gérard Rousset, *Observatoire de Paris* (Adaptive Optics); Daniel Enard, formerly VIRGO (Telescope Design); and Roland Gredel, Calar Alto (Site). The brief of the five ELT-WGs called for a two month burst of activity in January–February 2006 to produce an initial input to the ESO Team in the form of 'tool-boxes', synthesising and collating ELT-related present and projected capabilities in their respective topic areas, as well as a first cut at a prioritisation.

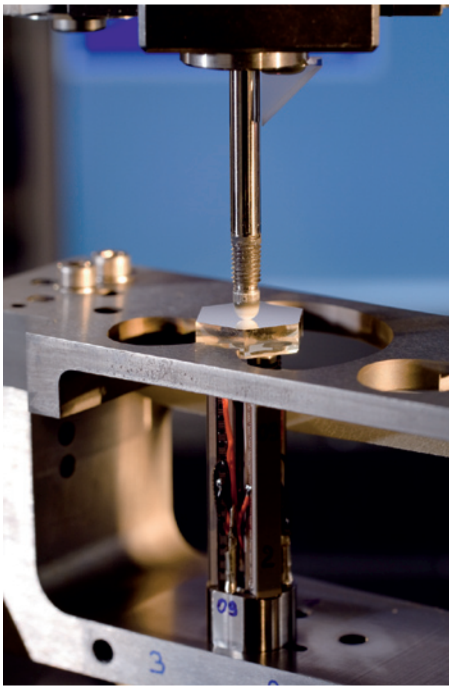
The FP6-sponsored ELT Design Study

The ELT Design Study is a generic technology development programme towards a European Extremely Large Telescope. It encompasses 11 main work packages, each of which subdivided into tasks.

The contract was signed in April 2005, with retroactive effect as of 1 January 2005. Although the majority of participating partners committed to maintain the originally proposed level of own funding even with a reduced contribution from the Sixth Framework Programme, the project has experienced the withdrawal of a number of participants due to lack of internal funding. All major objectives of the project could be preserved, however. The total number of participants is 25 (including ESO as coordinator) and the total estimated budget is 28.8 M€. The ESO contribution is 9.4 M€.

Critical activities are essentially on track, and several design reviews were held in December 2005, broadly in-line with the initial schedule. Some activities had to be delayed since priority was given to the OWL Phase A review. Others have been accelerated, for the same reason. This is the case for adaptive systems point designs, adaptive optics simulations, and for algorithms for reconstruction and control. As a result, these activities are ahead of the initial schedule.

The ELT Design Study relies extensively on feedback from specific design projects, and vice-versa. Examples of this constructive feedback include
- segment control, wind rejection and preferred actuator technology,
- possible instrument designs and the impact of adaptive optics on instrument studies, and on high contrast imaging techniques,
- control requirements for friction drives,
- requirements for and point designs of adaptive optics systems for a 100-m telescope, expected performance in relation to major science cases,
- preliminary tests of a promising technology (Borofloat glass) for large adaptive thin shells.



Testing of an Active Segmented Mirror prototype.

Symmetrically, the ELT Design Study provided regular feedback to European ELT projects, with e.g.
- trade-offs, identification of suitable edge sensors for segment position control;
- verification of wavefront phasing techniques, by way of simulations and laboratory experiments; development of pattern recognition techniques for the data reduction of the phasing camera signal;
- a thorough review of the effect of atmospheric dispersion, the definition and feasibility assessment of Atmospheric Dispersion Compensators for Euro-50 and OWL;
- the identification of potential alternatives to existing enclosure designs;
- AO simulations and subsequent performance assessment;
- site characteristics, including first measurements in Argentina.

Following the OWL review, and the convergence of all Community and ESO activities towards a unified European ELT design, some refocusing of the activities is planned for 2006.

Next page: Robert's quartet, a group of interacting galaxies, is located about 160 million light years away (FORS/VLT).

The Organisation

Office of the Director General[1]

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João Alves
Catarina Alves de Oliveira
Andreas Andersson Lundgren
Gonzalo Argandoña
Mustafa Basbilir
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Alejandra Araya
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Technical Developments

The Technology Division led or contributed engineering support to over 100 different ESO projects in 2005. This effort was split approximately evenly between projects from the Telescope Systems, Instrumentation, ALMA and Technology Divisions.

Electronic Engineering

The electronic control systems that were developed for the VLT over 15 years ago were developed according to the commercial standards and components available at that time. Although these systems have performed very reliably, some are now commercially obsolete and difficult or impossible to maintain. It has therefore become necessary to find alternatives, not only to replace already installed equipment but also to provide control hardware for new telescopes and instruments that are still under development.

Considering the size and technical complexity of the VLT Observatory today, such component upgrades are only feasible at all because of the strong emphasis placed on electronic standardisation during the VLT construction period. This strictly limited the number of different components installed and allows such upgrade programmes to be practicable within the manpower resources available. Nevertheless, the entire VLT operates as a complex system and extensive hardware and software testing both in Garching as well as at the Observatory is necessary to ensure that, by changing one component, there are not problems or incompatibilities generated elsewhere. Even upgrading to a newer version of a CPU, for example, which is nominally compatible with its predecessor, can create problems with some older equipment due to the increased speed of the newer units.

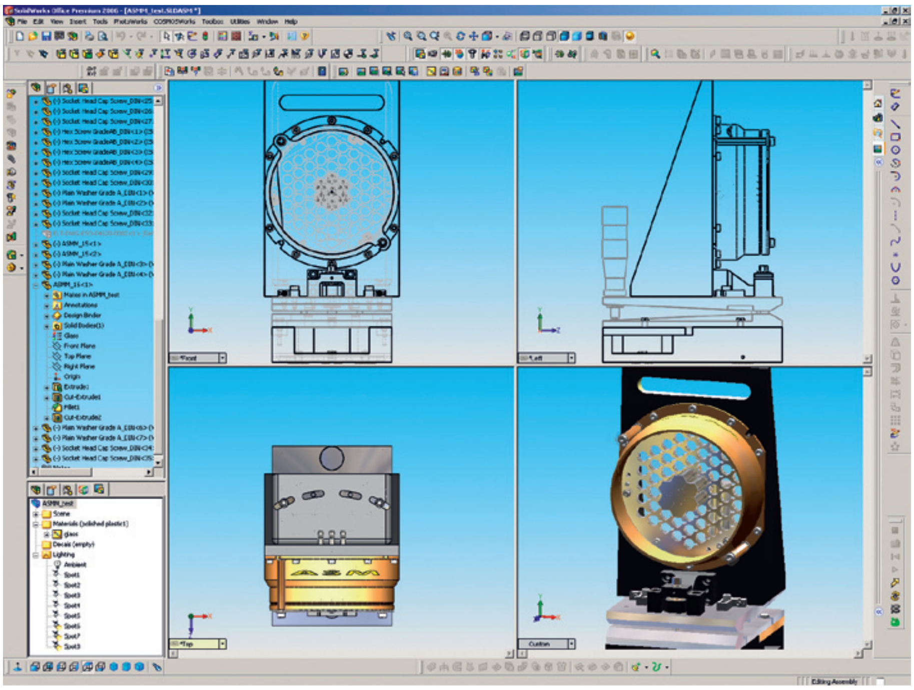
One of the main development thrusts within the Electronics Department over the last two years has been to develop a new generation of motor control systems for both DC and stepper motors. These will be used in second-generation VLT instruments as well as in other systems currently under development at ESO and its collaborating institutes. Prototypes of control units for both types of motor have been developed and tested, and delivery of serially produced units to projects is expected to start in the second half of 2006.

Upgrades have also been made to the ESO Standard Time Interface Module, the controller for the ESO standard cabinet cooling unit and the MACCON stepper-motor controllers during 2005.

Mechanical Engineering

Although we had selected *Catia V* as the new CAD tool for future major projects to replace the earlier *Euclid* system, contractual difficulties, which could not be satisfactorily resolved, have forced the Engineering Department to switch to another similar CAD tool, *SolidWorks*. *Inventor* will continue to be supported for instruments and other smaller projects.

As the CAD system has a close interface to the Product Data Management (PDM) System that we planned to introduce in 2005 for the ESO Technical Archive, the selection of the PDM system has now been delayed until the start of 2006. Nevertheless, many of the paper documents and drawings from the VLT and first generation instruments have now been scanned and stored in a temporary electronic technical archive that is accessible online to ESO technical staff. The data held in this temporary archive can be transferred rapidly to the PDM system when this becomes operational.



Screenshot of *SolidWorks*, the CAD tool used in the Engineering Department.

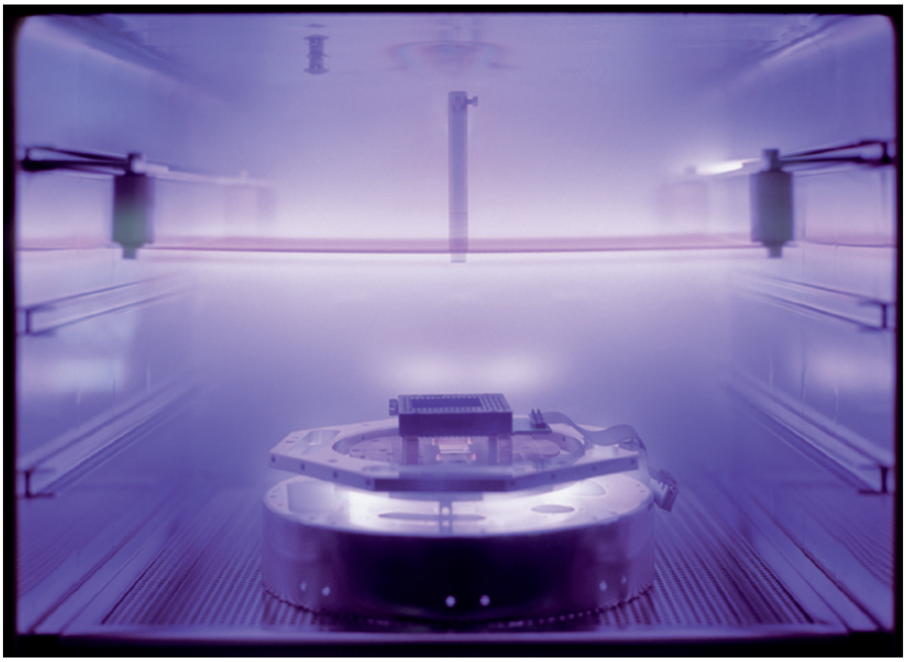
Software Engineering

A key internal activity of the Software Department has been the introduction of Linux as a replacement for HP-UX and Solaris operating systems. At the end of 2005, all the VLT Unit Telescopes, the NTT and several instruments were running under Linux with the JAN2006 VLT software release. This software release will be the last that supports HP-UX and Solaris. This change will reduce by two-thirds the amount of software testing that needs to be carried out.

As with electronics, all additions or modifications made to the VLT control software that are required to cater for new instruments, electronic hardware updates, etc., have to be rigorously tested. A nightly automatic sequence of integration, testing and quality control is carried out using the VLT Control Model in Garching to ensure that any software change does not have an unwanted impact on any other part of the VLT control system. As these tests have to be carried out separately on all supported operating systems, the motivation to reduce the number of platforms is obvious.

Another ongoing upgrade programme relates to the introduction of Gigabit Ethernet as a standard for the Paranal LAN networks. The change to Gigabit Ethernet is moving ahead hand-in-hand with the introduction of Linux at the Observatory.

Plasma cleaning of a CCD cryostat head.



IT Services

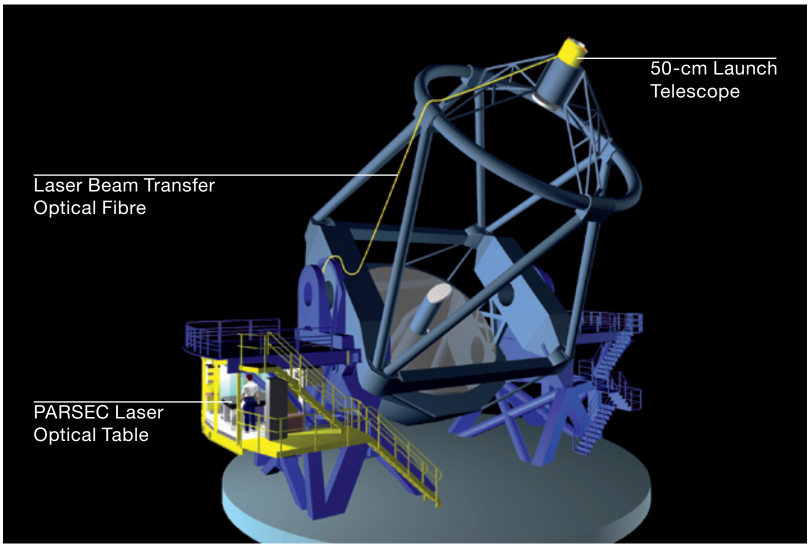
Following a study carried out by an Information Technology (IT) consultancy firm in 2004 on ESO's IT support services, several changes were introduced in 2005 to improve the inter-site coordination. A single IT Management Team has been established which has responsibility for global IT planning and coordination across all ESO sites in Germany and Chile. In addition, two new IT staff positions have been created with particular responsibility for the coordination of networks and communications. These are areas of strategic importance to the Organisation where responsibility cannot effectively or prudently be transferred to an outsourcing company. A few other staff IT positions with responsibilities for certain key areas are planned for 2006. These changes are expected to improve both the efficiency and effectiveness of IT support, harmonise IT policies across sites, bring some economies of scale as well as contributing to improved network security.

Another major event in the IT area was the re-tendering of ESO's IT support services. The contracts in Garching, Santiago and Paranal have been running for over six years and re-tendering was required by our financial rules, not due to dissatisfaction with our current service providers. The new contract will cover all these sites plus La Silla which, up to now, has been supported by ESO staff. This is also expected to contribute both to the efficiency and flexibility of this service. A new Outsource Service Contractor has been selected and it will take over operational responsibility in April 2006.

Following another tender undertaken in 2004 for inter-site communication services, new contracts were signed for internet access in Garching and Santiago as well as for dedicated communication links between Paranal–Santiago and La Silla–Santiago. This allowed us to benefit from the world-wide reduction in communications costs as well as to increase the bandwidth to Paranal from 2 Mb/s to 2 × 4 Mb/s, and to La Silla from 2 Mb/s to 2 × 2 Mb/s. Both upgraded links are now double-path for increased redundancy.

Instrumentation

Schematic drawing of the UT4 first-generation Laser Guide Star Facility.



Both SINFONI and VISIR began regular operations some 10 days ahead of the official start of P75, on 1 April. SINFONI, developed through an ESO-MPE collaboration, was the first adaptive optics corrected, 3D near-infrared integral field spectrograph to be installed anywhere and is routinely delivering outstanding results on a variety of astronomical targets from the solar system to distant galaxies. VISIR, the VLT spectrometer and imager for the mid-infrared, has brought new capabilities in the thermal infrared out to wavelengths around 20 µm and has also operated with high reliability and success for a wide range of studies. As the ultimate scientific performance of VISIR is currently limited by intrinsic instabilities in its detectors, we are therefore already actively engaged in investigating possibilities for procuring and installing better and larger next generation detectors in the longer term. Such detector upgrades have already proved to be a cost effective means of improving the performance and/or extending the competitive lifetime of several other instruments at the La Silla Paranal Observatory.

Of interest also in connection with SINFONI was the installation at the end of the year of the first-generation Laser Guide Star Facility. At its heart is the MPE-Garching developed PARSEC dye laser, located in a clean room laboratory under the Nasmyth A platform of Yepun (UT4). This feeds an ESO-developed relay and a 50-cm diameter launch telescope mounted above the M2 secondary mirror. Largely for safety reasons there are also sophisticated diagnostic and interlock systems. After completion of acceptance testing in Europe in August, re-integration on Yepun progressed substantially by the end of the year. The first artificial star over Paranal, created by resonant scattering in the thin sodium layer around the Earth at 95 km altitude, is expected in early 2006. Both SINFONI and NACO will make use of these artificial 'sodium' stars to improve dramatically the number of astronomical objects for which adaptive optics correction close to the diffraction limit of a VLT Unit Telescope (0.06 arcsec in the *K*-band) can be achieved.

Further modifications resulted in improved reliability of the massive multi-object optical spectrograph VIMOS and its throughput for high resolution spectroscopy in the red was increased by up to a factor of two by replacing the original grisms with volume phase holographic gratings.

The OmegaCAM wide field optical camera for the VLT Survey Telescope (VST) was almost finished and nearing the end of its Preliminary Acceptance Europe. The camera itself has been built by a German/Dutch/Italian consortium, while the detector system, comprising a mosaic of 32 CCDs, has been developed by ESO. Following a few additional tests the system will be stored until the VST, being supplied by the Observatory of Naples, has been installed and commissioned on Paranal.

CRIRES, the infrared (1–5µm), adaptive optics fed, high resolution, cryogenic spectrograph built for the VLT by ESO, was integrated and extensively tested, and is expected to achieve First Light on Paranal during the first half of 2006. One of the novel features of the instrument is its linear array of four 1k × 1k infrared detectors developed specially at ESO.

Manufacturing and procurement of components of the HAWK-I infrared camera for the VLT proceeded well. All four of its 2k × 2k detectors were delivered and two have been fully tested with excellent results. The large diamond turned mirrors of the camera itself were also finished and delivered and are well within specification. Integration should start in 2006 when the vacuum vessel and mechanics of the cryogenically cooled support structure are expected to be delivered. This camera is designed to later exploit ground layer adaptive optics correction provided by the recently approved Adaptive Optics Facility (AOF).

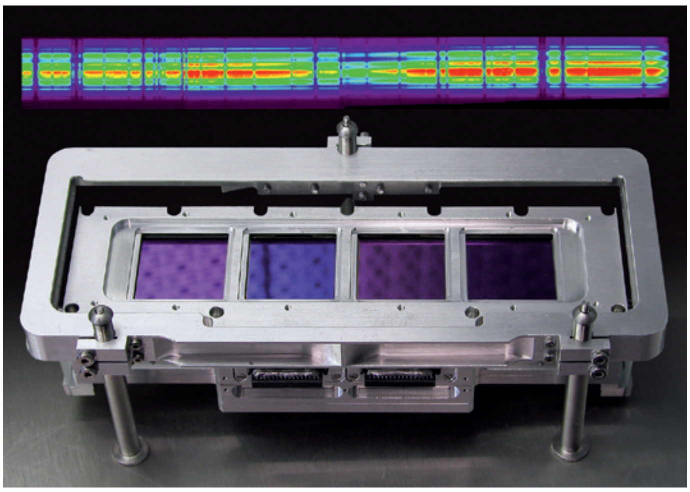
Following a comprehensive Conceptual Design Review by an external/internal review board at the end of September, the AOF was indeed approved by Council in December. This six-year project aims at transforming one of the four VLT Unit Telescopes into an adaptive one, with four sodium laser guide stars, a new M2 unit featuring a Microgate-developed high-order deformable mirror, as well as wavefront sensing systems for the HAWK-I and MUSE instruments. By correcting ground-layer turbulence, it will in effect 'improve' Paranal's natural seeing by a factor of about two in energy concentration. This development is in addition an important pathfinder towards the future ESO Extremely Large Telescope. It is based on extensive technological developments of advanced adaptive optics components (large deformable mirror, real-time computing and wavefront sensor) through the Opticon Joint Research Activities, and of second-generation Raman fibre lasers through a joint ESO-Industry programme with First Light of a 3W prototype achieved in Garching in August.

Development of the Multi-Conjugate Adaptive Optics Demonstrator also progressed well. This is a test-bench instrument to demonstrate and study many of the new Adaptive Optics (AO) approaches proposed in recent years for some second-generation VLT instruments and crucial for the ESO Extremely Large Telescope. It will be used both in the laboratory and on-sky at the VLT. First Light in the laboratory in classical (NACO and SINFONI-like) Single Conjugate AO as well as in the more exotic Ground-Layer AO and Multi-Conjugate AO correction modes was obtained during the year. Basic hardware for the new flavour of layer-oriented wavefront sensing (as opposed to classical star-oriented wavefront sensing) was developed by Arcetri Observatory and delivered to ESO. Validation of these various approaches will continue next year and is supported by extensive simulations conducted with the ESO PC-based cluster.

Design work advanced 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 and will have its Final Design Review in February 2006. Some long-lead items including the optical CCDs and infrared array detector have already been ordered. The Agreement for KMOS, a multiple, deployable integral field infrared spectrometer being developed by a UK/German consortium (with ESO providing the detector system) was signed and the instrument is in its preliminary design phase. Its Preliminary Design Review is planned for May 2006 when test results of a prototype pick-off arm and diamond turned image slicer are expected. The Agreement between ESO and the French/Swiss/German MUSE consortium was also ready for signature, 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. It will also be used together with the AOF described above in order to enhance its sensitivity and resolution. Following the two competitive Phase A studies concluded in December 2004, the approved Planet Finder instrument now contains elements of both proposals from the French and German led consortia. As the name implies, its main aim is to directly detect extra-solar planets, possibly down to 'Jupiters', achieving a contrast of at least 10^{-5} at 0.1 arcsec from a bright central star. It features a fast high-order adaptive optics system with a number of coronagraphic options, feeding three near-infrared instruments – a differential imager, a differential polarimeter and an integral field spectrometer. After positive recommendation by the STC in October, development is starting with LAOG (Grenoble) as the Principal Investigator (PI) Institute and MPIA (Heidelberg) as co-PI Institute. In parallel, development of key adaptive optics components (high order piezo deformable mirror, real-time computing, and wavefront sensor) is being actively pursued through the Opticon Joint Research Activities.

Progress was made in selecting the second-generation instruments for the VLT interferometer. Following a successful Workshop held in Garching to review the scientific achievements of VLTI and to discuss future instrument needs, several consortia made instrument proposals. Some were presented in December to the ESO Scientific Technical Committee that recommended the launch of an official Call for Proposals for Phase A studies. This was issued in December.

In addition to specific instrumentation projects, detector and related 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) advanced and saw First Light with both infrared and visible detectors. This is designed to meet the needs of all foreseeable detector systems for the next few 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. Moreover, 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 the fringe tracking systems needed for interferometric applications.



The specially designed CRIRES mosaic of four infrared detector arrays shown together with the first laboratory spectrum of molecular absorption bands of CO_2 at wavelengths around 4 μm.

Next page: Image of the spiral galaxy NGC 4565 based on data in the ESO Science Archive (FORS/VLT)

The Astrophysical Virtual Observatory

ESO's Virtual Observatory activities, conducted by the Virtual Observatory Systems (VOS) Department of the Data Management and Operations Division, included the third and last science demonstration for the Astrophysical Virtual Observatory (AVO) project, which was held on 25–26 January at ESAC, Madrid, concurrent with the sixth and last meeting of the AVO Science Working Group. It included two science cases: an extragalactic one, on star formation histories in galaxies, and a stellar one, on the transition between the Asymptotic Giant Branch and Planetary Nebula phases. The demonstration was truly multi-wavelength, covering the electromagnetic spectrum from the radio to the ultraviolet band, and included access to theoretical models, building of spectral energy distributions, and the concept of remote computing and workflows. The demonstration marked the end of the AVO project and the beginning of its successor, the EURO-VO. AVO's main achievements include three science demonstrations, the first significant VO refereed paper, progressively more complex VO tools, and a Science Reference Mission.

The EURO-VO work programme is the logical next step from AVO as a Phase B deployment of an operational VO in Europe. Building on the experience gained within the AVO Project, in coordination with the European astronomical networks OPTICON and RADIONET, and through membership and support of the International Virtual Observatory Alliance (IVOA), EURO-VO will seek to achieve the following: (1) technology take-up and full VO compliant data and resource provision by astronomical data centres in Europe; (2) support to the scientific community to utilise the new VO infrastructure through dissemination, workshops, project support, and VO facility-wide resources and services; (3) building of an operational VO infrastructure in response to new scientific challenges via development and refinement of VO components, assessment of new technologies, and design of new components and their implementation.

EURO-VO is open to all European astronomical data centres. Initial partners include ESO, 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 Tecnica Aeroespacial* (INTA, Spain), *Nederlandse Onderzoekschool voor Astronomie* (NOVA, Netherlands), the Particle Physics and Astronomy Research Council (PPARC, UK), and the *Rat Deutscher Sternwarten* (RDS, Germany).

EURO-VO will seek to obtain its objectives by establishing three new interlinked structures: (1) the EURO-VO Data Centre Alliance (DCA), an alliance of European data centres that will populate the EURO-VO with data, provide the physical storage and computational fabric and will publish data, metadata and services to the EURO-VO using VO technologies; (2) the EURO-VO 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; this will be located at ESO and will be managed by ESO and ESA; and (3) the EURO-VO 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 first VOFC activity was the organisation of a EURO-VO workshop at ESO Headquarters in Garching from 27 June to 1 July. The workshop was explicitly designed for data centres and large projects to acquire the knowledge and experience necessary to allow them to become 'publishers' in the VO. It attracted 120 participants, affiliated with 47 institutions in 16 different countries and representatives of 11 IVOA member projects.

The Euro-VO project web site (http://www.euro-vo.org/) served 90 GB of content resulting from 1.5 million web hits in 185 000 user sessions. VOS is also in charge of the IVOA project web site (http://www.ivoa.net), which in 2005 served 28 GB of web content resulting from 2.5 million web hits in 158 000 user sessions.

MIDAS and Python

Sampo is a three year project that began in January 2005. It is led by ESO and conducted by software engineers from Finland as an in-kind contribution to joining ESO. The goal of the project is to assess the needs of the ESO community in the area of data reduction and analysis environments and to create pilot software products that illustrate critical steps along the road to a new system. Those prototypes will not only be used to validate concepts and understand requirements but will also be tools of immediate value for the community. As an initial project the Sampo team has implemented an interface from the Python language to the ESO-MIDAS legacy software system. It allows a user to exploit the extensive legacy of MIDAS software and the power of Python scripting in a unified interactive and scripting environment that also opens up other Python-based astronomical analysis systems such as PyRAF. A new project has been initiated at the end of the year and is a direct response to requirements emerging from discussions within ESO. There is a clear need for ways in which pipelines may be run in more flexible ways and with greater control. Users wish to move away from the concept of 'black boxes' and need to be able to stop processing at intermediate stages and to visualise and check intermediate results. The ERDA project will study options for software infrastructure to achieve this in close collaboration with ESO astronomers in Garching and in Chile.

Science Archive Operation

The ESO Science Archive contains 44 TB.

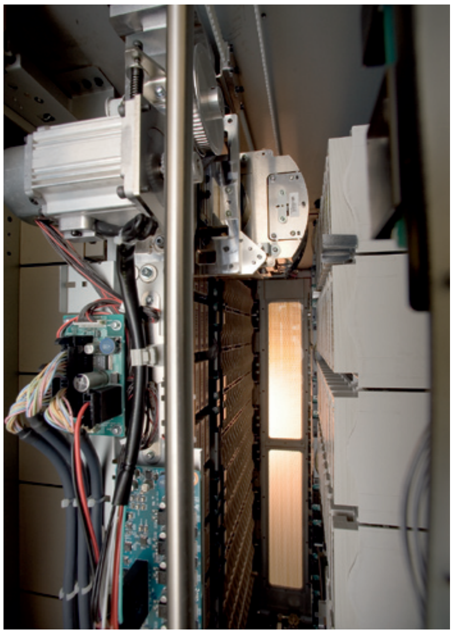
The Science Archive Operation (SAO) group is responsible for receiving and redistributing ESO and HST data, as well as providing front-line archive user support. In April 2005, we opened the ESO archive to the worldwide community. Its current total holding is 44 TB, corresponding to 5.1 million files. Roughly 12 TB of new data (1.2 million files) were archived during 2005, a 70 % increase over 2004. The archive is accessed via a Web-based data request submission system, whose interface was redesigned and deployed on 4 April, with the aim to facilitate data queries and convey maximum information to archival users who might not be familiar with ESO instruments. In addition to the general archive Web interface, all current VLT instruments and the VLTI MIDI instrument now have dedicated instrument-specific forms to query the data. Almost 15 000 unique archive requests were served in 2005, totalling 23 TB of data (30 % increase with respect to 2004). Of those requests, 13 500 were for ESO data, while the remaining 1 500 were for HST data. In addition, 1 600 data packages were prepared and delivered to Principal Investigators on 2 800 CDs/DVDs. These are 35 % more packages and 45 % more CDs/DVDs compared to the previous year. Finally, 140 calibrated pre-imaging datasets from FORS1, FORS2, VIMOS and VISIR were delivered automatically within 48 hours of acquisition at the telescope.

Beginning from April 2005 the first 2.6 TB of raw data from the UKIRT Infrared Deep Sky Survey (UKIDSS) executed with the WFCAM instrument at the UK Infrared Telescope (UKIRT) have started to flow into the ESO archive. The annual volume is expected to be between four and six terabytes a year until the survey completion, in 2012.

Work on the ESO Science Archive Facility proceeded at various levels with the final goal of setting-up the infrastructure necessary to build an archive, which complies with VO standards in terms of data access, format, and interface. The ADP/MVM pipeline, a data reduction system for the production of Advanced Data Products (ADP), specifically for WFI, SOFI and ISAAC and other imaging instruments on the VLT, was built around the core functionalities provided by the EIS/MVM software. The software was then used for the release to the astronomical community on 30 September of the ISAAC/GOODS science ready dataset (astrometrically calibrated stacked images and mosaics reduced from 11 600 science frames, 10 600 calibration frames, photometrically calibrated using pre-determined zero points from SOFI data).

The major milestones for 2006 include the archiving of APEX and VST/OmegaCam data. In particular, the latter instrument is expected to produce annually in excess of 30 TB of raw data and data products. In other words, OmegaCAM alone will provide 2.5 times more data than the inflow in 2005 from all of the instruments combined. With other DMD groups, SAO has begun the implementation of procedures and processes to handle this load. This preparation is also relevant to future high-volume instruments such as MUSE at the VLT and VIRCAM on VISTA.

Fundamentally, archive operations rely on a large number of hardware servers to store science data and their associated metadata in a reliable manner. It has been estimated that the archive data volume will grow to 1 petabyte by 2010. To deal with this volume challenge, a petabyte-class archive storage has been designed and described in a call for tenders for the provision of a new archiving system. This call for tenders was issued and the bids of the participating companies were technically reviewed. Finally, a contract for installation and maintenance of the compute stack storage (fast cache), the primary archive and the secondary archive, which holds the entire archive contents at another physical location, has been signed.



Archive operations rely on a large number of hardware servers.

ST-ECF

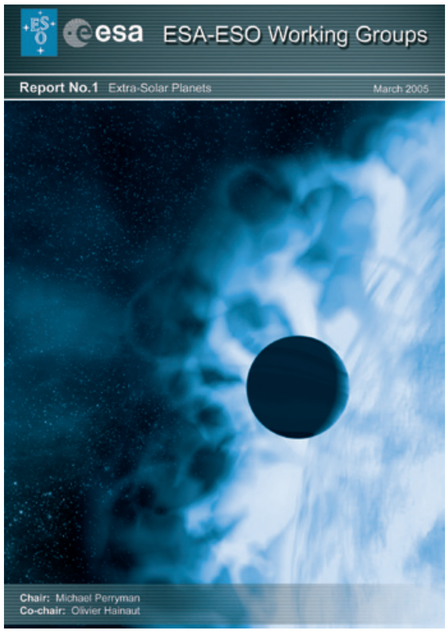
ESO and the European Space Agency continue to collaborate through the Space Telescope – European Coordinating Facility (ST-ECF), which provides European support of the Hubble Space Telescope (HST) and other projects of common interest to the two organisations. In April 2005, the HST celebrated the 15th anniversary of its launch. Following the early and painful tribulations over the incorrect primary mirror figure – and the remarkably successful efforts to recover imaging performance using iterative digital restoration techniques – the telescope and its instruments were restored to the exquisite design performance by the astronauts during the first servicing mission in 1993. Since then the telescope has produced a continuous stream of unique data and discoveries. In recognition of the anniversary, the ST-ECF produced a book and a DVD telling the Hubble story using accessible language and stunning pictures and graphics. There were over 60 public events across Europe to which material was contributed. Some 700 000 copies of the DVD have now been distributed worldwide in 16 European languages and the book is being published in English, German, Portuguese and Finnish.

During its 16th year, Hubble continues nominal operation with four active science instruments: three cameras and a fine guidance sensor that can be used for astrometric measurements. The 14th round of GO proposals were submitted early in 2005, resulting in an oversubscription rate of 4:1 for proposals and 5:1 for orbits. Some 34 % of the allocated time went to Large or 'Treasury' programmes. ESA astronomers won 26 % of the proposals and 18 % of the allocated orbits. Given the failure of Hubble's slit spectrograph (STIS) in August 2004, the only remaining spectrographic capability is provided by the slitless grism/prism modes of the Advanced Camera for Surveys (ACS) and the Near Infrared Camera and Multi-Object Spectrograph (NICMOS). ST-ECF is providing the calibration and data reduction software for these modes and is responsible for their support. Such spectroscopy accounts for more than 10 % of the allocated observing time on these instruments. ST-ECF scientists are collaborating in a number of substantial programmes using these capabilities. The low sky background and high spatial resolution means that the HST is the most sensitive facility for measuring continuum breaks in high redshift galaxies.

As part of our continuing provision of the European HST archive, we are working – within the ESO archive environment – with the Space Telescope Science Institute (STScI), Johns Hopkins University (JHU) and the Canadian Astronomy Data Centre (CADC) to design, develop and create the Hubble Legacy Archive (HLA). This process is being conceived to capture the instrument science knowledge associated with Hubble and to provide a range of high level science data products that will form the lasting legacy of the project. It will exploit Virtual Observatory (VO) standards and procedures and hopefully become an exemplar for the VO initiative.

In addition to the work done for the HST observatory, largely in collaboration with the STScI, we are engaged in a number of collaborations with ESO that are designed to share, as efficiently and effectively as possible, ground and space astronomy expertise and capabilities. These include data reduction, instrument modelling and calibration projects concerned with the VLT instruments FORS2, CRIRES and X-Shooter. The ST-ECF forms a tangible interface between ESA and ESO and is in an ideal position to play a role in coordinating various science planning activities being carried out by the two organisations. One of these is the establishment of a series of working groups tasked to look at scientific areas of common interest and also at synergies between space- and ground-based facilities being constructed. Three such groups have now been formed and have produced or are producing reports for wide distribution. The first, on Extra-Solar

The report of the ESA-ESO working group on Extra-Solar Planets has been published.



Planets and chaired by Michael Perryman (co-chair: Olivier Hainaut) was published in March 2005. A report on Herschel/ALMA Synergies, chaired by Tom Wilson (co-chair: David Elbaz), was completed in February 2006. The third, on Fundamental Cosmology and chaired by John Peacock (co-chair: Peter Schneider) is in preparation.

Following the completion of some projects carried out as part of the ESA/NASA Hubble agreement, the ST-ECF has reduced its staff from a maximum of 21 back to its original complement of 14, shared between ESA and ESO funding. This reduction was largely completed during 2005. Two of these staff – both concerned with the instrument physical modelling pioneered by Michael Rosa – transferred to the ESO Instrumentation Division where they are now working on related tasks in VLT instrument projects.

Public Outreach

As in the previous years, ESO continued with a very high level of activity with respect to public communication. These activities were carried out while the department underwent a major restructuring, taking the recommendations of the Visiting Committee into account and with a view to develop a wider, fully coherent set of public actions in support of ESO and European astronomy. The wider scope for activities and the name given to the restructured department (Public Affairs Department – PAD) reflect ESO's commitment to play an active role in the public sphere in terms of stimulating public awareness of and interest in astronomy, also in its European dimension.

To this end, the activities of the department are structured along three main axes:
– Communication
– Education
– Policy Support

With respect to Communication, the activities comprise press releases, press photos, video newsreels and films, TV support, press conferences and press events (including press visits), media relations, brochures and other printed matter and exhibitions, as well as the ESO website.

In the field of Education, they cover exercises and teaching kits, classroom activities, school visits and teachers' activities such as Summer Schools, as well as participation in the major longer-term EIROforum educational activities ('Science on Stage' and 'Science in School', the European Journal for Science Education, set to be launched in the Spring of 2006).

Finally, activities under 'Policy Support' include the Messenger, the Annual Report, organisation of 'High-level Events' in member-states and 'High-level Visits' often involving government ministers, industrial delegations, members of Parliaments, etc. Furthermore overall EU and EIROforum relations fall under the remit of the department. The EU interaction (see page 66), partly channelled through the EIROforum partnership, comprises a continuing awareness building effort, interaction with science policy makers and participation in EU-funded programmes.

In all areas, the primary goal for ESO is to secure the best possible conditions for European astronomers in the face of strong competition for support, both from other areas of science and from non-scientific spending needs.

Media

During the year, ESO issued 34 'formal' press releases, 21 of these on science. These press releases covered research highlights such as the confirmation of the first direct image of an exoplanet (obtained in 2004 with the VLT), the discovery of a Neptune-mass exoplanet around a small star, observation of the visible light from a short gamma-ray burst, the farthest known gamma-ray burst ($z = 6.3$) and the discovery of a triple asteroid. Seven press releases dealt with instruments and telescopes, but also included a release to mark the 1000th scientific paper based on VLT data. Furthermore there were press releases on institutional matters, including EIROforum activities.

A large effort is made to involve the whole community in the outreach activities, and many releases were done in collaboration with national organisations (e.g. PPARC, MPE, CNRS, INAF), the EIROforum or the leading research journal *Astronomy & Astrophysics*. Moreover, a Science Outreach Network, consisting of national representatives in all ESO member states, helps ESO to interact better with the national media in the member states.

ESO also issued 11 press photos. While 'Science Press Releases' are subject to a stringent procedure of approval, involving an internal ESO Press Committee acting in a peer-review mode to verify the scientific claims, 'Press Photos' are released primarily on the basis of their public appeal and are thus subject to a different selection procedure.

In addition to the 'regular' press releases, ESO published seven releases concerning the Deep Impact event in early July. Around the time of the collision between the Deep Impact space probe and Comet Tempel 1, all available ESO telescopes observed the comet, constituting the largest dedicated observing programme for any ground-based observatory in the world. On this background, ESO also organised a major media event at the Headquarters on 4/5 July, providing comprehensive real-time information to journalists from near and far. The event was carried out in collaboration with ESA/ESTEC and included videoconferences and live TV from Paranal and La Silla, as well as full access to, and participation in, ESA TV broadcasts. ESO also set up a dedicated web site with background information on the comet, the mission and the science done with ESO's telescopes, as well as photos, pre- and post-impact interviews with the scientists, and results provided as they became available. In total, the web site contains about 300 MB of data. It was seen by more than 100 000 visitors in the course of a month and on the day of the impact we registered nearly five million hits with 132 GB web traffic.

A major media event was organised at ESO in connection with the Deep Impact encounter with Comet Tempel 1.

Education

With respect to education activities, we concluded the 'Catch a Star!' 2004 contest with a record number of participating projects (364) from 25 countries. In March 2005, ESO hosted the General Assembly of the European Association for Astronomy Education (EAAE). The EAAE was established in the wake of a major science teaching conference held at ESO in 1994 and the 2005 General Assembly marked the 10th anniversary of the association. The EAAE constitutes a highly valued partner for ESO and an excellent interface with the educational systems in the European countries.

In November, the EIROforum Science on Stage 2005 Festival took place at CERN with around 500 participants from all over Europe (but also including a delegation from Canada). The Science on Stage programme is the flagship activity of EIROforum in the field of science teaching and aims to stimulate a rejuvenation of science teaching in Europe by fostering innovative teaching concepts and their integration into the teaching world, mostly at the lower and higher secondary stage.

Exhibitions and Events

During the year, the ESO PAD organised or participated in a number of events and exhibitions, both in Garching and across the continent. In January, an awareness meeting for Danish Industry was organised at Garching. In March the Venus Transit 2004 project was presented in a keynote address to a science communication conference in Brussels with about 900 attendants. In April a presentation of the EIROforum Science Policy Paper took place in Brussels. In June, ESO mounted a large information stand at the 1st *Salon Européen de la Recherche et de l'Innovation* in Paris. An estimated 28 000 visited this event and, among many other attractions, had the opportunity to enjoy live videoconferences from the VLT at Paranal. Later in June, ESO hosted a major international conference on Public Communication of Astronomy (following earlier conferences in the Canary Islands and in Washington, D.C.).

ESO stand at Chalmers Technical University in Gothenburg.

Following immediately after the Deep Impact media event, ESO also presented itself with an exhibition at the JENAM 2005 conference in Liège. Further exhibitions were organised in connection with the EPS-13 Annual Conference and at a conference at Chalmers Technical University in Gothenburg.

On 23 October, the Headquarters building was opened to the public and almost 2 500 people used this opportunity to learn more about our organisation and its exciting projects.

In November, at the "Communicating European Research" 2005 Conference, ESO took the lead in organising two seminars on behalf of the EIROforum, one on science education and one offering practical tips to science press officers. ESO was also present on the EIROforum stand at the associated exhibition.

As part of the overall changes at PAD, and in line with its strategic reorientation, we also developed a 'corporate identity' (CI), including a set of defined graphical standards, for ESO. The CI has been implemented incrementally during the second half of the year, beginning with the Annual Report 2004 and the September 2004 issue of the Messenger. Meanwhile, all ESO printed matter now reflect this CI. Further changes that have been implemented include style and presentation of press releases as well as a targeted effort to improve the awareness of ESO amongst journalists.

Finally, as of April 2005 the PAD has begun an effort to monitor the coverage of ESO in the printed and electronic media, enabling us to produce compilations of press cuttings for documentation purposes, but more significantly allowing us to assess the real impact of the various outreach activities.

On this basis, we see a marked increase in media coverage, which in turn is also reflected in the growing interest in ESO by the general public. Thus the public affairs web page keeps drawing increased attention. On average, about 250 000 visitors come every month to the site, with peaks above 300 000, and downloads per month total about 300 GB. This corresponds to roughly 8 500 daily visitors – a twofold increase compared to two years ago.

ESO Press Releases

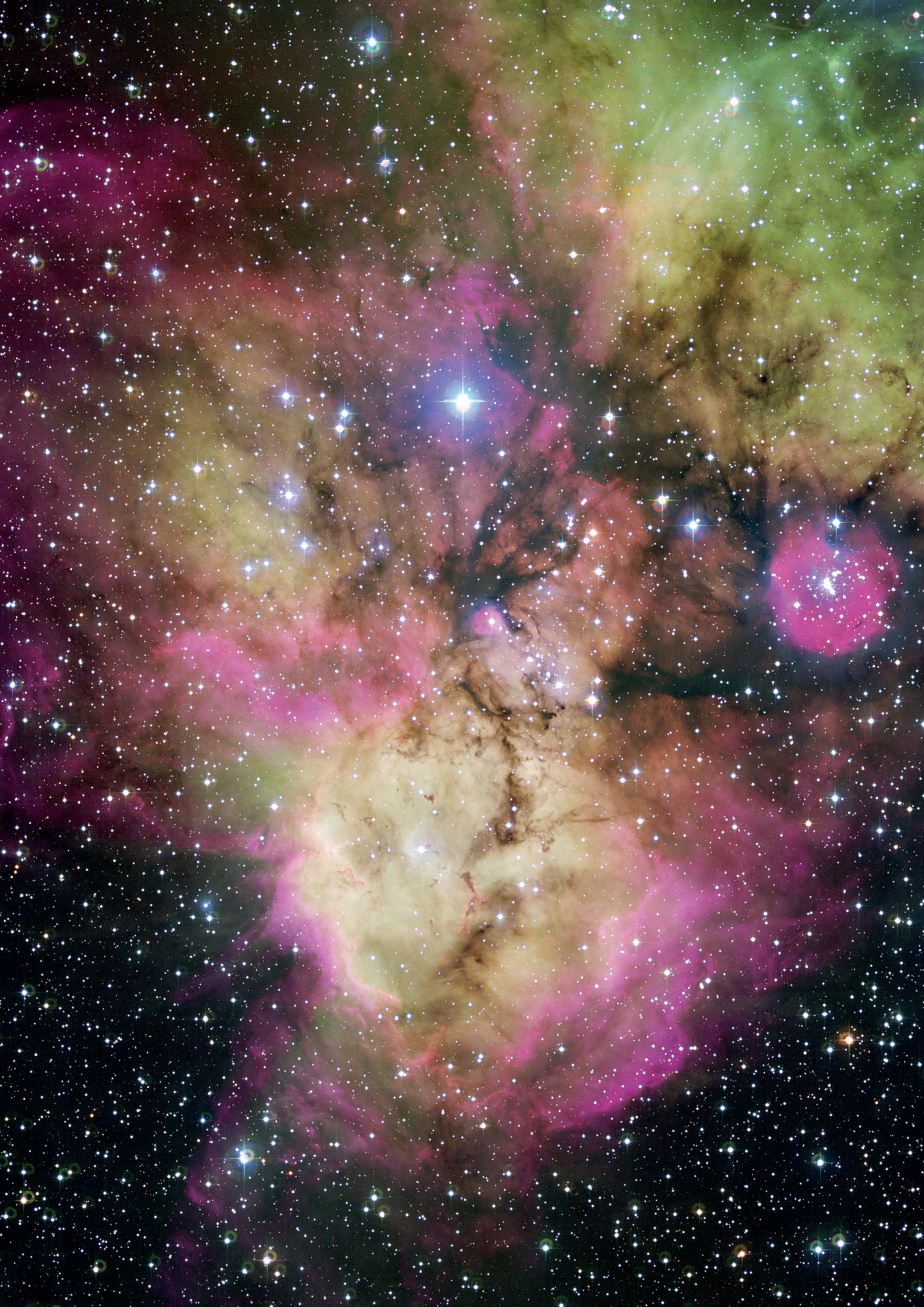
ESO Press Photo 01/05 (12 January): ESO PR Highlights in 2004
ESO Press Release 01/05 (13 January): Rebuilding Spiral Galaxies – Major Observing Programme Leads to New Theory of Galaxy Formation
ESO Press Release 02/05 (19 January): Weighing the Smallest Stars – VLT Finds Young, Very Low Mass Objects Are Twice As Heavy As Predicted
ESO Press Release 03/05 (21 February): ESO's Two Observatories Merge
ESO Press Photo 04/05 (24 February): Another Look at an Enigmatic New World – VLT NACO Performs Outstanding Observations of Titan's Atmosphere and Surface
ESO Press Release 04/05 (2 March): Surprise Discovery of Highly Developed Structure in the Young Universe – ESO-VLT and ESA XMM-Newton Together Discover Earliest Massive Cluster of Galaxies Known
ESO Press Release 05/05 (3 March): Undercover Stars Among Exoplanet Candidates – Very Large Telescope Finds Planet-Sized Transiting Star
ESO Press Release 06/05 (14 March): VLTI First Fringes with Two Auxiliary Telescopes at Paranal – World's Largest Interferometer with Moving Optical Telescopes on Track
ESO Press Release 07/05 (15 March): A Tale of Two Populations – VLT FLAMES Finds Hints of Helium-Richest Stars Ever Seen
ESO Press Release 08/05 (22 March): Young and Exotic Stellar Zoo – ESO's Telescopes Uncover Super Star Cluster in the Milky Way
ESO Press Release 09/05 (7 April): Is this a Brown Dwarf or an Exoplanet? – New Young Sub-stellar Companion Imaged with the VLT
ESO Press Release 10/05 (20 April): "Towards a Europe of Knowledge and Innovation", the EIROforum paper on science policy
ESO Press Photos 12a–e/05 (22 April): The Blob, the Very Rare Massive Star and the Two Populations – Striking Image of Nebula N214C taken with ESO's NTT at La Silla
ESO Press Release 11/05 (27 April): Thousand Papers and Counting – ESO's Very Large Telescope Passes the 1000 Refereed Publications Mark
ESO Press Release 13/05 (30 April): Catherine Cesarsky Elected Foreign Associate of the US National Academy of Sciences
ESO Press Release 12/05 (30 April): Yes, it is the Image of an Exoplanet – Astronomers Confirm the First Image of a Planet Outside of Our Solar System
ESO Press Release 14/05 (16 May): Dutch Minister of Science Visits ESO Facilities in Chile
ESO Press Release 15/05 (30 May): Preparing for the Impact – ESO Telescopes Take Snapshot of Comet 9P/Tempel 1 in Readiness for Major Observation Campaign
ESO Press Release 16/05 (7 June): ESO Receives *Computerworld* Honors Program 21st Century Achievement Award in Science Category
ESO Press Release 17/05 (9 June): Ultra-fast Movies of the Sky – Astronomers Commission New High-Speed Camera on the Very Large Telescope
ESO Press Photos 20a–c/05 (30 June): Einstein Ring in Distant Universe – Astronomers Using the VLT Discover Bright Cosmic Mirage Far Away
ESO Press Release 19/05 (14 July): Comet Tempel 1 Went Back to Sleep – Astronomers Having Used ESO Telescopes Start Analysing Unique Dataset on the Comet Following the Deep Impact Mission
ESO Press Release 18/05 (14 July): New Sub-Millimetre Light in the Desert – APEX telescope Sees First Light at Chajnantor
ESO Press Release 20/05 (1 August): Moving Closer to the Grand Spiral – VLT Enables Most Accurate Distance Measurement to Spiral Galaxy NGC 300.
ESO Press Photos 24a–b/05 (10 August): Midsummer's Dream Galaxies.
ESO Press Release 21/05 (11 August): Rubble-Pile Minor Planet Sylvia and Her Twins – VLT NACO Instrument Helps Discover First Triple Asteroid.
ESO Press Photo 26/05 (24 August): Celestial Blast in Bleak Reticulum
ESO Press Release 22/05 (12 September): Star Death Beacon at the Edge of the Universe – Astronomers Find Farthest Known Gamma-Ray Burst with ESO VLT
ESO Press Release 23/05 (14 September): Black Hole in Search of a Home – Astronomers Discover Bright Quasar Without Massive Host Galaxy
ESO Press Release 24/05 (22 September): A Cosmic Baby-Boom – Large Population of Galaxies Found in the Young Universe with ESO's VLT
ESO Press Release 25/05 (25 September): Desert Pathfinder at Work – Sub-millimetre APEX telescope inaugurated at Chajnantor

Many reports on the VLT and its science appeared in the media.

ESO Press Photos 31a–b/05 (29 September): The Colossal Cosmic Eye
ESO Press Release 26/05 (6 October): Flashes Shed Light on Cosmic Clashes – ESO's Telescopes See Afterglows of Elusive Short Bursts
ESO Press Photos 33a–b/05 (17 October): Feeding the Monster – New VLT Images Reveal the Surroundings of a Super-massive Black Hole
ESO Press Photos 34a–b/05 (4 November): Cosmic Portrait of a Perturbed Family
ESO Press Release 27/05 (9 November): Star on the Run – Speeding Star Observed with VLT Hints at Massive Black Hole
ESO Press Release 28/05 (10 November): Setting the Stage for Science in Schools – EIROforum presents the very best of European science teaching
ESO Press Release 29/05 (24 November): Sharp Vision Reveals Intimacy of Stars – AMBER instrument on VLTI Probes Environment of Stars
ESO Press Release 30/05 (30 November): The Dwarf that Carries a World – HARPS Instrument Finds Neptune-Mass Exoplanet Around Small Star
ESO Press Release 31/05 (7 December): ESO Signs Largest-Ever European Industrial Contract For Ground-Based Astronomy Project
ESO Press Release 32/05 (14 December): Witnessing the Flash from a Black Hole's Cannibal Act – Short Gamma-Ray Burst Confirms Formation Scenario
ESO Press Release 33/05 (21 December): Allo, Allo? A Star is Ringing – VLT Helps Measuring Tortoise-like Motion
ESO Press Release 34/05 (22 December): ALMA On the Move – ESO Awards Important Contract for the ALMA Project
ESO Press Photos 42a–b/05 (25 December): The Cosmic Christmas Ghost – Two Stunning Pictures of Young Stellar Clusters
ESO Press Photo 43/05 (29 December): Season's Greetings!

The ALMA project caught much attention.

The cosmic christmas ghost, NGC 2467 and its surroundings (WFI/2.2-m).



Relations with Chile

The supplementary agreement between Chile and ESO signed a decade ago has widened and strengthened the cooperative relations between ESO and the Chilean scientific and local communities. The Chilean population is increasingly interested in astrophysics and related sciences at all levels. The national and regional media cover astronomy as a hot topic almost every week and the media coverage in Chile of ESO's achievements increased by 150 % in 2005 compared to the previous year, according to independent monitoring services. Astronomy was among the 10 most asked for careers at the main Chilean universities in the last national selection process in December 2005. Moreover, local astronomy departments not only received more applicants, but also better-qualified students who faced stronger competition to become accepted.

More than 8 000 visitors were received in 2005 at the La Silla Paranal Observatory as part of the regular service offered on the weekends to local communities and also to European travellers who are strongly motivated by the exploration of the Universe.

In Antofagasta, the ESO-ALMA stands at Exponor, the most important industrial fair in Region II, were rewarded with the first prize of the exhibition, while the UCN Astronomy Institute, in a joint effort with ESO-Vitacura, offered an active programme of public talks and 'star parties' for people living in Antofagasta and Taltal, the closest neighbours to Paranal.

Children captivated by the Paranal model at the 2005 Fair of Physics.

Also in Taltal, a joint initiative between ESO and the local municipality granted scholarships to 163 undergraduate students. Near La Silla, an agreement with the municipality of La Higuera was reached to support local schools.

The ESO-Chile Joint Committee, a partnership with the Chilean Government launched in 1996 as part of the supplementary agreement, has played a crucial role in the establishment and strengthening of Astronomy Departments at Chilean Universities. In 2005, a total of 388 k€ was assigned for the development of astrophysics and related sciences in the country, in a competitive process where representatives from ESO and the Chilean Government selected the best proposals.

By the end of 2005, more than 200 students gathered at ESO-Vitacura for the first multi thematic Latin American Astronomy School, organised jointly by ESO and the Chilean Astronomical Society (SOCHIAS). Enthusiastic students from 18 different countries had the chance to learn about front-line areas of research. The event was the perfect prelude to the 11th Latin American Regional Meeting of the International Astronomical Union (IAU), held just the following week in Pucón, Chile. Given the success of the summer school and its impact on the education of future astronomers, it is now being proposed that such multi-thematic schools should take place regularly, in association with future Regional Meetings of the IAU.

Another event that generated a wide interest in Chile was the observational campaign of Comet Tempel 1 before and after the impact with the space probe Deep Impact on 4 July. A series of press conferences were held at the Vitacura office, with links to Paranal and La Silla. ESO also joined the Chilean Ministry of Education in organising a national educational videoconference that linked Paranal with young students in 18 different cities along the country. In addition, the main national TV network in the country presented, together with ESO, a 50-minutes special documentary that was watched by around 500 000 viewers.

A site museum was built along the access road to the ALMA operations site.

As a long-term approach to increase the public awareness of ESO's commitment to Chile and its people, a partnership with Explora/Conicyt (a governmental agency focused on the promotion of science among children and youngsters) was established. As part of the celebrations of the International Year of Physics, Explora and ESO launched the '100 years, 100 schools' initiative, which allowed the creation of 100 school teams along Chile, with children and teachers taking science measurements of their environment, from the Northern *Altiplano* to Antártica.

In the framework of ALMA, a regional fund created by ESO and AUI supported in 2005 several projects to improve equipments of local farmers, developing sustainable tourism initiatives, and improving health service in San Pedro de Atacama and Toconao. This fund was further increased with the joining of the National Astronomical Observatory of Japan, in a public ceremony in San Pedro de Atacama for the 25th anniversary of the local municipality. As part of these celebrations, ALMA offered to the community a mobile observatory to allow people to enjoy observations of the night sky.

Besides this, ALMA has contributed to the understanding and protection of archaeological heritage of the ancient *Lican Antai* culture. A site museum was built in an abandoned small *estancia*, located near the ALMA road, allowing visitors to learn more about the lifestyle and culture of the old native inhabitants of this area. The book 'Footprints in the Desert', edited and published by ESO, will further promote the cultural heritage of the ALMA site's surroundings.

During Exponor 2005, ESO received the award for the best exhibition.

European Affairs

ESO European Affairs are conducted partly through direct interactions, primarily with the European Commission, and through common initiatives carried out in the frame of the EIROforum partnership. While we are pleased by the continued positive, indeed very constructive, relations with the EU, the year was characterised by many changes on the side of the EU, with the still 'young' Parliament and the new Commissioner in office as well as further changes within the Commission Services. To this should be added the uncertainties associated with the preparation of FP-7, as it became entangled in the political struggle over the future Financial Perspectives of the EU. Meanwhile, FP-6 is approaching its final year.

Direct interactions

ESO's direct interactions include applications to the Framework Programme (FP). These applications follow in response to Calls for Proposals and are concentrated in areas in which ESO can make a unique contribution, but which cannot be covered by ESO's core funding, and/or where ESO's participation, as coordinator or member in consortia of institutes, is deemed useful. Major FP-6 contracts signed in 2005 were the ELT Design Study and the ALMA Enhancement Projects, both led by ESO. Another contract that should be mentioned was for the VO-Tech project, which is part of the overall European VO activities. For ESO, this contract was the first with DG Information Society. It is a clear sign that the VO activities are seen to be important also beyond astronomy.

Most projects under FP-6 with ESO participation are linked to R&D, but this year ESO also entered into a contract under the ERA-net scheme. This scheme provides support for transnational networking and coordination of national research programmes, thus it is primarily seen as a network of the main European funding agencies. The specific activity, called ASTRONET, aims at developing a strategic vision for the whole of European astronomy as expressed through a 'roadmap'. Main participants in ASTRONET are ESO, INSU, BMBF, INAF, PPARC, NOTSA, MEC (Spain) and NWO, while ESA and the Max Planck Society elected to become observers. ESO also joined the ARENA project, which seeks to investigate the possibilities for astronomy in Antarctica.

An important aspect of the direct interactions, which take place at various levels, is the participation in the consultative process carried out by the Commission in connection with the Framework Programme, particularly in the preparation of FP-7. Participating in this process provides us with an opportunity to raise issues that are important to us and to European astronomy.

EIROforum

As we have seen in the past years, the EIROforum serves the dual purpose of being an important platform for high-level political interaction and dialogue with the institutions of the European Union, and an effective instrument to undertake joint activities.

As the European Research Area evolves, the political dialogue remains very important, not the least with a view to ensuring that much valuable experience accumulated within the EIROforum partner organisations is injected into the debate on how to organise science and science management in the future in Europe. This was also the background for the presentation on 20 April of the EIROforum Science Policy Paper to an invited audience. The presentation, at the Berlaymont Building in Brussels, took place in the presence of EU Research Commissioner Janez Potočnik and the (then) Chairman of the Competitiveness Council, François Biltgen. The EIROforum Science Policy Paper discusses the relationship between Europe's Lisbon Strategy and the role for science within that strategy as well as proposing a series of concrete steps to which the EIROforum partners can contribute.

Presentation of the EIROforum Science Policy Paper on 20 April in Brussels at the Berlaymont Building.

Following up on this, EIROforum presented its views again in a meeting on 12 October at the European Parliament with prominent members of the Committee on Industry, Research and Energy (ITRE). Amongst the participants were Jerzy Buzek (former Prime Minister of Poland), Pia Locatelli, Vittorio Prodi and Philippe Busquin (former EC Commissioner for Research). This meeting followed on the heels of the regular autumn EIROforum Assembly (the joint meeting of the Directors General and the EIROforum Coordination Group) at ILL. This meeting also included a first formal exchange with Prof. John Wood, Chairman of the European Strategy Forum for Research Infrastructures (ESFRI).

The EIROforum was also invited to participate in the third European Conference on Research Infrastructures, held on 6–7 December in Nottingham under the auspices of the UK Presidency of the EU and organised jointly by the Commission and ESFRI. Representatives from ESO attended the conference and, among other things, participated with a talk on the future needs in astronomy and astrophysics.

The Danish Minister of Education, Bertel Haarder, at the ESO office in Santiago.

As regards joint activities, these are normally dealt with by thematic working groups and cover outreach and education, human resources, grid technologies, detector technologies/instrumentation and EU relations. Some activities under outreach and education have been mentioned on page 61. The Thematic Working Group on European Affairs, which is chaired by ESO, has proven to be an efficient mechanism both for exchange of information and for helping the EIROforum in its EU interactions. This includes the practical implementation of the Joint Actions between the EIROforum and the Commission, carried out under the Joint Statement of Intent that was signed by the Directors General and the European Commissioner in November 2003.

The Joint Actions comprise the field of Instrumentation (considerations of setting up a Network of Excellence or possibly a 'Technology Platform') and Human Resources (regarding the application of the 'European Charter for Researchers', the use of the Commission Mobility Portal for Researchers for EIROforum and ESO vacancy announcements, and possibly training for young scientists, etc.). The Joint Actions also include the EIROforum European Science Education Initiative (ESTI), now co-funded by EIROforum and the Commission, as well as discussions about a Pan-European Partnership for Science Education and EIROforum support for and participation in the EU Contest for Young Scientists.

In the spirit of the Joint Actions, the Commission invited EIROforum to organise a dedicated session on Science Education in Europe at the CER 2005 Conference (14–15 November 2005). This conference attracted around 2 500 participants.

Finally, under the Joint Actions are preliminary discussions aiming at examining the state of international relations of the EIROforum partner organisations and the EC, e.g. in the context of third country participation in the Framework Programme, with a view to see if some degree of coordination is merited.

Of course many of these activities will depend on the final shape of FP-7 including the financial resources allocated by the Commission. This remained unclear as the year drew to a close.

As in the previous years, ESO was pleased to welcome high-level visits from its member states and beyond. The visits included key members of the Danish and Dutch Governments as well as officials of the European Commission. Such visits are important, because they contribute to deepening the understanding of the many-sided activities carried out by our organisation.

The Observing Programmes Committee

The Observing Programmes Committee 2005

Alfonso Aragón Salamanca
Antonella Barucci (Period 76)
Rolf Chini (Period 76)
Søren Frandsen (Period 76–77)
Eva Grebel
Martin Groenewegen
François Hammer (Period 75)
Artie Hatzes (Period 77)
Rob Jeffries (Period 77)
Jens Knude (Period 75)
Jari Kotilainen
Matt Lehnert (Period 75)
Tommaso Maccacaro (Chairman)
Tom R. Marsh (Period 75)
André Moitinho de Almeida
Thierry Montmerle (Period 75–76)
Göran Östlin
Reynier Peletier (Period 75)
Christian Perrier (Period 75)
Timo Prusti (Period 75)
Daniel Rouan (Period 77)
María Teresa Ruíz
Paolo Saracco (Period 76–77)
Xander Tielens (Period 76–77)
Joachim Wambsganss (Period 76–77)
Lutz Wisotzki

The Observing Programmes Committee (OPC) met twice in 2005, in June and in November. For the Observing Period 76 (1 October 2005 to 31 March 2006), around 865 proposals were received, a new absolute record, while for the Observing Period 77 (1 April to 30 September 30, 2006), this number was of 850 proposals, following a long trend of slightly fewer proposals during the southern winter semester. From all the proposals received, it appears that there is a continuing high demand for the first generation VLT workhorses (FORS1, FORS2, ISAAC and UVES). Melipal (UT3) saw an increase of pressure due to its new instrument, VISIR, and the same happened for Yepun (UT4) with its new instrument SINFONI. With the continued high demand on FLAMES and on NACO, the pressure factor is now very high on all VLT units (about a factor of four). Instruments at La Silla experienced a slight increase of demand during 2005, when compared to previous years, mainly due to the number of Large Programmes asking for time on La Silla.

With the aim of taking full advantage of the complementarity of ground-based and space-borne observing facilities, ESA and ESO have agreed to establish a joint telescope time application scheme for those scientific programmes that require observations with both the XMM-Newton X-ray observatory and the ESO VLT(I) telescopes to achieve outstanding and competitive results. During P75, the first Period under this agreement, ESO received five proposals out of which three were recommended by the OPC (two of them top ranked). During P77, ESO received two such proposals, one being top ranked. All these proposals were successfully scheduled at both VLT and XMM-Newton telescopes, all them requiring simultaneous observations at the two observatories. From ESA's side two proposals were recommended time (one of which is a Large Programme) in P75 and four in P77. All were successfully scheduled at both observatories.

During 2005 there was a continued high pressure for Target of Opportunity (ToO) proposals, in particular in the field of gamma-ray bursts (GRBs). A large fraction of submitted ToO proposals in P76 and P77 were GRB proposals requesting the Rapid Response Mode of the VLT, meaning VLT observations in less than six minutes after a trigger (that can be submitted via mobile phone). Exceptionally, some proposals were granted override status over visitor mode programmes to maximise the chances of successful observations of these very time critical events. Time lost to visitor mode programmes during GRB observations is returned to the programme during service mode. To optimise the scientific return of the recommended GRB programmes ESO invited the successful PIs to an observational strategy meeting in Garching. These meetings will continue in the upcoming Periods.

OPC procedures

During 2005 the OPC worked very well and although there is currently no need for a fundamental revision, several procedural improvements were delineated and will be implemented during 2006. Given the growing number of submitted proposals every Period, the workload on OPC and OPC panel members is reaching a critical level, in particular for Panels C (Star Formation and Solar System) and D (Stellar Evolution). The OPC selection, structure, and general statistics on time allocation are available to the users via the ESO web.

Large Programmes

'Large Programmes' (LPs) are projects requiring substantial observing time (more than either 100 hours or 10 nights) for a well-focused scientific goal. The duration is limited to no more than two years (four semesters). Up to 30 % of the total time available for the community may be committed to LPs. In P76 the OPC was faced with eight LPs, recommended three, and several of the rest were partly converted into normal programmes. In P77 there were 20 LPs submitted and six were recommended. Between the start of VLT operations in 1999 (P63) and 2005 (P77), 63 LPs have been approved by the OPC for Paranal and La Silla telescopes. They cover almost all current astronomical topics, from the Solar System to the study of cosmological parameters.

Public Surveys

Surveys provide large, homogeneous data sets covering a variety of combinations in the parameter space of multiband, 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.

At ESO, surveys have been handled as LPs in recent years. Some of them have been conceived as Public Surveys, such as the various EIS surveys (e.g. Pre-FLAMES, Deep Public Survey, and the GALEX and XMM follow-up surveys), FIRES and GOODS. Others have been handled as proprietary (or private) surveys, such as the *U*-band VIRMOS survey and the SWIRE optical follow-up. Many of these surveys are also connected to legacy-type programmes at satellites and other observatories.

Surveys will constitute an important contribution to the science produced with ESO facilities in the forthcoming era of the dedicated survey telescopes, VST and VISTA. To tackle in the best way possible this 'paradigm change' a new concept for the implementation of Public Surveys was put in place during 2005, allowing Public Surveys to be treated as a separate category to Large Programmes. This new procedure calls for a deeper involvement of the community in the survey production as well as an effective cooperation between the community and ESO to ensure the scientific quality of the products. During 2005 the Public Survey Panel (PSP) met in Garching to evaluate the 15 VST Public Survey proposals received for the November 2004 Call, and identified three core programmes. The PSP then held a meeting with the PIs of these core programmes and with the PIs of not recommended but potential merger programmes, in order to optimise the science cases and the planning of the surveys. The majority of the potential merger programmes were incorporated in the core programmes. The PSP then made a formal endorsement of these optimised core programmes to the OPC in the November OPC meeting (P77). These three core programmes were recommended for execution by the OPC.

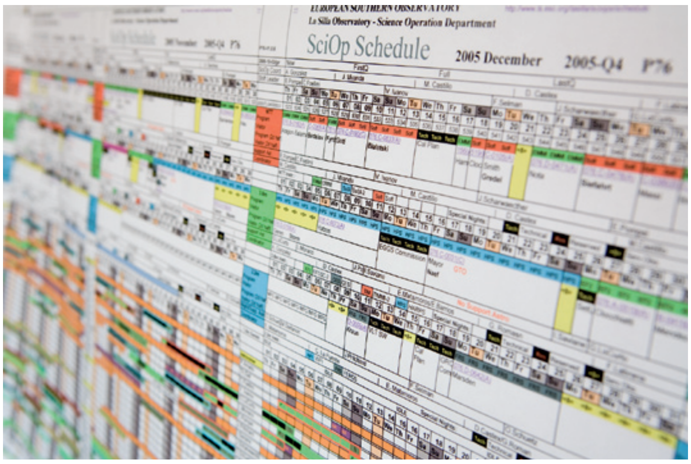
The Users' Committee 2005

Belgium	Griet Van de Steene
Denmark	Uffe Gråe Jørgensen
Finland	Merja Tornikoski
France	Pascale Jablonka (Vice-Chairwoman)
Germany	Sabine Moehler
Italy	Enrico Cappellaro
The Netherlands	Lex Kaper (Chairman)
Portugal	Nuno Cardoso Santos
Sweden	Sofia Feltzing
Switzerland	Pierre North
United Kingdom	Malcolm Bremer
Chile	Wolfgang Gieren

The Users' Committee (UC) held its annual meeting on 11 and 12 April. The meeting was chaired by Lex Kaper.

After hearing presentations from ESO on the La Silla Paranal Observatory, the status of ALMA, and the proposal submission and time allocation processes, the UC provided the feedback from the ESO users' community on the usage of ESO's facilities, partly based 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. The bulk of the expressed concerns rest with the availability of data reduction pipelines for the various modes of all instruments, the existence of alternative reduction tools for those instrument modes for which such pipelines are not provided, and the delivery of science-ready data to the community. The conclusions of the lively discussions about these topics are reflected in a number of action items and recommendations assigned by the UC to ESO. The effectiveness of this process for achieving progress in the direction expected by the users is reflected by the fact that most of the action items and recommendations that had been set by the UC at its previous meeting could be closed following corresponding action by ESO. Significant progress had been achieved on the remaining open issues.

As usual, the meeting featured a 'special topic', this time on Large Public Surveys, to which half a day was devoted. Presentations were given by frequent users and by ESO representatives, on the UKIRT Infrared Deep Sky Survey (UKIDSS), VISTA, VST, the OmegaCAM Guaranteed Observing Time, and the ESO Public Surveys. The subsequent discussion concentrated primarily on the expected status of reduction of the data that will be made accessible through the archive, and on the timescale and procedure for the proposal submission and time allocation processes for public surveys on the VST and VISTA. The input received from the UC proved very valuable for ESO within the framework of the implementation of the Large Public Surveys.



Observing schedule at La Silla.

The Scientific Technical Committee

The Scientific Technical Committee 2005

Arnold van Ardenne (NL)
Roland Bacon (F)
Andrea Cimatti (I)
Andreas Eckart (D)
Paulo J. V. Garcia (P)
Raffaele Gratton (I)
Thomas Henning (D)
Richard Hills (UK)
Hans Kjeldsen (DK)
Konrad Kuijken (NL)
Simon Lilly (CH)
Dante Minniti (RCH)
Nikolai Piskunov (S)
Jean-Loup Puget (F, Chairman)
Patrick Roche (UK)
Ilkka Tuominen (FIN)
Jean-Marie Vreux (B)

Following the recommendations of the Working Group on Scientific Strategy (SSWG), Council, at its 105th meeting in Helsinki, approved new terms of reference and new structure and membership for the STC. Thus, in the future, STC membership will be chosen not only by national representation, but also to ensure broad coverage of all the range of scientific disciplines required for VLT, VLTI, ALMA, and ELT. We reproduce the relevant parts of the Council decision below.

Structure and Membership

1. The STC consists of 14–16 members appointed by Council for their scientific and technical eminence, with at least one member from each Member State and Chile.
2. Members are elected by Council based on nominations by the Nominating Committee.
3. Members are appointed for three-year staggered terms so that about an equal number retire each year.
4. Good coverage of the relevant astronomical disciplines and techniques at all times should be aimed at in appointing the individual members and the actual size of the Committee.
5. The STC Chair is appointed annually by Council for no more than three consecutive years.
6. At its first meeting in each year, the STC elects from its members a vice chair to replace the chair at occasions when the latter is unable to fulfill her/his functions.

Conflicts of interest

1. The general definition and rules for dealing with conflicts of interest on ESO committees apply in full to the STC.
2. The Principal Investigator of an instrument or project in preparation, in study phase, or under construction in the ESO programme cannot serve on the STC.
3. Directors of the institute of a Principal Investigator as defined in 2. are similarly excluded.

As established by the new procedures, Council appointed a special Nominating Committee, composed of Drs. Teresa Lago (Chair), Jean-Loup Puget, Ewine van Dishoeck, Laurent Vigroux, and Christoffel Waelkens with the task of proposing the members of STC to be appointed by Council. In the interim period until the new STC was in place, Council extended the appointments of STC members whose periods expired in 2005, and who did not have conflicts of interests according to the precepts above. For these reasons, the composition of STC will change in 2006.

STC 59th Meeting

A full report about the status of the VLTI infrastructure, and about the results of the Workshop on second-generation VLTI instrumentation, were presented to the committee. Upon an in-depth review of the technical issues underlying the difficulties encountered in operating the fringe tracker FINITO, the review-panel presented a number of recommendations that were very much welcomed by STC. The committee encouraged ESO to pursue these recommendations, and to report the findings at the next meeting.

On the issue of second-generation multi-beam instruments for VLTI, STC encouraged ESO to continue contacts with the community with the aim of proposing ways forward in the next meeting when the VLTI recovery team may have identified the scale of the problems and solutions for efficient operation.

The PIs of the two competing proposals for Planet Finder – the last second-generation VLT instruments to be decided – Jean-Luc Beuzit (LAOG) and Markus Feldt (MPIA) – were invited by the Chair to present their proposals to the committee. STC congratulated the two teams for their excellent presentations and for the very substantial efforts undertaken in the design studies for Planet Finder. STC remarked that their developments in adaptive optics were not only relevant for the Planet Finder, but also for future ELTs for which characterisation of extrasolar planets is of very high scientific priority.

Noting that the addition of an integral field spectrograph – as foreseen by the MPIA proposal – to the LAOG system would substantially enhance the Planet Finder, STC strongly encouraged the collaboration between the two teams towards this goal. Thus, STC recommended to ESO to proceed to the next phase with the LAOG team, and to encourage and monitor the merger of the two projects with the particular aim of implementing the integral field spectroscopy and polarimetry options of the MPIA instrument into the LAOG proposal.

Because the anticipated strong competition from other observatories, a Planet Finder instrument is relevant only if the main scientific programme, which will require hundreds of nights, can be conducted quickly. STC thus recommended ESO to explore the optimum way of achieving this, including the possibility of wider collaborations and public surveys.

A substantial part of the meeting was devoted to the discussion of issues related to ALMA, in particular issues of cost, and the ALMA Regional Centres. On the first issue, while STC endorsed the recommendations of the ALMA Science Advisory Committee (ASAC) that the number of antennas would be set at 50, STC expressed concerns that increases in the cost of ALMA may impact other areas of the ESO programme.

At its previous meeting (No. 58) STC had endorsed the proposal by ESO to issue a call for expressions of interest by institutes willing to host ALMA regional centres. The idea about a distributed model with multiple European sites coordinated by a strong centre at ESO was welcomed by the committee.

STC 60th meeting

A substantial part of the meeting was devoted to issues related to the interferometric mode of the Very Large Telescope (VLTI). A special task force composed of staff from the Observatory and Garching (the Interferometry Task Force or ITF) was formed to investigate the issues identified by the VLTI Review Panel. FINITO seemed to be working as expected, so the failure to track fringes on sky with FINITO seemed to be related either to vibrations, or to residual high order wavefront aberrations. Detailed studies of these problems were underway. Other issues related to rail alignment were well understood and solutions in hand. STC appreciated the work carried out by the ITF to fully understand the issues related to fringe tracking with VLTI, and the operation of VLTI in general; STC was very impressed by the progress made and strongly encouraged the team to continue their work.

The PIs of the four teams proposing second-generation multi-beam instruments for the VLTI were invited by the STC Chair to present their instruments to the committee. Thus, STC heard presentations by Fabien Malbet (VITRUV – Near-IR spectro-imager using fibers), Bruno López (MATISSE – Mid-IR spectro-imager), Frank Eisenhauer (GRAVITY – AO assisted, two-object, multiple-beam-combiner), and Chris Haniff (BOBCAT – Near-IR spectro-imager using bulk optics). STC appreciated the presentations by the four groups and underlined the importance these instruments could have for the development of the VLTI programmes in the next decade owing to their imaging and spectroscopic capabilities. Because of the importance of the science cases for these instruments, including in particular the Galactic Centre case for general relativity, where the unique characteristics of the VLTI should allow important breakthroughs, STC considered that the developments of these capabilities should not be unnecessarily delayed.

Therefore, STC recommended ESO to solicit formal proposals for Phase A studies for next generation instruments with a deadline early in 2006, to be reviewed by ESO in time for the April STC meeting. These proposals should address not only the scientific capabilities and technical descriptions of the proposed instruments, but also the requirements on the VLTI infrastructure, observing strategies, telescope configurations, and observing time requirements required to conduct the key scientific programmes.

The preceding months had seen intense activity on many aspects of ALMA and therefore a substantial fraction of the meeting was also devoted to ALMA developments. In particular, a detailed rebaselining activity had been undertaken and an in-depth international cost review had just taken place. These reviews indicated that the new cost estimates could be regarded as robust and STC was pleased to hear that Council had determined that ALMA was affordable at the new increased cost level, without serious disruption to the other major elements of the ESO programme.

STC endorsed the view of the ALMA scientific advisory committees that the reduction from 64 to 50 antennas was painful, but would leave the major scientific capabilities of ALMA largely intact, while any further reduction would seriously erode these capabilities. STC also agreed with the ESAC and ASAC that further de-scoping options which would have substantial impact on ALMA's scientific capabilities should not be adopted, but noted that there was some limited scope for cost savings in the provisions for support facilities, e.g. at the OSF, and such items as travel.

Having heard the reports from the science advisory committees and the project management on the implications of having two different types of antennas (US and European; three types in fact considering the Japanese antennas), STC was satisfied that ALMA's science goals will be met with a heterogeneous array.

Following the recommendations of the 59th meeting of STC, the LAOG and MPIA joined forces to present a single proposal for Planet Finder. STC considered that the proposed instrument offers a powerful capability for finding and characterising exoplanets and should proceed to PDR. STC recommended that the guaranteed time (GT) programme be reviewed at PDR. Since the GT will not suffice to exhaust all of the potential targets, STC recommended that the OPC should be prepared to award very large amounts of observing time also to user programmes to ensure that the ESO community can undertake ambitious planet finding and characterisation projects. However, STC found it premature to consider a large public survey with the Planet Finder now.

The plan to develop an integrated approach for adaptive optics at the VLT, which had been reviewed by a panel of experts just before the meeting, was presented to the committee for recommendation. STC considered that the proposed Adaptive Secondary will provide significant improvements in efficiency for HAWK-I and MUSE as well as providing vital information on key ELT technologies, and recommended that it should proceed. At the same time, STC asked ESO to develop an optimised VLT instrument deployment plan that includes the second-generation instruments and AO developments. In particular, STC asked ESO to investigate whether all foci of the adaptive telescope can be exploited.

Extraordinary STC 61th meeting

Because of the fast cadence of ALMA developments during the second half of the year, the ESO Medium Range Implementation Plan and the Long Term Perspectives were not ready for discussion at the October meeting (60th), so an extraordinary meeting was scheduled on 22 November, ahead of the Council meeting that would discuss these plans. The meeting also provided the opportunity to discuss the OWL Review, which took place on 4–6 November, and the consequences of the review. Furthermore, a proposal for a wide field optical camera for VISTA (darkCAM), which arrived at ESO too late for discussion at the October meeting, was also presented in this special meeting.

The documents containing ESO's Medium Range Implementation Plan (MRIP) and Long Term Perspectives (LTP) were made available to STC well in advance of the meeting, and the Director General made a detailed presentation of the most relevant aspects of the plans at the meeting. The MRIP lays the foundations for ESO activities planned in the medium term (2003–2009) and contains detailed projections for carrying out ESO's mission, including completion of VLT/VLTI, VST, and VISTA, full operation of the La Silla Paranal Observatory, construction of the (re-baselined) ALMA, and all the steps necessary to enable the start of construction of an ELT in 2010. The Long Term Perspectives present an outlook of ESO's activities in the period 2003–2025. STC was pleased that the MRIP allows the important elements of the ESO programme to proceed without significant disruption after allowing for the ALMA cost increases, and endorsed the MRIP as presented.

The STC also discussed the Long Term Perspectives and emphasised the requirement to deliver an ELT on a competitive timescale to maintain ESO's world-leading position. STC encouraged Council to continue to pursue this goal, stressing their conviction that it would be premature to consider reducing investments in Paranal operations before the scientific capability, timescale, and costs of the ELT are defined. Indeed, STC expects the Paranal telescopes to remain vital for European astronomy well into the ELT era.

Cerro Paranal, home of the VLT, with VISTA in the foreground.

A full report on the OWL review was presented by Roberto Gilmozzi, but unfortunately due to unforeseen problems, the written panel recommendations were not available at the time of the meeting. STC was pleased with the review and the response of the OWL team to the (verbal) Panel recommendations. In particular, STC was very encouraged to have confirmation that a very large aperture telescope appears to be feasible. STC reiterated its disposition to becoming fully engaged in the scientific definition of the ESO ELT in 2006.

As mentioned, the proposal by a UK-led consortium to build a wide-field optical camera for VISTA had been received too close to the October STC meeting to be properly assessed by ESO staff in time for the meeting. In fact, the detailed analysis by the Divisions involved (presented at the November meeting) revealed several serious technical (and political) challenges for the implementation of the camera. Noting that there is an ESO/ESA Working Group on Fundamental Cosmology, the STC Chair invited the co-Chair of this WG, Peter Schneider, to present the views of the Working Group on the darkCAM science case. The darkCAM consortium is proposing a large (10 000 square degrees) multi-colour survey to investigate a number of burning issues in Cosmology, notably the equation of state of dark energy from a weak-lensing survey. STC concluded that a large multiband survey such as that proposed by the darkCAM team has great scientific potential that goes far beyond the lensing survey. But, given the difficulties reported by ESO, the committee could not recommend the approval of the darkCAM proposal as presented. However, STC encouraged ESO to explore ways of achieving the goal of a large, deep, multicolour survey, which would be substantially deeper than the multipurpose Sloan survey whilst also tackling the nature of dark energy.

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	4	7	33	48
	WFI	25	7	7	13	52
Total		**29**	**11**	**14**	**46**	**100**

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
3.6-m	CES	0	0	4	3	7
	EFOSC2	10	9	3	6	28
	HARPS	0	0	29	22	51
	TIMMI2	0	0	9	2	11
	Special-CIGALE	0	3	0	0	3
Total		**10**	**12**	**45**	**33**	**100**

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
NTT	EMMI	16	6	10	12	44
	SOFI	5	11	28	7	51
	SUSI2	0	2	2	1	5
Total		**21**	**19**	**40**	**20**	**100**

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT1	FORS2	20	15	6	8	49
	ISAAC	10	13	13	15	51
Total		**30**	**28**	**19**	**23**	**100**

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT2	FLAMES	1	7	8	11	27
	FORS1	5	9	5	8	27
	UVES	12	8	8	18	46
Total		**18**	**24**	**21**	**37**	**100**

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT3	VIMOS	23	20	5	3	51
	VISIR	0	10	24	5	39
	Special-ULTRACAM	0	1	3	6	10
Total		**23**	**31**	**32**	**14**	**100**

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT4	NACO	2	9	39	10	60
	SINFONI	16	16	3	5	40
Total		**18**	**25**	**42**	**15**	**100**

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
VLTI	AMBER[1]	0	1	5	12	18
	MIDI	0	8	19	55	82
Total		**0**	**9**	**24**	**67**	**100**

[1] AMBER went into operation in October 2005.

Council

Council held two ordinary meetings, in Helsinki in June and in Garching in December, and also met for an extraordinary session in September in Brussels, adopting a resolution about the overall affordability of ALMA, an essential precursor to placing the ALMA antenna procurement contract. The Committee of Council met three times during the year, in March in Garching, in the middle of September in Garching and at the end of September in Brussels. The meetings in the first half of the year were chaired by Prof. Piet C. van der Kruit, and those from September by Dr. Fernando Bello, the Vice-President.

In December Council adopted a resolution on the accession of Spain to ESO as the 12th Member State from 1 July 2006.

Council commended the OWL team for producing an in-depth Concept Design Study for a 100-m telescope which was presented at the September meeting and reviewed by an external panel chaired by Prof. Roger Davies.

Amongst the important issues addressed by Council and Committee of Council in the course of the year were the status, re-baselining, and affordability of ALMA, the recommendations of the Scientific Strategy Working Group, plans for the ELT/OWL, and the report of the OWL Concept review panel.

Council was informed on the smooth merging of La Silla and Paranal Observatories. The issue of a new Headquarters building in Garching continued to be of concern.

The agreements for the instruments KMOS and MUSE were approved by Council, which noted that guaranteed time was awarded on the basis of the standing rules.

Council received the regular 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 examined the document "ESO Long Term Perspectives 2003–2025" prepared by the Executive.

The Council's Scientific Strategic Working Group met four times in Garching during 2005, chaired by Prof. Tim de Zeeuw. At the May meeting the group produced a report containing terms of reference for STC and OPC, rules for the Nominating Committee, and rules on dealing with conflicts of interest on ESO committees. It also discussed proposed next steps for the European ELT.

The ESO Tripartite Group chaired by Dr. Ugo Sessi met two times during 2005, in March in Garching and in October in Grenoble. Among the discussion points, one very important topic was the CERN Pension Fund, as well as the question of the establishment of a *Kinderkrippe* (nursery) together with the *Max-Planck-Institut*, the improvement of the communication with staff members in Chile and the cost-of-living adjustment in Chile on the household and children allowance.

At the ordinary December meeting Prof. Richard Wade was elected President of Council for 2006 and Dr. Monnik Desmeth was elected Vice-President. Ms. Rowena Sirey was reappointed Chair of the Finance Committee for 2006. Dr. Lutz Wisotzki was appointed Chair of the Observing Programmes Committee for 2006 and Dr. André Moitinho de Almeida was appointed Vice-Chairman. For the Scientific Technical Committee Dr. Linda Tacconi was appointed Chair.

Dr. Ewine van Dishoeck and Dr. Laurent Vigroux were appointed members of the ALMA Board for 2006–2007. Prof. Roy Booth was appointed Assessor to the ALMA Board for 2006. The President of Council and the Director General are members *ex officio*.

Council and Committee of Council 2005

President	Piet C. van der Kruit
Belgium	Monnik Desmeth Jean-Pierre Swings
Denmark	Jens Viggo Clausen Henrik Grage
Finland	Kalevi Mattila Pentti Pulkkinen
France	Philippe Barré Laurent Vigroux
Germany	Ralf Bender Andreas Drechsler
Italy	Vicenzo Dovì Bruno Marano
The Netherlands	P. Tim de Zeeuw 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 Richard Wade

The H II region N213C in the Large Magellanic Cloud (NTT/SUSI2).

Finance Committee

In 2005 the Finance Committee held two ordinary meetings and one extraordinary meeting. All were chaired by Ms. Rowena Sirey and took place in Garching. The agenda items included various financial issues, such as annual accounts, budget, cash-flow situation, financial projections and member states' contributions as well as personnel issues concerning international and local staff.

A very important issue this year was the placement of the procurement contract for the ALMA production antennas.

Throughout the year Finance Committee meticulously dealt with the issue of the financial difficulties of the CERN Pension Fund, a pension scheme covering also the ESO staff members.

At the ordinary meetings Finance Committee received regular updates regarding VLTI, Instrumentation and status of the ALMA Project.

Finance Committee approved the awarding of 21 contracts exceeding 300 000 € and 22 single-source procurements exceeding 150 000 €. Information was received concerning procurement statistics, forthcoming calls for tenders, price inquiries, etc.

The Committee received regular progress reports on the status of the ERP system and on the implementation of additional features.

Finance Committee 2005

Chair	Rowena Sirey
Belgium	Alain Heyen
Denmark	Edel Bregnbæk (until 10/2005) Cecilie Tornøe (from 10/2005)
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

Finance

Since the financial year 2004, the ESO financial statements have been presented in a standard format comprising: the balance sheet, the statement of income and expenditure and the statement of cash flow.

After 2003 and 2004, the financial situation of ESO improved further in 2005. The positive cash flow development of +56.0 M€ in 2005 is reflected in the cash and short-term deposits as of 31 December 2005, which amounted to 76.9 M€.

The net result of the statement of income and expenditure for 2005 was +33.7 M€.

The approved budget for 2006 comprises three sections: the income budget, the payment budget and the commitment budget. The income budget amounts to 192.8 M€ and is thus foreseen to be higher than the payment budget, which amounts to 173.1 M€. The commitment budget for 2006 is 192.3 M€.

Financial Statements 2005
(in € 1000)

Balance Sheet	31.12.2005	31.12.2004
Assets		
Cash and short-term deposits	76 880	20 742
Claims, advances, refundable taxes and other assets	4 958	2 669
Total assets	81 838	23 411
Liabilities and equity		
Dues	18 336	3 711
Advance payments received and other liabilities	16 827	6 723
Total liabilities	35 163	10 434
Cumulated result previous years	12 977	–9 888
Annual result	33 698	22 865
Total equity	46 675	12 977
Total liabilities and equity	81 838	23 411

Statement of Income and Expenditure	01.01.2005–31.12.2005
Income	
Contributions from member states	126 922
Contributions from third parties and partners	13 825
Income from sales and other income	4 195
Total income	144 942
Expenditure	
Expenditure for staff	45 493
Operating and other expenditure	65 751
Total expenditure	111 244
2005 Result	33 698

Cash flow	01.01.2005–31.12.2005
Cash flow from operating activities	
Receipts	
Income	144 942
Net movements on accounts receivable	1 406
Total	146 348
Payments	
Expenditure	–111 244
Net movements on accounts payable	14 612
Total	–96 632
Net cash flow from operating activities	49 716
Cash flow from financing activities	
Net cash flow from financing activities	6 320
Net cash flow = Net increase/decrease in cash and short-term deposits	56 036

Budget for 2006
(in € 1000)

Income budget	2006
Contributions from member states	112 139
Other income from member states	59 597
Income from third parties	17 291
Various income	3 770
Total income budget	192 797

Payment budget	2006
Personnel cost	48 378
Other cost	124 689
Total payment budget	173 067

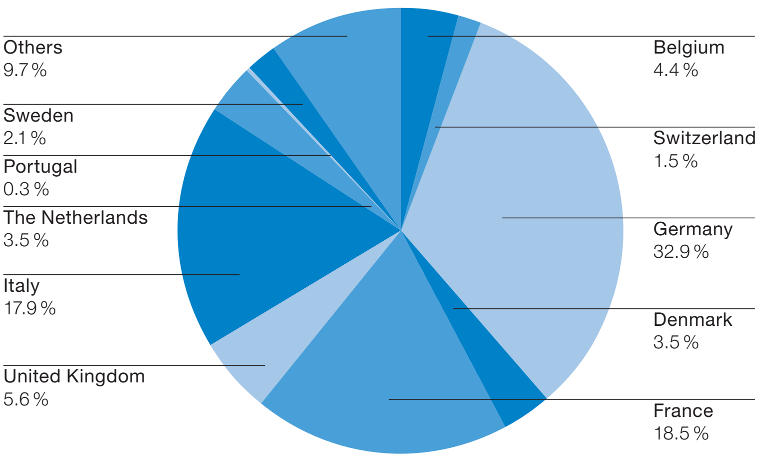
Commitment budget	2006
Personnel cost	48 378
Projects commitments w/o personnel	114 424
Operations commitments w/o personnel	29 450
Total commitment budget	192 252

Personnel

The activities of the Personnel Department Garching/Vitacura and General Services were focused on:

- Completion of the implementation of HR modules Payroll, Position Plan, Travel and Employee Self Service within the ERP system
- Review and restructuring of
  - the General Services in Garching
  - logistics and transport in Europe and Chile
  - the administrative procedures of visitors and visiting scientists in Garching and in Chile
  - the Personnel Department homepage now including information for all staff categories in Garching and Chile
- Preparation and implementation of induction courses at all sites in Chile
- Preparation of a call for tenders concerning the implant travel office, and implementation of the new travel office in Garching
- Concept, development and start of the implementation of the ESO/IPP *Kinderkrippe* (nursery)
- Common training for Staff Members offering administrative services at all sites in Chile concerning team building and communication
- Implementation of the Regulations of the Welfare Fund for Local Staff Members in Chile as well the outsourcing of its administration
- Assistance and advice in the process of the merging of the La Silla and Paranal Observatories
- Revision of the employment conditions of and further guidelines for International Staff Members and Local Staff in Chile particularly with respect to:
  - the application and calculation of the Cost of Living index,
  - the regulations of the 8/6 *turno* working schedule applied at the Observatory,
  - the guidelines on accreditation and official visas,
  - private shipments to and from Chile,
  - guarantee letters for medical emergencies,
  - visits of relatives at the Observatory,
  - family days in Antofagasta, La Serena and Santiago
- Revision and recommendation regarding the package of equilibration measures to the Pension Fund
- Revision and amendment of the Staff Rules and Regulations for International Staff and corresponding Administrative Circulars regarding working time and regular medical examinations
- Short-term and long-term office accommodation in Garching and assistance in the planning of the new building.

In the course of the year, 16 Local and 40 International Staff Members were recruited. In addition, 123 Students, Fellows, Paid and Unpaid Associates joined ESO. The diagram below shows the International Staff Members of ESO by nationality as of 31 December 2005.



Distribution of International Staff Members by Nationality as of 31 December 2005.


TORRE
M-3

Four Seasons at a Glance

January

The third and last science demonstration for the Astrophysical Virtual Observatory (AVO) project is held in Madrid. The demonstration marks the end of the AVO project and the beginning of its successor, the EURO-VO.

Official Preliminary Design Kick-off meeting for MUSE.

An Awareness Event for Danish Industry is held at ESO Headquarters.

ESO takes part in the *'Futuro Remoto'* exhibition, held at the *Città della Scienza* in Naples, Italy.

ESO's presence was manifest at the *Futuro Remoto* exhibition in Naples, Italy.

February

VLTI First Fringes were obtained with two Auxiliary Telescopes at Paranal.

ESO's two observatories, La Silla and Paranal, merge.

The first CRIRES laboratory infrared spectrum is obtained.

The European Science Advisory Committee and the ALMA Science Advisory Committee meet at ESO Garching.

ALMA Regional Centre meeting at ESO Garching.

ALMA Joint Antenna Technical Group Meeting, ESO.

March

VISIR and SINFONI, two new instruments for the VLT at Paranal, start regular operations.

The fourth MACAO is installed. All 8.2-m Unit Telescopes of the VLT now have their adaptive optics MACAO instrument to use in interferometric mode.

The Multi-conjugate Adaptive Optics Demonstrator has First Laboratory Light at ESO.

A management and technical review of KMOS takes place.

The European Association for Astronomy Education (EAAE) holds its triennial General Assembly at ESO Headquarters, following a meeting on "New Teaching Opportunities in Astronomy". This event marks the 10th year of existence of EAAE and is also the occasion to announce the winners of the 'Catch a Star!' 2004 contest.

The Committee of Council meets in Garching.

European ALMA Board, Garching.

ALMA Integrated Project Teams meeting at ESO Garching.

April

Astronomers confirm the first image of an exoplanet taken with NACO on the VLT. The five Jupiter mass planet orbits a young brown dwarf.

AMBER is offered with two and three UTs, thereby marking the coming of age of the VLTI.

865 proposals are received in answer to the call for proposals for observing time in Period 76. This is a new record for ESO.

A Preliminary Design Review of the ALMA tunable filter bank is held in Bordeaux, France.

Right: The announcement of the 'Catch a Star!' 2004 prize winners during the EAAE meeting.

Left: The colossal cosmic eye, the spiral galaxy NGC 1350 (FORS/VLT).

EIROforum's paper on science policy, "Towards a Europe of Knowledge and Innovation", is presented in Brussels in presence of European Commissioner for Science and Research, Mr. Janez Potočnik and the President of the EU Competitiveness Council, the Luxembourg Minister for Culture, Higher Education, Employment and Research, Mr. François Biltgen.

The VLT passes an impressive milestone with the publication of the 1000th peer-reviewed scientific article based on data collected with it.

ESO Workshop "The Power of Optical/IR Interferometry: Recent Scientific Results and Second-Generation VLTI Instrumentation", ESO Garching.

The Scientific Technical Committee meets in Garching.

ALMA Board meeting in Pasadena, USA.

ALMA Management Advisory Committee meeting in Pasadena, USA.

Fifteenth anniversary of the Hubble Space Telescope launch.

May

Mrs. Maria van der Hoeven, the Dutch Minister of Education, Culture and Science, visits Paranal and Chajnantor.

A Preliminary Design Review of the ALMA Front End Water Vapour Radiometer is held.

A workshop takes place at ESO Garching on the 'Universe Awareness' international education programme.

The Finance Committee meets in Garching.

ESO's Director General, Catherine Cesarsky, is elected Foreign Member of the British Royal Society and of the Royal Swedish Academy of Sciences.

Mrs. Maria van der Hoeven, the Dutch Minister of Education, Culture and Science, visited Paranal.

ESO exhibition at Chalmers, Sweden, in connection with the 16th International Symposium on Space Terahertz Technologies.

June

The Visitor Instrument ULTRACAM is commissioned on the VLT. ULTRACAM is an ultra fast camera that can take up to 500 pictures a second in three different colours simultaneously.

In a ceremony held in Washington, D.C. (USA), ESO receives the prestigious *Computerworld* Honors Program 21st Century Achievement Award in the science category for its visionary use of information technology.

Preliminary Design Review of the ALMA Band 4 and 5, in Japan.

A EURO-VO workshop is held at ESO Headquarters on Virtual Observatories.

ESO/ESA/PPARC Conference on "Communicating Astronomy to the Public II", ESO Garching.

The ESO Council meets in Helsinki, Finland.

ALMA Board meeting in The Hague, The Netherlands.

European ALMA Board, Garching.

Observing Programmes Committee meeting in Garching.

ESO is present at EXPONOR in Antofagasta, the most important industrial convention in northern Chile, and receives the award for the best exhibition at this event.

ESO is present at the European Research and Innovation Salon, Paris, France.

July

The Deep Impact spacecraft hits Comet Tempel 1. All ESO telescopes study the comet for almost a week thereafter. A major media event is held at ESO and the ESO web site receives 100 000 visitors and nearly five million hits during this period.

APEX, the Atacama Pathfinder Experiment, a 12-m modified ALMA prototype antenna, is successfully commissioned.

ALMA system requirements review, Charlottesville, USA.

JENAM "Distant Worlds", Liège, Belgium. ESO is also present with an exhibition stand.

"Relativity, Matter and Cosmology", an ESO/ESA/CERN Conference is held in Berne, Switzerland, as part of the European Physical Society 13th Tri-annual meeting "Beyond Einstein – Physics for the 21st Century". An 'Open Day' includes a public video conference with Paranal.

ESO Workshop, Garching: "Multiple Stars across the H-R Diagram".

August

NACO on the VLT allows astronomers to discover the first triple asteroid.

Auxiliary Telescope No. 3 (AT3) arrives at Paranal.

MPA/ESO/MPE/USM Joint Astronomy Conference about "Open Questions in Cosmology: the First Billion Years", at ESO Garching.

September

The farthest known gamma-ray burst is found with the help of the VLT.

The sub-millimetre APEX telescope is officially inaugurated at Chajnantor.

A delegation of Polish politicians visits ESO Garching.

The EU Young Scientists Contest Award Ceremony takes place in Moscow, Russia. ESO sponsors a main prize.

Extraordinary ESO Council Meeting, in Brussels.

European Science Advisory Committee and European ALMA Board, Garching.

October

The first optical afterglow of a short gamma-ray burst is observed from La Silla, helping resolve a 30-year-long puzzle.

MIDI is offered with the Auxiliary Telescopes on five different baselines.

In answer to the call for proposals for observing time for Period 77, 850 proposals are received.

EIROforum organises a Mini-hearing on European Science Policy at the European Parliament, Brussels.

The Danish Minister for Education, Mr. Bertel Haarder, visits ESO Santiago.

An extraordinary Finance Committee meeting is held.

An independent international Cost Review of the ALMA project is held in Garmisch-Partenkirchen, Germany.

ESO Garching opens its door to the public. More than 2 500 people visit the Headquarters.

Members of the PPARC Council pay a visit to the ESO Headquarters.

The ESO/EAAE Catch a Star! competition for European students is launched for the fourth year.

The ESO/Euro3D Workshop, "Science Perspectives for 3D Spectroscopy", is held at ESO Garching.

A one day workshop in honour of the scientific legacy of Alvio Renzini, former VLT Programme Scientist who retired from ESO, takes place.

Press Conference with ESO's Director General and Czech scientists at the Czech Academy of Sciences, during the Czech Science Week. ESO is present with an exhibition.

Scientific Technical Committee meeting in Garching.

Members of the PPARC Council visited ESO Garching.

Participants demonstrate the magic of chemistry during the Science on Stage festival.

The ALMA Science Advisory Committee meets in Santiago, Chile.

European ALMA Board, Garching.

November

First Light of Auxiliary Telescope 3 is achieved.

The OWL 100-m Telescope Concept international review takes place.

The EIROforum Science on Stage international festival brings together at CERN around 500 science educators from 29 European countries.

ALMA Board meeting in Santiago, Chile.

The Finance Committee holds its 112th meeting in Garching.

ALMA Software System Requirements meeting, Charlottesville, USA.

The international astrophysics conference "Relativistic Astrophysics and Cosmology – Einstein's Legacy", co-organised by ESO, is held in Munich.

ESO/MPA Workshop in Tegernsee, Germany, on "Carbon-Rich Ultra Metal-Poor Stars in the Galactic Halo".

An international conference "Communicating European Research" is organised in Brussels. It attracts more than 2000 participants. ESO is present as part of EIROforum, with a major exhibition and two dedicated sessions, one on Science Education issues, the other for press officers.

The Observing Programmes Committee meets in Garching.

Extraordinary Scientific Technical Committee meeting in Garching.

December

ESO signs a contract with a European consortium for the supply of 25 antennas for ALMA. It is the largest contract ever signed in ground-based astronomy in Europe.

ESO awards a contract to Scheuerle Fahrzeugfabrik GmbH, a world-leader in the design and production of custom-built heavy-duty transporters, for the provision of two antenna transporting vehicles.

The ESO Council meets in Garching, and adopts a resolution on the accession of Spain to ESO as the 12th Member State from 1 July 2006.

ALMA Antenna kick-off meeting takes place in Paris, France.

The Latin American Astronomy Summer School, organised by ESO and the *Sociedad Chilena de Astronomía*, takes place in Santiago.

ESO Workshop on "Groups of galaxies in the nearby Universe", held in Santiago.

ESO releases its 2006 Calendar.

Signature of the ALMA antenna contract at ESO in Garching.

Right: The Open House Day at ESO's Headquarters was very successfull, also among children.

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Glossary of Acronyms

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 Array
AMBER	Astronomical Multi-BEam combineR (VLTI Instrument)
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*)
AT	Auxiliary Telescope for the VLTI
AVO	Astrophysical Virtual Observatory
BMBF	German Federal Ministry for Education and Research
BOBCAT	Near-IR spectro-imager using bulk optics
CES	Coudé Echelle Spectrometer (3.6-m)
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 Cientificas*)
darkCAM	dark energy camera for VISTA
DCA	EURO-VO Data Centre Alliance
EAAE	European Association for Astronomy Education
EFOSC	ESO Faint Object Spectrograph and Camera (3.6-m)
EIS	ESO Imaging Survey
ELT	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)
ESFRI	European Strategy Forum for Research Infrastructures
ESTI	EIROforum European Science Education Initiative
EURO-VO	European Virtual Observatory
FE	Front End
FEIC	Front End Integration Centres
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)
FORS	FOcal Reducer/low dispersion Spectrograph
FP	Framework Programme
FP-6	Sixth Framework Programme
FP-7	Seventh Framework Programme
GENIE	Ground based European Nulling Interferometer Experiment (VLTI)
GRAVITY	AO assisted, two-object, multiple-beam-combiner (VLTI)
GRB	Gamma-ray burst
HARPS	High Accuracy Radial Velocity Planetary Searcher (3.6-m)
HAWK-I	High Acuity Wide field *K*-band Imager (VLT)
HLA	Hubble Legacy Archive
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)
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)
LERMA	*Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique* (France)
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	VLTI Instrument
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)
NGC	New General detector Controller
NICMOS	Near Infrared Camera and Multi-Object Spectrograph (HST)
NOTSA	Nordic Optical Telescope Scientific Association
NOVA	Dutch Research School for Astronomy (*Nederlandse Onderzoekschool voor Astronomie*)
NTT	New Technology Telescope
OmegaCAM	Optical Camera for the VST
OPC	Observing Programmes Committee
OPTICON	Optical Infrared Coordination Network for Astronomy
OSF	Operations Support Facility (ALMA)
OSO	Onsala Space Observatory
OWL	OverWhelmingly Large Telescope
PAD	Public Affairs Department
PARSEC	Sodium line laser for VLT AO
PDM	Product Data Management
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
R&D	research and development
RADIONET	Radio Astronomy Network in Europe
RDS	*Rat Deutscher Sternwarten* (Germany)
SAO	Science Archive Operation
SEI	System Engineering and Integration
SINFONI	Spectrograph for INtegral Field Observations in the Near Infrared
SOCHIAS	Chilean Astronomical Society
SOFI	SOn oF Isaac (NTT)
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)
TB	Terabytes
TFB	Turnable Filter Bank
TIMMI	Thermal Infrared MultiMode Instrument (3.6-m)
ToO	Target of Opportunity
UC	Users' Committee
UKIDSS	UKIRT Infrared Deep Sky Survey
UKIRT	UK Infrared Telescope
ULTRACAM	ultra-fast, triple-beam CCD camera
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)
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
VST	VLT Survey Telescope
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)

ESO Europe

Headquarters
Karl-Schwarzschild-Straße 2
85748 Garching bei München
Germany
Phone +49 89 320 06 -0
Direct lines

Director General	-226
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Fax +49 89 320 23 62
www.eso.org

ESO Chile

La Silla Paranal Observatory
La Silla Site
IV Región
Chile
Phone +56 2 464 41 00
Fax +56 2 464 41 01

La Silla Paranal Observatory
Paranal Site
II Región
Chile
Phone +56 55 43 50 00
Fax +56 55 43 50 01

APEX Radio Observatory
Séquitor
II Región
Chile
Phone +56 55 44 82 00

Santiago Office
Alonso de Córdova 3107
Vitacura
Casilla 19001
Santiago de Chile 19
Chile
Phone +5 62 463 30 00
Fax +5 62 463 30 01

La Serena Office
Avenida El Santo 1538
Casilla 567
La Serena
Chile
Phone +56 51 22 53 87
Fax +56 51 21 51 75

Guest House
Rey Gustavo Adolfo 4634
Las Condes
Santiago de Chile
Chile
Phone +56 2 208 42 54
Fax +56 2 228 93 33

Antofagasta Office
Avenida Balmaceda 2536
Office 504
Edificio ‘Don Guillermo’
Antofagasta
Chile
Phone +56 55 26 00 32
Fax +56 55 26 00 81

ESO is a partner in the international ALMA project

ALMA Office San Pedro de Atacama
Kilómetro 121 CH 23
II Región
Chile
Phone +56 55 44 84 16
Fax +56 55 44 84 81

ALMA Office Santiago
El Golf 40, Piso 18
Las Condes
Santiago de Chile
Chile
Phone +56 2 467 61 00
Fax +56 2 467 61 01

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Back cover photo: The sky above Paranal with some of the docking stations for the Auxiliary Telescopes of the Very Large Telescope Interferometer in the foreground. A ‘shooting star’ was also captured in this image (top right).