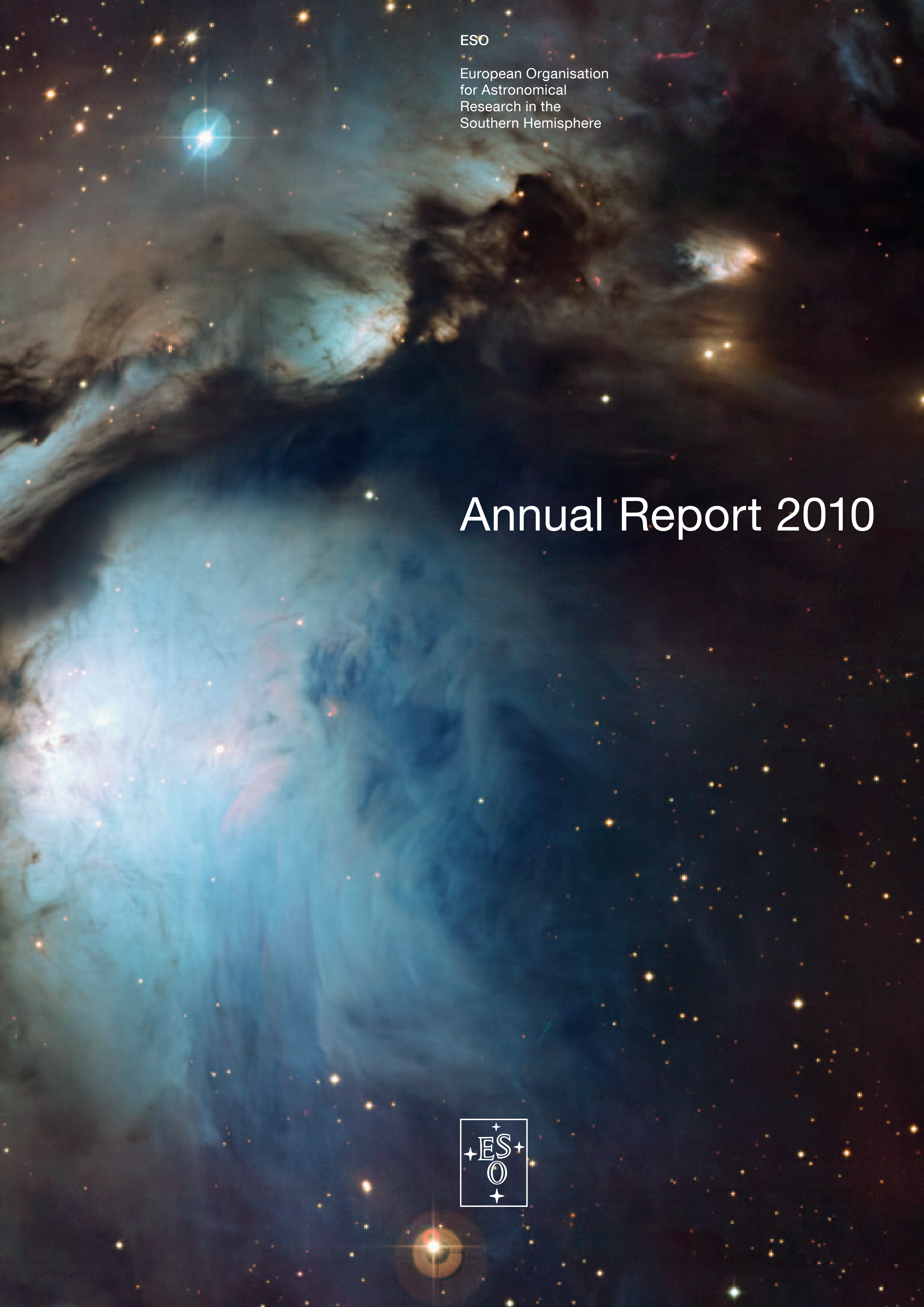
ESO

European Organisation
for Astronomical
Research in the
Southern Hemisphere



Annual Report 2010

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presented to the Council by the
Director General
Prof. Tim de Zeeuw

The European Southern Observatory

ESO, the European Southern Observatory, is the foremost intergovernmental astronomy organisation in Europe. It is supported by 15 countries: Austria, Belgium, Brazil[1], the Czech Republic, Denmark, France, Finland, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Several other countries have expressed an interest in membership.

Created in 1962, ESO carries out an ambitious programme focused on the design, construction and operation of powerful ground-based observing facilities enabling astronomers to make important scientific discoveries. ESO also plays a leading role in promoting and organising cooperation in astronomical research.

ESO operates three unique world-class observing sites in the Atacama Desert region of Chile: La Silla, Paranal and Chajnantor. ESO's first site is at La Silla, a 2400-metre high mountain 600 kilometres north of Santiago de Chile. It is equipped with several optical telescopes with mirror diameters of up to 3.6 metres.

The 3.5-metre New Technology Telescope (NTT) broke new ground for telescope engineering and design and was the first in the world to have a computer-controlled main mirror, a technology developed at ESO and now applied to most of the world's current large telescopes. While La Silla remains at the forefront of astronomy, and is still the second most scientifically productive in ground-based astronomy, the 2600-metre high Paranal site, with the Very Large Telescope array (VLT) and VISTA, the world's largest survey telescope, is the flagship facility of European astronomy. Paranal is situated about 130 kilometres south of Antofagasta in Chile, 12 kilometres inland from the Pacific coast in one of the driest areas in the world. Scientific operations began in 1999 and have resulted in many extremely successful research programmes.

View from the NTT to the smaller telescopes on La Silla.

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 metres in 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 those seen with the naked eye.

One of the most exciting features of the VLT is the option 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-metre moveable Auxiliary Telescopes. In this interferometric mode, the telescope has vision as sharp as that of a telescope the size of the separation between the most distant mirrors. For the VLTI, this is 200 metres.

J.L. Dauvergne & G. Hüdepohl/ESO

Aerial view of the ESO Very Large Telescope, atop Cerro Paranal, in the Chilean Atacama Desert.

[1] Brazil, having signed an Accession Agreement in December 2010, will officially become the 15th Member State of ESO on completion of the requisite ratification process.

Three of the first ALMA antennas at the Array Operations Site, where they are being tested as part of the ongoing Commissioning and Science Verification process.


ESO/José Francisco Salgado (josefrancisco.org)

Each year, about 2000 proposals are submitted for the use of ESO telescopes, requesting between three and six times more nights than are available. ESO is the most productive ground-based observatory in the world, which annually results in many peer-reviewed publications: in 2010 alone, more than 750 refereed papers based on ESO data were published.

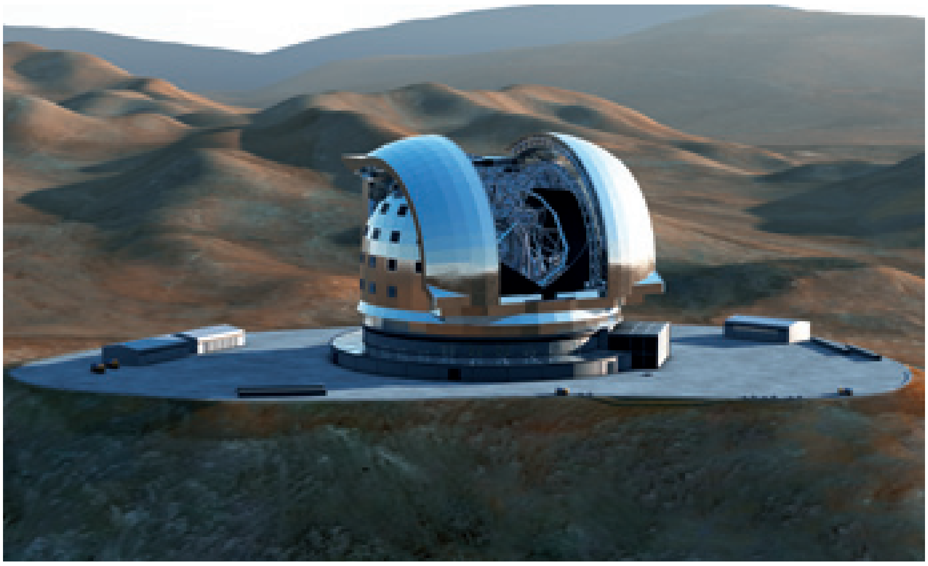
The Atacama Large Millimeter/submillimeter Array (ALMA), the largest ground-based astronomy project in existence, is a revolutionary facility for world astronomy. ALMA will comprise an array of 66 12- and 7-metre diameter antennas observing at millimetre and submillimetre wavelengths. Construction of ALMA started in 2003 and it will begin scientific observations in 2011. ALMA is located on the high altitude Llano de Chajnantor, at 5000 metres elevation — one of the highest astronomical observatories in the world. The ALMA project is a partnership between Europe, East Asia and North America, in cooperation with the Republic of Chile. ESO is the European partner in ALMA.

The Chajnantor site is also home to the Atacama Pathfinder Experiment (APEX) a 12-metre millimetre and submillimetre telescope, operated by ESO on behalf of the Max-Planck Institute for Radio Astronomy, the Onsala Space Observatory and ESO itself.

The next step beyond the VLT is to build a European Extremely Large optical/infrared Telescope (E-ELT) with a primary mirror 42 metres in diameter. The E-ELT will be "world's the biggest eye on the sky" — the largest optical/near-infrared telescope in the world and ESO is drawing up detailed construction plans together with the community. The E-ELT will address many of the most pressing unsolved questions in astronomy. It may, eventually, revolutionise our perception of the Universe, much as Galileo's telescope did 400 years ago. The final go-ahead for construction is expected in 2011, with the start of operations at the beginning of next decade.

ESO's 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. ESO's offices in Chile are located in Vitacura, one of the districts of Santiago. They host the local administration and support groups, and are home to ESO/Chile astronomers when they are not at the observatories. This site also contains the new ALMA Santiago Central Office. ESO Vitacura has become an active node for training new generations of researchers, acting as a bridge between scientists in Europe and Chile.

The regular Member State contributions to ESO in 2010 were approximately 143 million euros and ESO employs around 730 staff members.



Artist's impression of how Cerro Armazones, in the Atacama Desert, may look by early in the next decade.

Contents

Foreword

Impressive progress was made on all fronts of ESO's programme, with strong support from Council.

With unanimous enthusiasm, Council welcomed the accession of Brazil to ESO at the very end of the year, noting that this event heralds a profound change to the complexion of the Organisation. This strategic expansion of the membership to states outside Europe is a key step in the ongoing evolution to a worldwide endeavour. Brazil brings with it a much-welcomed scientific and technical community that will enrich ESO and its other Member States.

Council notes with pleasure the impressive range of scientific results that are flowing from the operation of all the ESO observatories: La Silla and Paranal, as well as the partnership in APEX on Chajnantor.

This year saw much progress towards the first open call for ALMA science observations due in 2011 (Early Science). The first eight antennas are working on the high site, the office accommodation both in Santiago and in Garching has been greatly improved and there have been many technical and civil engineering deliveries.

With ALMA well set for completion, the transition to the next major project is taking shape, with two significant steps being taken during the year. The choice of Armazones as the observing site will allow the E-ELT to be integrated closely with the VLT operation in Chile. The completion of the Phase B design and the positive result of the external review resulted in the panel concluding that the telescope was technically ready to move to its construction phase.

The economic situation in Europe, and also throughout the world, makes it a difficult time to seek funds for a major new project. The seriousness with which the Members States are considering this request is a testimony to the high regard in which they hold ESO and the potential that the project offers them for long-term technical and scientific benefits. During the year ESO examined many facets of its internal organisation, and made major progress in identifying and readying its own financial contribution in a way that ensures the continued success of its world-leading La Silla Paranal Observatory and of the ALMA partnership.

Finally, the visibility of ESO and its achievements to the general public and to decision makers in the Member States has reached a very high level, with beautiful and impressive material easily available for anyone to see and use; and this report is enriched by some of it.

President of the ESO Council
Laurent Vigroux

NGC 346, the brightest star-forming region in the neighbouring Small Magellanic Cloud galaxy.

Introduction

The year 2010 was both memorable and exciting. The major earthquake that shook Chile in late February left the Observatories intact, but led to significant worries about families and homes. Fortunately all ESO personnel turned out to be safe. The Vitacura office building suffered superficial damage, and operations had to be restricted to service mode as travel for visiting astronomers was not possible for some time.

Brazil

The visit to ALMA and Paranal by Dr Sergio Rezende, the Brazilian Minister of Science and Technology, was pivotal in moving the discussion about Brazilian membership of ESO forwards. After a clear recommendation by the Brazilian astronomical community, informal negotiations took place in June, July and August. This led to a unanimous decision by Council in October to formally invite Brazil to join ESO. Following negotiations in December, Council unanimously agreed to the conditions for accession during an Extraordinary meeting by teleconference on 21 December. The Accession Agreement was signed on 29 December in Brasilia. Brazilian membership now awaits parliamentary ratification.

Science

La Silla, Paranal and APEX continue to produce spectacular science and all telescopes are highly oversubscribed, together generating 751 refereed papers this year. Highlights include the first direct spectrum of an exoplanet taken by the near-infrared camera NACO, the discovery by the exoplanet hunter HARPS of the richest exoplanetary system to date, containing up to seven planets, the determination of the three-dimensional structure of Supernova 1987A by the integral field spectrograph SINFONI, the study of star formation in the deep Universe by APEX, and the identification of a galaxy at redshift 8.6. Retired ESO staff member Ray Wilson shared the 2010 Kavli Award for Astrophysics with Jerry Nelson and Roger Angel for his development of active optics.

Operations

The reliability of the laser guide star was stabilised, and it is now offered for up to eight nights per month; the backlog of approved observing programmes requiring it is steadily being reduced. The VISTA public surveys started officially on 1 April, although the first survey observations had already been taken during mid-February. The completion rates for the six surveys are lagging behind the planned schedule, but the data quality is generally good.

The Space Telescope - European Coordinating Facility (ST-ECF), funded jointly by the European Space Agency (ESA) and ESO, closed at the end of the year after 26 years of operations. The ST-ECF facilitated synergies between ground- and space-based observatories and Europe gained hugely from the collaboration in both science and operational methodology.

Programmes

The second generation instruments for the VLT and VLTI remain on track. The Phase A study for ESPRESSO, the ultra-stable high resolution spectrograph for the incoherent combined focus of the VLT, was completed, and development has started following the positive recommendation by the Scientific and Technical Committee (STC) in April and Council concurrence in June. The Visible Multi-Object Spectrograph (VIMOS) was equipped with new detectors, and the commissioning of the astrometric mode of the PRIMA facility on the VLTI was close to completion by the end of the year.

The refurbished M1 mirror cell for the VLT Survey Telescope (VST) arrived on Paranal mid-year, allowing the final integration of the telescope by Istituto Nazionale di Astrofisica (INAF) engineers to start, with substantial support from ESO. Technical first light was achieved during the first week of December.

ALMA

Most of the European deliverables for the construction of ALMA are on schedule and within specifications and cost. By the end of the year, six of the ALMA construction consortium (AEM) antennas were fully mechanically integrated at the ALMA Operations Support Facility (OSF) and the first one had entered acceptance testing with very encouraging initial results.

The Santiago Central Office for the Joint ALMA Observatory, on the ESO premises in Vitacura, was completed in late August. The formal handover of the key took place on 5 November. During this ceremony the ALMA Director expressed great satisfaction with the building.

The ALMA Construction Division at Headquarters was relocated to the main building in September, after a three-year stay in the International Thermonuclear Experimental Reactor (ITER) building across campus. This was made possible by the construction of a temporary office building on Plot B, which now houses all of the Data Management and Operations Division (DMO), freeing up space in the main Headquarters building so that the ALMA Construction Division (minus computing) could relocate there, strongly increasing integration within ESO. The software Integrated Product Team (IPT) moved to the Max-Planck Institute for Plasma Physics (IPP) building which already houses the Software Development Division (SDD). The result is seen as very positive.

European Extremely Large Telescope

Cerro Armazones was selected as the site for the E-ELT during an Extraordinary Council meeting on 26 April. Preparations included meetings with Presidents Bachelet and Piñera in Chile, and a visit to the State Secretary of Research, Professor Felipe Pétriz Calvo in Spain. The clear recommendation of the Site Selection Advisory Committee as well as the opportunity to insert the E-ELT into an already world-leading system and so lower the operational costs settled the issue. Both the former and the present Chilean governments confirmed that a sizeable tract of land including Cerro Armazones will be donated to ESO in 2011.

The E-ELT Phase B design effort was completed, and received a very positive report from the external review panel, which drew the unanimous conclusion that the design is technically ready for construction. A draft instrumentation plan was developed with the STC and the community. Significant progress was made on the funding scenario.

Organisation

The ALMA Construction Division became part of the Directorate of Programmes in mid-year, while the Technology Division (TEC) was moved out and combined with the SDD in the newly created Directorate of Engineering led by Michèle Peron and Roberto Tamai. The new Director of Programmes, Adrian Russell, succeeded Alan Moorwood, who retired in late May after a distinguished career at ESO. Upgrading of procedures continued with new Terms of Reference for the Users Committee, development of a policy for Technology Transfer, and new Procurement and Sales Procedures.

Headquarters building extension

By the end of the year the detailed design of the new Office and Conference building and of the Technical building was nearly completed. Close attention was given to cost control and to the sustainable/green energy requirements set by Germany.

Visiting Committee

Every three years an external group of eminent astronomers reviews ESO's programme. The 2010 Visiting Committee was chaired by Garth Illingworth and it visited Headquarters in March and all sites in Chile in July. The main conclusion of their report reads: "*ESO is a world-class scientific organisation. When the breadth of its facilities, the effectiveness of its operation of those facilities, and its scientific productivity are considered, ESO is arguably the best ground-based observatory that exists today. The ESO Member States should be proud of what they have achieved through their support of the Observatory.*"

In early December Adriaan Blaauw, one of ESO's founding fathers and the second Director General, passed away at the age of 96. He had visited La Silla and Paranal in February, expressing great delight in the continued expansion of ESO's programme.

Tim de Zeeuw
ESO Director General

This very detailed enhanced-colour image from ESO's Very Large Telescope shows the dramatic effects of very young stars on the dust and gas from which they were born in the star-forming region NGC 6729.

ESO/Sergey Stepanenko

This early morning shot shows the Visible and Infrared Survey Telescope for Astronomy (VISTA) in front of the Paranal summit.

Science

G. Hüdepohl/ESO

Research Highlights

Exoplanets

The scientific return of ESO telescopes has reached a new record number of 751 refereed publications. The impact can also be seen from the eleven publications in *Nature* and two in *Science Magazine*. The ESO Fellowship and Studentship programmes have seen record numbers of applications and the acceptance rate of the offers for Fellowships has been exceptional, with only a single rejection out of twelve offers. The visitor programmes in Garching and Vitacura continue to draw long-term visitors to the ESO sites. ESO organised five scientific workshops in Garching and one in Chile and participated in several educational activities.

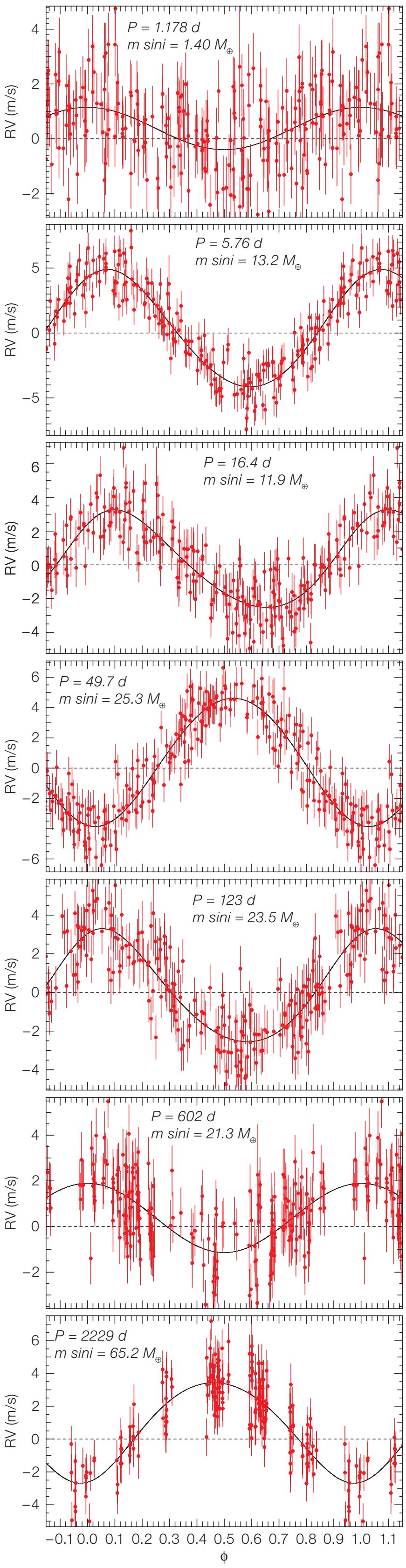
A powerful laser beam is launched from the VLT's 8.2-metre Yepun Telescope and excites sodium atoms high in the Earth's mesosphere, creating an artificial star at an altitude of 90 kilometres.

From hot Jupiters to planetary systems

Over the past 15 years ESO telescopes have played a crucial and highly prominent role in the truly impressive developments seen in the field of exoplanets. The subject has moved on from the discovery of the first giant gas planets, the hot Jupiters, to characterising the atmospheres of planets only a few times the size of the Earth. High precision radial velocity surveys, notably with HARPS on the ESO 3.6-metre telescope, are now able to find planets with masses as low as 1.9 Earth masses, and the data are hinting at the existence of many Neptune-like and super-Earth planets orbiting nearby solar-type stars. Transits observed from satellites are also finding more small-radius candidates, leading searches for low-mass exoplanets into a new era of discovery and exploration, and positioning the study of such objects to become a principal focus for exoplanet research in the coming years.

Large-scale, high precision radial velocity surveys are also revealing the existence of planetary systems with very different architectures, ranging from the lonely hot Jupiters to families almost as large as the Solar System. The newest and most populous planetary system, discovered by HARPS, has up to seven planets orbiting the solar-type HD 10180; a star that is only 6% more massive than the Sun. The new system has at least five Neptune-like planets of masses between 12 and 25 Earth masses at separations between 0.06 and 1.4 Astronomical Units (distance Sun–Earth; AU). There are also signals from a long-period planet of about 65 Earth masses, and a 1.4 Earth-mass body orbiting very close to the star at only 0.02 AU. The radial velocity signals from the seven planets are shown in the figure on the right.

Dynamical modelling indicates that the system is probably stable, which, if the current estimates of the planetary masses are confirmed, implies that it is a *bona fide* long-lasting "solar system". With this discovery, 15 stars are now



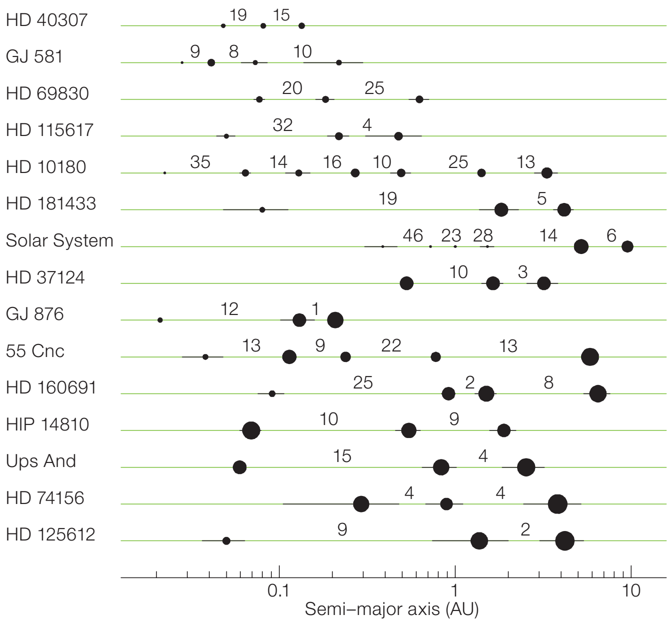
Radial velocity signatures, from the HARPS instrument at the ESO 3.6-metre telescope on La Silla, of the seven planet candidates in HD 10180. In each case, the contribution of the other six signals has been subtracted.

known to harbour at least three planets. The diversity of the architectures of these 15 systems is nicely illustrated in the figure on the right, and compared with the Solar System.

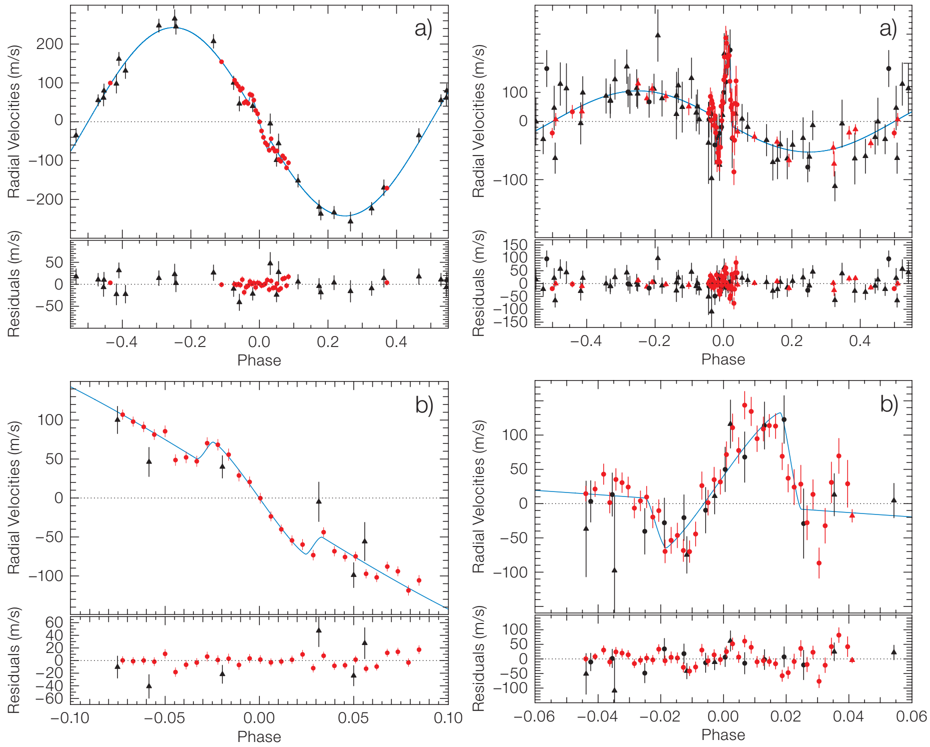
The origin of hot Jupiters

Long-term, high precision radial velocity observations of exoplanets reveal that, unlike low-mass planets, hot Jupiters — gaseous giants orbiting very close to their parent stars — tend to be lonely and not part of complex planetary systems. The origin of hot Jupiters, which were the first exoplanets ever discovered, has puzzled astronomers ever since the first object, 51 Pegasi b, was discovered in 1995. These planets could not have formed very close to their parent stars (where they are currently observed), but must have formed beyond the ice-line — the distance from the star beyond which free-floating molecules of water and other volatiles will be in the form of ices — where conditions are much more favourable for the formation of giant gaseous planets. But how did these planets subsequently move so close to their stars? Until recently, the preferred explanation was that hot Jupiters migrate inwards towards the parent stars by exchanging angular momentum with the protoplanetary discs.

Recently, however, the combination of high precision radial velocity data from HARPS, with light curves of the transits of the planets in front of the stars from space-borne and/or ground-based observatories has thrown new light on this important problem. Making use of the Rossiter–McLaughlin (RM) effect, astronomers have been able to establish that a substantial fraction of hot Jupiters have orbits that are highly inclined relative to the equatorial plane of their parent stars, which rules out the migration scenario, at least for those planets. The RM effect is observed as a radial velocity signature during a planetary transit: coplanar planets occult the rotating stellar disc blocking the approaching (blue-shifted) side first and the receding (red-shifted) side second, leaving a very distinct signature in the radial velocity curve. The signal becomes increasingly distorted as the angle between the planet's orbit and the stellar equator increases, and reverses for retrograde orbits. Observing the RM effect in transiting planets requires high precision and high cadence to resolve the transit, and HARPS is probably the only suitable instrument. The figure above shows examples of the RM transit for two different orbital inclinations. Panel b) of each figure shows the details of the RM effect.



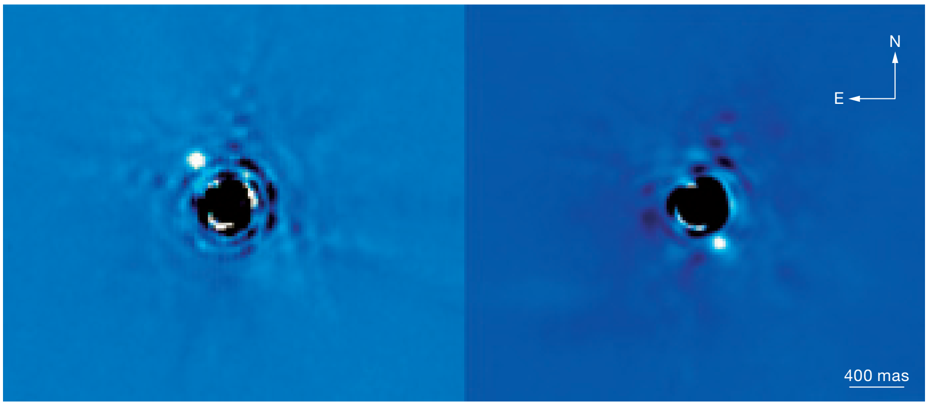
The 15 known (as of May 2010) planetary systems with at least three planets compared to the Solar System. The numbers give the minimum distance between adjacent planets measured in special units called Hill radii, which represent the gravitational sphere of influence of a planet in the presence of other massive objects. Symbol sizes are proportional to the logarithm of the planetary masses. Notice the great diversity of planetary architectures amongst these 15 systems.



Radial velocity curves for two transiting planets with different orbital inclinations. The left (first) panel shows the effect for the planet Wasp-4b, with an orbital inclination angle very close to zero. The right panel shows Wasp-17b, with a retrograde orbit and an inclination of 149 degrees. The black symbols are observations with the échelle spectrographs SOPHIE and CORALIE; the red symbols are observations with HARPS. Panels b) show the details of the Rossiter–McLaughlin effect. Fitting residuals are shown in the lower panels.

The Wide Angle Search for Planets (WASP) survey uses sixteen 11-inch telescopes in both hemispheres to search for transiting giant gaseous planets. The southern candidates are confirmed by large radial-velocity programmes with the CORALIE instrument on the Swiss 1.2-metre Leonhard Euler Telescope on La Silla, but the detection of the RM effect is done with HARPS on the larger 3.6-metre telescope. The team observed six new transiting hot Jupiters with HARPS and obtained impressive high cadence, high accuracy, radial velocity transits (such as those shown in the bottom figure on p. 12), which allowed them to measure the RM signal with excellent precision. Three out of these six planets were found to be in retrograde orbits and all of them have nearly circular orbits. In fact, only one planet (the most massive, Wasp-18b) showed some detectable orbital eccentricity. This is surprising because, if planets and stars condense out of the same collapsing gas clouds, their rotations should be aligned and coplanar.

Subsequently, the team went back and compiled all the published observations, many made with HARPS, of the RM effect in transiting planets; 26 systems in total. This allowed them to compute the distribution of inclination angles and compare the observed distribution with the predictions of models for planet formation. The results were even more surprising: between 45 % and 85 % of hot Jupiters have misaligned orbits with inclinations of more than 30 degrees. Aligned systems are not the norm, a discovery that radically alters the ideas of how hot Jupiters form. The presence of a third body is required to produce misaligned orbits. The conventional wisdom is now that hot Jupiters evolve through the Kozai mechanism, where the misalignment is induced by an unseen substellar companion orbiting at large distances from the parent star. The companion makes the planet move from the ice line, where it presumably forms, to the inner regions of the system in increasingly more inclined and eccentric orbits. As the planet gets closer to the primary star, it is tidally deformed and tidal friction breaks the Kozai cycles and circularises the orbits. Due, in no small measure, to the exquisite performance of HARPS, much is currently being learned about the orbital dynamics in exoplanetary systems.



β Pictoris b imaged at 3.78 μm with NACO on the VLT in 2003 (left) and in 2009 (right). The central star was occulted by a coronagraph and the diffracted and scattered light was removed using differential imaging techniques. The planet was recovered in 2009 close to the position where it was predicted to be from its estimated orbit.

Seeing exoplanets

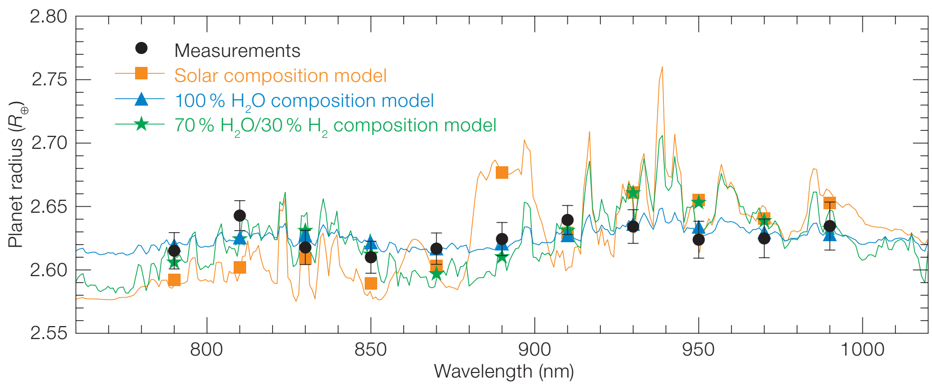
Radial velocities and transits allow exoplanets to be detected through their influence on the parent stars, but until recently it has not been possible to “see” these planets directly. Depending on wavelength, planets are millions to thousands of millions times fainter than their parent stars, and have very small angular separations from them, making direct observations extremely difficult for ground-based telescopes — due to the atmosphere — and space telescopes because of their relatively small mirrors. The advent of advanced coronagraphic techniques on large telescopes equipped with powerful adaptive optics systems is now changing this situation. Using a newly developed technique called angular differential imaging on the VLT NACO instrument, astronomers have been able to see the giant gas planet β Pictoris b clearly as it orbits its parent star. The new observations constrain the mass of the planet (about ten times the mass of Jupiter) and its orbital distance (between 8 and 13 AU) and so show that the planet is indeed beyond the ice line of its star, where theories predict that giant planets should form. The parent star β Pictoris has a prominent circumstellar disc whose structure has been studied in detail over the past 25 years. The presence of a giant planet within the disc was inferred sometime ago, but, until the new NACO observations were obtained, it was not clear whether the object was a planet or a background star by chance projected close to β Pictoris. The figure above shows the detection of the planet at two epochs, confirming its planetary nature and constraining its mass and distance from the star.

The β Pictoris system is very young (about ten million years old) and so the planet is likely to be close to the orbit where it was born, possibly through a core accretion process, where a rocky core several times the mass of the Earth forms first and this hot core then accretes material from the disc to grow rapidly into a gas giant. While β Pictoris b can be considered to be a proto hot Jupiter, whether it will ever move towards the star to become a *bona fide* hot Jupiter is still an open question. The disc of β Pictoris is probably starting to disperse and there is no evidence for a sub-stellar mass companion that could drive Kozai cycles.

The composition of low-mass planets

In contrast to planets with masses similar to that of Jupiter and higher, the compositions of planets in the super-Earth category (two to ten times the mass of the Earth) cannot be uniquely determined from measurements of their masses and radii, which are derived by combining radial velocity and transit measurements. For super-Earths (also called low-mass exoplanets), there are a number of theoretical models of their structure that can account for the observational data, but differ in their assumptions about the composition of the interior and that of a possible atmosphere. The recently discovered transiting super-Earth GJ 1214b is a good example of this problem. Three distinct models for the planet are consistent with the mass and radius determined from observations obtained at ESO and elsewhere. Distinguishing between these models requires knowledge of the planet's atmospheric composition.

Observations of the spectrum of the transit of GJ 1214b between 780 and 1000 nm with the FORS2 instrument on the VLT have provided new constraints on the composition of the planet. These are extremely challenging measurements that use the derived radius of the planet at different wavelengths as a proxy for the transmission spectrum of the atmosphere. An increase in atmospheric absorption produced by a molecular component such as water, results in an apparently larger planetary radius at that wavelength. The radius is computed by fitting models to the transit light curves using orbital parameters obtained from the photometric light curves. In order to control the systematic errors in these measurements, the observers made use of the multi-object spectroscopic capability of FORS2, which allows simultaneous spectral observations of many objects in the field. In this case, five reference stars of similar magnitude to GJ 1214 were used. The resulting absorption spectrum of the planet is shown in the figure above.



The transmission spectrum of the super-Earth GJ 1214b compared to atmospheric models. The theoretical predictions for atmospheres of solar composition (orange), 100% water vapour (blue), 70% water vapour plus 30% molecular hydrogen (green) are shown.

The lack of features in the spectrum rules out with high confidence cloud-free atmospheres composed primarily of hydrogen (solar composition). If the planet's atmosphere is hydrogen-dominated, then it must contain clouds or hazes that are optically thick at the observed wavelengths at atmospheric heights having a pressure below 200 mbar. Thus, of the models proposed for the planet based on constraints from the interior computations, only the spectra from cloud-free atmospheres composed predominantly of water vapour (steam) agree with the new observations, although a water-rich atmosphere is not necessarily indicative of a water-rich interior (a "water world"). More observations, particularly at infrared wavelengths where scattering from clouds and haze is less efficient, are needed to settle the question of whether the planet is surrounded by clouds or is dominated by water vapour.

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Massive Stars

Understanding how massive stars form

The physics of the formation of massive (high-mass) stars is still poorly understood. Massive stars are much more luminous than low-mass stars, but they are also rarer and hence generally more distant. Our own Sun is a low-mass star that can be studied in great detail and so it is not surprising that low-mass star formation is better understood. Stars form when molecular clouds fragment into pieces that collapse due to their own gravitational pull. The gas heats up during the collapse, but not enough to overcome the strong compression force of gravity. Eventually the central regions of the collapsing clouds become dense enough and hot enough to enable nuclear reactions to give birth to a star. Observations show that this mechanism works for stars of masses roughly comparable with the mass of the Sun, but it is not known whether this is the way in which stars more massive than ten times the mass of the Sun form. The problem with massive stars is that the radiation pressure from their powerful nuclear reactors is strong enough to prevent the star from accreting more gas during the collapse phase, and thus for the star to gain mass. Stars rotate and the conservation of angular momentum during the collapse of the protostellar clouds implies that young stars are surrounded by gaseous discs from which they accrete. For low-mass stars these discs, called protostellar discs, are the places where planets form and so, during later stages of evolution, they become known as protoplanetary discs. If massive stars form in the same way as low-mass stars, then massive protostars should also be surrounded by large gaseous discs. Non-spherical accretion through discs also helps to ease the radiation pressure

A VLTI/AMBER synthesis image at 2.2 μm of the dust disc around the massive young stellar object IRAS 13481-6124. The elongated structure has a size of 5 × 8 mas.

problem so that the detection of discs around massive protostellar objects provides an observational test for alternative theories of massive star formation, such as stellar merging. Protostellar discs are only tens of astronomical units across and so, even for nearby low-mass stars, these discs are not straightforward to detect and characterise even using large telescopes. Observing the discs of the more distant massive stars requires the use of interferometers.

Combining the light from three of the 1.8-metre Auxiliary Telescopes of the VLTI, a team of astronomers was able to resolve a disc around a young massive stellar object about 20 times more massive than the Sun. Using three different array configurations and taking advantage of the Earth's rotation to increase the sampling of the VLTI pupil, the team was able to reconstruct the image that a telescope with an 85-metre diameter would see, using a technique that is routinely used with radio interferometers. Short baselines, used to improve the fidelity of the reconstruction, were provided by very high cadence observations taken with the New Technology Telescope on La Silla using a technique called speckle interferometry. The reconstructed image shown in the figure has a resolution of 2.4 milliarcseconds (mas), which is about ten times better than the resolution obtainable with a single 8-metre-class telescope.

AMBER, the multi-beam combiner on the VLTI used for these observations, enables the measurement of the structure of the disc as a function of wavelength. The observations reveal that the disc gets significantly larger at longer wavelengths, a feature that is commonly observed in the circumstellar discs of lower-mass stars and which indicates that the disc material gets hotter towards the centre. The temperature information allowed the team to model the disc and thus to measure an inner radius of 9.5 AU, which is consistent with the disc parameters observed for low-mass stars (less than ten solar masses). In fact, the high quality of the observations allowed the team to construct a detailed physical model for the object that indicated a mass of 18 solar masses for the star and a size of about 130 AU for the flared disc (one that thickens with radial distance from the star) that contains about 20 solar masses of dust and gas. The observations provide strong evidence that the star formed through a "normal" gravitational collapse process and that the object is now in the short-lived phase where the strong radiation and stellar wind from the star have already stopped mass accretion and are beginning to dissipate the placental disc out of which the star formed.

How massive can stars get?

Massive-star formation theories do not predict an upper mass limit for stars and so astronomers have long been trying to constrain this limit observationally. This is important not only to constrain the physics of star formation and stellar evolution, but also because stellar population models, which are essential to interpret the observations of distant unresolved galaxies in the Universe, are strongly dependent on the value of this mass limit. It is also known that, through stellar winds and supernova explosions, massive stars are decisive in shaping their environments in ways that depend on their total mass.

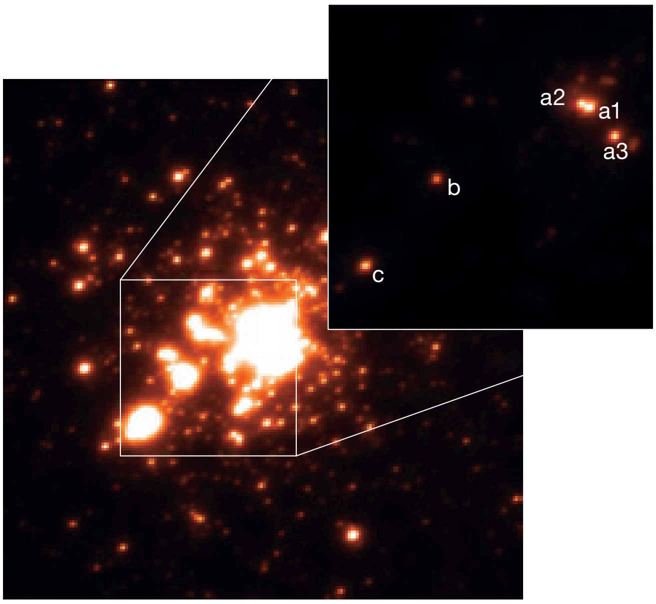
In a normal population, the number of stars of a given mass is roughly inversely proportional to the square of the mass, so very massive stars are extremely rare. The greater a star's mass, the shorter its lifetime, so the lifetimes of stars with 100 times more mass than the Sun are only two–three million years (compared to ten thousand million years for the Sun). Therefore, in order to constrain the upper stellar mass limit one needs to observe very young and very massive star clusters, and these young massive clusters are very rare in the Milky Way. The Arches Cluster, near the centre of the Milky Way, is one of the most massive young clusters known in our galaxy and is both massive and young enough to provide useful constraints on the upper stellar mass limit. The Arches Cluster is hidden behind tens of magnitudes of visual extinction, making it rather difficult to observe even at infrared wavelengths. The best observations of this cluster taken with NACO on the VLT provide a very stringent limit to the upper mass of stars: if stars more massive than about 180 solar masses exist they would have been detected — and they are not. However, the Arches Cluster is around 2.5 million years old and it is possible that very massive stars may have lived and died before now. Since no supernova remnants have been detected in the cluster, if these stars existed, they must have collapsed directly into black holes, leaving no observable remnants.

The 30 Doradus Cluster in our nearest neighbouring galaxy, the Large Magellanic Cloud (LMC), is more massive and somewhat younger than the Arches Cluster and so it should provide even more stringent statistical constraints. The 30 Doradus Cluster is about seven times further away and so resolving its stars requires observations from space at visible wavelengths or from the ground using the most advanced adaptive optics techniques.

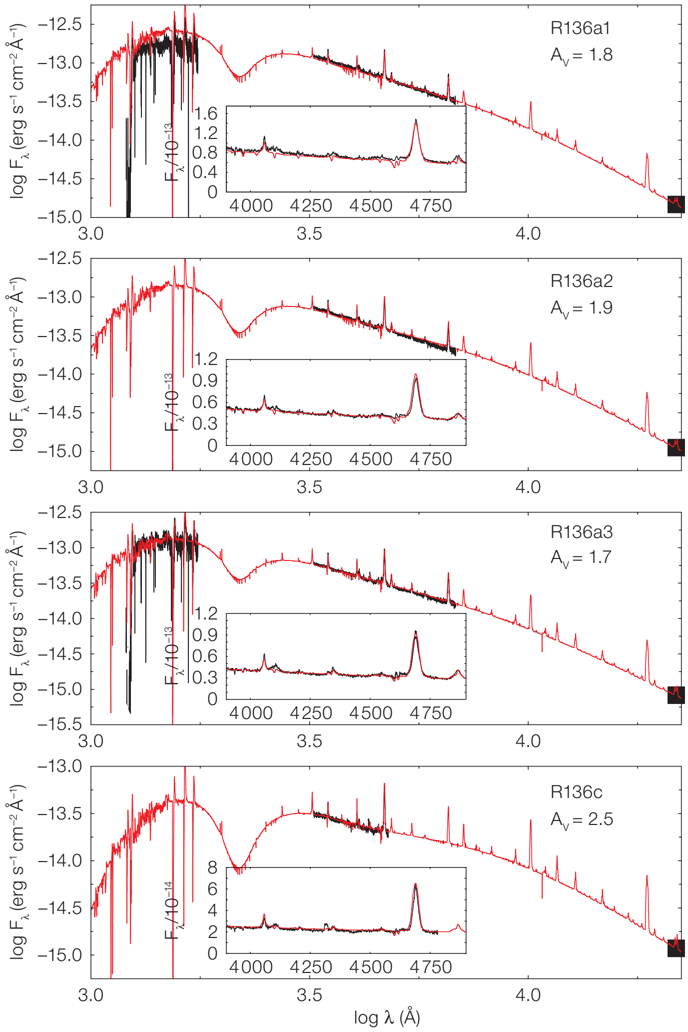
Recently a team of astronomers used two of the most advanced instruments on the VLT, the Multi-conjugate Adaptive optics Demonstrator (MAD) and SINFONI, to observe the brightest components of R 136 in order to measure their physical properties, in particular their effective temperatures. The top figure shows the MAD image of the core of the 30 Doradus Cluster where the brightest five components of RMC 136 (also known as R 136) are clearly identified. The full dataset resolves R 136 into a myriad of stars, which tells us that, if the brightest stars are also hot, they must be extremely massive indeed!

In order to estimate the temperatures of the brightest stars in R 136, the team fitted state-of-the-art theoretical stellar atmosphere models to the spectral energy distribution of the stars as measured by MAD and SINFONI on the VLT, and by the Faint Object Spectrograph (FOS) on the Hubble Space Telescope (HST). The comparison between the best-fitting models and the observations is presented in the bottom figure for the four hottest stars. Since the spatial resolution of FOS (0.26 seconds) is insufficient to separate stars a1 and a2, there is contamination between the two and so only RMC 136a1 is plotted. Also, the uncertainties in extinction are significantly larger in the ultraviolet (UV) than in the near-infrared (IR), so only the MAD and SINFONI data were used directly to constrain the models.

The extreme temperatures and luminosities indicated by the model fits to the observed spectral energy distributions imply that the four stars must indeed be extremely massive. To gain further insight into the nature of these stars required the comparison of the observations to stellar evolutionary models that only existed for



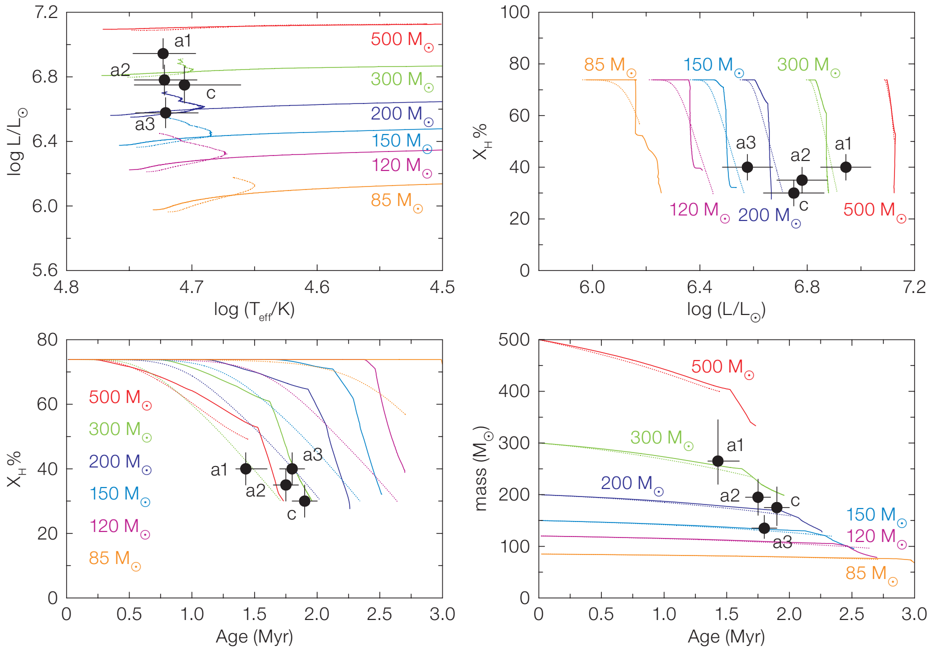
VLT MAD *K*-band image of the core of the 30 Doradus Cluster RMC 136 with a view of the central 4 × 4 arcseconds, the region previously thought to be a single extremely massive star called RMC 136a.



Spectral energy distributions of the four hottest components of RMC 136a. Observations from HST/FOS in the UV, and VLT/MAD+SINFONI in the near-IR are shown in black, and the best-fitting models are shown in red. Since FOS cannot completely resolve stars a1 and a2, and because the uncertainties in the extinction are much larger in the UV than in the near-IR, only the MAD+SINFONI data were used to constrain the models.

stars of masses lower than the hitherto accepted upper limit of 150 solar masses. For a given mass, the evolution of a star depends on its chemical composition and rotational velocity, which could be estimated from fitting models that reproduce their emission line intensities and shapes. This allowed the grid of evolutionary models to be extended to stars of initial masses up to 500 solar masses. The results are shown in the figure to the right that compares the new evolutionary tracks with the observations of temperature, luminosity, mass, and surface hydrogen content, showing that the four stars have initial masses well above 150 solar masses, and that RMC 136a1 had an initial mass between 300 and 500 solar masses, with a best-fitting value of 320 solar masses. The two sets of models shown in these plots correspond to two extreme values for the rotation velocity, indicating that rotation does not play a critical role in this conclusion.

An important underlying assumption in these models is that the stars are single. Thus, if RMC 136a1, for example, were not a single star, but an equal-mass binary, then the mass of each component would be about 150 solar masses, not exceeding the upper mass limit inferred from the previous observations of the Arches cluster. However, the observations of R 136 do not provide any indication of binarity in these stars, with the possible exception of RMC 136c, which shows marginal evidence for radial velocity variations. The conclusion that the upper mass limit is much larger than previously thought appears difficult to avoid. But, if stars more massive than 150 solar masses exist, then why haven't they been seen in the Arches Cluster? The first answer is the direct collapse to a black hole already mentioned. The second is that some of the stars in the Arches may be much more massive than previously thought. The same methodology used to estimate the masses of the R 136 stars was also applied to the Arches Cluster, and to the prototypical Milky Way young massive cluster NGC 3603. Thus, five stars in the Arches Cluster and two in NGC 3603 were found to have masses close to or exceeding 150 solar masses. Clearly, this investigation opens a new field of theoretical and observational research that promises to be fruitful and exciting.



Comparison between LMC-metallicity models calculated for the main-sequence evolution of 85–500 solar-mass stars [initially rotating at v_{init}/v_{crit} = 0.4 (dotted) or 0 (solid)] and the physical properties derived from the spectroscopic analysis. Notice the excellent agreement for initially rapidly rotating, 165–320 solar-mass stars at ages of ~ 1.7 ± 0.2 Myr.

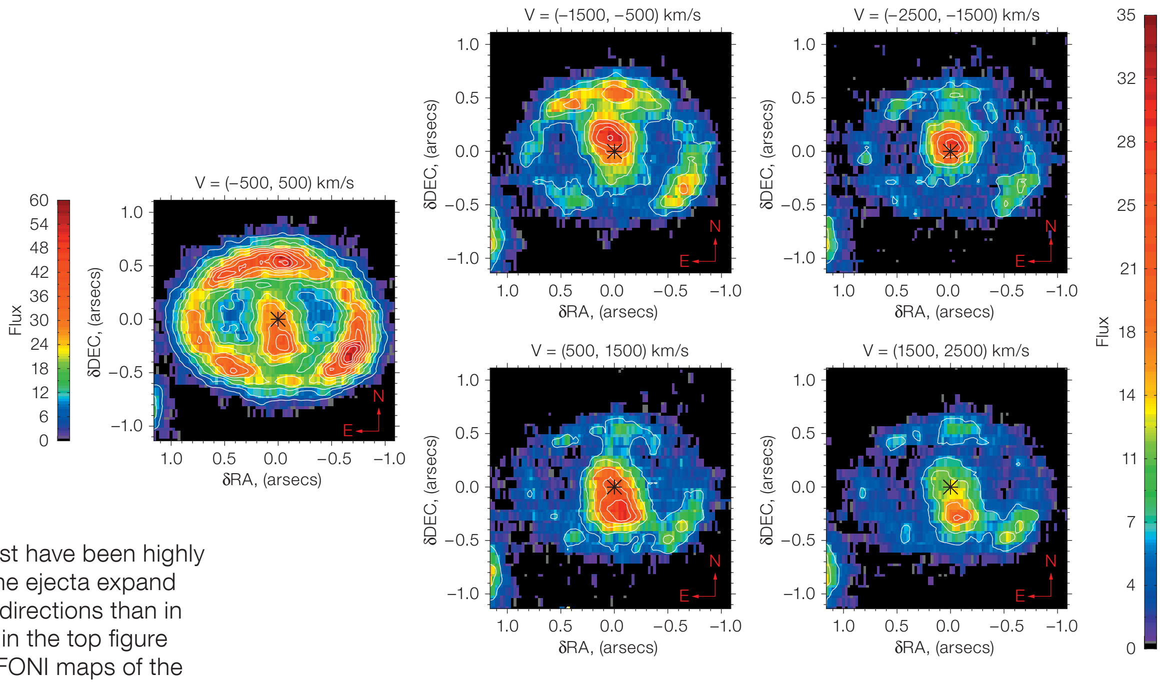
The beauty of dead, massive stars

Most massive stars end their lives as core-collapse supernovae, also known as Type II supernovae: colossal explosions that leave behind a neutron star or a black hole. Between masses of about 130 solar masses and 250 solar masses, stars end their lives as pair-instability supernovae, an event that is thought to completely disperse the star, leaving no compact remnant behind. Even more massive stars such as RMC 136a1 (> 250 solar masses) are conjectured to collapse directly into a black hole that completely swallows the star producing, in a sense, an implosion, and leaving no radio-loud remnants, which are usually the telltales of past supernova explosions. Because stars more massive than 130 solar masses are extremely rare, core-collapse supernovae have been studied extensively, while the other two types are just beginning to be investigated both theoretically and observationally.

But even the "good old" Type-IIs have posed enormous challenges to theoreticians and it has not been until very recently that they have succeeded in making their stars "explode" in their computers. In a nutshell, computer stars explode in simulations including turbulence and large asymmetries in the explosions. Spherical collapse models always fail. It is very interesting, therefore, to search for the presence of asymmetries in the ejecta of real-life Type-II supernovae. This is possible for only a handful of objects, one of them being the famous Supernova 1987A in our closest neighbouring galaxy, the Large Magellanic Cloud. SN 1987A, as it is generally called, is unique in being a very recent explosion where astronomers have been able to follow the evolution from the original event continuously since the explosion over 23 years ago.

After this time, the ejecta (i.e., the original envelope of the star that was sent flying out by the explosion at velocities of tens of thousands of kilometres per second) has reached an angular size that is ideally suited for observations with SINFONI on the VLT. The 3D reconstruction of the ejecta from the SINFONI data shows

Images of the 1.644 μm emission line of SN 1987A and its circumstellar ring in different velocity bins showing the spatial distribution of the ejecta at different velocities. The colours indicate the intensity levels of the line (coded by the side bars). The asterisk marks the centre of the inner ring.



that the explosion must have been highly asymmetric indeed: the ejecta expand more rapidly in some directions than in others. This is shown in the top figure that presents the SINFONI maps of the forbidden silicon (Si) plus iron (Fe) lines at 1.644 μm in five different velocity bins.

The SINFONI maps show that the elongated ejecta are predominantly redshifted in the north and blueshifted in the south. The helium ejected by the explosion behaves in a similar way to the Si/Fe, indicating that these constituents are well mixed. Thus, the new observations confirm the asymmetric shape of the inner ejecta inferred from early speckle-imaging observations and show that the ejecta are confined roughly to the plane of the equatorial ring. Also, the northern and southern lobes are not symmetric and show slightly different radial velocities. This suggests two separate angles in the line-of-sight of the emission sites. The observations are fully consistent with the predictions of recent explosion models of core-collapse supernovae and therefore provide strong observational support for these models.

About ten years after the explosion, the shockwave that was produced by the explosion, moving at about one tenth of the speed of light, caught up with the old stellar wind from the progenitor star and generated the fantastic display of fireworks revealed by images taken by telescopes around the world and also by HST. The bottom figure shows an artist's rendition of the 3D architecture of SN 1987A twenty years after the explosion, where the three main components that characterise SN 1987A are nicely illustrated: the two outer rings, the inner ring of pearls, and the deformed innermost region of expelled material.

Artist's impression of the material around SN 1987A based on the SINFONI observations that, for the first time, revealed a three-dimensional view of the distribution of the expelled material. This image shows the different elements present in SN 1987A: two outer rings, one inner ring, and the deformed innermost region of expelled material.

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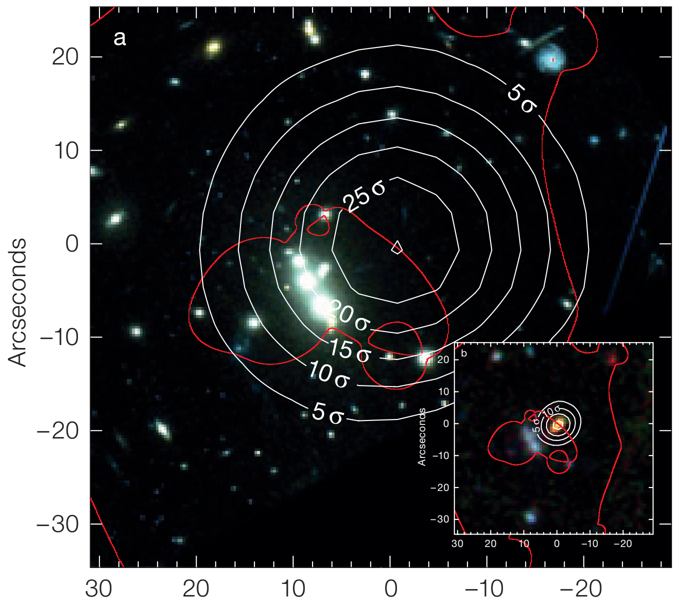
The History of Star Formation in the Universe

For 300 000 years after the Big Bang, the remanant fireball expanded until it became transparent and released the radiation that we now see as the Cosmic Microwave Background (CMB). The Universe entered a period when stars had yet to form. To discover the time in the history of the Universe when the very first stars formed is one of the driving motivations of 21st century astronomy. Observations of the CMB, the fossil record of the Big Bang, indicate that the Universe was opaque to visible light with neutral hydrogen and helium gas blocking the radiation from reaching us from the first stars. Eventually the cosmic fog was cleared by the energetic photons from massive young stars in the first galaxies. So the Universe gradually became transparent to visible and ultraviolet light: a few pockets first, then others until the cleared regions started to overlap and all the neutral gas was ionised. The distortions in the CMB tell us that this process began when the Universe was only a few tens of millions of years old and finished when it was about one billion years old. Technically, one says that the Universe was completely re-ionised by a redshift of $z = 6$. The higher the redshift of a galaxy is, the earlier it is being seen in the history of the Universe. So the game is to find the highest redshift, corresponding to the most distant galaxies. In 2010 the VLT confirmed the photometric of redshift $z = 8.6$ of the most distant candidate galaxy known until then. Its name is UDFy-38135539.

Thus, the star formation history of the Universe has now been mapped over most of the age of the Universe from about 500 million years at $z \approx 9$ to the present age of 13.75 billion years ($z = 0$). Combining the results from space and ground observatories, including the largest ESO telescopes, shows that the star formation rate rose steadily from $z = 8$ to $z = 2$ (and rather steeply between $z = 10$ and $z = 8$ according to very recent HST results), and then decreased steadily to the present low value. Thus the period between redshifts of $z = 2$ and $z = 3$ contained the most active epoch of star formation in the Universe, with galaxies forming stars at rates much higher than observed in the local Universe.



This is a *V,I* image of the galaxy cluster MACSJ2135-0102 taken with HST. The insert shows a Spitzer Space Telescope mid-infrared image of the cluster where the infrared counterpart of the submillimetre galaxy is clearly seen. The white contours show the images obtained at 850 µm with LABOCA (main image) and at 350 µm with the bolometer camera SABOCA (insert). The red lines correspond to the $z = 2.3$ critical lines of the cluster marking the maximum gravitational magnification by the cluster lens.

Stars form out of dense clouds of gas and dust, so forming lots of stars requires lots of gas and lots of dust. Young star-forming galaxies are therefore generally shrouded in dense dust clouds that make them invisible to optical and near infrared radiation. They can, however, be found in submillimetre and radio surveys. Such submillimetre galaxies are the strongest star-forming galaxies known, and many of them have been discovered as a result of large surveys such as those with the LABOCA bolometer array camera at the Atacama Pathfinder Experiment telescope, the pathfinder for ALMA.

While these galaxies can be detected with single-dish radio telescopes, large arrays such as ALMA are required to resolve them and study them in detail. The LABOCA 850 µm camera on APEX has now discovered the first example of a strongly gravitationally-lensed submillimetre galaxy, called SMM J2135-0102 at $z = 2.3$. The galaxy lies behind a rich cluster of galaxies that amplifies its flux by a factor of 32 by magnifying the image. This has allowed, for the first time, the spatial resolution of the star formation regions in one of these galaxies at scales of 350 light-years at submillimetre wavelengths. The observations show that the star-forming regions in these objects have remarkably similar conditions to those in the local Universe, but on scales about 100 times larger, and with ten million times higher luminosities.

These observations give a taste of the science that will be possible with the full ALMA array, as Early Science verification images with ALMA are beginning to demonstrate.

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ESO/J. Emerson/VISTA/ Acknowledgment: Cambridge Astronomical Survey Unit

Infrared view of the Cat's Paw Nebula (NGC 6334) taken by VISTA. NGC 6334 is a vast region of star formation about 5500 light-years from Earth in the constellation of Scorpius.

Allocation of Telescope Time

Observing Programmes Committee (OPC) Categories and Subcategories

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

A: Cosmology

B: Galaxies and Galactic Nuclei

C: Interstellar Medium, Star Formation and Planetary Systems

D: Stellar Evolution

Percentage of scheduled observing time/telescope/instrument/discipline

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT1	CRIRES	0	1	17	10	27
	FORS2	32	10	11	21	73
Total		32	11	27	30	100
UT2	FLAMES	0	8	1	11	19
	UVES	9	2	5	5	21
	X-shooter	27	10	10	13	60
Total		36	20	16	29	100
UT3	ISAAC	4	8	10	5	27
	VIMOS	35	11	1	5	53
	VISIR	0	6	10	5	20
Total		39	25	21	15	100
UT4	HAWK-I	9	0	3	3	15
	NACO	3	8	29	7	47
	SINFONI	19	14	3	2	38
Total		30	22	35	13	100
VLTI	AMBER	0	0	35	28	63
	MIDI	0	8	10	9	27
	Special VLTI	0	0	10	0	10
Total		0	8	54	38	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
2.2-metre	FEROS	0	0	11	42	53
	WFI	11	6	22	8	47
Total		11	6	33	50	100
3.6-metre	HARPS	0	0	78	22	100
Total		0	0	78	22	100
NTT	EFOSC2	9	0	16	13	38
	SOFI	2	0	15	14	31
	Special NTT	0	0	9	22	31
Total		10	1	40	49	100
APEX	APEX-2A	0	2	2	0	3
	LABOCA	12	11	19	2	44
	SABOCA	1	2	3	1	7
	SHFI	10	12	19	0	41
	Special APEX	5	0	0	0	5
Total		28	26	43	3	100

The numbers in this table have been rounded to integers for clarity. The underlying arithmetic uses the full numbers.

Full sky image of the Milky Way above the VLT Platform. The VST enclosure is seen at the top.

Operations

ESO/José Francisco Salgado (josefrancisco.org)

La Silla Paranal Observatory

The Directorate of Operations is responsible for all activities related to science operations, including the preparation and execution of observing programmes, the operation of the La Silla Paranal Observatory with its La Silla, Paranal and Chajnantor sites, and the delivery of raw and calibrated data. This involves user support, data flow management, operations technical support and the development and maintenance of a science archive as provided by the Data Management and Operations Division. The archive holds all the data obtained with ESO telescopes as well as highly processed, advanced products derived from them. Operations further includes ESO's contribution to ALMA operations through the European ALMA Support Centre (EASC) and the operation of the Space Telescope - European Coordinating Facility.

Night falls at ESO's Paranal Observatory, home of the Very Large Telescope, and the sky produces a palette of intense colours, putting on a beautiful show for observers.

Operations

The ESO Very Large Telescope at Paranal operates with four 8.2-metre Unit Telescopes (UTs), a suite of ten first generation instruments and the first of the second generation instruments. The Laser Guide Star Facility (LGSF) provides two of the three instruments of the VLT supported by adaptive optics with an artificial reference star. The VLT Interferometer combines the light of either the Unit Telescopes or the Auxiliary Telescopes (ATs) to feed either one of the two interferometric first generation instruments with a coherent wavefront, which is then further stabilised by the VLTI fringe tracker or the newly established VLTI visitor instrument focus. VISTA, the Visible and Infrared Survey Telescope for Astronomy, has been in regular science operation since the beginning of the year.

On La Silla, the New Technology Telescope, the 3.6-metre and the 2.2-metre telescopes operate with a suite of six instruments. The La Silla site further supports six national telescope projects including the latest addition: the TRAPPIST (standing for TRAnsiting Planets and PlanetesImals Small Telescope) project led by the Université de Liège (Belgium) and the Observatoire de l'Université de Genève (Switzerland).

The Observatory further provides the operations support for the Atacama Pathfinder Experiment with its 12-metre submillimetre radio antenna located on the high plateau of Chajnantor at an altitude of 5100 metres with its suite of heterodyne and bolometer facility instruments and a number of visitor instruments.

For Periods 85 and 86, the scientific community submitted respectively 988 and 977 Phase 1 observing proposals for the La Silla Paranal Observatory including APEX. These numbers document the continued high demand for the ESO observing facilities. Eighty percent of the proposals are for the Paranal site using the VLT and VLTI.

The Observatory continued its efficient operation through high availability and low technical downtime of its telescopes and instruments — key contributors to productive scientific observations. In 2010, a total of 2385 nights were scheduled for scientific observations with the four UTs at the VLT, and with the three major telescopes at La Silla. This is equivalent to about 93% of the total number of nights theoretically available over the whole year. The remaining 7% were scheduled for planned engineering and maintenance activities to guarantee the continuous performance of the telescopes and instruments and to include time slots for commissioning new instruments and facilities. The new VISTA telescope delivered 252 nights of survey observations after the formal beginning of science operation in April 2010. Out of the available science time for VLT and VISTA, only 4% was lost due to technical problems and about 13% due to adverse weather conditions. On La Silla, bad weather accounted for losses of about 12% and technical problems for 1.3%.

Complementing the regular VLT operations, the VLT Interferometer was scheduled for an additional 164 nights to execute scientific observations using baselines with either the UTs or the ATs. The remaining nights of the year were used for technical activities and for the further development and commissioning of the interferometer and its infrastructure. In addition to 120 engineering nights, some 65 nights were invested in the continued installation and commissioning of the new PRIMA facility. A total of 8.7% of the scheduled VLTI science time was lost due to technical problems and 23% to bad weather.

The combination of high operational efficiency, system reliability and up-time of the La Silla and Paranal telescopes and instruments for scientific observations has again resulted in a high scientific productivity. We have counted 507 peer-reviewed papers that were published in 2010 in different scientific journals and are at least partially based on data collected with VLT and VLTI instruments at Paranal. In addition, 296 refereed papers were published referring to observations with ESO-operated telescopes at La Silla and 29 to APEX observations in ESO time. The total number of independent papers stands at 751.

Paranal instrument upgrades

To maintain the competitiveness of the VLT and VLTI, it is not sufficient to continue to deliver new instruments, but also to follow a rigorous upgrade programme for the existing instruments. In 2010 these efforts were concentrated on the first of a three-phase upgrade plan for the VIMOS instrument at UT3, with the goal of increasing the efficiency and ease of maintenance of the instrument for future large spectroscopic surveys. The upgrade started with the replacement of the four science detectors with red-sensitive, deep-depletion Charge Coupled Devices (CCDs), which provide double the quantum efficiency at a wavelength of 900 nm and reduce fringing across the detectors. Together with the installation of an active flexure compensation system to keep the instrument perfectly aligned, independent of its actual angular orientation at the Nasmyth focus, the CCD upgrade has considerably improved flat-fielding and sky-subtraction capabilities.

Changes in the technical and science operations scheme are expected to further reduce technical downtime of the instrument. The second and third phases of the upgrade project will tackle known problems in the different complex mechanisms of the instrument and are in preparation for implementation in 2011 and 2012.

In February 2010, a new 14 × 14 lenslet array was installed in the NAOS–CONICA (NACO) visible wavefront sensor. Compared to the previously available array, this new array has a shorter focal length and hence a field of view that is large enough for the extended Laser Guide Star (LGS) spot. It quickly became clear during the commissioning nights that the new lenslet array brought the expected gain in performance with the achievement of *K*-band Strehl ratios of up to 35% and image quality of around 80 milliarcseconds FWHM (full width at half maximum) in good observing conditions. Also, the operation with the new lenslet array is virtually identical to that with the previous arrays, so the upgrade is largely transparent for the users. This successful upgrade results in improved adaptive optics correction of the turbulent atmosphere delivered by NACO when used together with the artificial LGS.

VISTA operations

VISTA is the latest addition to the operational telescope suite of the Paranal Observatory site. VISTA is a 4-metre-class wide-field survey telescope for the southern hemisphere. It is located on its own peak about 1.5 kilometres from the four UTs. The telescope has an altitude–azimuth mount and quasi-Ritchey–Chrétien optics with a fast f/1 primary mirror delivering an f/3.25 focus to the instrument at Cassegrain. VISTA is equipped with the near-infrared camera VIRCAM, which covers a field of view 1.65 degrees in diameter with a loosely packed detector mosaic totalling some 67 million pixels, with a mean pixel size of 0.34 × 0.34 arcseconds^2. Each VISTA image captures a section of sky covering about ten times the area of the full Moon. This allows the detection of objects over the whole southern sky with high sensitivity.

VISTA was delivered to the La Silla Paranal Observatory by the Science and Technology Facilities Council's UK Astronomy Technology Centre (STFC, UK ATC) and provisionally accepted by ESO in December 2009. The first five years of VISTA operation are dedicated primarily to the execution of six public surveys. Public survey operation with VISTA formally started with Period 85 in April 2010 after an extended period of technical activities and so-called operation dry runs. During the first nine months of regular science operation, VISTA was available for 92% of the time for execution of public surveys despite continuing technical activities. After the first observing period, which extended until October 2010, the various public surveys have made good progress and achieved completion rates between 47% and 99% with respect to the observations planned for the respective period.

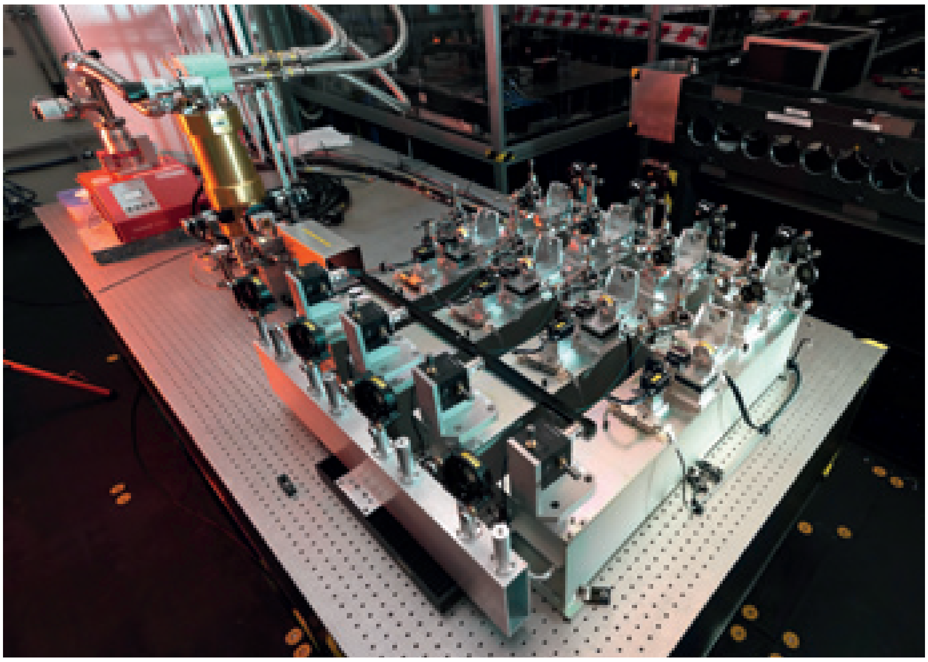
The operation team continues to collect experience with VISTA during real operating conditions and have observed that operational overheads are larger than expected. These additional overheads result primarily from the increased time necessary to slew the telescope from one position on the sky to the next and to read and save the data from the large detector array of the VISTA camera. Despite the individual delays being small, just a few seconds, the large number of telescope pointings required for the surveys means that the sum of these small additional overheads leads to a lower efficiency than anticipated. The scientists and engineers of the VISTA team have also noticed a decreasing sensitivity and this has been traced to a decreasing reflectivity of the two telescope mirrors. Consequently, a previously unplanned renewal of the reflective mirror coatings has been added to the VISTA schedule in early 2011 to bring the telescope back to full sensitivity.

New facilities

The VLT/I and VISTA telescopes and instruments produce an average amount of compressed data of, respectively, 25 gigabytes (GB) and 75 GB per day. It is expected that the optical survey telescope VST and second generation VLT instruments, such as MUSE and SPHERE, will double this data production rate over the next two years. The VLT/I data are currently transferred to ESO's central Science Archive Facility at ESO Headquarters in Garching through commercial internet providers, with the bottleneck being the microwave links from Paranal to the Chilean communication backbone. Adding the VISTA data to the scientific online data transfer stream is already beyond today's capabilities due to the isolated location of the Paranal Observatory. VISTA data are therefore saved to portable hard disks and shipped to Garching through regular parcel services.

To overcome this bottleneck and to open up new opportunities for ESO's observatories in the north of Chile in the future, ESO is member of the international EVALSO consortium (www.evalso.eu) of astronomical organisations and research network operators, part-funded under the European Commission's FP7 programme. EVALSO stands for Enabling Virtual Access to Latin-America Southern Observatories and is a new network infrastructure connecting the observatories at Armazones and Paranal to Santiago de Chile. From there it is possible to connect via existing networks, including REUNA and RedCLARA, the transatlantic link, GÉANT and European national research networks to the observatories' parent institutions in Europe including ESO Headquarters. In November 2010, a major milestone of the project was achieved with the completion of the installation of the high-capacity, high-speed data facility. It uses 100 kilometres of newly installed fibre-optic cable to connect the observatories to existing commercial infrastructures. The fibre-optic cable between the observatories and Antofagasta and the backbone between Antofagasta and the communications hub in Santiago carry data at speeds of 10 Gbs^{-1} using dense wavelength division multiplexing technology. From the hub to the end users in Europe, the entire network can eventually operate at up to speeds of 1 Gbs^{-1} (equivalent to 10 800 GB per day). ESO plans to integrate the new infrastructure with its existing operational networks by mid-2011 to achieve initial scientific data transfer capacities from Paranal to Garching of 250 GB per day, as required by the anticipated future data volume produced by Paranal. In the future, the EVALSO infrastructure will further provide new opportunities for advanced communication concepts like virtual presence and remote and robotic telescope operations.

ESO & B. Lazareff (LAOG)



The VLTI visitor instrument PIONIER.

The VLT Interferometer

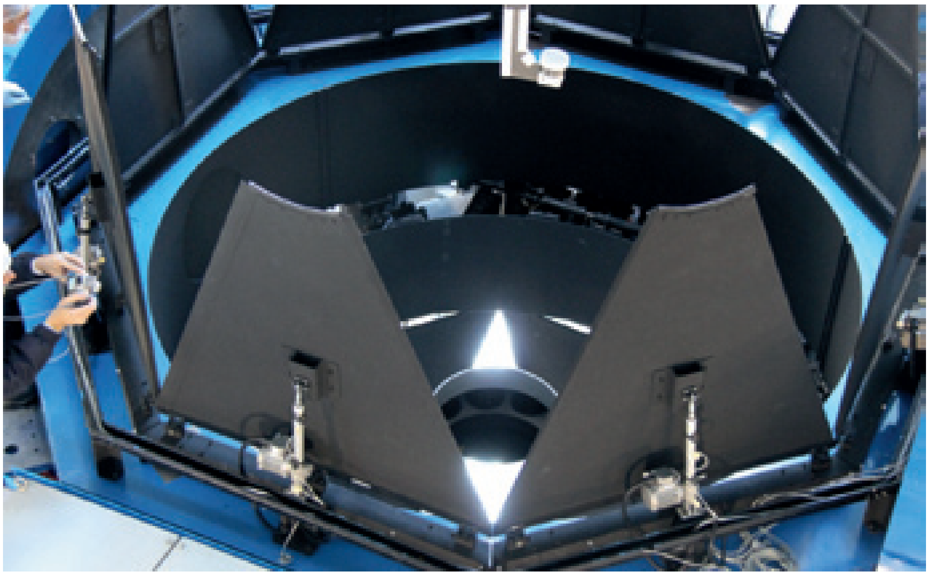
In 2010, the VLT Interferometer executed about 164 nights of scientific observations with the MIDI and AMBER instruments using UT and AT baselines. The remaining time was intensively used for engineering and commissioning activities to complete and improve the interferometer infrastructure. The installation and commissioning of the new PRIMA astrometric and phase-referencing facility continued over the course of the year and required an investment of some 65 commissioning nights.

The requests for scientific observing time with the VLTI in Period 85 peaked strongly in the months from April to June with almost no requests for the June to September months. During the preparation of the observatory schedule this uneven distribution was recognised as a unique opportunity to reserve a large slot of time dedicated to technical and commissioning activities. Therefore, a number of technical activities to improve the VLTI infrastructure, which could not be carried out in the regular short technical-time periods of a few days, were interleaved with the PRIMA commissioning runs during the second half of the period. One group of activities centred on the ATs: upgrades of the control networks to the new observatory standard; coating of the secondary mirrors of the ATs with a layer of silver, taking advantage of the new VISTA coating facility; installation and testing of the first OBAMA (Optical Bidule for Aberration Measurement on the ATs) autofocus system to monitor the wavefront and focalisation of the ATs; completion of the installation and commissioning of the STRAP four-quadrant guiding sensors and introduction of fast guiding; and preparation of the VLTI Sub Array (VISA) for four-telescope (4T) operation with the ATs by opening new telescope stations. On the UTs, the long-term investigation of the vibration sources affecting the achievable sensitivity of the interferometer was intensified. As a result, the average residual variations of the optical path difference for all four UTs were reduced from 610 nm rms (root mean square) in 2008 to 270 nm rms in 2009 and 205 nm rms in 2010. The VLTI Delay Lines (DL) underwent advanced mechanical maintenance and tuning of the DL control-loop electronics and software to further optimise their performance. In the VLTI laboratory, the guiding and alignment facilities IRIS and ARAL were upgraded for increased sensitivity and 4T operation. The science instruments MIDI and AMBER also took advantage of the dedicated technical time. As an example, AMBER now profits from the recording of the real-time status of the fringe tracker and the DL positions as developed for PRIMA and made available through the Reflective Memory Network (RMN). This information, obtained through the RMN, in addition to the recorded scientific data, is used to improve the calibration of the measured visibilities and therefore results in higher accuracy and precision in the derived diameters of the astronomical sources. AMBER has now reached operational maturity and was granted its Preliminary Acceptance Chile, which fully transfers the responsibility for the instrument to the observatory.

The four Auxiliary Telescopes that form the VLTI Sub Array are offered to the science community in three different 4T configurations. Within every month of science operation, VISA is reconfigured such that each of the three four-telescope configurations is available for about a week. This considerable increase in the number of available AT baseline combinations within a given time, together with the opening of new AT stations allows the VLTI to come closer to the astronomers' increasing desire to obtain milliarcsecond resolution images of the surfaces and close environments of stars. The first scientific instrument taking full advantage of the availability of 4T operation is the VLTI visitor instrument PIONIER, which was developed by the Laboratoire d'Astrophysique de Grenoble (LAOG) in France. The acronym stands for Precision Integrated Optics Near-infrared Imaging ExpeRiment and emphasises the expected imaging capability of this instrument. The heart of the instrument is a remarkable integrated optical circuit — smaller than a credit card — that finally brings the light waves from the four different telescopes together to create interference. The resulting resolving power of the telescope array has the sharpness not of the individual 1.8-metre AT, but that of a much bigger virtual telescope some 100 metres across, limited only by how far apart the telescopes can be positioned. After two short and successful installation and commissioning runs in October and November, PIONIER had its first scientific observing run in December and the observatory and the scientific community are increasingly curious to see the first scientific images produced by PIONIER and the VLTI.

VST construction

The VLT Survey Telescope is the optical counterpart to the VISTA infrared survey telescope. Construction of the VST by INAF continued next to the UTs on the Paranal telescope platform. After the major setback to the project due to damage to the main mirror cell and its mirror support and actuator systems during its transport from Italy to Chile in 2009, the project has seen considerable progress in the second half of the year, following the successful delivery of the refurbished mirror cell. Shortly after the installation of the main mirror cell, the successfully coated primary and secondary mirrors could be in installed. On 7 December, the VST team reported that the optical alignment of the telescope had been successfully completed, including the large optical corrector for the OmegaCAM instrument, and that first (technical) light has been achieved. The



The coated and integrated primary mirror of VST.

INAF–ESO commissioning activities for telescope and instrument are planned to continue until mid-2011 with the goal of delivering an operational survey telescope by the end of July.

La Silla Observatory

The La Silla Observatory has completed its first year of successful operation according to the streamlined operations model. The La Silla 2010+ model supports the continued operations of the three major telescopes and their instrumentation, i.e., the 3.6-metre telescope with HARPS, the NTT with SOFI, EFOSC2 and visitor instruments, and the 2.2-metre telescope with the FEROS spectrograph and the Wide Field Imager (WFI). The 2.2-metre telescope operates according to an agreement with the Max-Planck-Institut für Astronomie (Heidelberg, Germany). This agreement ensures the continued operation of the 2.2-metre telescope until 2013 with an ESO share of 25 % of the available observing time in response to the continued high demand by the community for the FEROS and WFI instruments.

Despite streamlined operations, ESO and the Observatoire de l'Université de Genève (Switzerland) continue to upgrade their most successful exoplanet-hunter HARPS at the 3.6-metre telescope with the goal of pushing the achievable radial-velocity accuracy below the well-established 1 ms^{-1} level and to open up new discovery space for HARPS. To this end, a new Fabry–Perot (FP) calibration system has been developed in Geneva and tested with HARPS. The FP calibration unit provides a reference spectrum with numerous equidistant spectral lines of equal intensity and achieves a photon-noise limited accuracy of about 3 cms^{-1}; long-term drifts are of the order of few centimetres per second per hour and follow the pressure variations inside the HARPS instrument vessel. The new device is being characterised further before it is offered to the HARPS user community. In parallel, ESO has developed a secondary (tip-tilt) guiding unit for the 3.6-metre telescope to correct for high-frequency tracking errors of the telescope and to further stabilise the light injected into the HARPS spectrograph at the fibre entrance. This new device has also been successfully tested on-sky and will be released for operation in early 2011. The combined effect of these two improvements to HARPS is expected to result in an improvement in radial-velocity accuracy down to 50 cms^{-1}. The commissioning of the new polarimeter unit for the HARPS spectrograph was successfully completed by Uppsala Universitet (Sweden) and so turns HARPS into the most powerful high-resolution spectropolarimeter in the southern hemisphere.

TRAPPIST/E. Jehin/ESO

TRAPPIST first light image of the Tarantula Nebula.

This new capability has been available to the scientific community since October 2010.

The La Silla Observatory continues to support observations with the Danish 1.54-metre, the Swiss 1.2-metre Leonhard Euler, the Rapid Eye Mount (REM), the TAROT and the ESO 1-metre Schmidt telescopes, the latter for the La Silla Quasar Equatorial Survey Team (QUEST) Variability Sky Survey (VSS) project. TRAPPIST has been added to the national telescopes operating at La Silla and is devoted to the study of planetary systems through two approaches: the detection and characterisation of exoplanets through the photometric observation of the transits in front of their suns and the study of comets orbiting around the Sun. The new telescope is installed in the building that housed the old Swiss T70 Telescope. The TRAPPIST project is on a fast track: only two years passed between taking the decision to build it and first light in June 2010. The 60-centimetre telescope is fully robotic and now remotely operated from a control room in Liège, Belgium.

APEX project

In 2010 APEX reached its full complement of facility instruments with the delivery of the SABOCA camera developed by the Max-Planck-Institut für Radioastronomie (MPIfR, Bonn, Germany) in 2009 and the Swedish Heterodyne Facility Instrument (SHFI) developed by Onsala Space Observatory (OSO, Sweden) this year. SHFI covers all four atmospheric windows from 200 to 1400 GHz and was initially delivered by OSO in 2008. The last band, APEX band 3 (385–500 GHz) was successfully installed in SHFI during the altiplanic winter break and fully commissioned during 2010.

APEX operations continue in the recently implemented 24-hour operation mode, which allows almost continuous scientific observations during day and night with its suite of submillimetre facility instruments. This new operations mode maximises the exploitation of the exceptional conditions available at the site of Chajnantor at an altitude of 5100 metres.

The operation agreement between the MPIfR, ESO and OSO, partners for the APEX project, was expected to expire after six years of science operation, i.e., by the end of 2012. However, considering the success of the project, all APEX partners have expressed their wish to continue to extract maximum scientific benefit from this unique facility and therefore proposed extending the current APEX operation agreement to 31 December 2015 with unchanged shares of the observing time, i.e., MPIfR 50 %, ESO 27 % and OSO 23 %. Signing of the corresponding formal agreement is expected in early 2011.

C. Durán/ESO/APEX (MPIfR/ESO/OSO)

The APEX telescope, 12 metres in diameter, points towards the afternoon sky, ready for an observing run of milimetre and submilimetre wavelength astronomy from the Chajnantor plateau.

Data Management and Operations Division

The beginning of regular VISTA operation and the preparation for ALMA Early Science have determined the focus of much of the activity of the Data Management and Operations Division in 2010.

Developed in previous years in close collaboration with the La Silla Paranal Observatory and the Software Development Division, new procedures and tools developed for implementing the end-to-end operations paradigm for VISTA have proved their effectiveness for the management of the ESO public surveys carried out with the new telescope. The public surveys have been progressing at a good pace during their first year of execution. At the same time, the infrastructure — again a joint DMO/SDD effort — for the submission to ESO of the science-ready data products produced by each ESO public survey, has been completed in anticipation of the first releases of data products expected in 2011.

In preparation for meeting the major milestone represented by the start in 2011 of Early Science, the European ALMA Regional Centre (ARC) has intensified its activities in a range of critical areas. These comprise the participation in onsite commissioning and science verification, the testing and validation of user support tools, the publicising of ALMA operations and capabilities to the community, the coordination of the European ARC nodes and ensuring the availability of a variety of user services.

The user community continues to increase its demand for VLT observing time in service mode and the Garching-based segment of operations hosted by the DMO plays a major role in ensuring its proper execution. The large fraction of the observing time using this mode is recognised as a key to ensuring that the highly rated scientific programmes can exploit optimal conditions.

The beginning of VISTA operations, with its leap in the rate of data gathering on Paranal, has brought a long-anticipated acceleration of the data ingested in the ESO Science Archive Facility (SAF), which, at the end of 2010, was nearing a volume of 200 TB. Concurrently, collections of highly processed, science-ready data products have continued to be released through the SAF.

The proven concepts of VLT end-to-end operations, now expanded to include VISTA, form the basis of the science operations model proposed for the E-ELT as part of its construction proposal. This determines the direction for the further development of operations on Paranal over the coming years and of the infrastructures that support them.

User Support

Providing efficient support for six public surveys on the new VISTA telescope has been a remarkable achievement of the User Support Department (USD) this year. Public surveys imply not only extra-large sets of observing material that are verified by us, but also the need for effective monitoring tools. The survey team in USD, in close collaboration with the Data Flow Infrastructure Department in the SDD, has played a major role in driving the upgrade of the observation preparation and execution tools used at the VLT. These tools have introduced a high degree of automation in the operations workflow. USD has also adapted its VLT progress report pages to include VISTA so that each public survey can be efficiently monitored.

Other highlights in 2010 include:

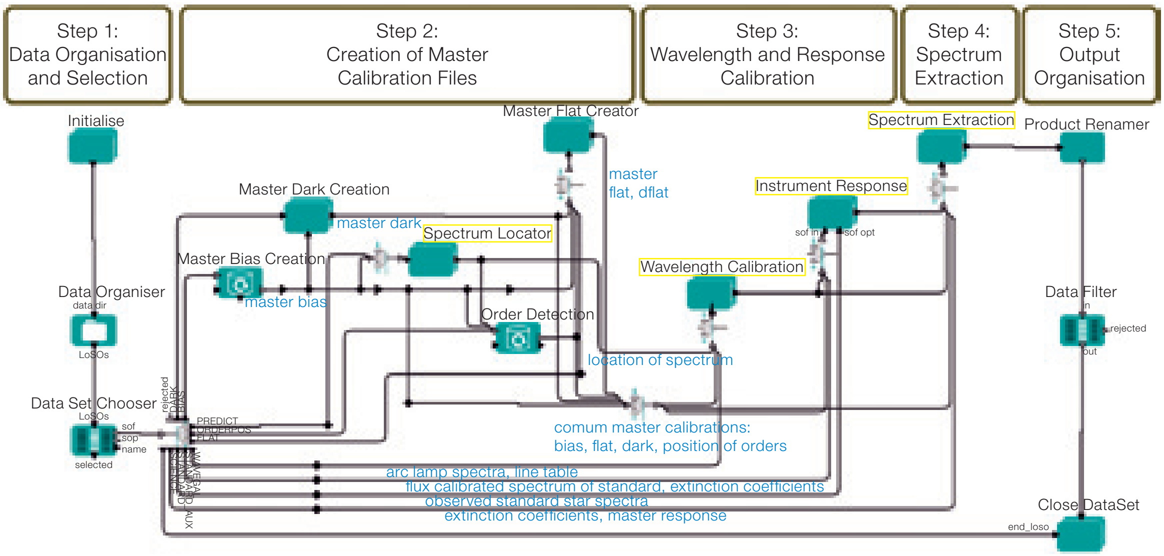
– The successful installation of the visitor instrument Z-Spec on APEX. The ESO APEX project scientist within the USD contributed substantially in coordinating the design of the mechanical and optical interfaces, organising the shipment of the instrument from the Jet Propulsion Laboratory to APEX and the logistical arrangements of the commissioning team. First scientific results were obtained in October and presented soon afterwards at international meetings. The instrument will be offered as a Principal Investigator (PI) instrument to the ESO community during Period 87.

– The strong involvement of USD astronomers in two instrument upgrade projects (the VLT spectrograph VIMOS and VISIR) launched and led by the Instrumentation Division. USD evaluated the impact of the proposed implementation plans on observing queues and operations workflow and provided feedback given by the users when requested.

European ALMA Regional Centre

The year 2010 was exciting for the ARC and its network of nodes in Europe as final preparations were made for the start of ALMA Early Science operations in 2011. As in previous years, ARC was fully involved with a broad range of activities at the Joint ALMA Observatory (JAO) in Chile. An important part of the commissioning activity consisted of testing observing modes using the ALMA Observing Tool (OT) delivered by ESO. ARC staff were also involved in reducing commissioning data and took a leading role in

The poster designed for the ESO ALMA Community Days to be held in early 2011. Encompassing a variety of presentations on ALMA, the user support available as well as hands-on tutorials for the OT, the Community Days should enable users to submit observing proposals that optimally exploit the Early Science capabilities of ALMA and make use of its unique potential.



A screenshot of Reflex supporting data reduction with the UVES echelle mode: the data reduction cascade is rendered graphically in the form of a scientific workflow, with data flowing from the left to the right. Data are first classified and associated and are then dispatched to the various processing modules. Annotations on the canvas provide convenient access to information and instructions.

setting up the data archive, as well as readying it for Early Science operations. Given the call for Early Science proposals in early 2011 and the start of operations, a special focus was placed on educating the community on ALMA capabilities and software tools. Members of the ESO ARC travelled to the other ARC nodes and events such as the Joint European and National Astronomy Meeting (JENAM) to lead software tutorials and generally promote ALMA. The efforts of the ARC to prepare the European user community for ALMA Early Science operations will culminate in the ALMA Community Days, to be hosted at ESO in April 2011.

Data products

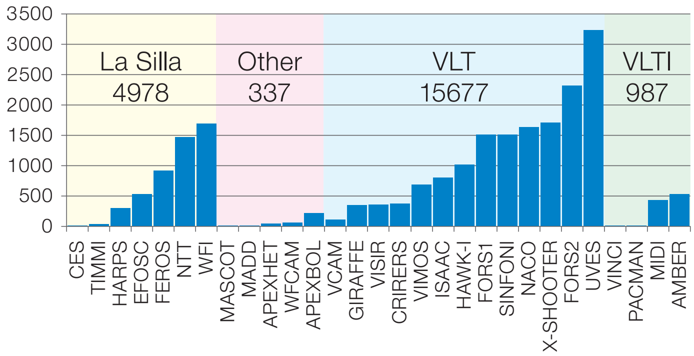
During 2010, the Quality Control and Data Processing group processed more than 10 TB of VLT/VLTI raw data in more than 250 000 processing jobs. In addition, 50 TB of data from the VIRCAM camera on the VISTA telescope, i.e. five times as much as the entire suite of VLT/VLTI instruments, were processed to monitor the instrument performance and data quality.

Following ESO policy, VISTA advanced science data products will be returned to the SAF by the PIs of the six public surveys currently running so that the community at large can exploit them. The External Data Products group has developed, in close collaboration with the SDD, a set of standardised procedures and tools to streamline this process. By analogy with the submission of observing proposals (Phase 1) and the specification of the detailed observing strategies (Phase 2), the submission of science data products to ESO was dubbed Phase 3.

In 2010, the highlight of ESO's efforts to improve the scientific quality of the data products was the public release of Reflex. This task was coordinated by the Science Data Products group and was the outcome of a close collaboration with the SDD. Reflex is a software platform for running ESO data reduction modules in a user-friendly way. The data reduction cascade is rendered graphically in the form of a scientific workflow, where each box corresponds to a step in the process and data flow seamlessly from one to the next (see figure above). In addition to the capability for running the data reduction modules, Reflex provides, amongst others, the capability to organise and associate the input data and makes it possible to custom tools written in popular languages such as Python.

Science Archive Facility

The total archive holdings comprise some 182 TB following the addition of 63 TB in 2010, including 16 TB of data from the first full year of VISTA operations. In support of operations, 1118 VLT/VLTI PI service mode packages were prepared and delivered to the respective PIs and the new online PI-pack download service completed 327 orders. New data releases in 2010 were the FEROS spectroscopic time series data supporting asteroseismic observations from the French satellite CoRot, PACMAN/PRIMA commissioning, HARPS polarimetry mode commissioning and X-shooter science verification.



Archive requests for data in 2010 per instrument. Note: the NTT bin combines the EMMI, SOFI and SUSI2 instruments.

Further to the PI-pack processing, a total of 21 979 other archive data requests were made and these correspond to the activities of approximately 2000 unique archive users in conducting research with the various datasets available per instrument as depicted in the bottom figure on p. 33.

Archive requests are generally triggered by queries posted on the archive main query and instrument specific query pages. New forms for X-shooter (February 2010) and VISTA/VIRCAM (May 2010) were deployed and the option to search by galactic coordinates on all instrument specific query forms was introduced. The ambient conditions for Paranal, including meteorological data, have been published since January 2010, with a database extending from 17 August 1998.

The archive databases captured metadata pertaining to 1.75 million raw observation frames and 950 000 pipeline processed products. The database containing the repository of FITS (a data format for images) keywords ingested full header information from 3.2 million frames and the database now contains 8.2 billion (thousand million) individual entries from 16.8 million frames. The operation logs database ingested 650 million entries and now contains a grand total of 4.25 billion rows. The databases to support operational activities have been separated from those supporting queries, with the query databases moved to a new schema that can generate derived items and allows a fast reaction in the provision of new entries. A new access control system and supporting databases have been established, which is one element in a range of interdepartmental projects to upgrade the handling of data requests and provide enhanced services to end-users for the direct download of data and delegating access to co-workers. These projects were successfully carried out in 2010 and are now pending final release on completion of commissioning activities.

The first phase of a detailed study of the metadata, intended to aid the future development of the archive and improve customer services, was completed. This study encompassed all archive interfaces related to archive operations and the exploitation of the archive contents, covering all aspects of data and metadata flow into and out of the archive. In preparation for the eventual creation of an ESO Catalogue Facility, a data model and catalogue query interface specification was defined with the Data Products Department and the SDD. In parallel, feasibility studies of several database management systems have been carried out to support efficient spatial indexing.

Virtual Observatory

In 2010, the Virtual Observatory Project Office (VOP) has continued to provide input to various archive and data related DMO projects to ensure progress toward Virtual Observatory (VO) compatibility of archive holdings and services. It has also continued to represent ESO at the International Virtual Observatory Alliance (IVOA) and the Euro-VO consortium.

The second Euro-VO Astronomical Infrastructure for Data Access (AIDA) School was held in Strasbourg on 25–28 January 2010 with strong VOP involvement. The aim of the school was to expose young European astronomers to the many available VO tools and services for research purposes. The school involved 40 students and 14 tutors. Based on the input received from the participants during the feedback session the school was a great success.

VOP staff, within the framework of the Euro-VO AIDA project supported by the EC, and in collaboration with other AIDA partners, have organised and led a series of VO Days across Europe to expose European astronomers to VO tools and services. These included VO Days in Switzerland, Sweden, the Netherlands, Bonn, and Heidelberg, as well as a lecture given at a course on Modern Data Mining in Astronomy in Utrecht.

The 7th meeting of the Euro-VO Science Advisory Committee (SAC) took place at Imperial College in London. During this meeting, SAC members were briefed on the latest Euro-VO activities and provided detailed input on VO Schools, VO Days, VO tools and services, the Euro-VO web pages and the photometry data model.

Operations Technical Support

During the past year, the primary ESO database server was upgraded to Sybase Adaptive Server Enterprise version 15. This process involved almost 50 databases, with over 2000 relational tables containing 530 million rows which correspond to 50 GB of data. In addition to the server upgrade, the database devices have been migrated to fibre-channel storage. As a result of the upgrades, there has been a sizeable increase in database server performance and a considerable reduction of timeouts for mission-critical database services.

Operations Technical Support (OTS) has stepped up the deployment of servers and services within virtual environments. Such deployments increase the efficiency on multiple fronts, such as procurement, maintenance, serviceability, power consumption and data centre footprint. This effort has proved to be very successful over the last year and almost 70 systems have been migrated to the virtual machine environment, consisting of four physical servers with 80 cores and over half of a TB of main memory. After a successful proof of concept, virtual database servers are now available to test application subsystems that access databases in parallel, reducing interferences and errors. The virtual machine environment has allowed OTS to restructure the existing system and to set up separate development, integration, and operational system environments on the same physical hardware. In addition to the immediate benefits, virtual environments have allowed OTS to increase the fault tolerance, to provide scalable solutions and to complete installations in short times, sharing existing resources and improving the service quality.

The nearby star-forming region around the star R Coronae Australis imaged by the Wide Field Imager on the MPG/ESO 2.2-metre telescope at ESO's La Silla Observatory in Chile.

ESA/ST-ECF and NASA

This image of the Hubble Space Telescope is set against a background of hundreds of unique slitless spectra obtained by HST.

ST-ECF

Following decisions made by both ESA and ESO during the last few years, the Space Telescope - European Coordinating Facility closed and ceased operations on 31 December. Established as a joint venture between these two organisations in 1984, the ST-ECF has worked in close collaboration with the Space Telescope Science Institute (STScI) in Baltimore to support European users of Hubble and to provide significant contributions to the operation of the observatory and its instruments. The history of the activities of the group in Garching is captured in the 48 issues of the *ST-ECF Newsletter*, the last of which appeared in January 2011.

During its last year of operation, the principal achievements have been to:

1. Make the planned public release of around 48 000 fully calibrated slitless spectra extracted from all suitable observations made with the Advanced Camera for Surveys before Servicing Mission 4 (actually the fifth servicing mission to Hubble since launch in 1990). This dataset is now available as part of the Hubble Legacy Archive and a paper describing the process and the product is in press.

2. Provide observation simulation and data reduction software, calibration and user support for the slitless (grism/prism) modes of the HST cameras and, towards the end of the year, to ensure that all the relevant information, software and data were transferred, in an agreed and controlled manner, to STScI where they have now become available to the worldwide community of users of these increasingly utilised instrument modes. Users were supported during proposal preparation at the start of the year and with a successful and well-attended Stitless Spectroscopy Workshop held at STScI in November.

3. Continue to prepare the European HST data archive for efficient, low-cost operations from 2011 onwards. This was achieved with the completion of a cache system, built in collaboration with the Canadian Astronomy Data Centre, which serves online the most recently calibrated data products. A novel, new user interface scheme has also been developed and made available.

4. Co-organise with STScI a major international conference on Science with the Hubble Space Telescope – III: Two decades and counting, hosted by the Istituto Veneto di Scienze Lettere ed Arti (IVSLA) in their Palazzo Cavalli–Franchetti in Venice during October. This was the third in a series of such conferences organised by the ST-ECF in Europe. The conference took place during the last week of a month-long exhibition of Hubble images and artefacts in the IVSLA's neighbouring Palazzo Loredan. This beautiful exhibition, organised by STScI, the ST-ECF, NASA and ESA, attracted over 12 000 visitors including many school parties. During the week of the conference, an art installation: *From the Distant Past*, conceived by artist Tim Otto Roth and ST-ECF head Bob Fosbury, projected Hubble images and associated slitless spectra onto the Palazzo Franchetti; and was clearly visible to travellers on the Grand Canal.

ESA/Hubble

The Hubble Space Telescope: Twenty Years at the Frontier of Science exhibition at the Istituto Veneto di Scienze, Lettere ed Arti in their beautiful and historic Palazzo Loredan.

5. Continue Hubble outreach activities, started in response to a request from NASA more than a decade ago and delivered through www.spacetelescope.org. From 2011, this activity will continue at a substantial, but somewhat more modest, level financed by ESA, with the continued involvement of the ESO education and Public Outreach Department (ePOD).

Until the end of 2010, it was intended to keep the European Hubble Data Archive at ESO, where it was originally the model for the development of the ESO Science Archive Facility. The intention now, however, is to create a European access point for Hubble data at the European Space Astronomy Centre (ESAC) in Spain. ESO will cooperate as far as possible in achieving this transfer in a way that avoids an interruption in public availability in Europe. Most of the recent ST-ECF archive features were developed in close collaboration with the Canadian Astronomy Data Centre (CADC) and are available at their website. All Hubble data remain accessible at both the STScI and CADC through their respective archive interfaces.

Arrangements for the travel of European scientists to the USA on ESA Hubble business — previously dealt with by the ST-ECF — will now be handled by ESA's Hubble Mission Manager at STScI.

European ALMA Support Centre

ESO formally instituted the European ALMA Support Centre on 1 October 2009. EASC is expected to develop into the "face" of ALMA for the European scientific community and institutes and to international ALMA partners during ALMA operations. EASC is an important component for the success of ALMA as a scientific instrument and for ESO as a partner in the ALMA project.

EASC comprises the roles of ALMA regional centre operations, ALMA offsite technical maintenance and development support, ALMA science as well as ALMA outreach. The high-level scientific representation and scientific guidance of the European ALMA project will continue to be provided in the operations phase by the European programme scientist, who acts in close collaboration with the VLT and E-ELT programme scientists to exploit scientific synergies with ESO's other major programmes.

For the scientific user community, the central ARC at ESO Garching and the ARC nodes in Europe are the primary interfaces to the individual ALMA users. In the case of the VLT, this function is successfully performed by the User Support Department in DMO, which has many commonalities with the function of the central ARC. Other functions foreseen for the ARC have their correspondence in other departments in the support to VLT operations (e.g., the archive, etc.). The share of core and additional functions between the central ARC and the ARC nodes has been detailed in the ARC node implementation plan. In 2010 the ARC and ARC nodes continued their preparation for ALMA Early Science (ALMA proposal cycle 0), for which a call for proposals is expected in the first quarter of 2011.

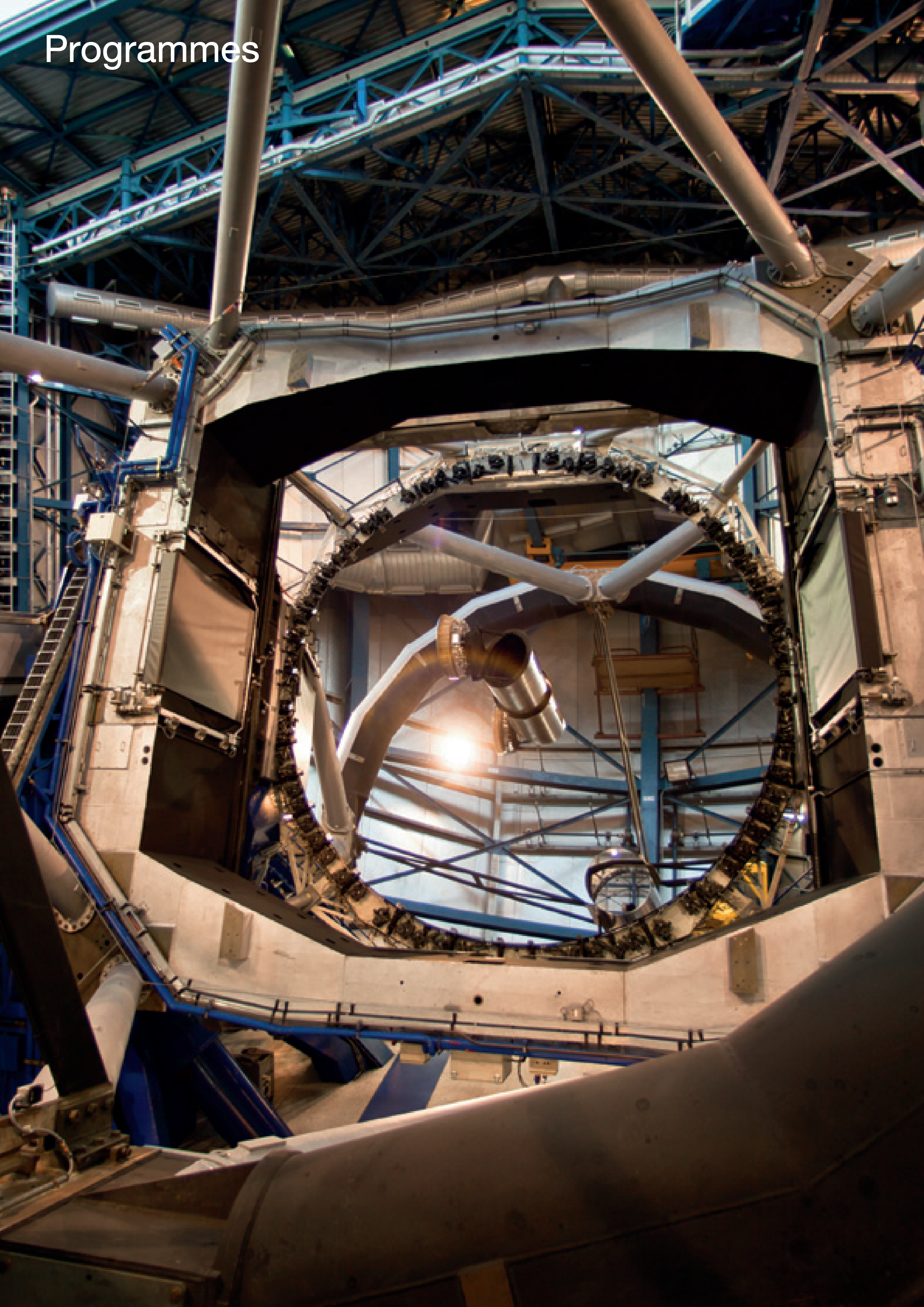
The ALMA partnership foresees continuous upgrades to, and development of, new software, front ends (e.g., additional receiver bands) and other hardware or system capabilities during the operations phase. The interface at ESO for the technical community in Europe will be the ALMA Technical Support group of EASC. The ALMA upgrade and development programme will be funded through the ALMA operations budget using a competitive proposal process. EASC will ensure and enable high quality proposals from the European instrumentation community, coordinate and manage the programme in Europe as well as represent Europe in the international ALMA collaboration. In 2010 EASC initiated a first call for studies for ALMA upgrades and development in Europe. It is planned to launch selected studies early in 2011.

Outreach and media presentation of ALMA and its achievements will be provided by the ESO education and Public Outreach Department, in coordination with the outreach department of the JAO and those of the other ALMA partners.

ALMA (ESO/NAOJ/NRAO)

A European ALMA antenna takes a ride on Lore, one of the ALMA Transporters, at the 2900-metre altitude Operations Support Facility in the Chilean Andes.

Programmes



Instrumentation for the La Silla Paranal Observatory

The Directorate of Programmes underwent some significant organisational changes during the year. At the end of May, after over 30 years of dedicated service, Alan Moorwood retired as Director of Programmes. His replacement, Adrian Russell, took up his post on 1 July. At that time, the structure of the Directorates changed with TEC moving into the newly created Directorate of Engineering and ALMA moving into the Directorate of Programmes.

The year also saw some tremendous highlights, including significant progress in all areas on ALMA, similar excellent progress on the second generation instrumentation programme and a series of increasingly successful PRIMA commissioning runs that culminated in the first ever three-minute integration on a faint source whilst locking fringes on a nearby bright star.

Without doubt though, the highlight of the year was the conclusion of the E-ELT Phase B design study and the subsequent External Review which concluded that, from a technical perspective, the E-ELT is ready to enter the construction phase.

One of the four 8.2-metre Unit Telescopes as it is opened at sunset and readied for observations.

Upgrades and maintenance

ESO has a continuing programme of instrument upgrades and maintenance to keep existing instruments as close to state of the art as possible. Upgrades may be as simple as replacing a detector with another of the same type, but with better performance, or as complex as a major redesign of instrument subsystems involving changes to optics, electronics and mechanical systems.

The upgrade of the VISIR instrument was approved as a project in May 2010. The plan comprises upgrades to the hardware (especially the mid-infrared detector), improved software support and enhancements to the science operations of the instrument. As part of the project, the decommissioned La Silla instrument TIMMI2 was refurbished, upgraded and brought into operation as a general-purpose test facility for thermal IR detectors. The new blocked impurity band 1 k × 1 k Si:As detector array (Aquarius) achieved first light in the cryostat in 2010. The Aquarius detector will be used to upgrade VISIR, which presently suffers from unsatisfactory detector performance. It will also provide the mid-infrared detector technology for the MATISSE instrument, and in future, for the E-ELT. All the electronics development required for full Aquarius detector operation has been completed and full performance characterisation of a science detector at cryogenic temperatures is in progress and will be completed in 2011. In addition, designs for upgraded (prism-based *N*-band spectroscopy) and new (coronagraphy) modes have been developed at ESO and collaborating institutes.

VIMOS is a multi-slit optical spectrograph on UT3. In 2010, a major upgrade to the instrument started and the first step was completed: the installation of new red-sensitive deep-depletion charge coupled detectors. An active flexure compensation system was also installed. This is an assembly of two motor actuators which, via reduction levers, pushes and pulls two of the three fixation points of a large folding mirror mounted on a deformable membrane system. This corrects for the motion of images on the detectors due to mechanical flexure arising when the instrument rotates to track objects on the sky. A first investigation of a new generation of more reliable slit-mask cabinets has also been made; a prototype is being manufactured and should be tested in early 2011. Work is also proceeding to reduce the weight of the cabinets and, more importantly, to develop a better and easier positioning and installation system. The new system will be locked into place with a single action. As a result of these upgrades, the red sensitivity, the calibration stability and accuracy and the instrument reliability will be improved and hence the efficiency with which large surveys of the faintest objects can be made will be significantly enhanced.

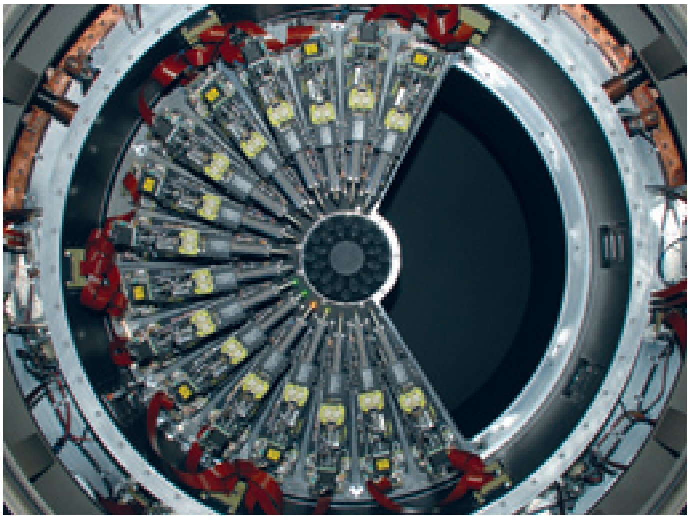
Since it is such an important and productive activity, a number of special maintenance tasks and small upgrades were performed in 2010. These included small repairs to the instruments HAWK-I and CRIRES, as well as more major interventions such as the installation of a new blue cross-disperser grating on UVES. One large maintenance intervention was made on SINFONI, requiring the complete instrument to be brought down to the integration laboratory. At the same time the opportunity was taken for a complete examination of the optics and verification of correct operation of all functions.

Instruments and technology under development

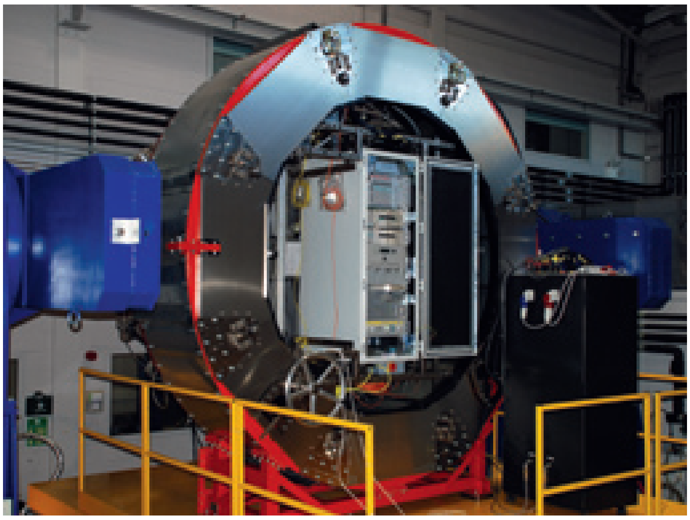
A large programme of instrument construction is currently underway for the VLT, involving collaborations between Member State institutes and ESO. The programme represents a large investment of resources by ESO and the community, and aims to keep our facilities at the forefront of world astronomy.

The preliminary design of two new VLTI instruments, MATISSE and GRAVITY, continued during the year. MATISSE will be a general-purpose imager/spectrometer operating in the 3–5 μm and 10 μm atmospheric windows and able to combine beams from either four 8.2-metre Unit Telescopes or 1.8-metre Auxiliary Telescopes. Excellent progress was made during the year in the design of cold optics, mechanics and cryogenics. Testing of a Hawaii 2RG detector in fast-readout mode was successfully completed. Good progress was made in developing the final technical specifications. A second Preliminary Design Review took place for the instrument in December 2010 and revealed no show-stoppers for the design, recommending that the project proceed to final design. GRAVITY is a second generation VLTI instrument for precision narrow-angle astrometry and interferometric imaging, combining four telescopes in the *K*-band. Following the successful Preliminary Design Review at the end of 2009, the GRAVITY team focused on the final design of the instrument with its various subsystems. The planning for the seven infrared detectors was detailed, with the detectors for the four wavefront sensors and the fringe tracker emerging from a new development of avalanche photodiode arrays. The wavefront sensor subsystems went through a delta-Preliminary Design Review in September, which showed a significantly strengthened design and concluded the preliminary design process. GRAVITY uses a novel laser-metrology approach to calibrate the narrow-angle baseline of the VLTI. A prototype of this metrology was tested on UT4 in August and October. Various other items were addressed in these two runs, including the image- and pupil-tracking concepts of the instrument and the need to monitor quasi-static higher-order optical aberrations. The ESO Council approved a guaranteed time allocation in June.

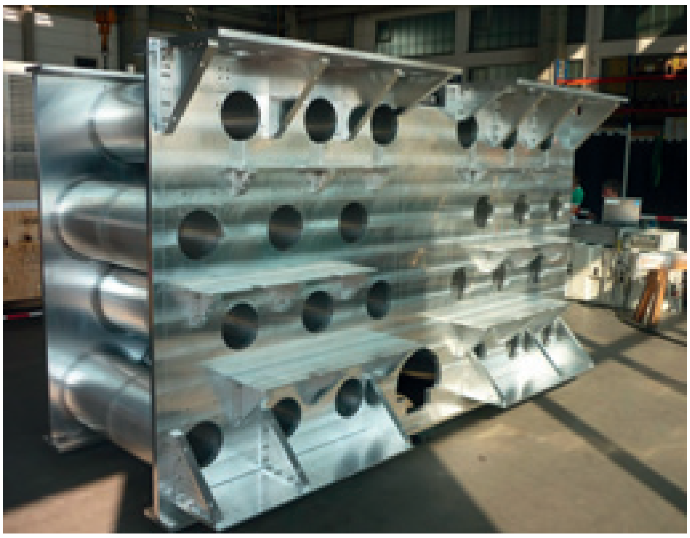
KMOS is a second generation instrument that should be delivered to the VLT in 2012. This near-infrared multi-field spectrometer can observe 24 fields simultaneously and take spectra of points within each. During the year, the project has moved from the process of manufacturing the individual components to the important phase of installing and integrating the subsystems into the KMOS cryostat. End-to-end testing of the instrument is now well underway, exploring the performance and reliability of the opto-mechanical components, the control electronics and instrument control software, and the data reduction pipeline. Two of the three modules of the instrument are now built into the cryostat. The subsystems for the remaining third are undergoing tests before integration. Sixteen arms of KMOS have already been mounted in the cryostat.



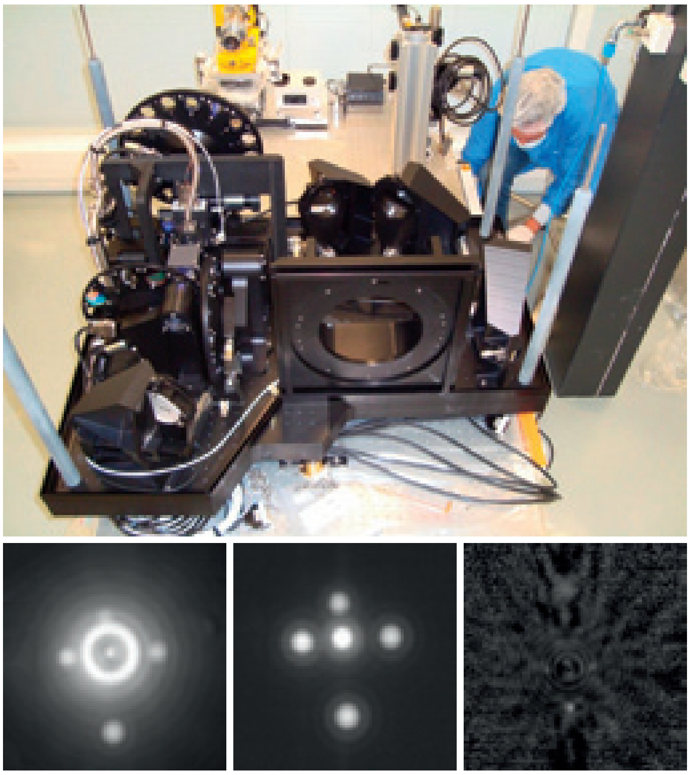
The picture shows 16 cryogenic pickoff arms in the KMOS focal plane. Eventually, 24 will be installed.



Since the KMOS instrument will rotate, all cables leading to it must also be rotated. This picture shows the cable co-rotator that will carry all electrical and high-pressure helium cables to the instrument.



This large welded structure will hold all 24 MUSE spectrographs precisely in position.



The ZIMPOL optical bench shown above is part of the SPHERE instrument. The three pictures are of an artificial star with four “planets” taken with the instrument. Left: an intensity image of the uncovered star and planets. Middle: an intensity image with planets dimmed by a factor of $< 10^{-3}$ and the bright star masked with a coronagraph. Right: In polarimetric mode a factor of 3×10^{-7} in differential contrast between planet and star is achieved.

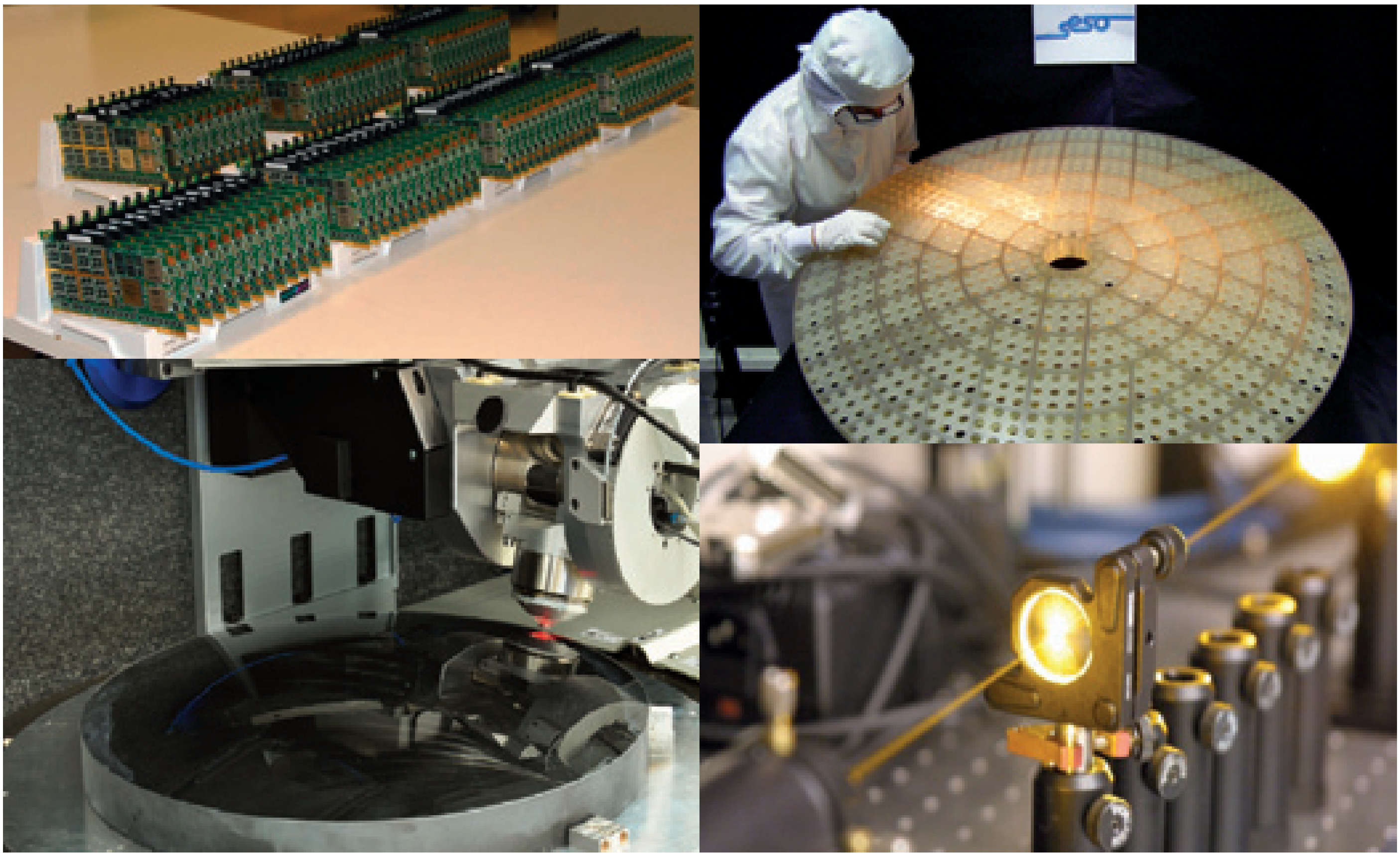
MUSE is an integral field instrument, with a field of view of 1 × 1 arcminutes, fine sampling, intermediate spectral resolution (R = 3000) and a large spectral coverage. It contains 24 parallel spectrographs with complex image-slicers and large-area detectors. Delivery is expected in 2012. Following the manufacturing item acceptance review for the first Integral Field Unit (IFU) in February 2010, the integration and validation of the first IFUs took place in the course of the year. It is planned to receive the last IFU by summer 2011. The instrument main structure, which will eventually keep the 24 IFUs in precisely defined positions, was delivered to Göttingen, Germany, in July. The manufacturing item acceptance review for the vacuum and cryogenic system, which was built at ESO and supports the detector units of all 24 IFUs, took place in September and the system was shipped to Lyon, France, in November. All contracts for instrument hardware have now been placed and the majority of items have been delivered to the consortium.

SPHERE is the exoplanet imaging instrument planned to have first light at the VLT in 2012. It combines high performance adaptive optics with coronagraphy and various differential imaging concepts and instruments (IRDIS: near-IR camera and spectrograph; IFS: near-IR integral-field spectrograph; ZIMPOL: optical differential polarimeter) to provide the required large intensity contrasts, better than one part per million, at subarcsecond angular separations. During the last year, the SPHERE consortium has procured all the components of the instrument, largely integrated them and begun testing the individual subsystems. Important ESO contributions to SPHERE include the deformable mirror, real-time computer and wavefront sensor camera for the adaptive optics system as well as cryogenic and detector systems. As a highlight, the differential polarimeter ZIMPOL reached the important milestone of laboratory first light and demonstrated that it is capable of detecting signals with a 3×10^{-7} intensity contrast between the star and planet. This contrast still needs to be improved to 1×10^{-7} to meet the design specifications.

The Adaptive Optics Facility (AOF) is a large project to convert UT4 into an AO-optimised telescope, comprising sodium lasers, wavefront sensors and a Deformable Secondary Mirror (DSM) with 1170 actuators. The year 2010 saw the completion of the AOF final design phase and the launch of several important procurements. Many of these assemblies have been received and the project will focus on integration of its systems in 2011. In April 2010 the AOF project successfully completed the important system Final Design Review whose main focus was management, system aspects, operations, the required modifications to UT4 and the early review of a commissioning plan. In terms of hardware, the laser launch telescope has been designed and procurement and manufacturing have started. The laser development and the associated assemblies are progressing well towards final design. Among the highlights of 2010, the DSM reference body, an intricate light-weighted Zerodur component, was delivered for integration. The major wavefront sensing structural assembly for MUSE (GALACSI) has been delivered to ESO Garching for integration, along with handling tools and test stands. The main assembly for HAWK-I (GRAAL) has also been completed and will be delivered to ESO in 2011. The ASSIST test bench main mirror, a 1.7-metre aspheric, is undergoing its final polishing phase and delivery is expected early in 2011. The real-time computer, SPARTA, has achieved first closure of a fast servo-loop at ESO. The wavefront sensor camera prototype with an e2v CCD220 detector has achieved first light in the lab at a frame rate of 1 kHz.

In a continued effort to stay at the forefront of ground-based astronomy, ESO has pushed the development of detector technology in several key areas in 2010. Apart from commissioning the standard large format HgCdTe near-infrared arrays with the New Generation Controller (NGC) in second generation VLT instruments, progress has also been made in other areas.

A key ground-breaking detector development is targeted at meeting the stringent speed and noise requirements of the VLTI for fringe tracking and wavefront sensing, which cannot be met by conventional CMOS technology. Hence ESO has initiated the development of a near-infrared avalanche photodiode (APD) array that takes advantage of the noiseless avalanche effect in HgCdTe, a unique



This figure shows various components under development for the AOF. Clockwise from top left: electronic boards for the deformable secondary mirror, reference shell for the DSM with 1170 holes for actuators, sodium laser tests in the lab, measuring the shape of the laser launch telescope objective lens.

property of this infrared-sensitive material. After successful completion of three pre-development studies a new multiplexer is being developed which is specifically tailored to the requirements of the VLTI.

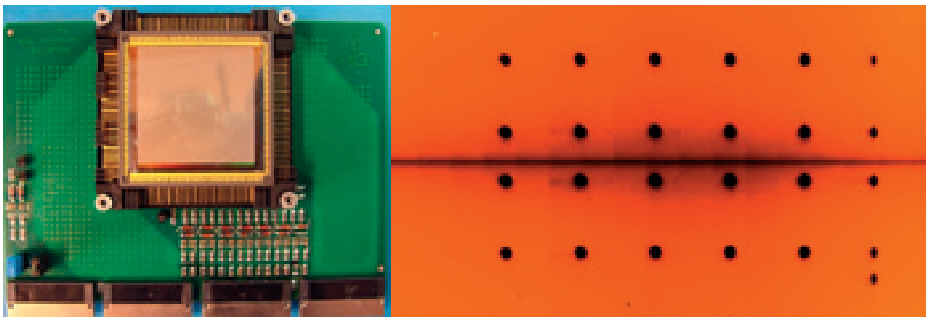
Another development focuses on the high-speed readout of Hawaii-2RG arrays. ESO's NGC presently achieves data rates of 80 megapixels per second, but faster boards are under development. The ASIC (Application Specific Integrated Circuit) is an alternative to the NGC and integrates a complete controller, including digital conversion, on a single chip operating at cryogenic temperatures next to the detector. An ASIC was successfully tested and able to clock and read out a Hawai-2RG detector. The ASIC will eventually simplify the deployment of large detector mosaics at the E-ELT.

With increasing telescope aperture, the number of resolution elements needed by adaptive-optics systems increases, while the available time for corrections decreases. This double challenge was tackled in 2010 by a collaboration with the firm of e2v (UK), which has developed an L3Vision®-based 240^2-pixel CCD operating at up to 1200 frames/second. A prototype controller designed in France has demonstrated sub-electron readout noise at this speed — an amazing result. This technology is now integrated into ESO's NGC.

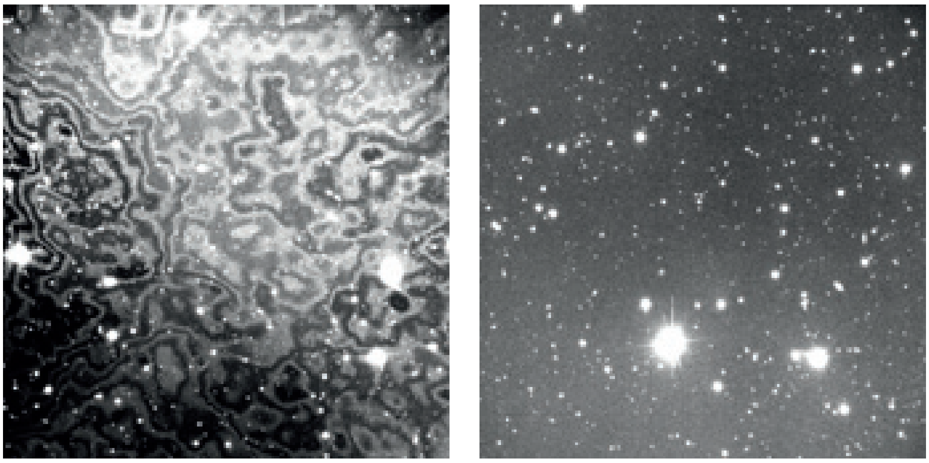
Precision instruments, especially those for interferometry, require very stable conditions. Vibrations, notably those caused by cryogenic refrigerators in instruments, can be especially problematic. As part of a programme to reduce induced vibrations at the VLT, a test instrument was constructed containing six helium refrigerator heads in two different arrangements: three radial and three axial. A first vibration-test campaign was carried out in November and December 2010 on three possible VLT instrument locations: Cassegrain focus, Nasmyth adaptor and Nasmyth platform.

VLTI infrastructure development and PRIMA

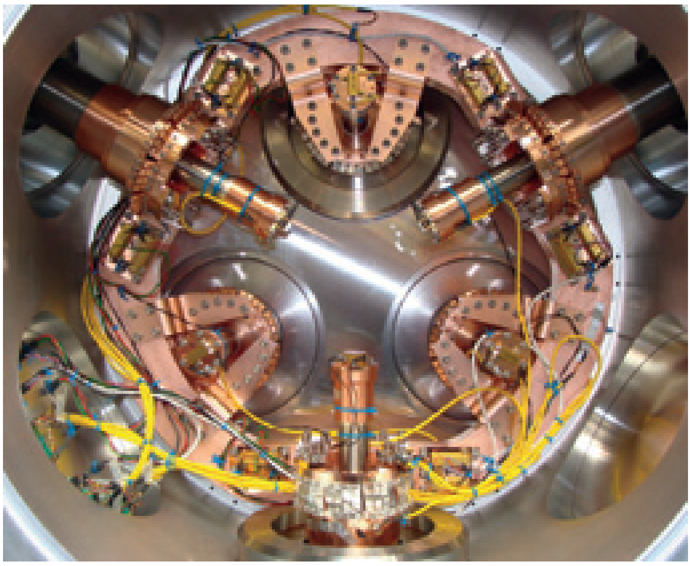
After several years of hard work fighting mishaps and various technical problems, PRIMA finally reached its main technical milestone in January 2011: obtaining a first full astrometric measurement on a pair of stars (see the top figure on p. 46). This involved the simultaneous operation



The new Aquarius mid-infrared detector (left) and first image with an engineering-grade device showing test spots (right).



This figure shows the great reduction in optical fringing in VIMOS achieved with the newly installed detectors (right) compared to old (left). The fringing is caused by interference of light originating from the Earth's atmosphere.



This picture shows the open cryostat of a test instrument for studying induced vibrations at the VLT. The three radial and three axial helium refrigerators can be seen.

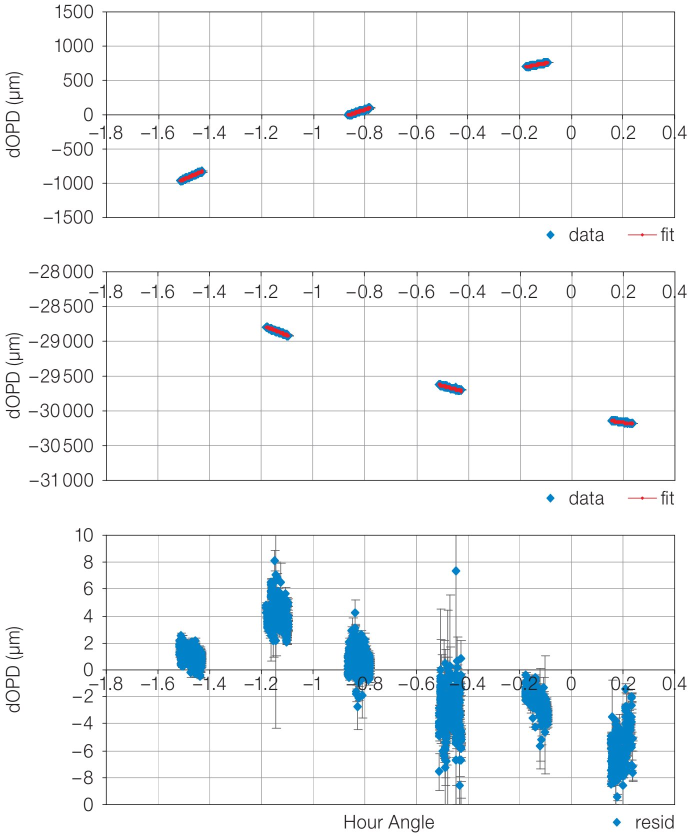
of many highly accurate and sensitive systems, with several intricate real-time control loops. The PRIMA team is now starting to commission the astrometric mode, trying to push its limits in terms of limiting magnitude and precision. Faint object observations that rely on the off-axis fringe-tracking capability will also be explored.

To accomplish the technical milestone, the light coming from two stars had to be separated at the focus of two telescopes and propagated along hundreds of metres through delay lines to the interferometric laboratory such that the optical paths of the two pairs of photons were the same length to the nearest micrometre. Then the beams coming from the two telescopes were recombined separately for each star and the position of the obtained fringe patterns were measured to the nearest nanometre. At the same time, a dedicated laser metrology beam was propagated along the same path inside the VLTI infrastructure, measuring the internal path. This measurement is the yardstick that allows the angular separation of both stars to be determined with sub-milliarcsecond resolution. To maintain this accuracy, the star beams have to be stabilised in angular position and the laser metrology beams in lateral position with great care to avoid any interruptions to the signal at the detectors during the several hours that an observation requires. With an optical train consisting of about 30 mirrors, many of them moving during the observation, distributed over a length of more than 100 metres, it was a challenge. This is now working routinely. The detection and stabilisation of the elusive fringes, which jitter strongly due to atmospheric turbulence, was also particularly difficult, but is now achieved for relatively bright stars.

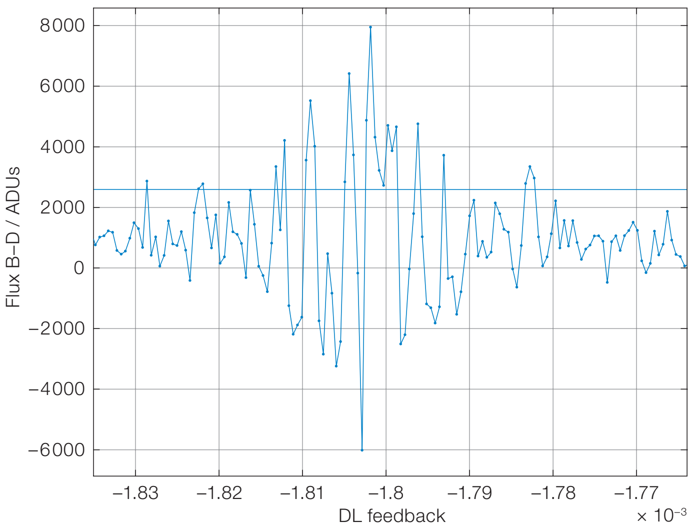
Analysis of the numerous data taken during the 2010 commissioning runs is continuing to study the stability of the system, identify and reduce systematic errors, detect the remaining instrumental bugs and improve the hardware. Commissioning of the astrometric performance has started and will continue for the next year. The sensitivity limits of the system will also be explored by slowing down the detection rate on the faint star, while stabilising the fringes on the brighter one of the pair, in astrometric mode, but also when PRIMA is used as an off-axis fringe tracker for the VLTI instruments AMBER and MIDI. As shown in the lower figure, integration times of one second have been achieved (typical integration times in interferometry are of the order of milliseconds) and there is still some room for improvement.

In parallel with the PRIMA activities, the conceptual design for NAOMI (the adaptive optics system for the Auxiliary Telescopes) has been developed and was successfully reviewed. This system, to be installed on each Auxiliary Telescope, will improve the ATs' optical quality and correct for atmospheric turbulence, obtaining very stable beams that can be injected into the optical fibres of the VLTI instruments. This should improve the operability and average limiting magnitude obtained on the VLTI. The plan is to install the NAOMI systems at Paranal in 2014.

Finally, the development of the infrastructure necessary to enhance the second generation VLTI instruments is starting slowly, with the procurement of some hardware (extending PRIMA to four telescopes) and with a detailed breakdown of the implementation plan.



The first astrometric measurements obtained with PRIMA. The two upper graphs show how the distance (differential optical path difference) between the fringes of both stars is evolving with time, due to the Earth's rotation. Between the upper and the middle graph the two stars have been optically exchanged between the two fringe sensors to remove the arbitrary zero term of the *y*-axes. In the lower graph, the residual errors are compared to a very simple model. Detailed analysis to reduce these residuals is ongoing.



Fringes obtained on the secondary (faint) object while fringe stabilising on the bright star. Each point of this scan is a full one-second integration. If the fringes were not stabilised, no fringe modulation would be visible due to the atmospheric turbulence.

The telescope in the image is the fourth 1.8-metre Auxiliary Telescope, part of the Very Large Telescope Interferometer. The VLTI consists of four 8.2-metre telescopes, and the four smaller Auxiliary Telescopes, which have mirrors 1.8 metres across.


ESO/José Francisco Salgado (josefrancisco.org)

Four ALMA antennas gaze up at the star-filled night sky, in anticipation of the work that lies ahead. The Moon lights the scene on the right, while the band of the Milky Way stretches across the upper left.

ALMA

ALMA, the Atacama Large Millimeter/Submillimeter Array, is a new observatory that will comprise 66 high-precision antennas located on the Chajnantor plain of the Chilean Andes at 5000 metres altitude in the district of San Pedro de Atacama. It is being built by an international collaboration between Europe, North America, and East Asia in collaboration with the Republic of Chile. ALMA will operate at wavelengths between 0.3 and 9.6 millimetres, where the Earth's atmosphere above a high, dry site is largely transparent. It will provide astronomers with unprecedented sensitivity and resolution. ALMA's 12-metre antennas will have reconfigurable baselines ranging from 15 metres to over 16 kilometres. Resolutions as fine as 5 milliarcseconds will be achieved at the highest frequencies, a factor of ten better than the Hubble Space Telescope at optical wavelengths.

Construction has continued throughout 2010 and considerable progress was made by the end of the year, including:

– the installation of eight antennas at the 5000-metre site, operating as an interferometer, see figure below;

– obtaining the first science test images, demonstrating the potential capabilities of ALMA;

– the full integration of six European antennas, two in acceptance testing with more on-stream;

– the completion of major infrastructure work on the Santiago Central Office (SCO), on 192 antenna foundations and road surfacing, and the development of the ALMA power system;

– the delivery of a large number of Front-End (FE) elements, e.g., 53 water vapour radiometers (completed), 83 power supplies (completed), more than half the European FE receiver cartridges, and many others.

Since the start of Commissioning and Science Verification (CSV) in January 2010, ALMA has been expanded from three to eight operational antennas. The first science test images, obtained with eight antennas, give a glimpse of ALMA's capabilities. Given this progress, ALMA is moving towards the start of Early Science observations in late 2011.

Site construction work

The ALMA Observatory comprises three sites:

– the ALMA Operations Support Facilities at an altitude of 2900 metres;

– the Array Operations Site, located at 5000 metres altitude on the Llano de Chajnantor; and

– the Santiago Central Office at ESO's Vitacura premises.

The OSF is the operations centre for the entire ALMA observatory and is also the place where the final assembly of the antennas is carried out. The Assembly, Integration and Verification (AIV) of antennas and other advanced equipment is being completed there before transport to the AOS.

Operations at the AOS are limited to an absolute minimum due to the harsh environment. The AOS technical building hosts the correlator, a specialised computer that processes the digitised signals from the antennas before they are transmitted via fibre optic lines to the data storage facilities at the OSF.

ESO has, within the agreement concluded with its international partners, assumed the responsibility of providing several major construction works on all three ALMA sites. In addition, ESO has managed the construction of roads leading from the public Chilean highway to the OSF (15 kilometres), and continuing to the AOS (28 kilometres): see top figure on next page.

The surfacing of these two road sections, which are 14 metres wide, with a salt stabilised surface, was completed as planned in mid-2010.

At the OSF, ESO is in charge of:

– the construction of the OSF technical facilities;

ALMA (ESO/NAOJ/NRAO)

Eight antennas at the 5000-metre high site working as an interferometer.

MBV Ingeniería y Construcción/ESO

View of the first part of the paved ALMA road. The OSF is at the top right. From there the road continues to the AOS.

– the installation of the permanent power supply system for the entire ALMA observatory;

– the construction of the ALMA residence.

In June 2010, the contract for the supply of a multi-fuel power generation system consisting of three turbines, each one with a power generation capability of 3.8 MW (shown in the figure below), was awarded. The project progressed according to schedule with the completion of the preliminary and detailed design phases and the procurement of components. The turbine engines successfully passed the functional tests and are being integrated into the system.

The contract for the supply of the liquid petroleum gas tanks to provide the fuel storage for the power generator was awarded. The second major component of the ALMA power system, the medium voltage (23 kV) power distribution, progressed according to schedule in 2010. All equipment was manufactured and, after passing the factory tests, shipped to the site where the integration started. In the meantime, the 30-kilometre electrical and optical underground line connecting the OSF to the AOS was installed. The optical cable was tested and entered into operation in December, providing high speed and high reliability communication between the two sites and replacing the limited microwave link. Acceptance tests of the electrical cables started at the end of the year.

The development of the OSF technical facilities continued throughout 2010 with the upgrade of the heating, ventilation and air conditioning system to meet refined requirements (shown in the figure below). This included the installation of additional chillers, boiler, piping etc. This work will be completed in 2011.

The requirements for the ALMA residence at the OSF have been defined in the technical specification and statement of work documents that have been reviewed and approved by the European ALMA project office. The procurement strategy has been defined and the process started with a preliminary enquiry for the design contract.

At the AOS, ESO is in charge of the construction 192 antenna foundations.

This task was completed during 2010 and, by the end of the year, more than 50 % of the antenna stations were outfitted with the high precision mechanical interfaces. This part of the work is expected to be completed during 2011.

At the SCO, ESO is in charge of the building construction. In June 2010 the

One of the three ALMA turbines.

TSK Electronica y Electricidad S.A./ESO

The OSF computer room showing the Heating, Ventilating and Air Conditioning (HVAC) ducts and the high precision air handlers that were installed during year 2010.

ALMA (ESO/NAOJ/NRAO)/J. Arancibia (ALMA)

R&Q Ingeniería/ESO

Eight antennas at the AOS positioned on antenna stations delivered by ESO.

construction of the SCO (see figure below) was completed and accepted from the contractor. During the following two months the final outfitting and the installation of communication equipment and furniture took place. At the end of August, ALMA staff moved into the SCO.

ALMA antennas

ESO is providing 25 high-precision antennas 12 metres in diameter to ALMA. The antennas are manufactured by the AEM Consortium, composed of Thales Alenia Space (France and Italy), MT-Mechatronics (Germany) and European Industrial Engineering (Italy). The consortium has engaged many specialised subcontractors throughout Europe for the production of antenna elements. During the year, key activities of the ESO ALMA antenna group were the follow-up of the assembly at the OSF and the start of the acceptance testing. Supervision of key antenna elements and their inspection in Europe prior to shipping to Chile was continued to ensure that all parts are subject to the rigorous tests defined in the verification plans and that they conform to design.

Early in the year the AEM consortium continued the mechanical and electrical integration of the first antenna. In March the completely assembled reflector was mounted on the steel structure and cabin. The subsequent verification of the reflector surface by laser tracker demonstrated that this mounting had little effect on the reflector surface previously adjusted to around 40-μm accuracy inside the Reflector Assembly Building (RAB). This important result validated the envisaged assembly process of antennas in which the steel structure and cabin are assembled in parallel with the reflector. This allows the integration of a fully equipped reflector whenever a steel structure and cabin is available. Since the steel structure and cabin assembly takes much longer than the reflector integration, five antennas can be assembled on the five antenna stations, while two reflectors are prepared in parallel inside the temperature-controlled RAB.

In the spring, ESO completed the manufacture of two additional antenna stations. These can be illuminated from the holography tower that is used for the reflector surface setting and control. In June the first two antennas were moved to these two stations (see figure below), where they will remain until the handover to ALMA.

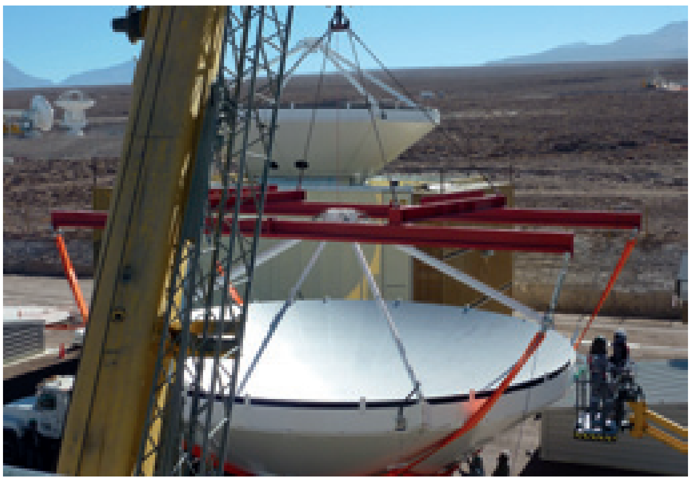
In late June power was supplied to the first antenna and its commissioning started. By the end of 2010 four antennas had power, two others were undergoing electrical checking, and a seventh was being integrated. Work had started on assembling the seventh and eighth reflectors.

The ALMA Santiago Central Office building.

Iglesis & Prat Architects/ESO

Lifting the second reflector onto the antenna structure with the first fully assembled European antenna in the background.

AEM consortium/ESO



AEM consortium/ESO

Relocation of the first European antenna.

ESO/S.Stanghellini

By the end of 2010 six antennas were assembled. Installation of the seventh reflector started in the shelter.

In September ESO and ALMA held the Test Readiness Review (TRR) of the first antenna, which marks the start of the official acceptance testing phase. Tests were performed related to the engineering performance and science operations.

Excellent performance was immediately reported for the all-sky optical pointing, routinely achieving better than the two arcseconds specified. Efforts started on the commissioning of the antenna metrology by assessing the stability of the pointing model as function of time and temperature. The TRR of the second antenna was held in December. First all-sky pointing tests repeated the performance already recorded on the first antenna.

Two holography campaigns were run in October and November, allowing the setting of the first antenna's reflector surface to an accuracy of approximately 12 μm. Final verification of the surface accuracy and stability is scheduled for the beginning of 2011. Complete acceptance testing of the first antenna is expected to be finished by April 2011.

Although the manufacture of antenna parts in Europe was never on the critical path, difficulties were encountered with some subcontractors of the AEM consortium who had been affected by the economic crisis and therefore were operating at half of their normal production capacity. Despite these difficulties, it was possible to avoid interruptions in the supply chain. At the end of 2010 measures were put in place to accelerate the antenna assembly in Spain (see figure below). The production of all antenna parts is proceeding in accordance with schedule, and for some parts the production has already finished or is close to completion.

By the end of 2010, seven European antennas were on site; two were in the process of acceptance testing; four others were fully assembled and assembly had started on the seventh. Parts for two further antennas are on site or in transport to Chile.

Surface setting of the first antenna using manual tools. An automatic tool will be used later for routine tasks.

AEM consortium/ESO

Assembly of antenna structures in Spain in late 2010.

ESO/S.Stanghellini

The front-end subsystem

Significant progress was made by the European Front End Integrated Project Team (FE IPT) in achieving important high level milestones. Front-end components and sub-assemblies were completed and delivered to the three ALMA FE Integration Centres (FEIC), as well as to the ALMA observatory in Chile.

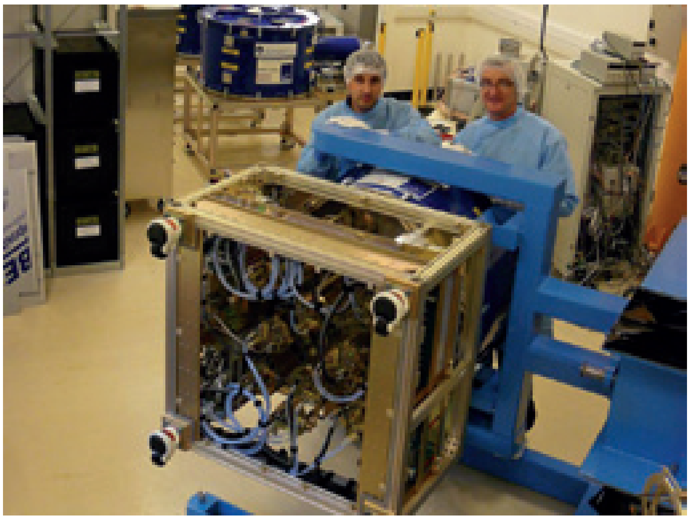
Building upon the solid basis of the many subassembly reviews held over recent years, the FE Subsystem Critical Design Review (CDR) was held on 16 and 17 February. The review panel responded positively to the material presented and concluded that the FE subsystem design was "very advanced and mature". Formal closure of this CDR was conditional on completing a limited number of action items. A team of ESO experts from the ALMA and TEC divisions assisted in closing some of these action items related to design verification. Although originally these design verification tasks were a North American FE IPT responsibility, the presence of available expertise resulted in this being transferred to ESO.

A very important review milestone for the European FE IPT was the second operational readiness review of the European FEIC, held on 30 September and 1 October at the European FEIC at the Rutherford Appleton Laboratory (RAL) in the UK. The passing of this marked the start of full operations of the European FEIC. The review panel members were impressed by the performance of the test equipment, e.g., the beam scanner (see figure below) resulting in credit being given to the RAL and ESO staff involved in setting up the European FEIC.

The project goal of having ten FE assemblies delivered to the OSF by the three FEICs was met this year. The European FEIC provided two units in 2010.

Two major European FE production work packages delivering equipment directly to

FE unit integration at STFC/RAL.



ESO/Peter Hekman

FE unit undergoing measurements with the beam scanner (the large structure in the upper half of the photo, the FE unit is below).

ESO/Peter Hekman

Water vapour radiometers arriving at the OSF.

Omnisys Instruments AB/ESO

FE power supply unit installed on an ALMA antenna.

ESO/Ferdinand Patt

the ALMA observatory were completed during the year:

– All 53 Water Vapour Radiometers (WVRs) operating at 183 GHz were produced by Omnisys Instruments (Sweden). The last batch of ten WVRs was accepted in December (see bottom left figure on p. 54). Staff from the ALMA CSV group had demonstrated earlier that correcting variations in the atmosphere due to water vapour can be accomplished with these WVRs.

– All 83 FE DC power supplies (see bottom right figure on p. 54) were produced by CAEN Spa (Italy). Within 18 months the custom-designed unit was developed and production completed.

By the end of 2010 a substantial fraction of the required receiver cartridges had been assembled. They are listed with their suppliers below.

Receiver band	Number of units assembled by the end of 2010	Supplier
3	35	HIA (Canada)
4	1	NAOJ (Japan)
6	38	NRAO (USA)
7	41	IRAM (France)
8	1	NAOJ (Japan)
9	53	NOVA (The Netherlands)

The ALMA observatory requires 73 units for each receiver band. We note here that production of the band 4 and band 8 receivers started much later than the others. The ESO ALMA Division, which is in charge of providing receiver bands 7 and 9 to the observatory, continued efforts to ensure the timely supply of these units.

By the end of 2010 STFC/RAL had delivered 39 cryostats (see figure above) and the production of the remaining 31 units is on schedule.

After the successful completion of the design phase of the Amplitude Calibration Device (ACD) at the end of 2009, the start-up of the actual production was initially slow. In 2010 only eight ACDs could be delivered to the observatory, although this was still sufficient to equip all the new antennas as they became available. In the second half of 2010 the team at ESO working on the integration and verification of ACDs went through a major restructuring. This change, together with the outsourcing of ACD components for the complete series, was designed to significantly accelerate ACD production. By December four more units had been integrated and verified. The production of all ACDs is scheduled for completion by early 2012.

ESO/Peter Hekman

Cryostats produced by STFC/RAL.

Chalmers University (Sweden) and STFC/RAL (United Kingdom) progressed with the production of six band 5 receivers; work done within the ALMA Enhancement Programme and entirely funded by the European Commission (EC-FP6). The delta-CDR of the band 5 receivers was passed in May and marked the completion of the design phase as well as the readiness for production. The first band 5 receiver, consisting of a cold cartridge containing the SIS mixers and a warm cartridge containing the phase-locked local oscillator, was delivered to the European FEIC in November. The integration of this band 5 receiver into a FE assembly was accomplished with support of staff from the Department of Astronomy of the University of Chile. This receiver has undergone an extended post-integration verification programme. The first results, which became available at the end of December, showed excellent performance and met the requirements set by the project.

The back-end system and the correlator

Most of the Back-End (BE) components to be supplied by ESO were provided to the ALMA observatory on schedule and are being integrated into the overall ALMA system.

Signals coming from the FE of an antenna are processed, digitised and converted to one single optical signal transmitting the scientific data through one single optical fibre at a rate of 96 Gbit/s to the AOS technical building. The optical demultiplexer/amplifier receives, amplifies and de-multiplexes the optical signal from the antennas and conveys it to the tunable filter installed in the correlator. Each correlator input can be connected to each antenna station by means of a fibre optic patch panel and associated patch cables. The table below summarises the supply of BE components by ESO.

By the end of 2010 ESO had delivered more than half of the antenna BE racks to the observatory. The essential and challenging European delivery of the high-speed digitiser that samples the analogue signal from the sky coming from the FE receiver is reaching its final phase.

The first part of the CDR of the antenna BE, focusing, was concluded in the last quarter of 2009 with the approval of the design. The second part of the BE CDR

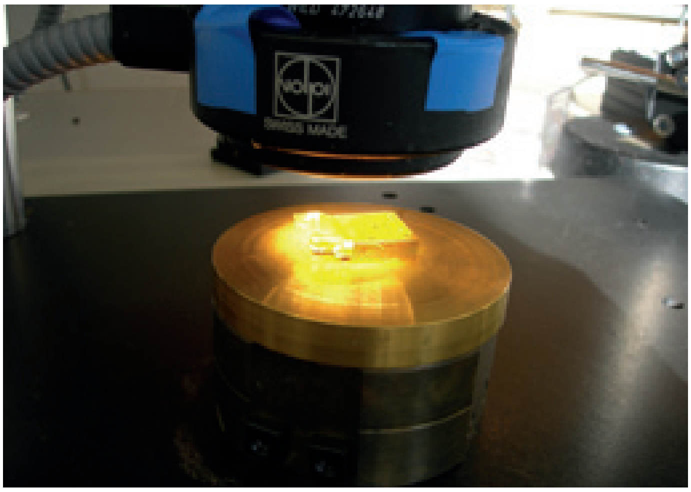
Component	Supplier	Total	Received
Photomixers	RAL	500	240
Digitiser	Univ. Bordeaux	281	210
Digitiser clock	IRAM	68	68
Opt. transmitters multiplexers	ESO	80	80
Optical fibre patch cable sets	Huber+Suhner	2	2
Fibre patch panel	Huber+Suhner	2	2
Opt. de-multiplexers and amplifier	ESO	80	80
Tunable filter	Univ. Bordeaux	554	554

ALMA BE system components provided by ESO.

ESO/H. Kurlandczyk

Cleanroom operation for photomixer production.

ESO/H. Kurlandczyk



Photomixer gold-plated block on microscope ready for photodiode.

addressed the photonic local oscillator system and was successfully concluded in March.

The ALMA correlator is a specialised computer, operating at the AOS, which can process data at a rate of the order of 10^{15} operations per second. The third of four correlator quadrants was installed in 2010 in the technical building at the AOS by NRAO.

Testing of the correlator quadrants at the AOS continued in 2010 with signals from the antennas. This testing has confirmed that no issues related to the peculiar site conditions (which could not be pre-tested in the lab, e.g., cosmic rays) are likely to affect its operations.

The ALMA correlator contains 512 Tunable Filter Bank (TFB) cards, a sophisticated high speed digital filter processor based on state-of-the-art field programmable gate array technology. All TFB cards, including spares, were delivered by the University of Bordeaux under an ESO contract.

ALMA computing

The ALMA computing team is developing software that covers nearly all aspects of ALMA's activity: creating and executing observing projects on behalf of proposing astronomers, managing the monitoring and maintenance of the observatory's antennas, correlators and other hardware, and making the data available to the proposer and subsequently to the astronomical community and the general public via the internet.

The computing team made significant strides towards the software system that will support ALMA Early Science in 2011:

– by developing and deploying software releases R7.1 and R8.0 (that are in constant use by the CSV and the AIV teams) and a user portal for general access to the data was brought online in Santiago;

– by developing and deploying several tools essential for the support of Early Science, testing them live in two integrated tests conducted by the ALMA Department of Science Operations (DSO) with the participation of DSO and community astronomers; a tool to help reviewers evaluate proposals for ALMA observing time; a tool to configure the ALMA online hardware and software, the ALMA Quality Assurance application; the shift log tool for operators and astronomers on duty, and a project tracker to allow staff and researchers to follow the progress of an observing project throughout its life cycle, as shown in the figure below.

The ALMA project tracker, showing the execution of an observing unit (Scheduling Block) from the time it is first ready to run, through its execution, the processing of its acquired data, up to verification of its quality by ALMA staff.

– by enlisting the help of Human–Computer Interface (HCI) experts from two French research institutes (Institut National de Recherche en Informatique et en Automatique [INRIA] and Conservatoire national des Arts et Métiers [CNAM]) to make the ALMA operator interface both intuitive and capable of handling ALMA's 66 antennas and more than 2000 baselines. At the start of the Chilean summer, the joint ESO–HCI team led brainstorming workshops with operations staff at the OSF to understand their needs and evaluate possible solutions. The team exploited the user feedback received to prototype the top-level interface shown in the figure below, and presented it to the staff, where it was received with enthusiasm and a host of additional requests for the final version that will be delivered in 2011.

In addition, the ALMA archive, developed at ESO, is now able to ingest scientific and engineering data 24 hours a day.

System engineering and integration

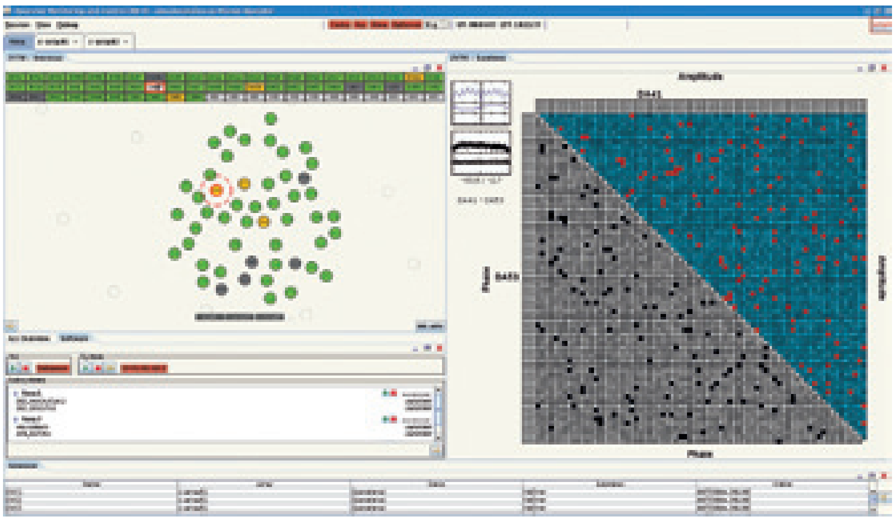
The ALMA System Engineering (SE) team continues to work on the system design. ALMA is now entering the phase in which work is shifting more and more to requirements verification, analysis, troubleshooting and acceptance. In parallel, project-level documentation is kept up to date. The required technical oversight and support is given to all technical fields and teams. SE personnel participate or chair all design reviews and acceptance events. Major reviews in 2010 included the FE CDR and several reviews of the ALMA infrastructure. Several antennas, FE assemblies, BE articles, one correlator quadrant, antenna stations, and miscellaneous other articles have been accepted.

A specific SE task is the verification of the ALMA cryogenic system. Tests at the AOS continued to verify the performance of the cryogenic and vacuum system under the very harsh operational conditions. The design for the compressor enclosures was completed and seven sets were manufactured and delivered. The contract for the enclosure production was placed and the first unit was accepted. Several cryogenic subsystems were installed on antennas and are operating well.

The ALMA computerised maintenance management system was handed over to the ALMA observatory.

Product Assurance continued to organise most of the acceptance reviews and is carrying these out in close co-operation with SE. Product assurance audits were performed on antenna subcontractors, the antenna integration activities at the OSF and also on FE subcontractors. Processes were further optimised to allow a rapid treatment of action items and non-conformances.

The integration team in Chile was reorganised and is now fully integrated into the ALMA Department of Engineering. SE supports the integration team on various system aspects.



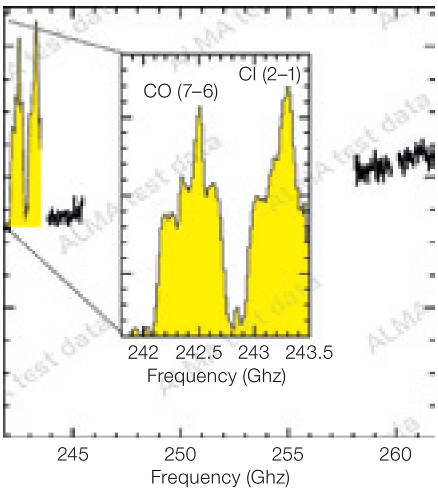
The operator's interface to the ALMA observatory. On the lefthand side the antenna layout enables users to see at a glance which antennas are working correctly and which are in an offline, a degraded or an error state. The righthand panel shows a matrix whose rows and columns are antennas, and whose cells represent baselines connecting each pair of antennas. Colour-coded cells indicate out-of-norm amplitude (red) and phase (black) values.

ALMA science activities

The science activities related to the CSV of the scientific performance of the ALMA hardware have followed and exploited the increasing availability of more functional antennas and infrastructure at the high site. In January, with three fully equipped antennas working as an interferometer, CSV activities officially started at the AOS (see *The Messenger*, 139, 52). The CSV team has steadily tested and improved the performance of the whole ALMA system. This process culminated in the production of the first ALMA test data in the second part of the year (see figure on p. 58 and *The Messenger*, 142, 17). In 2011, the CSV team will focus on obtaining science demonstration data at the AOS and refining the calibration plan, in addition to continuing the commissioning activities on the equipment that is being delivered. The first call for Early Science proposals is planned be issued in the first half of 2011, for observations towards the end of the year. Several expert visitors from European institutes are actively participating in the CSV activities in Chile in addition to ALMA, ESO and partner institute staff.

The joint effort with APEX to explore the use of asteroids as calibrators, in coordination with ESA's Herschel and Planck missions, has been continuing and a substantial amount of data has been collected with LABOCA in 2010. The data are currently being analysed in the framework of theoretical thermo-physical models of asteroids with encouraging preliminary results.

Several workshops, meetings and tutorials on ALMA science were organised in 2010. The scientific potential of combining ALMA and VLTI observations to study



ESO/ALMA CSV Team

ALMA test data on the strongly lensed submillimetre galaxy SMM J2135-0102 discovered by APEX (see p. 19). The broad instantaneous frequency coverage offered by ALMA allows the simultaneous observation of the fine structure line of atomic carbon, the $J = 7–6$ line of carbon monoxide as well as the strong dust continuum.

the formation, evolution and death of solar-mass stars was the focus of a meeting held in Garching in March (see *The Messenger*, 140, 53). The possibilities offered by ALMA when fully equipped with band 5 receivers were reviewed and discussed in Frascati in May at a meeting jointly organised by INAF, ESO and the EC-FP6 ALMA Enhancement Programme (see *The Messenger*, 141, 41). The impact of Herschel surveys on ALMA Early Science was the focus of a meeting held in Garching in November (see *The Messenger*, 143, 52). The preparations for Early Science and associated opportunities were presented at JENAM 2010 in Lisbon and at several meetings organised by the ARC nodes in various European countries.

The process for the ALMA development plan started in 2010. ESO issued a call for ALMA development plan studies, and several groups proposed ALMA upgrades to be studied with the goal of implementing them to keep ALMA at the forefront of (sub)millimetre astrophysics. Studies were selected with the scientific input from the ALMA European Science Advisory Committee to be carried out in 2011 and 2012.

ESO/José Francisco Salgado (josefrancisco.org)

In this picture, taken at sunset looking toward the southeast, are four ALMA antennas at the Operations Support Facility. The ALMA array will initially be composed of 66 antennas, provided by the different partners. When the antennas are delivered by the partners to ALMA, they are tested and inspected before their final acceptance.

European Extremely Large Telescope

The E-ELT Phase B concluded in 2010 with the successful completion of the Construction Review in September. This demonstrated that the baseline 42-metre project is ready to move forward towards construction. The review team had received a full construction proposal and had been given access to over 300 supporting documents and reports. The feedback was very supportive and the recommendations have been adopted.

The Science Case was finalised for the construction proposal. Together with its ancillary documents it was reviewed in September during the Phase B external review. Two key science outputs from Phase B were released to the public: the Design Reference Mission and Design Reference Science Plan reports are now publicly available on the E-ELT web pages. The Science Office was involved in the review of the Phase A Instrumentation Studies and assisted in bringing them to conclusion. We have now started work on the points identified by the external review board, in particular on the issues of the high emissivity of the E-ELT and the performance of the Single-Conjugated Adaptive Optics (SCAO) system under high wind conditions.

The Observatory Operation Plan document, which includes both site and science operations, has been finalised and reviewed externally. It takes into account the choice of Armazones as the future E-ELT site. The plan takes as reference the VLT science operation model and the engineering and maintenance models. It also takes into consideration aspects that are specific to the E-ELT, making important changes in areas where technology will make major improvements possible by the time the E-ELT enters operations. The plan identifies several possible synergies with Paranal and with the Garching segment of science operations and treats the E-ELT in a natural way (as “just another telescope” added to the Paranal Observatory).

The systems engineers for the project continue to ensure that configuration control is maintained, in particular at the interfaces between the telescope and the instruments, as well as for those issues that have an overall impact on observatory operations. Common systems engineering tools are used by the various systems engineering offices (Telescope, Instrument and Operation) acting in the different areas of the project. In addition, systems engineering has developed the support strategy for E-ELT, coordinating activities so as to ensure maximum synergy with Paranal.

Front End Engineering Design (FEED) studies for the E-ELT dome have been reviewed and have provided firm fixed-price offers for the construction of the dome. An independent contractor assisted with the review of the design work by the main contractors. An additional consulting engineering company was contracted to review the requirements generated by ESO for the dome and the erection sequences. Further external review of the erection sequence was provided. To assist in understanding the effects of seeing and cooling, the project concluded their analysis of the results of the computational fluid dynamics studies undertaken by the FEED contractors, and a consulting company concluded an analysis of the wind tunnel results. This use of external consultants has been key to ensuring that the project meets its requirements, is efficient to manufacture and has reduced risk as regards cost.

The FEED of the main structure was concluded and delivered along with a comprehensive set of documentation, including all design and analysis information. All of this information has been reviewed by ESO, its consulting engineers and the external review committee. The design meets the required specifications. The FEED included a firm fixed-price offer for the construction.

The control system for the telescope and subsystems has been fully designed and reviewed. The baseline solution relies on industrial products and avoids custom solutions. It only uses specialist software at key interfaces. This solution has been further validated in reviews carried out by industrial providers. Prototyping has now concluded in the areas of timing systems, real-time computing, networking, local control and interlocks. The E-ELT baseline solution has now been adopted by Paranal Observatory as the path forward for the evolution of the existing system in areas where obsolescence demands changes to the existing system. One UT enclosure is now operating using an E-ELT control system. This work is being undertaken under the auspices of the Software Development Division of ESO in close collaboration with Paranal and the E-ELT Project Office. It is the intention to further develop this work towards HVAC and axis control.

In the area of wavefront control, the two adaptive mirror unit contracts are closed, and the firm fixed-price offers have been delivered to ESO. Prototype systems have been built and tested to demonstrate techniques and prove technological solutions. The risks identified during this work, in particular the cooling issues and the use of reinforced carbon fibre as a back plate are being mitigated by continuing work.

The M5 mirror electromechanical unit FEED has concluded with the close support of the E-ELT control engineers. Following this, the system performance was satisfactory and acceptance has been granted. The prototype system has been delivered to ESO. The project is satisfied that it has achieved a key success in the control of the M5. A viable solution for this very light mirror has been identified and additional work undertaken to provide a good basis for an extremely light-weighted glass mirror. Further exploration of a silicon carbide solution is warranted within a risk mitigation strategy and this is currently being contracted.

Following a first paper study of fast detectors and a second prototype pixel development, both with multiple suppliers, ESO tendered for the production of a prototype scale-one device meeting the telescope’s needs. The procurement has been contracted for this work and been partially funded by Opticon.

The detailed analysis of the emissivity and scattered light performance of the telescope was updated following the recommendations of the mid-term review. The final report was provided to the external review and updates to the telescope requirements have been recommended.

The production of the prototype primary mirror segments is well advanced. The

The M5 electromechanical unit on stand in Garching, ready for the Council Meeting.

Segment integrated with its support before final polishing.

first segments have been integrated with the mirror supports manufactured under FEED contracts and polished further using ion beam polishing. The manufacture of the M1 primary mirror test system is advancing with the integration of the facility and the test setup. In addition, to ensure that all polishing options have been examined, contracts have been offered to demonstrate the efficacy of alternate polishing technologies and mitigate the risk resulting from a limited source of supply for the polishing.

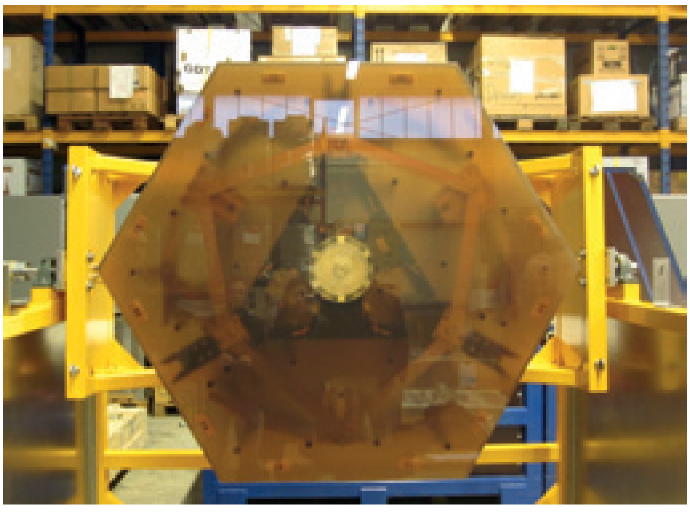
Work on the mirror segment support systems has been completed. The mirror support contracts have concluded with the delivery of prototypes and three of these have been integrated with the mirror substrates as described above. The position actuator contracts have resulted in three actuators each. The measured performance is limited at this time by the stability of the testing equipment. The project will integrate the actuators into the primary mirror segments provided by the segment suppliers. This will include the fitting of edge-sensor prototypes. An additional contract for the provision of three more edge-sensor pairs has been put into place. The mounting flanges for the edge sensors have been integrated onto the segments. Further lifecycle testing of the edge sensors is planned.

The secondary mirror (M2) subsystem, which includes the mirror and M2 support and control assemblies, is currently being designed under a FEED contract. Three industrial studies for the production of the secondary mirror blank have concluded, two in Europe and one in the USA.

A baseline design of the pre-focal stations has been completed. The prototype mirror actuator, which controls the mirrors within the pre-focal station, has been tested in industry with ESO staff. The activity was particularly fruitful as a number of issues were identified. The work has concluded with the preliminary design.

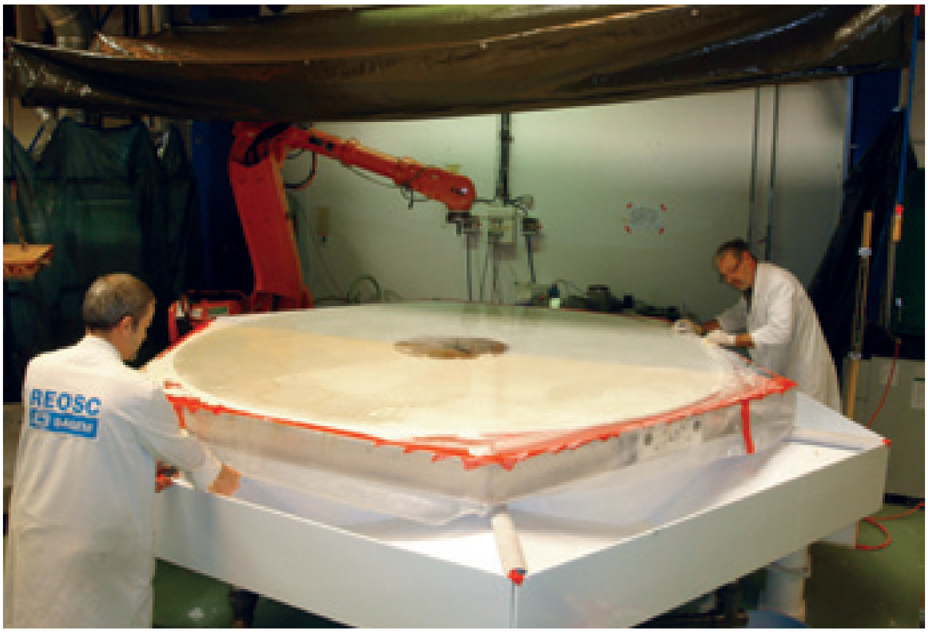
The instrumentation and post-focal adaptive optics activities in Phase B are planned and carried out within the Instrument Team of the E-ELT. The work at ESO is executed by staff seconded to the E-ELT Programme from the Instrumentation Division and is supported by staff of the Telescope and Technical Divisions.

In the last year, the activities of the Instrument Project Office have mainly



M1 segment integrated on stand in Garching.

REOSC Sagem



M4 thin shell prototype 2.7 metres in diameter, 2 mm thick.

concentrated on the definition of the instrument–telescope interfaces and on the Phase A studies for E-ELT instruments. In the most recent six-month period, the reviews of the Phase A studies have been completed with the outcome that all were passed by the Review Boards. This result generates confidence in the future successful delivery of instruments to the E-ELT from the large and capable community of instrument builders within the ESO Member States.

Following the conclusion of the reviews, the Instrument Project Office has prepared the Instrumentation Plan for the E-ELT based on the advice of the ESO scientific and technical committees and the outcomes of the reviews.

The project saw it as due diligence to address in more depth some of the points raised at the review through a delta Phase B that is now underway. The goal of the delta Phase B, which will last until mid 2011, is to reduce risk and the cost of the E-ELT by exploring variations of the current design and assessing their science impact.

E-ELT instrumentation

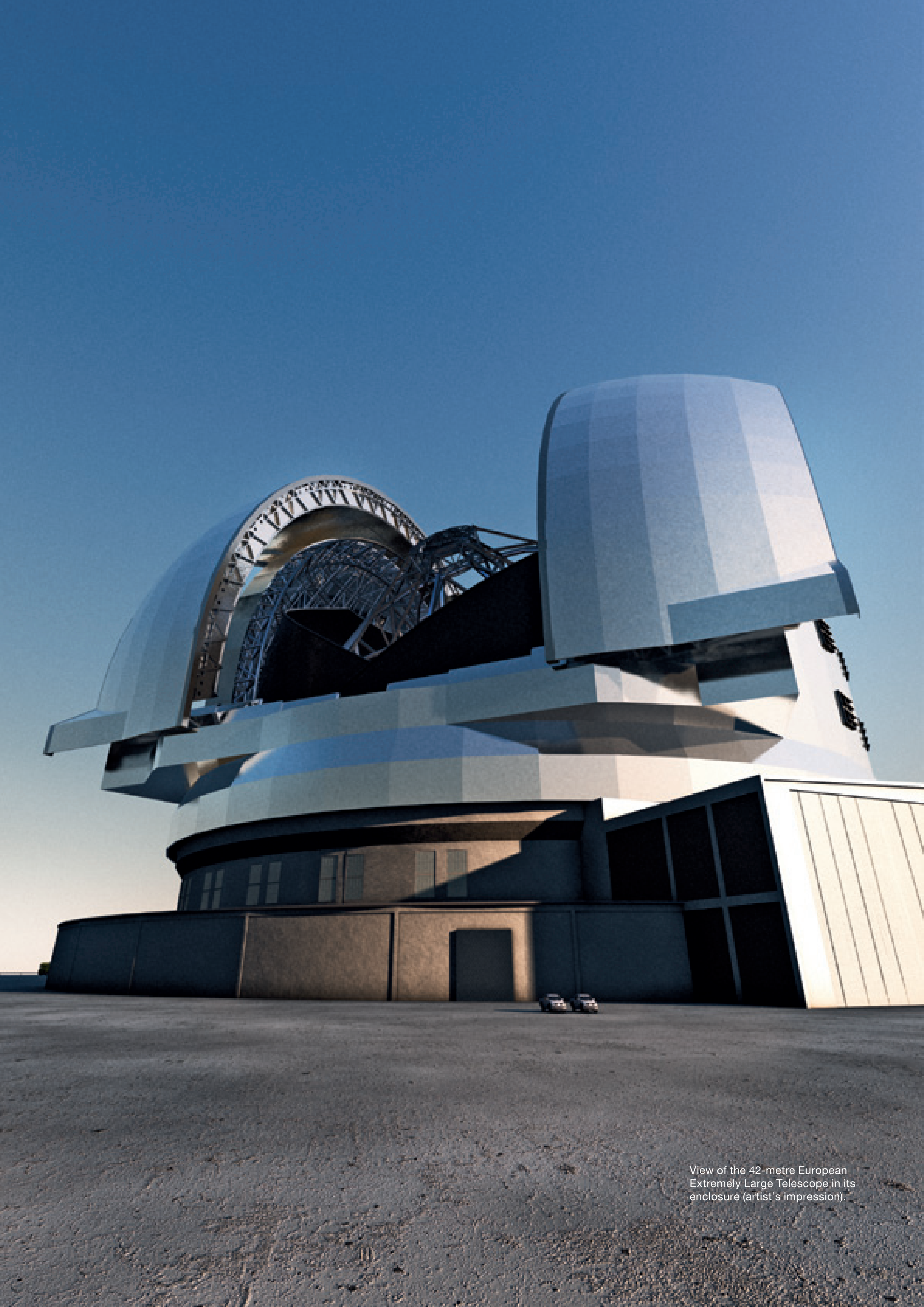
An important milestone in the development of the plans for the new telescope was reached in 2010 with the selection of the instruments that will be the first to be used on the E-ELT. Over the previous three years, ESO has worked with the community of instrument builders in the Member States and Chile to develop ideas and concepts for nine possible future instruments and two adaptive optics facilities.

The purpose behind the undertaking of this major study, which has involved more than 300 scientists and engineers in 40 institutes, was to develop ideas for the astronomical observations that would be carried out with the telescope and to start the design of the instruments that could perform them. This enabled an understanding of the cost, risks and timescales for building them and the exploration of the performance that will be required from the telescope to deliver the scientific results.

The diverse selection of instruments studied included wide-field optical spectrographs capable of measuring spectra from hundreds of objects simultaneously over the full field of view of the telescope; cameras and spectrometers exploiting the sharp images delivered with the telescope in the infrared using adaptive optics; an infrared spectrograph that combines the technique of integral field spectroscopy with the new concept of multi-object adaptive optics to study clusters of galaxies in fine detail; an imaging spectrometer observing at mid-infrared wavelengths which will take advantage of the excellent high and dry site selected for the telescope; an instrument specialised in the detection and characterisation of exoplanets and a very high stability optical spectrograph that is expected to be able to measure the expansion of the Universe directly over a timescale of 30 years.

Each instrument project delivered a final report of 500–1000 pages describing their instrument concept and the scientific programme it would carry out. These were reviewed by ESO with help from external experts (from outside the ESO Member States) and the final conclusions presented to the ESO advisory committees. The selection of the first instruments was based primarily on the scientific programme that they will deliver and took into account that these instruments will be used in an era when astronomers will already be making major discoveries with new facilities such as ALMA and the James Webb Space Telescope.

The first instruments for the E-ELT will be a near-infrared camera, designed to exploit the diffraction limit of the telescope, and an optical to near-infrared spectrograph. These are based on the initial studies for the MICADO and HARMONI instruments. The adaptive optics facilities required by the instruments will also be built. Following these first light instruments, new instruments will be selected every two years. This allows ESO to build an instrument programme for the E-ELT that will respond to developments in other areas of astronomy, ensuring that the ESO community remains at the forefront of optical/infrared ground-based astronomy.



View of the 42-metre European Extremely Large Telescope in its enclosure (artist's impression).

Engineering

Technology Division

In July, a Directorate of Engineering was created, incorporating the two divisions that currently provide most of the engineering services to the whole organisation, namely the Software Development Division and the Technology Division. Support is provided in the following engineering areas: control systems, electronic systems, information technology, laser systems, mechanical systems, optical engineering, software, structural and systems analysis.

The directorate was created in response to ESO's plan to consolidate the implementation of a matrix structure for all engineering services. Its mission is to deliver the requested services with high quality and in a cost-effective way. This is now achieved by optimising the allocation of resources, developing and maintaining engineering standards that meet the project requirements, and promoting synergies between projects where it is applicable.

The Directorate of Engineering plays an instrumental role in the clarification of roles and interfaces between projects and the matrix as well as the required optimisation of business processes.

The 3.6-metre telescope at ESO's La Silla Observatory. La Silla, in the southern part of the Atacama desert of Chile was ESO's first observation site.

By supplying engineering support and solutions to most ESO projects, TEC is reinforcing the matrix approach that ESO is applying to the whole organisation. A highlight has been the provision of most of the engineering input for the E-ELT construction proposal that passed its external review in September. During the year, TEC hired several new engineers in order to strengthen capabilities, to follow technological growth and to support the various projects in several disciplines such as electrical, laser, mechanical and control systems. This section gives examples of the engineering tasks that have been carried out.

E-ELT

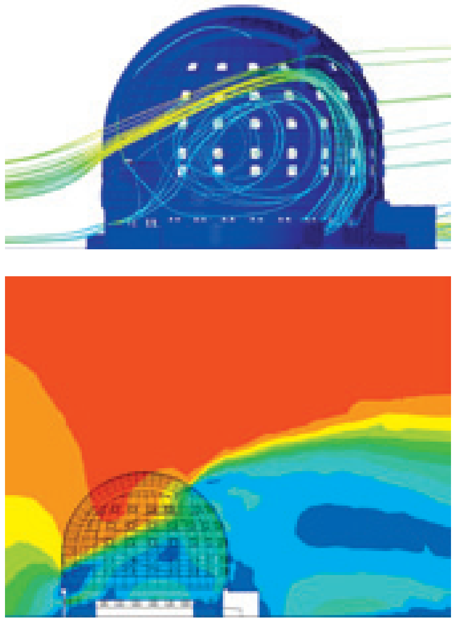
Finite Element Analysis (FEA) of the E-ELT main structure, including detailed subunit models, was performed by the Structures and System Analysis Department. The aim was to investigate the impact of the various structure designs on the overall optical performance and error budget. Thanks to these analyses, we have ascertained that the local wind acting on the M2 unit makes a major contribution to the error budget and have also identified the need for a seismic isolation system to reduce effect of the "shaking" energy of an earthquake on the telescope and its subsystems.

Optical performance analyses of the E-ELT have been carried out to simulate the propagation of numerous error sources, supported by ray-tracing models with temporal and spatial resolutions adapted to the spectral properties of the errors.

Computational fluid dynamics analyses of the E-ELT dome were performed to assess the wind flow conditions and their influence on telescope seeing. This work resulted in the decision to implement louvres in the dome foundation design.

FEA support was provided to verify the integrity of ASSIST under earthquake loads and to simulate the sensitivity of the M1 segment edge sensor to temperature changes.

The Control System Department has provided extensive support to the E-ELT in terms of analysis, contracts management and follow-up of all subsystem contracts. It has also led the work on the definition of the instrument control system and has managed several actuator prototype contracts.



Streamline distribution in the E-ELT dome structure (top); Velocity distribution in the E-ELT dome at the symmetry plane (bottom).

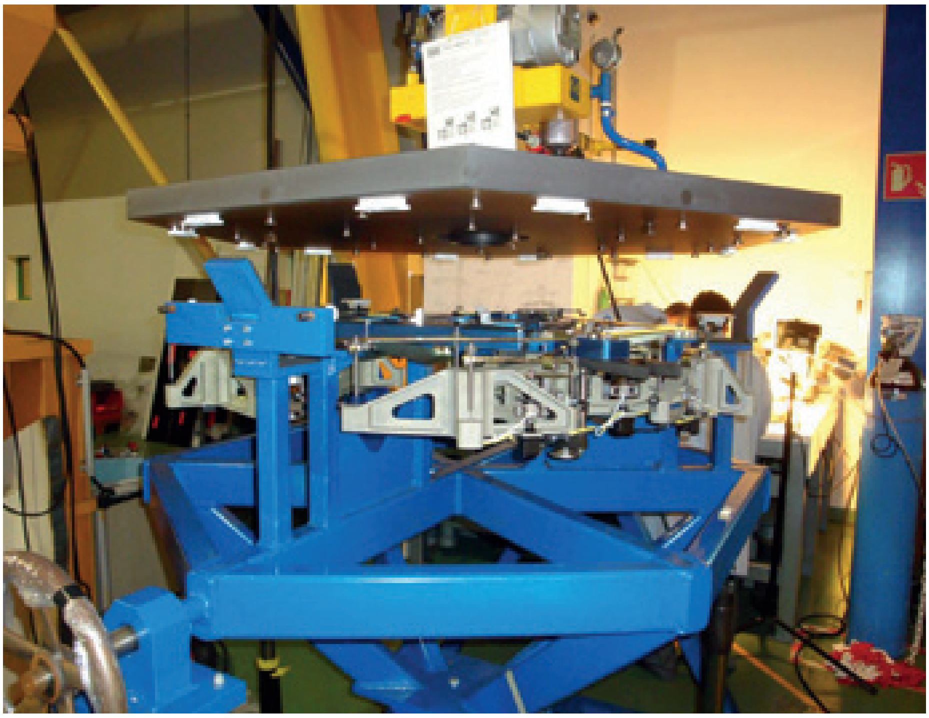
We are also involved in the E-ELT Phase-B demonstrator technical contract follow-up, focusing on the edge sensor contract.

The Mechanical Systems Department has provided support to the running of various E-ELT FEED studies. These include the handling and lifting requirements; cooling systems for the dome and telescope structure; infrastructure; and M1 segment supports. The top figure on p. 66 shows one M1 segment being integrated with its support structure at SAGEM.

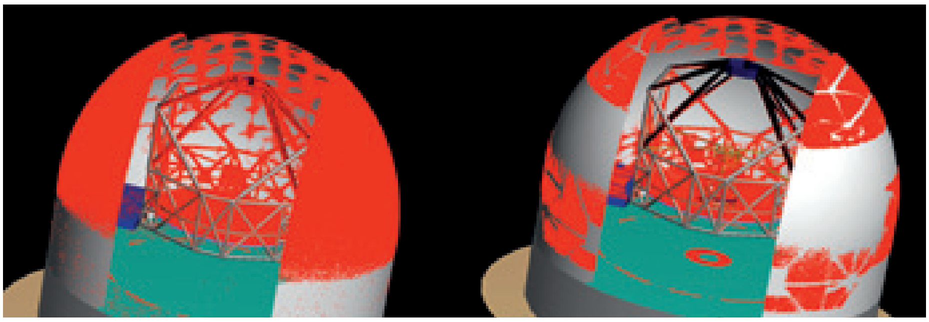
The Optical Department has continuously monitored and adjusted the optical design of the telescope to take into account the results of the various subsystem design contracts. A new optical design has been done with the tertiary mirror of the E-ELT located at the same height as the primary mirror.

The effects of stray light and emissivity have been studied with a dedicated software package. The bottom figure shows in red the surfaces of the dome and the structure that can be seen from the focus through, as examples, the mirrors M1 and M4. Assuming an emissivity of 3% for the mirrors and 20% for the structural elements, the total thermal self-emissivity is, including dust scattering, of the order of 23% of the radiation that the mirrors would emit if they were blackbodies.

Significant progress has been made on the manufacture of prototypes for the E-ELT segments, in particular on the quality of the surface at the edges. The mirrors are polished first into a circular shape before being cut into their final hexagonal shape. New technologies for the optical measurement of steps between adjacent segments have been tested at the VLT. The test bench has been reinstalled in the optical laboratory and upgraded to test, in addition, the impact of adaptive optics corrections and a potential double segmentation on the step measurements.



One E-ELT M1 segment being integrated with its support structure at SAGEM.



This shows (in red) the surfaces of the dome and the structure that can be seen from the focus through, as examples, the mirrors M1 and M4.

VLT/VLTI

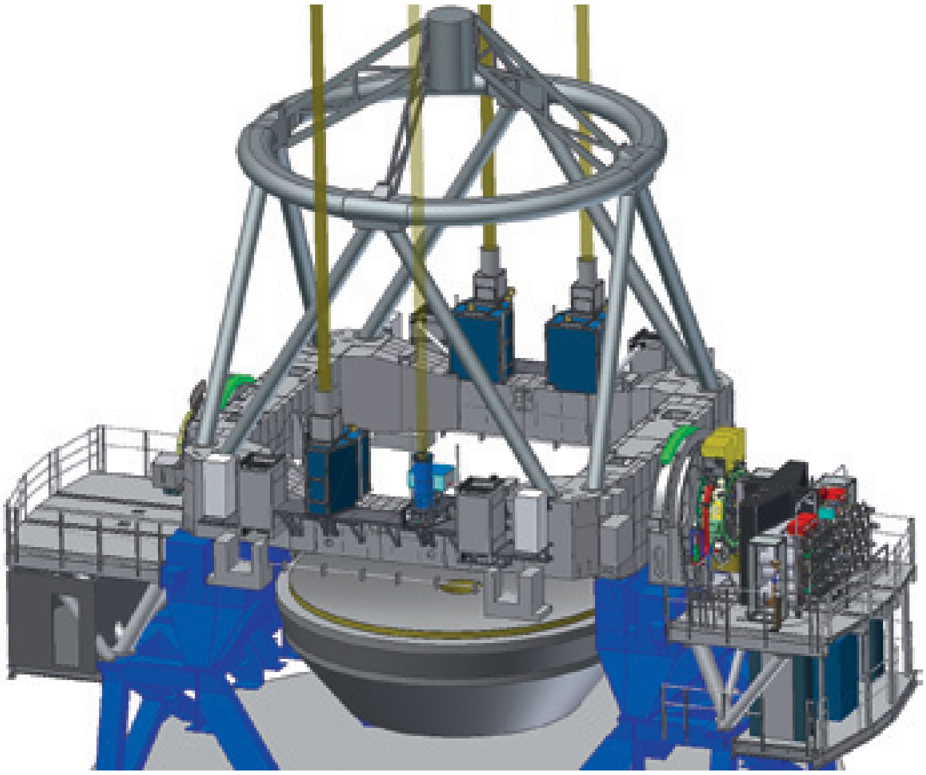
For the La Silla Paranal Observatory, we have participated in the VLT enclosure control system upgrade, performed hazard analysis and the design of a safety and interlock system for the 4-Laser Guide Star Facility (4-LGSF). We have also provided support to the VLTI in the form of a detailed analysis of the control systems of PRIMA and the auxiliary telescopes.

With the aim of supporting the VLT instrumentation plan, the Electronics Department has designed, developed and produced a complete toolbox extending from motion controllers to test benches. Batches of 50 motion controllers, 10 DC and 10 stepper test benches were produced in 2010.

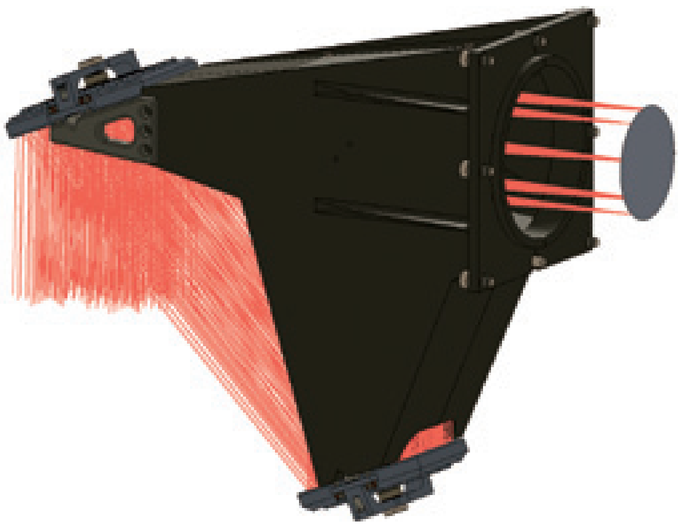
The Mechanical Systems Department has provided designs for several Adaptive Optics Facility projects. A CAD model of UT4 with the proposed designs of GALACSI, GRAAL and 4-LGSF is shown in the top figure on p. 67.

The AO system for the VLT second generation instrument MUSE is called GALACSI and it is mounted on the Nasmyth rotator of UT4. The mechanical design of this was completed and the hardware is currently being delivered to the integration hall in Garching. MUSE itself requires a change in the back focal length of the UT4 Nasmyth focus. To facilitate this, a new derotator guider arm with two extra fold mirrors has been designed using silicon carbide instead of the existing beryllium.

The AO system GRAAL (see bottom figure on p. 67), which is used for HAWK-I, is mounted on the other UT4 Nasmyth rotator. The design and manufacture of GRAAL was subcontracted out, but our engineers were responsible for providing technical support for its design and manufacture. This figure also shows the laser tracker used to measure the position of key points of the instrument. A Wavefront Sensor (WFS) camera is required for both GALACSI and GRAAL and these have all been designed and are currently being tested by our engineers.



A CAD model of UT4 with the proposed designs of GALACSI, GRAAL and 4-LGSF.



The AO system GRAAL, used for HAWK-I. The red lines show the laser-tracker used to measure the position of key points of the instrument.

A new 4-LGSF is being designed by our engineers. This is currently at the stage of a Final Design Review. The Laser Department has continued to work on the final design of the 4-LGSF for the new AOF and procurement of the main outsourced subsystems is underway. A European patent was granted for the narrowband Raman fibre amplifier technology developed by our department; this technology has been licensed to two companies and it will be used in the 4-LGSF. We also contributed to the laser source part of the E-ELT construction proposal. In our development labs we have constructed a 10 W laser in-house for high-power testing of optical coatings and the optical tube assemblies of the 4-LGSF. This and other developments will be used to support the assembly integration and test phases of our projects and continue to advance towards the next generation of laser guide stars.

ALMA

Full support has been given to the ALMA antenna acceptance test. Control engineering support to ESO standardisation includes design and definition of a programmable logic controller-based standard cryogenic and vacuum control system. Contributions were made to the ESO Control Engineering Handbook that describes the essential definitions and procedures necessary when designing or specifying control systems.

The department is also providing expertise in the domain of Electromagnetic Compatibility (EMC) tests, electrical safety and CE-marking. During this year, efforts were focussed principally on the first European ALMA antenna acceptance process.

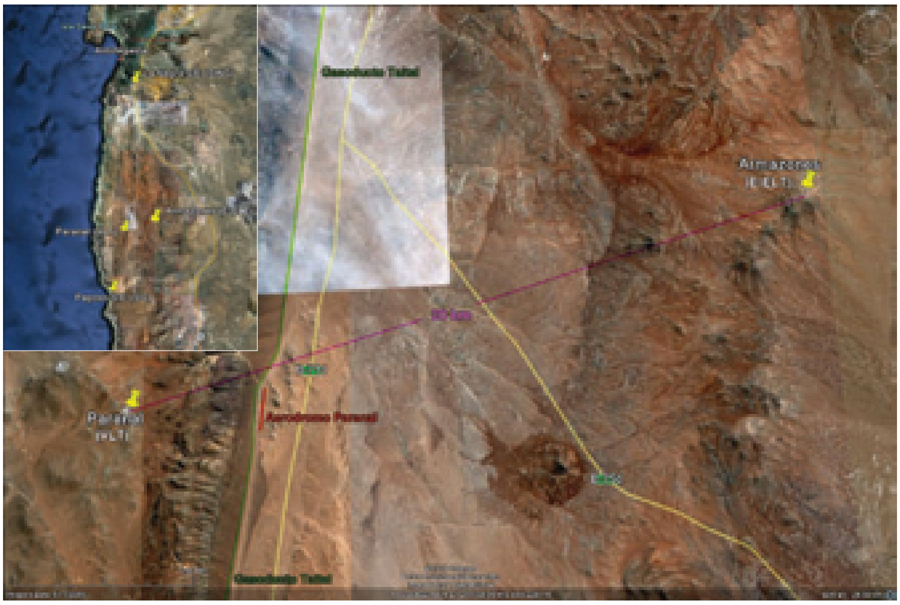
The Electronics Department has provided extensive support to the ALMA project concerning the upgrade and production of the Alma ACD system.

The Mechanical Systems Department has provided two engineers on temporary transfer to Chile. They are responsible for the antenna foundation/station installation and for setting up and running the cryogenic procurement. Other members of the mechanical group have provided vital support by monitoring the antenna production. The build-to-print contract for two beam scanners, used to test the stability of the cartridges, has been managed.

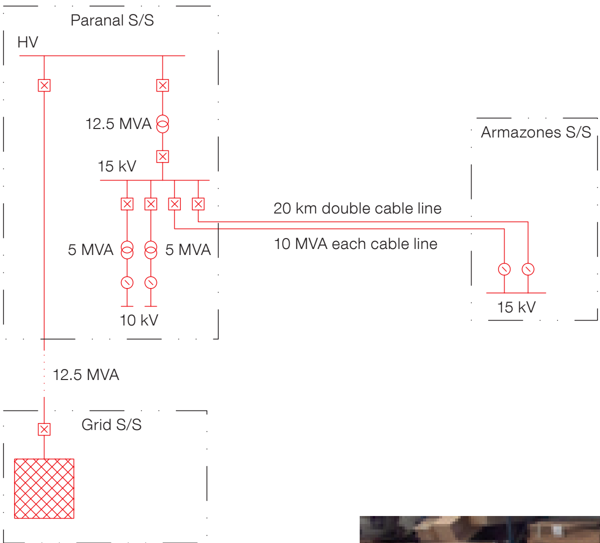
Site support

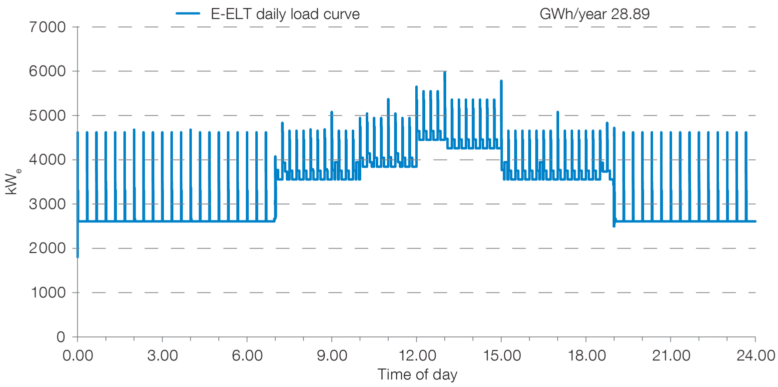
The Electronic Department of TEC has identified various options for the electrical power supply connection to the Chilean national grid for the whole Paranal Observatory including the future E-ELT on Cerro Armazones.

At the end of the year, we organised and prepared an exhibition of E-ELT prototypes for ESO Council Members in the ESO Headquarters storage hall. This was also an occasion to inspire ESO staff with a display of E-ELT prototypes, presenting the assembled and available pieces (most in scale 1:1) of our future giant telescope.



ESO Observatory connection plan to the Chilean grid.





ESO staff at the E-ELT exhibition prepared for Council members.

Star trails above the VLT on a long exposure photograph.

Software Development

As in previous years, the challenge for the SDD in 2010 was to provide each project and operations team with the requested resources and products, whilst keeping an eye on the quality of the work being done, the standards in use and, where appropriate, the commonalities between projects.

The General IT Department

Being responsible for providing general Information Technology (IT) services to the whole organisation, the IT Department is in charge of the e-mail infrastructure. A concept and architecture for a unified collaboration and messaging system based on MS Exchange was developed in 2009 and deployed (at least partially) in 2010. As a result, users will be able to share calendars and book meetings in a unified manner across the organisation. The installation and deployment of the Web Content Management System (Day CQ) also progressed. Most of the static pages have been migrated to the new system. This application will allow users who have little knowledge of web programming to develop and maintain the pages for which they are responsible.

A primary focus of the IT department was, and will continue to be, improving service quality and the resulting user satisfaction. A change management process was defined and put in place during the year. It ensures that standard procedures are followed for the handling of all changes in the IT infrastructure to minimise the number of problems following upgrades.

The Software System Engineering Department

The Software System Engineering Department provides the development teams with software engineering services such as the environment and tools to support software lifecycles, quality assurance and control. The department is also in charge of integrating software modules and preparing and validating releases before they are delivered to the customer.

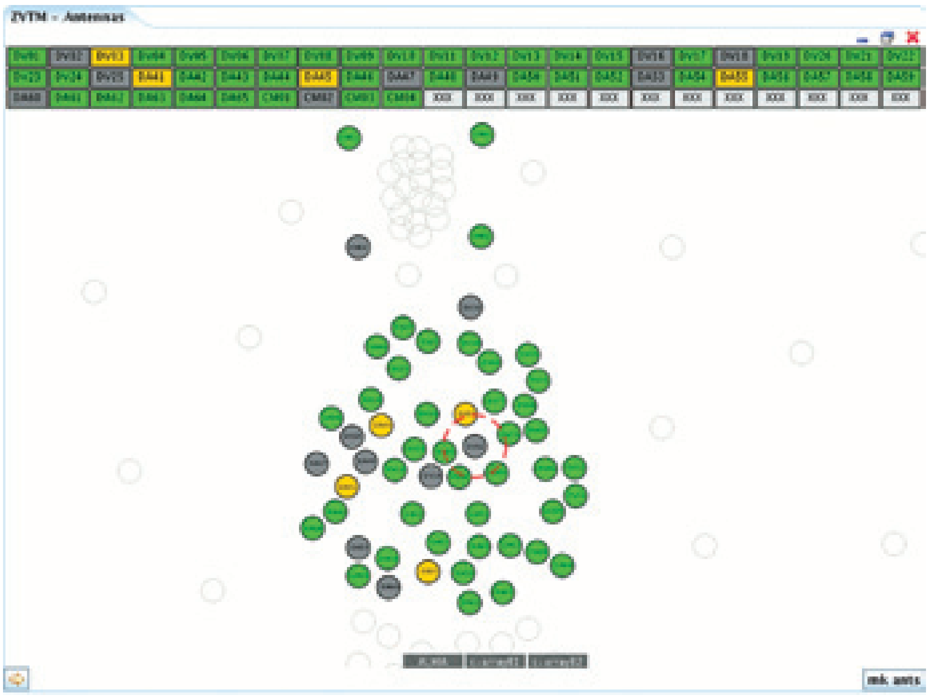
In order to promote commonalities between projects where appropriate, a number of working groups have been created within the department. In 2010, these groups tested virtualisation platforms, looked at tools that could help the testers automatically verify and validate Graphical User Interfaces (GUI) and web applications and create a plan for migrating the currently used version of the control system at the VLT (cmm) to the newer system (svn) that has been chosen as a baseline for the E-ELT.

The team was heavily involved in the integration of VLT and ALMA releases as well as in the verification and validation of ALMA and VLT data flow software. As software integration and software validation and verification will be very important activities for the E-ELT, the team commenced, together with the E-ELT Project Office, to devise plans and strategies for these activities.

The Control & Instrument Software Department

The Control & Instrument Software Department shares its software development activity between the VLT/VLTI observing facilities, ALMA and the E-ELT. As for the La Silla–Paranal instruments and facilities, much effort was expended in following up the contracts for the second generation VLT/VLTI instruments, designing control software for some for the AOF subsystems (e.g., 4-LGSF, GRAAL, GALACSI), and preparing a new release of the VLT software.

The ALMA software, from the low-level ALMA common software to the high-level GUI — the Executive, which is the operator interface to the ALMA system — continued to be extensively used and tested during the commissioning of the antennas at the OSF. We are all looking forward to bringing the software into operation to enable a successful Early Science programme!



A closer look at the ALMA operator master console with the new generation, context sensitive zoom and geographical information (also see p. 57).

The control system for the E-ELT will be a complex entity that needs to be built with a clear systems approach. The Control & Instrument Software Department, in collaboration with the E-ELT Project Office, continued to work on Phase B of the project. In addition, the VLT control was launched with its first milestone, the upgrade of the enclosure control system. The aim of the project is to test the E-ELT technologies (LabView, DDS, programmable logic controllers [PLCs]) in the field, to provide the VLT with an upgrade path for the long term that solves the obsolescence issue and to train the engineers on Paranal in readiness for the commissioning of the E-ELT. The enclosure control system is Ethernet-based. It uses a specialised middleware based on data distribution for the communication between the telescope control system workstation and the PXI local control unit and the OPC industry standard for the communication between the local control unit and the PLC.

The Data Flow Infrastructure Department

The department continued to develop tools for handling data generated by astronomical survey programmes using VISTA and, ultimately, the VST. The PIs of large programmes at ESO are requested to deliver their final data products to the ESO science archive at the time of publication of the results. The department has developed an application called Phase 3 submission infrastructure that facilitates this submission process. In addition, a sophisticated access control model can be used by the PIs to delegate upload permissions to people who are registered within the ESO portal. The same model will be used in the future to support delegation in Phase 2 (e.g., in the preparation of Observation Blocks) using P2PP.

Development and testing were carried out in preparation for the deployment of the next generation request handler. This is a modern web application for online dataset retrieval from the ESO archive. It is integrated with the single sign-on to the user portal, supports the standard and PI pack requests and maintains a complete request history. It provides an efficient download manager using parallel streams to optimise network throughput and operates an intelligent resume after network breakdown. In conjunction with the ACE web application, it allows access permissions to be delegated to other users. As a good example of exploiting the synergy between projects, some of the code used for the development of the ALMA request handler is used for this tool.

The Pipeline Systems Department

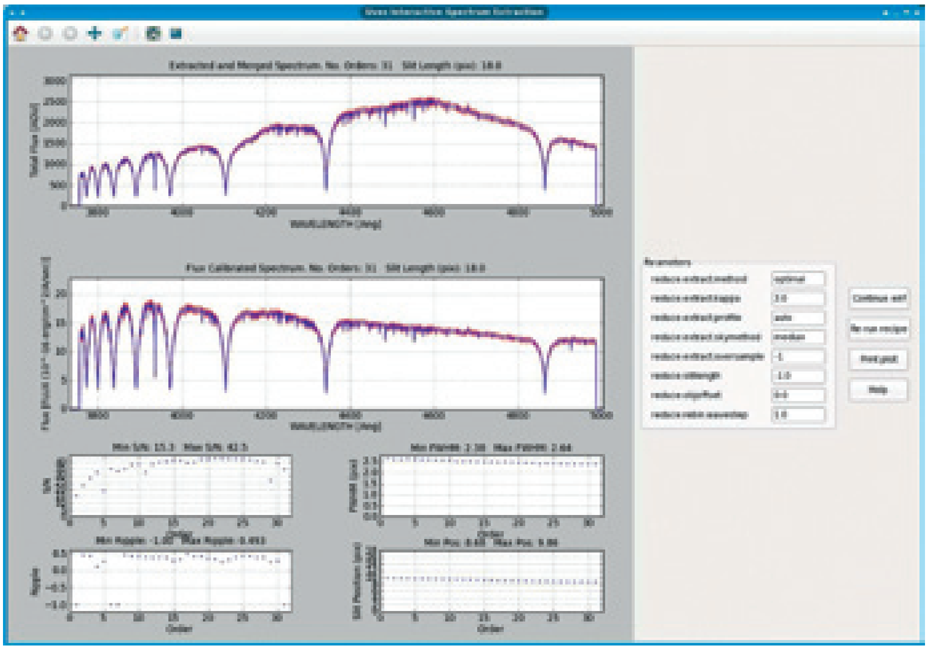
Together with the Data Flow Infrastructure Department, the Pipeline Systems Department released the first release of Reflex to the user community, together with a UVES workflow. Reflex is a front-end GUI to pipelines based on a workflow engine called Kepler. We hope that this tool will encourage astronomers to make use of the ESO pipelines (also see p. 33).

Considerable effort was expended in following up the work done by external instrument consortia in building the second generation VLT instruments, MUSE, KMOS and SPHERE.

The VIMOS pipeline was upgraded to enable the processing of data from the new detector mosaic that was commissioned in August.

Part of the department's mission is to improve the quality of the science products generated by selected pipelines. Improvements were implemented to the HAWK-I pipeline, particularly to the sky background subtraction. The GIRAFFE pipeline was enhanced with better error computation for the extracted spectra, improved noise-based threshold computations, and the implementation of a gradient-based fibre-tracing algorithm.

All ESO pipelines are based on ESO's common pipeline library in order to facilitate maintenance and the sharing of functionality. They are released for public use via www.eso.org/pipelines when they have reached an acceptable level of quality and stability.



Spectral extraction window for the UVES workflow. This window displays the extracted spectrum with error bars and allows the user to tune the extraction parameters or to continue the workflow.

Administration

Administration staff preparing for the
Finance Committee Meeting.

The Finance Department worked with the new ESO auditors from the Portuguese Court of Auditors on the Financial Statements 2009 and on the accounting changes required for the preparation of the Financial Statements 2010 under the International Public Sector Accounting Standards (IPSAS) standards. The internal budgeting process was reviewed. Funding scenarios for the E-ELT were elaborated as well as financial scenarios for the accession of Brazil.

The Contracts and Procurement Department focused on contract execution since natural departures from the original plans meant that adjustments were required. The contracts for the construction of the multi fuel power generation system and for the storage of liquefied petroleum gas for ALMA were concluded. The review and update of the ESO procurement and sales procedures were completed as planned and released by the Director General in December. The extra effort initiated in 2009 to address the imbalance for some Member States of their industrial return was actively continued during 2010, with noticeable results for some countries. Unexpected staff turnover affected the procurement teams both in Chile and in Germany, leading to a partial reorganisation of the department.

The administrative information system (ERP) implemented new applications such as the Full-Time Equivalent (FTE) allocation and budget tool, blanket orders, commitment approvals via e-mail etc. A new version of the system will go live in March 2011.

The ESO Council officially approved the ESO Technology Transfer Policy on 21 December 2010. A European Patent was granted on 1 September 2010 for the ESO fibre raman amplifier. A new European Patent application regarding an image slicer developed at ESO was submitted to the European Patent Office at the end of the year.

ESO participated in eight EU 7th Framework Programme projects during 2010. The ASTRONET, RadioNet and OPTICON projects provide the European astronomical community with essential networking opportunities to prepare for future scientific and infrastructure developments in astronomy. The EVALSO project delivered a high-speed data infrastructure between the observatories in Chile and ESO Headquarters. The first individual Marie Curie fellow at ESO started his two-year long period of research at ESO in 2010 on VLT-related science. The nine Marie Curie COFUND fellows conduct research on ALMA-related subjects either at ESO Garching, or hosted at one of the ALMA ARC nodes.

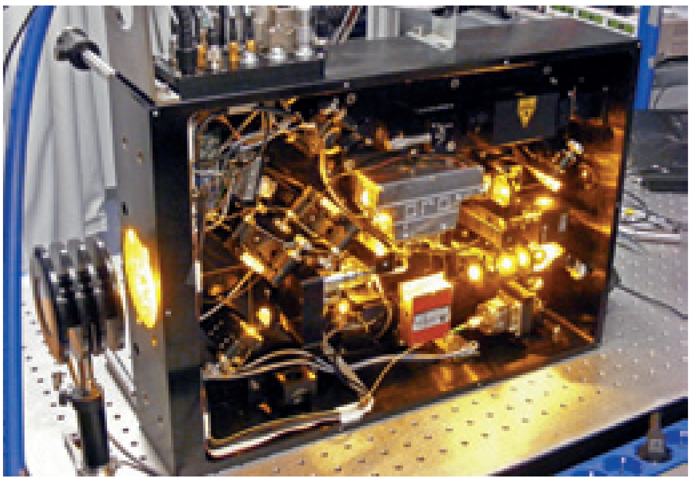
A Corporate Risk Register was introduced in 2010 and will be updated continuously.

The new Site Safety Engineer started work early this year, building on past achievements. The current safety manuals and communications were put under revision and a full cycle of training and drills was organised for the Garching Headquarters.

Due to the need for more office space and to enable to the return of the ALMA Division in the main building, a temporary office building was built at ESO premises to accommodate approximately 80 people. In preparation for the construction of the new Headquarters extension, one of the portacabins was relocated next to the temporary office building.

The design of the new ESO Headquarters extension progressed well during the year and culminated in the submission of the For Construction documentation. The documentation has now been revised by ESO and is scheduled to be ready for tendering in early April 2011, leading to Finance Committee approval in November and to the start of construction in February 2012. A construction period of 14 months is envisaged. A fund-raising exercise was started to fund part of the project.

The earthquake in Chile in February 2010 caused some damage to buildings at the ESO premises in Vitacura, but this was quickly repaired. At the end of the year, ALMA staff moved to the new building on the Vitacura site.



ESO's Raman fibre laser, which is used to create an artificial laser guide star in the Earth's atmosphere at 90 km altitude. ESO has signed an agreement to license its cutting-edge laser technology to two commercial partners, Toptica Photonics and MPB Communications. This marks the first time that ESO has transferred patented technology and know-how to the private sector, offering significant opportunities both for business and for ESO.

Guests and VIPs gather at the inauguration of the EVALSO project.

Finance and Budget

Financial Statements 2010
Following the International Public Sector Accounting Standards (2009 restated)

Accounting Statements 2010
(in € 1000)

Statement of Financial Position	31.12.2010	31.12.2009
Assets		
Cash and cash equivalents	50 859	115 961
Receivables, advances and other current assets	11 837	8 089
Non-current assets	992 834	901 805
Total Assets	1 055 530	1 025 855
Liabilities		
Payables, advances received and other current liabilities	42 137	35 476
Non-current liabilities	154 871	92 645
Total Liabilities	197 008	128 121
Accumulated surpluses/deficits	897 734	842 489
Net surplus/deficit for the year	−39 212	55 245
Total Net Assets	858 522	897 734
Total Liabilities and Net Assets	1 055 530	1 025 855

Statement of Financial Performance	01.01.–31.12.2009	01.01.–31.12.2009
Operating revenue		
Contributions from Member States	131 725	130 307
Contributions to special projects	18 474	14 147
In kind contributions	7 617	27 514
Sales and service charges	3 779	3 654
Other revenue	292	601
Total Operating Revenue	161 887	176 223
Operating expenses		
Installations and equipment	7 998	4 753
Supplies and services	37 540	35 946
Personnel expenses	91 000	41 562
Depreciation of fixed assets	47 912	44 082
Other operating expenses	602	911
Total Operating Expenses	185 052	127 254
Net surplus/ deficit from operating activities	−23 165	48 969
Financial revenue	3 885	8 607
Financial expenses	19 933	2 331
Net surplus/deficit from financial activities	−16 047	6 276
Net surplus/deficit for the period	−39 212	55 245

Cash Flow Statement	2010	2009
Cash flow		
Net receipts	165 264	167 027
Net payments	−230 366	−200 890
Net cash flow	−65 102	−33 863
Net decrease in cash and cash equivalents		

Budgetary Reports 2010
(in € 1000)

Income budget	Budget	Actual
Contributions from Member States	142 919	142 694
Income from third parties	13 775	13 770
Other income and advances received	4 955	6 966
Astronomy & Astrophysics (A&A) Journal	530	481
Total Income Budget	162 179	163 911
Payment budget		
Programme	174 936	140 227
Operations	57 588	55 932
Science support	9 161	6 953
Cross-directorate functions	25 514	25 675
Astronomy & Astrophysics (A&A) Journal	454	426
Total Payment Budget	267 653	229 213

Budget for 2011
(in € 1000)

Income budget	2011
Contributions from Member States	144 468
Income from third parties	16 498
Other income	2 200
Total Income Budget	163 166
Payment budget	
Programme	112 658
Operations	60 698
Science support	8 349
Cross-directorate functions	25 643
Total Payment Budget	207 348

The revised Financial Rules and Regulations adopted by the ESO Council in December 2009 required the Organisation to follow the International Public Sector Accounting Standards. The presentation of ESO's financial statements for 2010 has been modified accordingly and the 2009 accounting statements have been restated for comparability. The External Auditors, Tribunal de Contas[1] of Portugal, have expressed their opinion that the financial statements give a true and fair view of the affairs of the Organisation.

The accounting statements for 2010 show a net deficit of −39.2 million euros for the period. The year 2010 represented a peak with respect to ALMA's financial requirements, as had been foreseen in the financial planning. The cash flow of –65.1 million euros for the year has resulted in a decrease of the cash position to 50.9 million euros as of 31 December 2010. The non-cash accounting transactions have however had a net positive impact, as the increase in the Organisation's fixed assets, resulting from the high level of investment, has exceeded the increase in provisions due to the re-evaluation of our liabilities for retirement benefits towards the shared CERN/ESO pension fund. The increase in the provision for pension benefits has resulted from a change in actuarial assumptions to reflect the position of the financial markets, combined with the loss in value of the euro against the Swiss franc over the period. The change in this provision appears under personnel expenses in operating activities and under financial activities.

In 2011 the cash position is expected to be further reduced, with a 2011 payment budget in excess of the planned income for the period.

The budget for 2011 was approved by the ESO Council in December 2010. The 2011 payment budget amounts to 207.3 million euros and covers the next annual tranche of ALMA's construction costs and the last part of the extended E-ELT design phase. The income budget amounts to 163.2 million euros.

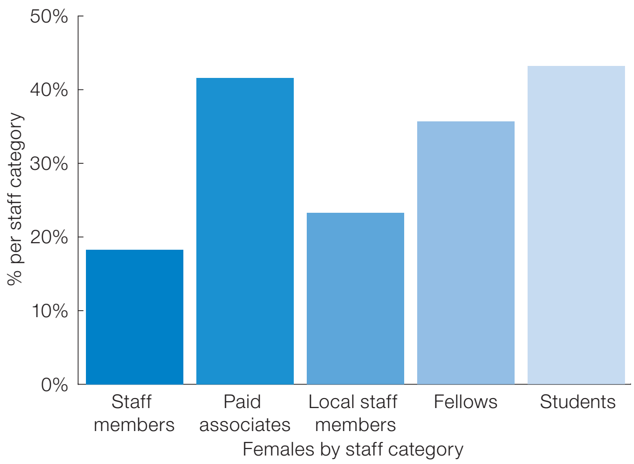
The massive star factory known as the Trifid Nebula was captured in all its glory with the Wide-Field Imager camera attached to the MPG/ESO 2.2-metre telescope at ESO's La Silla Observatory in northern Chile.

[1] João Pinto Ribeiro (Member of the Portuguese Court of Auditors), Maria da Luz Carmezim (Head of Audit Department) and António Pombeiro (Senior Auditor).

Human Resources

The responsibility of the Human Resources Division (HR) lies within the following areas:

– HR strategy policy and planning
– Professional advice
– Recruitment and selection
– Pay and benefits
– Occupational health and welfare
– Employee relations and communications
– Employment contracts
– Social security
– Training and professional development
– Family matters and education



Breakdown of female fraction for each staff category at the end of 2010.

Recruitment and selection

During 2010 we published vacancy notices for 55 positions and received a total of 1537 applications:

Contract Type	No. of Campaigns	No. of Applications
Staff members	38	980
Local staff members	5	300
Fellows	12	257

All positions were advertised on the ESO website. In addition, for international positions, notifications were sent to all members of Council, the Finance Committee and the delegates of other ESO Committees, as well as to national and international research centres and observatories. To increase awareness within all Member States, prominent advertisements for selected positions were placed in appropriate specialist publications and on recruitment web pages.

Eight contracts were awarded for the PhD studentship programmes in Garching and Chile. Nine Chilean students were recruited for the summer student programme that enables engineers to gain first-hand work experience in the engineering and maintenance departments of the La Silla Paranal Observatory.

All ESO advertisements contain a statement regarding our commitment to equal opportunities. In the last year, the number of female staff has risen from 163 to 168, and now represents 23 % of the overall count. The breakdown by staff category is shown in the figure.

The distribution of female job applicants over the different staff categories was as follows:

Category	Female applicants	Total applicants	% 2010	% 2009
Staff members	231	981	23.5	18.6
Local staff members	101	299	33.8	32.6
Fellows	94	257	36.6	38.4

Temporary transfers to Chile – In order to further improve the transfer of knowledge between development and operations, the number of opportunities to temporarily transfer personnel between the sites has increased. In addition to the five transfers already started in the autumn of 2009 to support the various commissioning activities for ALMA, another five staff members were temporarily transferred to Chile during 2010.

HR strategy policy and planning

During 2010, the following activities were organised in this area.

Policy on fair treatment, courtesy and respect – A policy on fair treatment, courtesy and respect has been introduced. Although harassment has never been tolerated within the ESO culture, it is important that staff understand what action they can take and what support is available should they feel they are subject to harassment and/or bullying in the workplace. A corresponding policy paper was released in April. Training to support its implementation was completed during the period 18 May to 30 June for both Chile and Garching. As specified in the policy, external mediation services have been secured in Chile.

Budget planning and preparation – In close interaction with the Finance Department, HR reviewed and tested a new FTE tool; participated in the preparation of the budget documents and guidelines; made corresponding updates to the position plan; and designed, in close interaction with the Directorate of Engineering, the process for FTE allocation to the matrix divisions.

Review of the staffing for the Space Telescope - European Coordinating Facility – In anticipation of the termination at the end of 2010 of the hosting of the ST-ECF within ESO, a review of staff requirements and the availability of suitable positions for transfers was undertaken. By the end of 2010, eight of the ten staff members had been reassigned to suitable positions in other ESO divisions.

Memoranda of understanding – In close consultation with other ESO divisions, HR contributed substantially to the following memoranda between ESO:

– and IRAM, concerning the allocation of scientific personnel to the ALMA Observatory;

– and the Ministry of Science and Innovation of the Kingdom of Spain for the training of graduates in advanced technologies for large ground-based astronomical facilities;

– and TUBITAK, the National Observatory of Turkey, for on-the-job training of TUBITAK technical graduates in advanced technologies for mid-sized telescopes.

Indefinite appointments – Following the recommendation of the Indefinite Appointments Advisory Board, chaired by the Director of Programmes, the Director General granted eighteen staff members indefinite appointments with effect from 1 August 2010. Furthermore, twelve local staff members in Chile were granted indefinite contracts during the year.

Training and professional development

A comprehensive programme of training was offered and organised and a revised version of the circular on training and professional development was issued. A total of 340 staff attended a training event during the year.

The areas covered included technical training in systems engineering and LabVIEW; project coordination skills for the astronomers and scientific staff in Chile; a new initiative on retirement preparation for staff and spouses and, following a proposal by the ESO management team, a Leadership Development Programme for division heads and directors to be held early in 2011. In conjunction with the HR thematic working group of EIROforum, combined training activities in project management and presentation skills and a seminar on career development will be offered to postdocs and Fellows in 2011. In order to maximise the availability of training at the operational sites, we have worked with the training group at Paranal to establish the feasibility of introducing an e-learning platform.

To achieve a clearer understanding of performance management activities we have delivered, in both Chile and Garching, presentations to all staff outlining the purpose, responsibilities and expectations within the process.

Employee relations and communications

Relations with staff representatives and joint committees in Garching and Chile – Regular consultation and interaction with the international staff committee and the unions in Chile have continued throughout 2010. In total, 25 meetings in Garching and Vitacura, as well as on the sites in Chile, were held in order to inform, to discuss and to exchange opinions in the areas of organisational developments, amendments in policies, regulations, training and individual cases. The meetings took place in a constructive and open atmosphere with a shared wish to find mutually satisfactory solutions for the various issues.

In the course of the year, two rehabilitation boards examined cases concerning the nature of an accident/illness and an incapacity case. An advisory appeals board was appointed and its substantiated recommendation was followed by the Director General. Two meetings of the Standing Advisory Committee took place in order to evaluate proposed amendments to the staff regulations and specific guidelines.

Members of the personnel in both Garching and Chile attended a number of informational presentations.

Collaborations and representation of HR

As a member of the ALMA HR advisory group and involved in the recruitment of international staff for the Joint ALMA Office/Observatory, ESO HR has participated in monthly meetings and contributed decisively towards, among others: collective bargaining, recruitment guidelines, rules and policies applicable at the Operation Site Facility and staff transfer from construction to operation.

From 1 July 2008, the Head of HR has chaired the HR thematic working group of EIROforum. Two meetings were held during the year, the main subjects being: the implementation of training activities for researchers in project management and presentation skills which took place in October and November 2010; a programme for possible short-term secondments and staff exchanges amongst the EIROforum organisations; the planned seminar for the career development of researchers in 2011; and establishing priorities for 2011 and their budgetary implications.

HR organised and participated in two meetings of the ESO tripartite group concerned particularly with the development of the CERN Pension Fund, the annual salary adjustment, changes to staff regulations and administrative circulars, and the preparation of a staff survey and the five-yearly review for 2011.

Social security

CERN Pension Fund – New procedures have been introduced to facilitate the opening of bank accounts in Switzerland for beneficiaries of the CERN Pension Fund. In September, the CERN Pension Fund Annual General Meeting was held for all staff in Garching and Chile and also representatives of the CERN management consulted ESO regarding proposed measures to restore full funding of the CERN Pension Fund. It was further agreed to set up a common working group consisting of representatives of CERN management, ESO management and the CERN Pension Fund, to evaluate and find an optimal solution to the calculation and payment of contributions and pensions for ESO staff on the basis of effective ESO salaries. The working group started its work in December 2010.

Health insurance – Two meetings of the ESO internal working group on health insurance matters and one meeting with Vanbreda took place. Amendments were implemented in the areas of psychotherapy and outpatient psychiatric care, vaccinations for children, and procedures regarding prior approvals for treatments for dental prosthesis.

In addition, actions were agreed regarding: a review of current reimbursement levels; the analysis and benchmarking of

ESO's health insurance compared with other comparable organisations regarding coverage levels and spending patterns; staff members' use of basic and complementary health insurance coverage; "white listing" of care providers; a review of the claims handling fee; and a procedure for the recognition of occupational and non-occupational accidents and illnesses.

Other matters – Following the presentations by HR in the spring of 2010, at all sites in Garching and Chile, on ESO social security (CERN Pension Fund, long term care and health provision), a new Administrative Circular on the protection of the members of the personnel against the financial consequences of illness, accident and disability has been developed and will be released in the spring of 2011.

Family matters, education, occupational health and welfare

Following the earthquake in February, the HR team in Chile provided exceptional support to staff and spouses, particularly in the areas of health insurance and support networks and counselling.

Resulting from its successful operation and the increasing need for places at the common Kinderkrippe of the Institute for Plasma Physics and ESO, the number of secured places has been increased to 20. The Kinderkrippe is a day-care facility for children and is much appreciated by staff since it supports families effectively. Additionally, the number of places allocated for the Kinderkrippe and Kindergarten is being reviewed to ensure that priority is given to the Kinderkrippe, which is the facility with the least alternative availability in Munich. An amended contract to safeguard the access of children of ESO staff members to the European School Munich (ESM) was agreed in June 2010 with the European Patent Office and the Office of the Secretary General of the European Schools in Brussels.

To support the relocation of professional couples to ESO and the Munich area, a collaboration has been formed with the Technical University Munich — Munich Dual Careers Office — which provides a service to help the partners of ESO staff seek employment. With effect from April a tax advisor has been appointed to help staff in Garching. A presentation was made to all staff in Garching in May. For the staff members in Chile, we are currently developing guidelines and information concerning the status of spouses and dependents in cases of divorce or death. In cooperation with the unions in Chile and partly as a follow-up of our last year's collective bargaining, HR is currently discussing and developing possible solutions for the recognition of partnerships and their dependent children.

HR administration

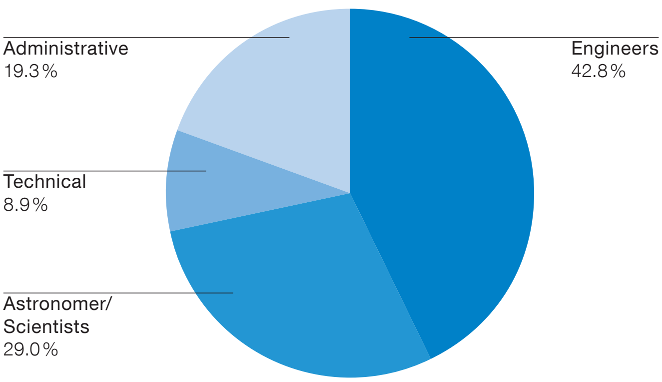
In addition to a comprehensive, service-oriented contract administration, HR handles a wide spectrum of personnel-oriented activities including operation of the payroll and the adjustment of the social security systems, presentations to staff, FTE allocation, budget preparation and control, statistics, the settlement of about 3400 travel claims, special services for international staff in Chile (accreditation, schooling, accommodation and relocation, insurance etc.), review and update of the HR internet web pages, coordination with the ESM, organising regular medical examinations and many other tasks. As an integral part of this service, a variety of pertinent documents are produced and issued.

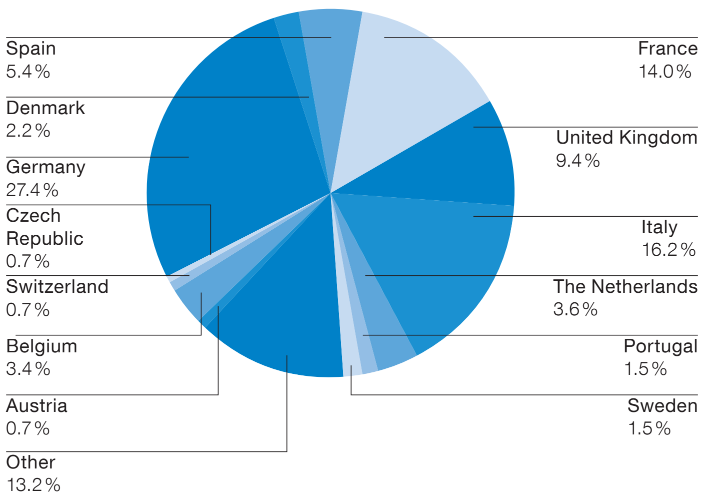
Staff departures

The departure of staff members in 2010 fall in the following categories:

Reasons	Staff member	Local staff member
Resignation	13	3
Expiry of contract	3	
Retirement	3	4
Mutual agreement	2	1
Dismissal		
Death	1	1
Total	22	9

This leads to an average annual fluctuation rate of 5% for staff members and 5% for local staff. Seven out of the 22 departures of staff members were in Chile.





(Left) Distribution of staff by job category — 31 December 2010.

(Right) Staff members by nationality — 31 December 2010.

List of Staff

As of 31 December 2010

Office of the Director General

Tim de Zeeuw

Mary Bauerle
Laura Comendador Frutos
Gabriela Gajardo
Nikolaj Gube
Isolde Kreutle
Anna Krueger
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Rowena Sirey
Massimo Tarenghi
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Claudia Silvina Cerda
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Alain Delorme
Tommaso Di Dio
Evelina Dietmann
Andrea Dinkel
Günther Dremel
Sabine Eisenbraun
Willem Arie Dirk Eng
Jörg Eschwey
Rebonto Guha
Leonardo Guzman
Robert Hamilton
Priya Nirmala Hein
Charlotte Hermant
Kristel Jeanmart
Georg Junker
Katarina Kiupel
Hans-Jürgen Kraus
Caterina Kuo
Ignacio López Gil
Qiao Yun Ma
Maria Madrazo
Maria Angelica Moya
Christian Muckle
Hélène Neuville
Ester Oliveras
Oscar Orrego
Enikő Patkós
Thomas Penker
Rolando Quintana
Elke Rose
Johannes Schimpelsberger
Guido Serrano
Erich Siml
Alexandra Specht
Albert Triat
Florine Vega
Maritza Vicencio
Elisabeth Völk
Michael Weigand
Yves Wesse
Gerd Wieland
Irmtraud Zilker-Kramer

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Angela Arndt
Samantha Austin-May
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Nathalie Kastelyn
Elizabeth Kerk
Katjuscha Lockhart
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Mauricio Quintana
Rosa Ivonne Riveros
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Marcia Saavedra
Nadja Sababa
Heidi Schmidt
María Soledad Silva
Roswitha Slater
Betül User
Lone Vedsø Marschollek

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Luigi Andolfato
Andrea Balestra
Pascal Ballester
Klaus Banse
David Bargna
Thomas Bierwirth
Reynald Bourtembourg
Blanca Camucet
Alessandro Caproni
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Diego Sforna
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Michael Esselborn
Gerhard Fischer
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Volker Heinz
Guy Hess
Renate Hinterschuster
Ronald Holzlöhner
Georgette Hubert
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Andreas Jost
Dimitrios Kalaitzoglou
Lothar Kern
Barbara Klein
Franz Koch
Maximilian Kraus
Steffan Lewis
Paul Lilley
Christian Lucuix
Juan Antonio Marrero Hernandez
Jean-Michel Moresmau
Michael Müller
Lothar Noethe
Lorenzo Pettazzi
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Bernardo Ahumada
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Javier Alarcon
Jaime Alonso
Fernando Alvarez
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Gaetano Andreoni
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Juan Pablo Araneda
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Juan Carlos Arcos
Pablo Arias
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Erito Flores
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Michael Fritz Sterzik
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Pierre Vanderheyden
Enrique Vera
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Gundolf Wieching
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Palle Møller
Sangeeta Mysore
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Dieter Suchar
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Mario Van Den Ancker
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Ignacio Vera Sequeiros
Markus Wittkowski
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Martin Kümmel
Harald Kuntschner
Marco Lombardi
Kim Nilsson
Piero Rosati
Jeremy Walsh

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Karla Adriana Alamo
Alvaro Alvarez Candal
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Daniel Asmus
Giuseppina Battaglia
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Maxime Bois
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Margherita Bonzini
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André Müller
Silvia Munding
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Olja Panic
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Luca Ricci
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Richard Hills
Jorge Ibsen
Rüdiger Kneissl
Richard John Kurz
Jacques Lassalle
Stéphane Leon Tanne
Gianni Marconi
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Lars Åke Nyman
Pere Planesas
Mark Rawlings
Russell Smeback
William Snow
Baltasar Vila Vilaro
Eric Villard
Nicholas Whyborn
Gert Tommy Wiklind

View of the central hall at the Paranal Residencia, with the swimming pool and the main indoor garden.

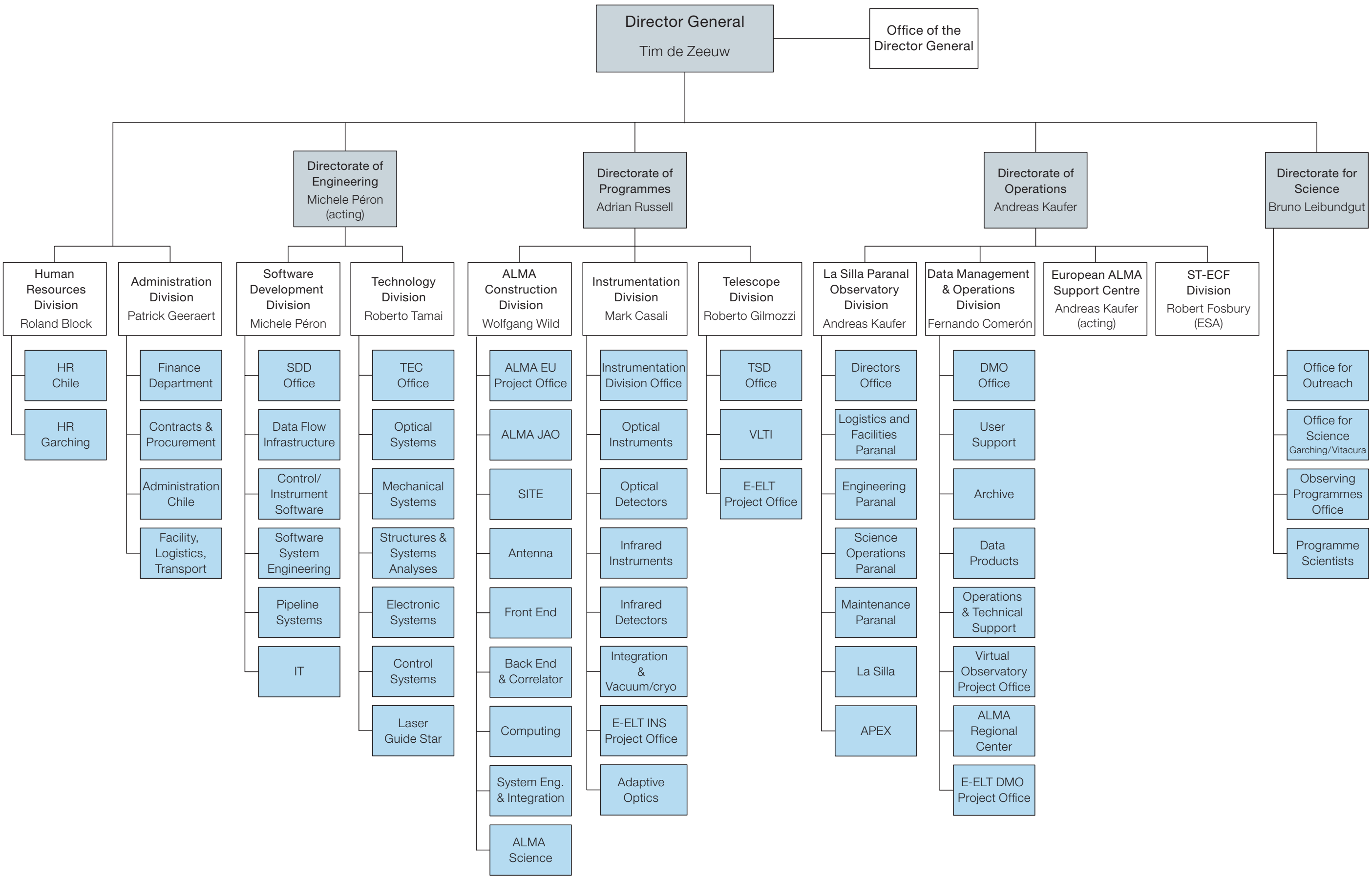
ESO/José Francisco Salgado (josefrancisco.org)

ESO & ALMA (ESO/NAOJ/NRAO)

Main gate of the ESO premises located in the Vitacura district of the Chilean capital.

Organigram

As of 31 December 2010



International Relations

Top: ESO Director General Tim de Zeeuw visited the Austrian Minister of Science and Research, Beatrix Karl, on 21 May 2010. Bottom: Statement of Intent signed on 24 June 2010. The European Commission and the members of EIROforum, including ESO, formalise their desire to maintain and further develop their cooperation, for the benefit of European science.

International Relations Office

The International Relations Office (IRO) continued discussions with Member States regarding the planning for the funding and construction of the E-ELT. Visits to Member States in February helped to give a better understanding of their preparedness to begin the E-ELT construction, which was presented to Council in April. Visits in September contributed further to the development of the funding profile and mechanism, while also giving Member States the opportunity for individual discussions with ESO on specific issues and concerns. An Information Day was held at ESO Headquarters in September for the Science and Commercial attachés of current and potential Member States to raise awareness of ESO and its programme and the potential opportunities it offers for industry.

Reception in the ATC foyer during the opening ceremony of the EMBL Advanced Training centre.

IRO also participated in discussions with non-Member States about the possibilities for involvement with the E-ELT and/or membership of the organisation. This included visits by representatives of several potential candidate states to ESO Headquarters.

Throughout the year IRO represented ESO in a variety of international events, including the official closing ceremony of the International Year of Astronomy 2009, the opening of the European Molecular Biology Laboratory (EMBL) Advanced Training centre, the SKA Forum, the inauguration of the Low Frequency Array (LOFAR), the European Conference on Research Infrastructures (ECRI), the EC Expert Group on cost control and management issues of global research infrastructures, the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and in the OPTICON Board and Executive Committee.

IRO is responsible in particular for ESO's involvement in the EIROforum Coordination Group and the Thematic Working Group for International Affairs, and supports the Director General in the DGs' Assembly. In 2010 IRO supported the EIROforum presence at the MIT Careers Fair and at the Euroscience Open Forum (ESOF) and represented EIROforum at the Science on Stage Board meeting. In June, IRO assisted in the hosting of the signing ceremony between the EIROforum and the EC Commission of the new Statement of Intent between the two organisations.

ESO Council meeting, on 26 April 2010 at ESO Headquarters, in Garching, Germany.

Chile Relations

2010 was an eventful year for Chile with the change of government on 11 March, the earthquake registering 8.8 Richter scale on 27 February, and the operation to save 33 trapped miners dominating the scene. ESO's selection of Armazones as the site for the E-ELT was the highlight of the scientific year and further increased the interest in and support for astronomy in Chile.

The impact of ESO's activities in Chile was well demonstrated by the visit of the ESO Director General both to President Michelle Bachelet and to the incoming President Sebastian Piñera; and through frequent and cordial discussions with the Minister of Foreign Affairs, Alfredo Moreno and with the Minister of National Assets, Catalina Parot.

On 12 January, the ESO Director General Tim de Zeeuw met Chilean President Michelle Bachelet at the Palacio La Moneda in Santiago. The Chilean Vice-Minister of Foreign Affairs, Ángel Flisfisch, Ambassador Gabriel Rodriguez from the Ministry of Foreign Affairs and the ESO Representative in Chile, Massimo Tarenghi also attended.

The Brazilian Minister of State for Science and Technology Sérgio Rezende made an important visit to Paranal and ALMA in February. This represented a significant contribution to Brazil's understanding of the advantages in becoming an ESO Member State.

On 6 July, the Chilean President Sebastián Piñera received the ESO Director General at the Palacio La Moneda in Santiago to discuss the selection of Cerro Armazones in Chile as the home of the future E-ELT. The Chilean Minister of Foreign Affairs, Alfredo Moreno, Ambassador Gabriel Rodríguez from the Ministry of Foreign Affairs and the ESO Representative in Chile also attended.

Also in July, the ESO Director General, the ESO Representative in Chile and the Head of the Legal Service held an interview with the Chilean Minister of National Assets, Catalina Parot and a visit to Paranal and ALMA was made by the Chilean Ministers of the Environment, the Undersecretary of Public Assets and other officials.

Prof. Adriaan Blaauw (1914–2010), the second ESO Director General (from 1970–1974), visited some of ESO's sites in Chile in February 2010, at the age of 95. He also spent time in Vitacura and proved to be a great source of inspiration for the young astronomers.

In collaboration with the Chilean National Commission for Environment, Chilean universities and the Office for the Protection of the Quality of the Skies in the North of Chile, ESO organised the Second International Seminar on Light Pollution. This event was supported by the Ruinas de Huanchaca Foundation, the Antofagasta Municipality and the Chilean Astronomy Society in order to promote the protection of dark skies as a scientific heritage.

ESO's powerful telescopes, located in a remote and barren desert landscape in Chile, became more accessible than ever to astronomers around the world, thanks to a new high-speed data link. Members of the press were invited to attend the launch of the new communications data link and to view a demonstration of the technology from the project site in the middle of the Atacama Desert. The high-speed data link is part of the EVALSO project which is co-funded by the European Commission FP7.

On 14 January, a new book, *Voices from the Universe*, written by the poet Margarita Schultz and the astronomer María Teresa Ruiz and including spectacular astronomical images from ESO, was presented at the ESO Office in Santiago.

In addition to the visits detailed on this page, several VIPs visited the ESO sites in Chile including:

- Her Royal Highness Maha Chakri Sirindhorn, Princess of Thailand and her entourage.
- NASA astronaut John Grunsfeld, who has flown a record three times to service the NASA/ESA Hubble Space Telescope in orbit, and greatly admired our large telescopes.
- The Swiss Secretary of State Mauro Dell'Ambrogio and delegation visited Paranal and ALMA, accompanied by the ESO Representative in Chile.
- Ms Inge Mærkedahl, Head of the Danish Research Agency, visited Paranal and ALMA.

Top: ESO Director General Tim de Zeeuw meeting Chilean President Michelle Bachelet in January. Bottom: In July, Chilean President Sebastián Piñera received the ESO Director General to discuss the selection of Cerro Armazones as the site for the E-ELT.

Legal Service

The key mission of the Legal Service is to ensure that the Organisation's administrative dealings are lawful by providing legal counsel and participating in negotiations and proceedings.

The Legal Service assisted the Director General and the Management Team with the preparation of Council and Finance Committee documents. It drafted the Terms of Reference and Rules of Procedure of the Users Committee and prepared the book *ESO Reference Texts*. It participated in meetings of the Council, Finance Committee, Tripartite Group and the Working Group on CERN Pension Fund matters, answering legal and procedural questions. And it assisted the Director General in the follow-up of ESO tasks concerning the ALMA Board, ALMA Director's Council and the APEX Board, including the assessment of legal implications regarding new projects on the ALMA concession and the preparations for an ALMA Trilateral Agreement.

Much effort was devoted to interaction with Member States (for example, concerning the in-kind contributions of the UK, Austria and Spain and the agreements with Sweden and the Czech Republic on early funding for the E-ELT) and to negotiations with potential new Member States. In particular, the Legal Service had a major role in the negotiation and drafting of the Brazilian accession agreement and in preparing the subsequent correspondence. The Legal Service was also active in the working groups that negotiated with Spain and Chile concerning conditions for the E-ELT, including the legal assistance required for the definition of the site and its protection.

Legal support was provided to the Administration Department in the review, development and implementation of terms, conditions, regulations and internal procedures (for example, the review of the Procurement and Sales Procedures). The Legal Service contributed to the negotiation and conclusion of contracts, resolution of claims and disputes about the execution of contracts and provided advice on tax-related matters and legal support for the Headquarters extension. It concluded the extension of the land lease contract with the Max-Planck-Gesellschaft for the land on which the extension will be built and contributed to the attainment of building permits issued first for the temporary office building and subsequently for the new Headquarters extension. It also gave advice on delicate Human Resources matters such as on acquired rights for pensions; contributed to the update of the Staff Rules and Regulations and to the review of internal memoranda, administrative circulars, CERN Pension Fund matters, internal appeals and complaints in front of the Administrative Tribunal of the International Labour Organisation (ATILO).

In Chile, the Legal Service was fully engaged in the negotiations with the Ministries of National Assets and Foreign Affairs regarding the precise terms and conditions under which the land containing Cerro Armazones will be added to the Paranal property. It dealt with various lawsuits in front of Chilean tribunals and contributed to the site protection, especially in cases of illegal mining activities, water and geothermal matters. Diverse environmental aspects (mainly for ALMA), accidents and safety issues were reviewed. It also provided support to the ESO Representative in Chile on agreements, *Nota Verbale* and in interactions with local authorities and the Ministry of Foreign Affairs.

This night-time photo shows Cerro Armazones in the Chilean desert, near ESO's Paranal Observatory, site of the Very Large Telescope. Cerro Armazones was chosen as the site for the planned European Extremely Large Telescope, which, with its 42-metre diameter mirror, will be the world's biggest eye on the sky.

Four Seasons at a Glance

January

PRIMA finally reached its main technical milestone by obtaining a first full astrometric measurement on a pair of stars.

Closing ceremony of the International Year of Astronomy 2009, held in Venice.

ESO Director General Tim de Zeeuw met Chilean President Michelle Bachelet at the Palacio La Moneda in Santiago.

The first direct spectrum of an exoplanet was observed with the VLT.

ESO was present with an exhibition at the UK E-ELT Science Workshop III in London.

Construction of all 192 antenna foundations at the ALMA Operations Site completed. Installation of high precision mechanical parts and electrical/signal connections started.

ESO was present with an exhibition at the International Year of Astronomy closing ceremony in Santiago, Chile.

ALMA Commissioning and Science Verification started at the ALMA Operations Site at an altitude of 5000 metres.

ESO was present with an exhibition at the Astroday 2010 in La Serena, Chile.

February

An earthquake hit the south of Chile and was noticeable at the Paranal and ALMA sites. No damage to the observatories occurred.

Manufacturing item acceptance review for the first integral field unit for MUSE.

127th meeting of the Finance Committee.

Adriaan Blaauw, one of ESO's founding fathers and the second Director General, visited La Silla and Paranal, expressing great delight in the continued expansion of ESO's programme.

ESO Astronomers and ePOD staff on the ESO stand at Astroday 2010, a public outreach event celebrated every January in La Serena, Chile.

March

ESO Workshop on: The Origin and Fate of the Sun: Evolution of Solar-mass Stars Observed with High Angular Resolution, Garching, 2–5 March.

76th meeting of the Committee of Council, Garching.

The first two European ALMA antennas are mechanically complete at the integration site at an altitude of 3000 metres.

ESO was present with an exhibition at the ELT hearing in Stockholm, Sweden.

The 2010 Visiting Committee, chaired by Garth Illingworth, visited ESO Headquarters.

ESO was present with an exhibition at ECRI in Barcelona, Spain.

April

ESA/ESO Workshop on: JWST and the ELTs: an ideal combination, Garching, 13–16 April.

VLTI Training School, Centre IGESA, Porquerolles Island, Côte d'Azur, France, 17–28 April.

The new VISTA telescope formally started science operations (and delivered 252 nights of survey observations during the rest of the year).

The AOF project successfully completed the important Final Design Review for the system.

The second European front end unit was delivered to the ALMA observatory.

ESO was present with an exhibition at the RAS NAM2010 in Glasgow, UK.

72nd meeting of the STC.

116th Extraordinary Council meeting.

Cerro Armazones was selected as the site for the E-ELT during the Extraordinary Council meeting.

34th meeting of the Users Committee.

ALMA Board meeting in Santiago.

A Hubble 20th-anniversary campaign was carried out with almost 100 partners.

ESO present with an exhibition at the Hannover Messe in Hannover, Germany.

May

Completion of Critical Design Review for ALMA band 5 receivers.

Workshop on Science with ALMA Band 5 (163–211 GHz) at Osservatorio Astronomico di Roma (Italy).

ESO was present with an exhibition at the Inauguration of the Museum of the Desert at Ruinas de Huanchaca in Antofagasta, Chile.

The upgrade of the VISIR instrument was approved as a project.

128th meeting of the Finance Committee.

86th OPC with 977 proposals submitted.

ESO was present with an exhibition at the Giant Telescopes — Large Eyes on the Sky in Copenhagen, Denmark.

The prestigious Kavli Prize in Astrophysics for 2010 was awarded to Jerry Nelson, Raymond Wilson and Roger Angel (from left to right) for their contribution to the development of giant telescopes.

June

The refurbished M1 mirror cell for the VST arrived on Paranal.

The NEON Observing School, Calar Alto Observatory, Spain, 16–28 June.

ESO Workshop on: Central Massive Objects: The Stellar Nuclei – Black Hole Connection, Garching, 22–25 June.

73rd Extraordinary meeting of the STC.

The new Director of Programmes, Adrian Russell, succeeded Alan Moorwood, who retired in late May after a distinguished career at ESO.

Retired ESO staff member Ray Wilson shared the 2010 Kavli Award for Astrophysics with Jerry Nelson and Roger Angel, for his development of active optics.

117th Council meeting.

First light for TRAPPIST at La Silla, led by University of Liège (Belgium) and Geneva Observatory, University of Geneva (Switzerland).

Five antennas at the ALMA Operations Site were undergoing Commissioning and Science Verification.

ESO was present with an exhibition at the SPIE Astronomical Telescopes and Instrumentation conference in San Diego, CA, USA.

Road pavement from Chilean Highway 23 to ALMA Operations Site (43 kilometres) completed.

Signing ceremony at ESO Headquarters between the EIROforum, represented by the then Chair, Iain Mattaj, Director General of EMBL, and the EC Commissioner for Research, Innovation and Science, Máire Geoghegan-Quinn, of the new Statement of Intent between the Commission and EIROforum.

E. Jehin/ESO

TRAPPIST, a new robotic telescope had first light at ESO's La Silla Observatory, in Chile, in June 2010.

ESO was present with an exhibition at the Royal Society Summer Science Exhibition in London, UK.

July

Directorate of Engineering established.

MPA/ESO/MPE/USM Joint Astronomy Conference on: Galaxy clusters: observations, physics and cosmology, Garching, 26–30 July.

The 2010 Visiting Committee visited all sites in Chile.

ESO was present with an exhibition at ESOF in Torino, Italy.

On 6 July, Chilean President Sebastián Piñera received the ESO Director General at the Palacio La Moneda in Santiago to discuss the selection of Cerro Armazones in Chile as the home of the future E-ELT.

Using the VLT, astronomers discovered the most massive stars known to date, one weighing at birth more than 300 times the mass of the Sun.

ESO was present with an exhibition at the MIGA 2010 — Anniversary of Taltal, Chile.

August

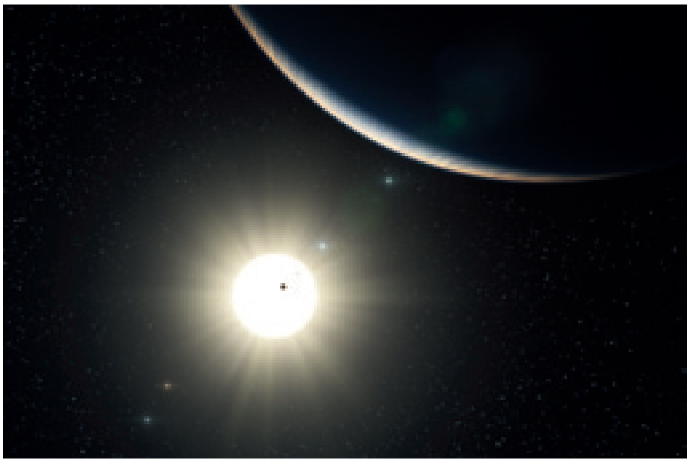
Acceptance testing of the first European ALMA antenna started in Chile.

ESO was present with an exhibition at the Light Pollution international conference in Antofagasta, Chile.

ALMA staff move into the new ALMA Santiago Central Office building, built on the ESO Vitacura premises.

The richest planetary system so far was discovered containing at least five planets, orbiting the Sun-like star HD 10180.

ESO was present with an exhibition at the ELT: Opportunities for Chilean industry, Santiago, Chile.



This artist's impression shows the remarkable planetary system around the Sun-like star HD 10180.

September

Public exhibition: The Hubble Space Telescope, twenty years at the frontier of science, Venice, Italy, September 16 – October 17.

Demonstration of the high frequency capabilities of ALMA obtained with band 9 receivers: a CO $J = 6–5$ line and continuum interferometer map of NGC 253.

The E-ELT External Review took place in Garching from 16–20 September.

A European patent was granted for the narrowband Raman fibre amplifier technology.

ESO participated with an exhibition at JENAM 2010 in Portugal. Several gatherings were arranged, such as the ESO Hour and the launch of the *Postcards from the Edge of the Universe* book.

ESO was present with an exhibition at the Framtidens Jätteteleskop (Giant future telescopes), Stockholm, Sweden.

Manufacturing item acceptance review for the MUSE vacuum and cryogenic system, which was built at ESO and supports the detector units of all 24 IFUs, took place, before the system was shipped to Lyon.

An Information Day was held at ESO Headquarters in September for the Science and Commercial attaches of current and potential Member States to raise awareness of ESO and its programme and the potential industrial opportunities.

ESO present with an exhibition at the Patrimonial Day — Chile Bicentenary, Santiago, Chile.

October

ST-ECF/STScI conference on: Science with the Hubble Space Telescope - III: Two Decades and Counting, Venice, Italy, 11–14 October.

The 77th Committee of Council meeting was held in The Netherlands.

118th Extraordinary Council meeting in The Netherlands.

74th meeting of the STC.

ESO present with an exhibition at the Fiesta Explorando Chile exhibition, Santiago, Chile.

Visit of the Racing Green Endurance electric SRZero supercar at Paranal as part of its Pan-American Highway journey.

The distance to the most remote galaxy so far was measured with the VLT (a redshift of 8.6).

ESO was present with an exhibition at the Des Chiliens a Liege in Liege, Belgium.

November

ESO Workshop on: The impact of Herschel surveys on ALMA Early Science, Garching, 16–19 November.

PIONIER first light as VLTI visitor instrument.

ESO/Glenn Arcos/ www.racinggreenendurance.com

The SRZero electric supercar arrived at Paranal on October 27 after touring the Pan-American Highway from Alaska's Prudhoe Bay and on their way to Ushuaia.

ESO & ALMA (ESO/NAOJ/NRAO)

The official hand over of the Santiago Central Office headquarters of the ALMA project, in the Vitacura district of the Chilean capital.

ESO was present with an exhibition at the Astrophotography Congress in Santiago, Chile.

The EVALSO high-speed data link was inaugurated at ESO Vitacura, Chile.

Ceremony for the official handover of the ALMA Santiago Central Office to the Joint ALMA Observatory.

ESO present with an exhibition at the IV Cono Sur Planetariums meeting in Santiago, Chile.

ALMA Board meeting in Santiago.

Plans for Early Science with ALMA to start in late 2011 endorsed by the ALMA Board.

ESO present with an exhibition at the Our Place in Space #2 — BCO at Discovery, Cork, Ireland.

First band 5 receiver shipped to European Front End Integration Centre at STFC/RAL.

129th meeting of the Finance Committee in Chile with visits to the sites of Paranal and ALMA.

87th OPC with 966 proposals submitted.

ESO present with an exhibition at the Galway Science and Technology Festival, Galway, Ireland.

December

Adriaan Blaauw, one of ESO's founding fathers and the second Director General, passed away at the age of 96.

VST first technical light.

119th Council meeting.

The ESO Council officially approved the ESO Technology Transfer Policy.

The budget for 2011 was approved by the ESO Council.

120th Extraordinary Council meeting (teleconference).

All 58 water vapour radiometers for installation on ALMA antennas delivered to Chile.

ESO Director General, Tim de Zeeuw, in discussion with the Brazilian Minister of Science and Technology, Sergio Machado Rezende, during the accession ceremony in Brasilia on 29 December 2010.

ESO present with an exhibition at the Closing the Deal event, Leiden, Netherlands.

All 83 power supply units for ALMA front ends produced and delivered to Chile.

60% of the ALMA band 7 receivers (41 units), and 75% of the band 9 receivers (53 units) have been delivered.

ESO was present with an exhibition at the Technology World fair, London, UK.

Using the VLT, the atmosphere around a super-Earth exoplanet was analysed for the first time.

One hundred antenna stations at the ALMA Operations Site have already been equipped with high precision mechanical parts.

By the end of the year the detailed design of the new Office and Conference building and of the Technical building in Garching was nearly completed.

The Federative Republic of Brazil signed the formal accession agreement paving the way for it to become a Member State of ESO.

Closure of the Space Telescope - European Coordinating Facility.

Committees

Council

As its ruling body, the ESO Council determines the policy of the organisation with regard to scientific, technical and administrative matters, while delegating the day-to-day running of the organisation to the Director General. Both the Council and the Committee of Council (the informal body of Council) normally meet twice during the year. However, as there were a number of important matters arising for which approval was sought from the Member States, there were two Ordinary and three Extraordinary Council meetings during 2010. Ordinary meetings were held in Garching on 8–9 June and 9–10 December, with Extraordinary meetings taking place on 26 April (Garching), 5 October (Den Haag) and 21 December (by teleconference). Meetings of the Committee of Council took place on 2–3 March and 4–5 October in Garching and Den Haag respectively. All meetings were chaired by the President of Council, Laurent Vigroux.

During their first Extraordinary meeting in April, Council agreed to the selection of Cerro Armazones in Chile's Region II as the baseline site for the construction of the European Extremely Large Telescope.

At the June meeting, Council received updates on all areas of ESO programmes. Approval was given for the extension of the appointment of the E-ELT Standing Review Committee (ESRC) Chair, Roger Davies, and the ESRC members Reinhard Genzel, Bengt Gustafsson, Matt Mountain, Monica Tosi and Robert Williams, pending the Council decision regarding the construction proposal of the E-ELT. Also approved were the ESO Financial Statements for 2009, as was the External Audit Report 2009, with Council unanimously granting discharge to the Director General for that year.

For the October Extraordinary Council meeting, Council met at Den Haag and unanimously agreed to authorise the Director General to send a formal invitation to Brazil to apply for membership of ESO. In conjunction, Council confirmed that a negotiating team, consisting of Laurent Vigroux, Thomas Henning, Bruno Marano and the Director General, should be appointed to formally discuss the terms of the accession of Brazil to ESO with their Brazilian counterparts. This team was supported by Patrick Geeraert and Laura Comendador, ESO Head of Administration and Head of Legal Services, respectively.

As part of the same meeting, Council approved the appointment of two new European members, Wilfried Boland and Karl-Friedrich Schuster, to the ALMA Management Advisory Committee for the ALMA Annual External Review. Council also unanimously agreed that Claes Fransson should become Chair of the Scientific Strategy Working Group (SSWG).

During the December meeting, Council was provided with the current situation in relation to all aspects of ESO's workings, including the findings and recommendations from the Visiting Committee who had completed their very positive assessment of ESO's entire programme earlier in the year. A number of appointments were agreed including the reelection of Laurent Vigroux as President of Council for 2011, with Xavier Barcons being elected as Vice-President.

For the ALMA Board, Laurent Vigroux and Tim de Zeeuw were reappointed as *ex officio* members, with Patrick Roche and Ewine van Dishoeck as members. Also approved was the appointment of Johan Holmberg as FC Chair while Willy Benz was re-elected as Chair of the STC. For the OPC, Michael Rowan-Robinson and Jean-Louis Monin were appointed Chair and Vice-Chair respectively. Finally the members of the SSWG were confirmed to be Jens-Viggo Clausen, Konrad Kuijken, Pat Roche, Willy Benz, Bruno Leibundgut and Adrian Russell, with the Director General also attending these meetings. During this meeting, Council also approved the budget for 2011 and the respective scale of contributions for the Member States.

To end the year and as a result of fast-moving developments, an Extraordinary Council meeting took place on 21 December where approval was unanimously given for the accession of Brazil into the organisation. This meeting also saw the appointment of David Edvardsson as Assessor of the ALMA Board.

Council and Committee of Council 2010

President	Laurent Vigroux
Austria	Sabine Schindler Daniel Weselka
Belgium	Christoffel Waelkens Werner Verschueren
Czech Republic	Jan Palouš Jana Bystřická
Denmark	Jens Viggo Clausen Henrik Grage
Finland	Kalevi Mattila Pentti Pulkkinen
France	Jean-Marie Hameury Julien Galabru
Germany	Thomas Henning (Vice President) Andreas Drechsler
Italy	Bruno Marano Vincenzo Dovì
The Netherlands	Konrad H. Kuijken Jan van de Donk
Portugal	Teresa Lago Fernando Bello
Spain	Xavier Barcons Jordi Torra
Sweden	Claes Fransson David Edvardsson
Switzerland	Georges Meylan Martin Steinacher
United Kingdom	Patrick Roche John Womersley

Finance Committee

Finance Committee 2010

Chair	Alain Heynen
Austria	Daniel Weselka
Belgium	Robert Renier
Czech Republic	Jiri Toifl
Denmark	Cecilie Tornøe
Finland	Jaana Aalto
France	Patricia Laplaud
Germany	Gisela Schmitz-DuMont
Italy	Germana Di Domenico
The Netherlands	Coen van Riel
Portugal	Fernando Bello
Spain	Luis Ruiz López
Sweden	Johan Holmberg
Switzerland	Maurizio Toneatto (February) Astrid Vassella (from May onwards)
United Kingdom	Colin Vincent

The Finance Committee (FC) held two ordinary and one extraordinary meeting during the year, all chaired by Alain Heynen. The meeting in November was held in Chile and was followed by site visits.

The committee approved the award of twelve contracts exceeding € 500 000, as well as two single-source procurements exceeding € 250 000. Twelve amendments to existing contracts were approved. One contract was approved by written procedure. Information was received concerning procurement statistics, forthcoming calls for tenders and price enquiries exceeding € 150 000. An additional form of presentation for the procurement statistics was requested by the FC, to be provided in 2011. A new version of the ESO Procurement & Sales Procedures and a proposal for a Technology Transfer Policy at ESO were discussed and commented.

The ESO Budget 2011 was discussed and sent without a recommendation to Council for approval. Savings requests by the Member States were taken into account as much as possible. The FC also dealt with financial issues such as annual accounts and external audit reports, budgets, the cash-flow situation, financial statements, Member State contributions, financing of the E-ELT and related subjects. A new method for calculating the scale of Member State contributions to decrease the sometimes sharp annual variations was presented and discussed.

General personnel issues concerning staff members and local staff members as well as the CERN Pension Fund were discussed by the committee.

Finance Committee on Paranal during 129th FC meeting.

Scientific Technical Committee

The Scientific Technical Committee 2010

Austria	Josef Hron (ESE)
Belgium	Joris Blommaert (ESE)
Czech Republic	Michael Prouza (LSP)
Denmark	Johan Fynbo (LSP)
Finland	Lauri Haikala (ESAC)
France	Yannick Mellier (LSP Chair)
Germany	Tom Herbst (ESE Chair)
Italy	Alessandro Marconi (STC Vice-chair, LSP)
The Netherlands	Marco de Vos (LSP)
Portugal	José Afonso (ESAC)
Spain	Santiago Arribas Mocoroa
Sweden	Göran Olofsson (ESE)
Switzerland	Didier Queloz (ESE)
United Kingdom	Rob Ivison (ESAC)
Chile	Leonardo Bronfman

Members at Large

Willy Benz (STC Chair)
David Crampton (ESE)
Elaine Sadler (ESAC)
Linda Tacconi (ESAC Chair)

The Scientific Technical Committee had two regular meetings and an extraordinary meeting to discuss the process of instrument selection for the E-ELT. The STC subcommittees met before the STC meetings to discuss several of the topics in more detail, leading to recommendations by the STC itself. The organisation of all meetings was smooth and all parties have adjusted to the procedures introduced in 2009.

72nd STC meeting

The STC met for its 72nd meeting on 20 and 21 April in Garching. The meeting organisation was severely hampered by the limitations imposed on European air traffic due to the ash cloud from the volcano Eyjafjallajökull. The agenda was shortened and half the STC attended by video conference. Despite these limitations, the STC covered all agenda items with sufficient discussion time. The La Silla Paranal (LSP) and the E-ELT Science and Engineering (ESE) subcommittees had met the week before the STC, while the ESAC met several weeks earlier in preparation for the ALMA Science Advisory Committee. The main topics of the meeting were discussions of the Phase A study of ESPRESSO, the progress of the VLTI, the implementation of spectroscopic surveys, building the user community for ALMA, E-ELT site selection, E-ELT science support and E-ELT instrument selection.

The STC appreciated the careful Phase A study for ESPRESSO and recommended that the instrument should be built after negotiations with the consortium. The STC particularly liked the flexibility in usage of either a single VLT Unit Telescope or the combination of four UTs with this instrument. The continuing progress on the VLTI and the commissioning of PRIMA was noted, but the committee asked to be presented with an implementation plan for the VLTI extending until the start of the two second generation instruments MATISSE and GRAVITY. The STC reconfirmed its intention that ESO implement spectroscopic surveys and call for an instrument concept study related to large-scale spectroscopic surveys. It was further concerned that ESO ensured a rapid data distribution from the recently started VISTA surveys. The STC was in general pleased by the progress of ALMA, but recommended that ESO put sufficient resources into the education and training of the European ALMA community. The E-ELT site selection process was presented to the STC and it concluded that the methods employed and considerations applied by the Site Selection Advisory Committee were appropriate. The STC recommended that monitoring of the chosen site be continued. The process for the selection of the first E-ELT instruments was of great concern to the committee and it recommended the definition of a complete set of first generation instrument capabilities before selecting the first-light instruments, thus ensuring that the first-light instruments would be able to deliver the unprecedented level of science expected from the E-ELT.

73rd STC extraordinary meeting

An extraordinary STC meeting lasting one and a half days was organised on 15 and 16 June with the main task of thoroughly discussing and commenting on the E-ELT instrumentation plan. This meeting was carried out jointly with the ESE. Some time was devoted to the presentation and discussion of the telescope itself, but the emphasis was clearly placed on the instrumentation plan. The STC noted the large amount of high quality work carried out by the instrument consortia and the thoroughness of the reviews. The STC urged that the E-ELT instruments be commensurate with, and well matched to, the expectations the community has for an E-ELT. It appreciated the plan submitted by ESO for the selection of the first instruments and added the following recommendations.

The combination of a spectrograph and an imager with the associated adaptive optics modules was seen as an attractive package. The STC asked that the original instrument concepts undergo revision before moving to the next phase. Also, both instruments rely on advanced adaptive optics systems to deliver their full scientific potential. The STC recommended that ESO ensure that the required Research and Development (R&D) activities take place in phase with telescope and instrument development. Additional instrument capabilities, beyond the first-light instruments, were also discussed. Of major concern is maintaining the flexibility to follow the rapid evolution foreseen in some top science areas. The potential of new Member States to participate in instrument development should be kept in mind and, in some cases, the results from precursor instruments need to be analysed. The STC recommended that ESO depart from the traditional instrument generation concept and instead move towards having a pool of instrument capabilities that are studied and sequenced or down-selected at the appropriate time (starting roughly a year after the beginning of construction), based on their expected science return, technical feasibility and the evolution of the E-ELT. For the third instrument, the STC recommended a concept that did not rely on adaptive optics for reaching its full potential. Complex instruments should be considered only when their technical feasibility has been properly demonstrated. The STC was of the opinion that competitive open calls lead to the best possible instrumentation. It asked to remain involved in the selection process.

74th STC meeting

On 19 and 20 October the STC met for its 74th meeting in Garching. The subcommittees had again met during the previous week. Reports on those subcommittee meetings were given verbally at the STC in addition to the written reports. The STC regretted that, as in previous years, the budget document was delivered only a few days before the meeting, making a thorough assessment of the scientific and technical implications difficult.

The STC recommended that reaching the expected science capabilities of the E-ELT warranted a high budgetary priority. It reaffirmed that maintaining Paranal as a world-leading facility is essential so that ESO can continue to provide services to the bulk of ESO's astronomical community; to provide maximum flexibility for the development and exploitation of new instrument capabilities; to ensure the health of the instrumentation groups in the Member States; to make certain of the integration of the E-ELT into a state-of-the-art observatory and to maximise the synergy between E-ELT and VLT/VISTA with ALMA and future space-based observatories. The STC cautioned against any budget cuts that would jeopardise ESO's highly successful core programme. It was of the opinion that upgrading existing facilities and the development of new facilities are an essential part of the core programme. It did not support the cancellation of the upgrade programme, but welcomed the continued selection and planning of new second generation instruments beyond 2016. The STC expects a long-range instrumentation plan for presentation at the April 2011 meeting. The STC is ready to rank future plans for upgrades and new instruments to help balance the budgetary requirements to achieve the optimum of science capability.

The STC took note of the results of the recent Call for Letters of Intent for a wide-field multi-object spectrograph. It recommended that high weight should be given to projects for facilities in which ESO is a major partner or where significant observing time could be guaranteed to the ESO community. The window of opportunity for surveys with the VST continues to narrow and the STC urged the preparation of a commissioning plan for the telescope to ensure that the planned surveys could start before the end of 2011. Any additional delay would require a re-evaluation of the survey priorities. It further supported the proposal to use all available observing time for the first two years for public surveys and guaranteed time observations. The STC welcomed the report on the plans of delivery of large datasets from surveys to the community.

As at its previous regular meeting, the STC was pleased to see major steps towards successful completion of the European ALMA deliverables such as the European antennas, receiver bands 7 and 9 and work on the ALMA archive. The STC recommended that, with the imminent Call for Proposals for Early Science with ALMA, a calibration plan and the proposal implementation process were put in place well before issuing the Call.

The STC congratulated the E-ELT team on producing a credible proposal within schedule and the subsequent successful completion of the external review. It was pleased to see the positive statements expressed by the review panel. The STC reiterated the importance of a high contrast planet-imaging instrument and a multi-object spectroscopic capability on the E-ELT for reaching its unique science goals. It recommended exploring ways of incorporating extreme adaptive optics during E-ELT construction and not waiting until the results from SPHERE become available.

Observing Programmes Committee

The Observing Programmes Committee 2010

Ralf Bender (Chair)

Almudena Alonso-Herrero (P86, Member-at-large)
Felipe Barrientos (P87, Member at large)
Jacqueline Bergeron
Piercarlo Bonifacio (P86)
François Boulanger (P86)
Christopher Conselice (P86, Member at large)
Sofia Feltzing (P86, Member at large)
Annette Ferguson (P87)
Eileen Friel (Vice-chair)
Emmanuel Jehin (P87)
Hans Kjeldsen (P87)
Jean-Paul Kneib (P87)
Leon Koopmans
Martin Kürster
Henny Lamers (P87)
Daniel Lennon (P86)
Simon Lilly
Diego Mardones
Michael Merrifield
Jean-Louis Monin
Bianca Poggianti
Regina Schulte-Ladbeck
Matthias Steinmetz (P86)
Antonella Vallenari (P87)
Paul van der Werf (P86)
Kim Venn (P86)
María Rosa Zapatero-Osorio (P86, Member at large)

During its meetings in May and November, the Observing Programmes Committee evaluated the proposals submitted for observations to be executed in Periods 86 (P86; 1 October 2010 to 31 March 2011) and 87 (P87; 1 April 2011 to 30 September 2011). The number of proposals for observation with the ESO telescopes in these two periods, 977 and 966, is comparable to the number of Period 85 proposals (988). In P86, ESO also received nine large programme proposals for time on the GRANTECAN telescope (GTC) within the framework of the accession agreement of Spain into ESO. The distribution of proposals across the different scientific areas remained similar to recent periods. There were about twice as many proposals for galactic scientific projects, pertaining to OPC categories C (interstellar medium, star formation and planetary systems) and D (stellar evolution), as for extragalactic topics, which comprise categories A (cosmology) and B (galaxies and galactic nuclei). The OPC categories are specified in full at www.eso.org/sci/observing/proposals/opc-categories.html.

As in previous periods FORS2, which is mounted on Antu (Unit Telescope 1 of the VLT, or UT1), remained as the VLT instrument on which the largest amount of observing time was requested, ahead of X-shooter on Kueyen (UT2). Kueyen was again the most popular UT, with a ratio between the requested and the available time, or pressure, of almost seven, while the pressure on both Antu and Yepun (UT4) was close to four. The possibility of installing a visitor instrument at the VLT Interferometer, offered for the first time in Period 85, generated considerable interest in the community. Between P86 and P87, proposals requesting a total number of 50 VLTI nights were submitted for PIONIER, a near-infrared interferometric visitor instrument designed for imaging and fed by four telescope beams. These proposals were allocated 37 nights with the four Auxiliary Telescopes. Open-time proposals for the VISTA survey telescope were invited for the first time in P87 and twelve were submitted, of which two were scheduled.

On La Silla, HARPS and EFOSC2 remained in high demand. The interest of the community in the installation of visitor instruments at the NTT, already noted in 2009, continued to grow in 2010 with a total of 36 proposals of this type submitted in P86 and P87. Over these two periods, 65 nights were allocated to the visitor instruments ULTRACAM and AstraLux Sur.

Observations with a visitor instrument, Z-Spec, were also scheduled with APEX in P86. For P87, this instrument was offered to the ESO community, and three proposals using it were scheduled.

Within the framework of the continuing agreement between ESO and ESA for a joint telescope time allocation scheme for coordinated observations with the VLT and XMM-Newton, proposals for such observations were invited again, for the seventh time, in 2010. ESO received one joint application in P87, which did not qualify for allocation of telescope time. Time at both facilities was granted to four joint proposals evaluated by the XMM–Newton Observing Time Allocation Committee.

Targets of Opportunity

The definition of what constitutes a Target of Opportunity (ToO) programme was refined in P86. Despite the stricter criteria, the number of ToO proposals submitted in 2010 remained similar to previous years. For P86 and P87 respectively, the OPC evaluated 47 and 53 proposals, of which 18 and 15 were scheduled.

Calibration Programmes

Calibration Programmes (CP) are meant to allow users to complement the existing coverage of the calibration of ESO instruments. Their main evaluation criterion is the comparison of the potential enhancement of the outcome of future science that can be expected from their execution with the immediate return of current period science proposals directly competing for the same resources. One CP was accepted in P86 from two submitted and none in P85 from the three submissions.

Large Programmes

Large Programmes (LPs) are projects requiring a minimum of 100 hours of observing time that have the potential to lead to a major advance or breakthrough in the relevant field of study. LP execution is spread over several observing periods with a maximum duration of four years for observations to be carried out with the La Silla telescopes and of two years on the VLT/I and on APEX. Significantly fewer LP proposals were received in 2010 than in previous years: 18 in P86 and 12 in P87. The small number of such proposals in P87 can probably be attributed in part to the call issued by ESO in the last quarter of the year for letters of intent for Public Spectroscopic Surveys. Following the OPC recommendations, four new LP were implemented in P86, and six in P87. The trend towards using a large fraction of the science time on the La Silla telescopes for the execution of LPs, encouraged by ESO and already embraced by the community last year, continued. Six LPs were scheduled on the 3.6-metre telescope in P87, receiving a total allocation of 100 nights (60 % of the science time). At the NTT, five LPs were under way, totalling 59 nights of observing time.

ESO/GTC Programmes

The third call for ESO/GTC proposals was issued along with the P86 call for proposals for observations with ESO telescopes. It invited Principal Investigators from ESO Member States to submit LP proposals to take up the observing time offered on the GRANTECAN within the framework of the accession agreement of Spain into ESO. Two members-at-large appointed by Spain assisted the OPC in evaluating the proposals. Notwithstanding this difference, the OPC handled the ESO/GTC proposals in the same way as regular ESO LPs. In a second step, the ESO–Spain Liaison Committee reviewed the proposals deemed suitable for implementation by the OPC by considering the relevant technical and operational constraints. As an outcome of this process, ESO/GTC time was allocated to three programmes.

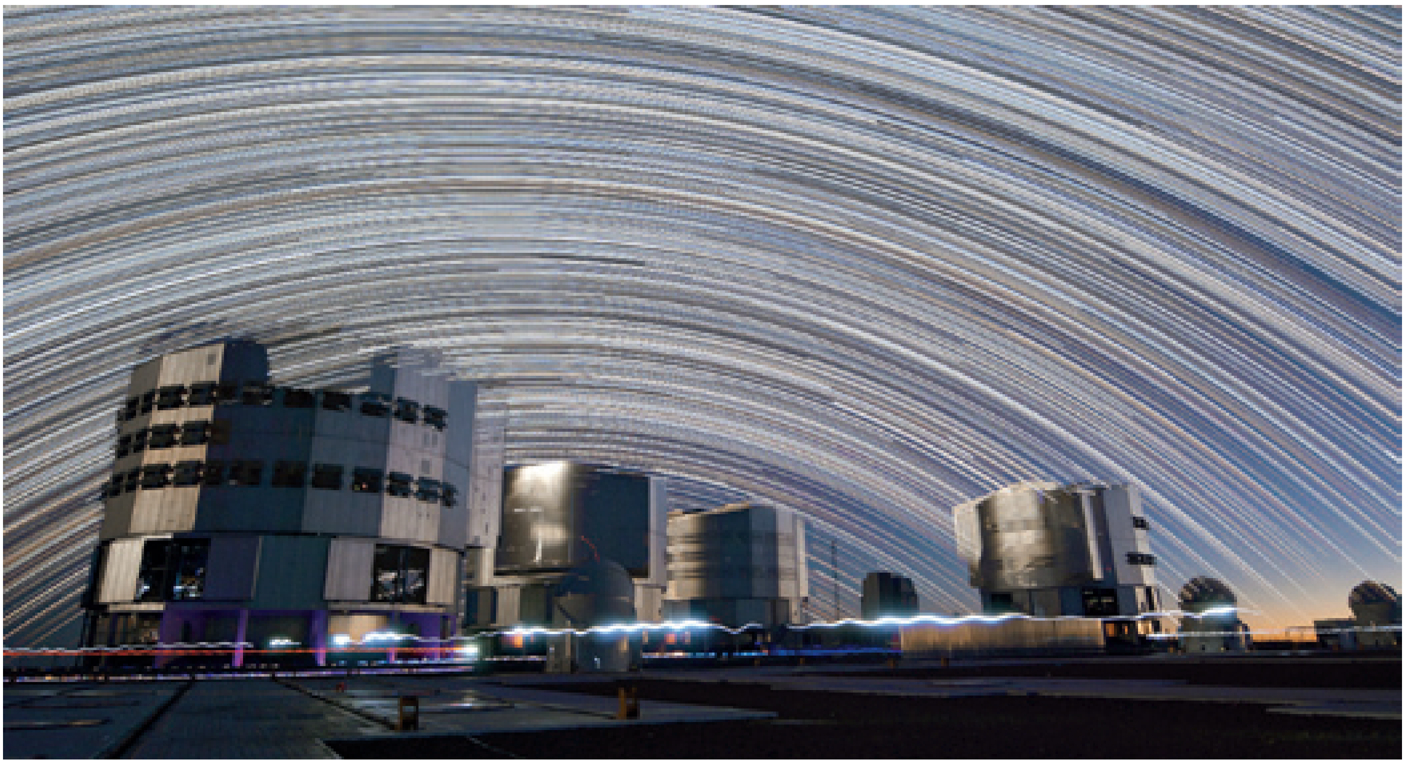
OPC procedures

The OPC Working Group created by the Director General in 2009, with the mission to evaluate the current ESO proposal selection process and to study possible improvements, continued its work this year. Following one of its recommendations, the Short and Normal Programme proposal types were merged in P87 and a new proposal form was created with the purpose of alleviating the review work of the OPC.

Director's Discretionary Time

As in previous years, the ESO user community submitted about 120 proposals asking for Director's Discretionary Time (DDT). Such proposals may be submitted throughout the year for programmes that present a level of urgency incompatible with the regular proposal cycles handled by the OPC. After taking advice from an internal committee comprising ESO staff astronomers, the Director General approved about half of the DDT proposals submitted in 2010 for implementation.

Star trails over the VLT. During the night astronomers with flashlights walked across the VLT platform.



(c) José Francisco Salgado (josefrancisco.org)/ESO

Users Committee

The Users Committee 2010

Austria	Werner Zeilinger (Vice-chair)
Belgium	Martin Groenewegen
Czech Republic	Jiří Grygar
Denmark	Frank Grundahl
Finland	Seppo Katajainen
France	Vanessa Hill
Germany	Thomas Preibisch
Italy	Stefano Benetti
The Netherlands	Scott Trager
Portugal	Jorge Meléndez
Spain	Ignacio Negueruela
Sweden	Nils Ryde
Switzerland	Hans Martin Schmid
United Kingdom	Jacco van Loon (Chair)
Chile	Mario Hamuy (Replacement for Manuela Zoccali)

The annual meeting of the Users Committee (UC) took place at the ESO Headquarters in Garching on 29 and 30 April. The meeting was organised by the User Support Department within the Operations Directorate.

After a presentation on ESO's long-term strategies and priorities (Andreas Kaufer, on behalf of the ESO Director General), the relevant ESO operations staff members presented the highlights of their respective departments. These included reports from La Silla Paranal Observatory and APEX, Paranal Science Operations, User Support and Data Products (i.e., front- and back-end), and the Observing Programmes Office (OPO).

From the committee side, the UC Chair (Jacco van Loon) reported on the preceding UC/OPO/OPC liaison meeting. All UC members mentioned the overall positive feedback that they had received from their respective communities, giving special praise to the release and availability of the PI-packs, which consist of both raw and reduced proprietary data made available in real time. During the general discussion — to which ample time was allocated — specific topics treated included ESO's handling of guest/visitor instruments, the oversubscription of some telescopes (e.g., Kueyen), the retirement of first generation instruments, leading to the loss of specific capabilities and coverage (e.g., NACO), and the support of various ESO tools and pipelines under Mac OS.

The special topic selected this year was ALMA Operations since both the UC and ESO thought it was an appropriate time to present and discuss together the ramping up of activities in preparation for ALMA Early Science. Since ALMA has not yet commenced its operational phase, this special session consisted mostly of presentations given by representatives of the ALMA Regional Centre, who covered different topics ranging from general concepts to detailed demos of the ALMA tools. The general discussion that followed touched upon the operational scheme of the ARC nodes and emphasised the role of the UC in raising awareness about ALMA and its capabilities within the ESO community at large.

Subsequently, during its December meeting, the ESO Council approved the updated Terms of Reference for the UC that reflect its current mission, most importantly its expanded scope, which now includes ALMA.

The ESO Users Committee meeting which took place at ESO headquarters in May 2010.

ESO's headquarters in Garching. The image shows the view from the roof of the main building just after sunset.

Outreach

Following the International Year of Astronomy 2009 (IYA2009) it was expected that 2010 would be quieter, allowing the ESO education and Public Outreach Department to take stock and return to more stable day-to-day operations. We have managed to streamline all our core activities, and the increased visibility that ESO has gained from its involvement in IYA2009 has enabled interesting new outreach opportunities. This has resulted in several important operational advances, using improved workflow and infrastructure. In operational terms we now have, due to improved organisation and planning, an increased ability to cope with larger personnel changes, illness or leave periods, and large unexpected tasks. From these outreach efforts, ESO has achieved greater public visibility and popularity and opened more collaborative opportunities with the media and other stakeholders.

The year saw a continued high output of press and photo releases, announcements and pictures of the week, with media teleconferences for particularly significant stories. The accession of Brazil generated significant media attention, which was handled during the Christmas vacation. In the ensuing weeks, Brazil was rapidly integrated into the ESO outreach products and channels.

The development of a new workflow facilitated the handling of unconventional media visits, events and partnerships. These requests — such as the visit of the Racing Green Endurance electric supercar to Paranal, which resulted in ESO being the topic of one episode of a BBC series dedicated to this project — are arriving more frequently as a result of ESO's increased public visibility. These efforts have resulted in an increase of 33 % in the number of web visitors to www.eso.org compared to 2009.

Two successful competitions were run: ESO Hidden Treasures 2010 and Hubble Pop Culture, the latter being part of ePOD's campaign of celebrations for the NASA/ESA Hubble Space Telescope's 20th anniversary.

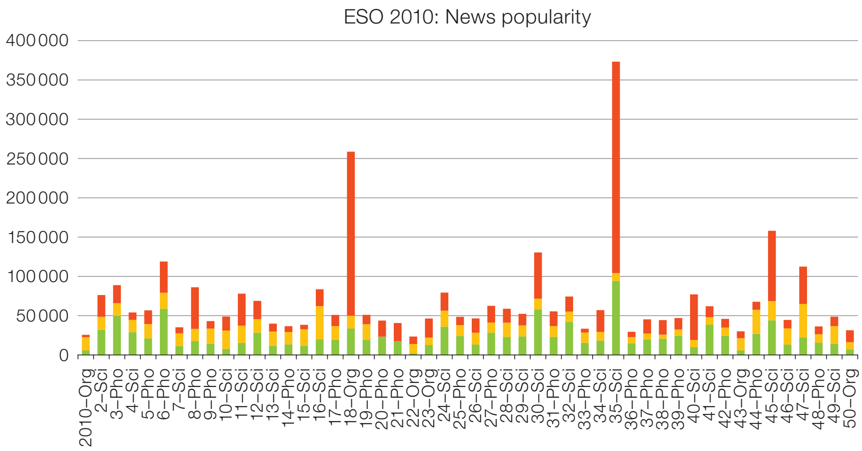
Planning for ESO's 50th anniversary campaign also started in the run up to the year 2012.

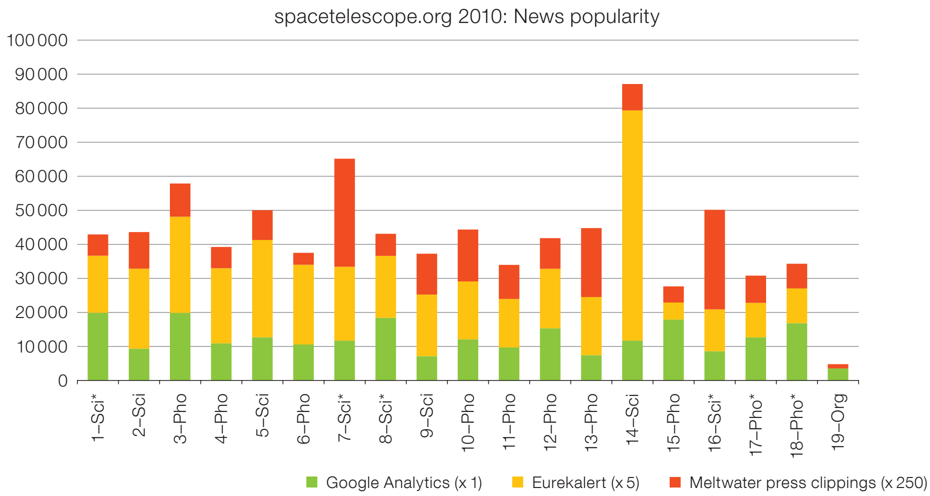
Further implementation of the ePOD outreach strategy, which commenced in 2008, took place with the expansion of community coordination, promotion and marketing, the introduction of exhibition and education strategies, and a plan to achieve greater coherence between ePOD/Garching and ePOD/Chile.

ePOD also received awards this year: the movie *Eyes on the Skies — 400 Years of Telescopic Discovery* (now at 450 000 copies distributed) received the International Association for Media in Science's Award at the 47th International Festival TechFilm 2010 in Prague. The IYA2009 live webcast, Around the World in 80 Telescopes, was awarded the first runner-up position in the IYA2009/Mani Bhaumik Prize for Excellence in Astronomy Education and Public Outreach.

Press activities

The production of press releases and announcements with their associated visuals has continued with improvements in both quality and quantity. We have refined our ability to select the appropriate





Popularity of 2010 press releases, for eso.org (top) and spacetelescope.org (bottom). The news releases are identified by their release number. Google Analytics measures the number of visitors to the news release web page. Eurekalert counts how many journalists followed the news release link on the Eurekalert website (a news concentration and distribution site for journalists). Meltwater is an electronic press clippings service; the metric being the number of online newspaper articles about the news release.

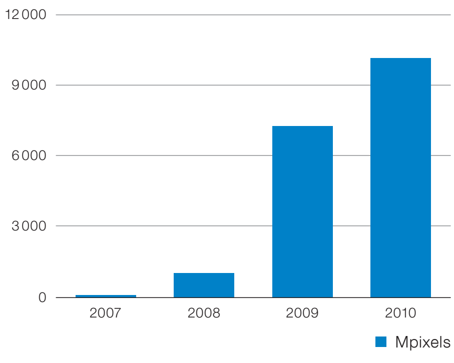
These three metrics have widely different values and have been scaled to the range of Google Analytics values. The decrease for the later releases is expected, as it takes time for the metrics to reach their final numbers.
Releases to be highlighted are: eso1018 concerning the E-ELT site selection process; eso1035, on the richest planetary system; eso1045, about the planet from another galaxy; and heic1014 regarding dark energy and weak lensing.

channel for a given story, from a full press conference to a concise social media post, and have added specific promotion and distribution steps to increase the impact of each release.

ePOD published 50 press releases for ESO (a similar number to 2009), and 36 press releases for ESA/Hubble, the International Astronomical Union (IAU) and IYA2009 combined. Due to a renewed focus on smaller, but still newsworthy stories, ESO issued 102 announcements (up 142% from 2009). IAU, ESA/Hubble and IYA2009 press activities are listed below in the IYA2009 section.

Fifty-two ESO Pictures of the Week were issued and these are becoming increasingly popular. ePOD also organised two press conferences, on "Clearing the Cosmic Fog — the most distant galaxy ever measured" and "Planet from another galaxy discovered". Media attendance was good, with about 20 journalists on average per conference.

An important component of the pipeline production of press releases, image processing and systematic mining of the ESO and HST science archives, continued to yield high impact imaging results. In 2010, the number of processed image pixels increased by 40% with respect to the previous year.



Publications

The production of publications continued, with several highly visible print products. In some cases, the publications were issued solely in electronic form. The number and volume of ESO print products increased 90% from 2009 to 2010 (from 37 to 72 publications).

Periodicals	The Messenger: 4 issues
	ST-ECF Newsletter: 1 issue
	CAPjournal: 2 issues
	Science in School: 4 issues (jointly with EIROforum)
Books	Postcards from the Edge of the Universe
Brochures	A Universe of Discoveries (English)
	A Universe of Discoveries (German)
	A Universe of Discoveries (Spanish)
	A Universe of Discoveries (Italian)
	A Universe of Discoveries (Portuguese)
	IYA2009 Executive Summary
	IYA2009 Final Report
	EVALSO flyer
	Exhibition catalogue HST3 exhibition
	ESO flyer (English, Spanish)
	EIROforum flyer (jointly with EIROforum)
Other	ESO Annual Report 2009
	8 handouts
	7 conference posters
	3 picture posters
	4 media kits
	22 postcards
	ESO Calendar 2011
	ESO Christmas cards
	Engraved iPods for prizes
	Conference/press folders
	1 bookmark
	4 Safety flyers
	ESO pin
	JWST/E-ELT conference proceedings (partly produced)
	1 banner for the HST3 exhibition
	Lanyard
	Conference mug
	ESO basic texts
	Finance Committee Rules
	VLT laser-engraved glass cube
	ESO Christmas Card
Electronic publications	Hubble Calendar 2011

ePOD's publications in 2010.

Audiovisuals

Thirteen episodes of the popular ESOcast video podcast were published during the year.

ESO had three video news releases during 2010, on the E-ELT site selection, the most distant galaxy ever measured, and the first planet of extragalactic origin.

Photos were taken for a variety of events and occasions such as conferences and meetings, and staff photos were taken for the kiosk display in the lobby area at ESO Headquarters, Garching.

A project to provide subtitles in multiple languages for ESOcasts and Hubblecasts continued and the product will be launched in 2011.

Events and exhibitions

ESO was present at 62 exhibitions this year (down 25%). In many cases the exhibitions were carried out in partnership with local organisers to reduce the load on ESO's resources. This strategy will also be pursued in the future where possible.

Our eight permanent exhibitions continued to draw crowds. These are:

– *Ruinas de Huanchaca* (Antofagasta, opened 2009);

– MIM Santiago;
– Science Tunnel (with MPG);
– Sci & Tech Museum Santiago (refurbished in 2009);
– Taltal (close to Paranal);
– ALMA site museum (on the road to Chajnantor);
– Deutsches Museum;
– Paranal Visitors Centre.

Our ninth permanent exhibition will be the La Silla Visitors Centre, which will open in 2011.

A highlight among the exhibitions this year was ESO's participation at JENAM 2010 in Portugal. Apart from having a stand and an exhibition in place, ePOD also organised several gatherings such as: the ESO Hour and the launch of the book *Postcards from the Edge of the Universe*.

Web and software development

Important infrastructure developments were the result of a targeted effort by the advanced developments group.

A credit-card payment module for conference registration, dinners and the like was integrated into v2 of the Hubbleshop and will be implemented for the ESOshop during 2011.

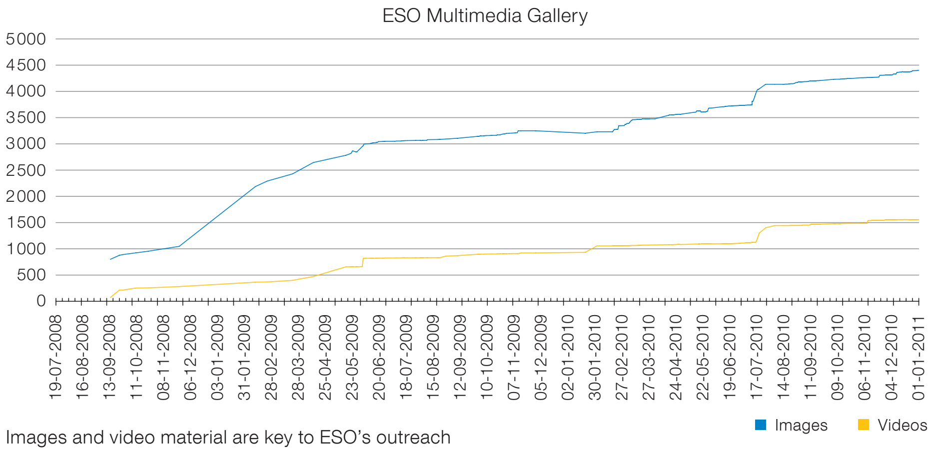
Version 3.0 of the popular ESA/ESO/NASA FITS Liberator plug-in for Photoshop was completed and released. This has been developed to deliver long-term stability and to operate in a stand-alone mode outside Photoshop.

In collaboration with the IT department, several important improvements were made to the infrastructure of the web servers. The implementation of the IT department's content management system project for the static web pages was supported.

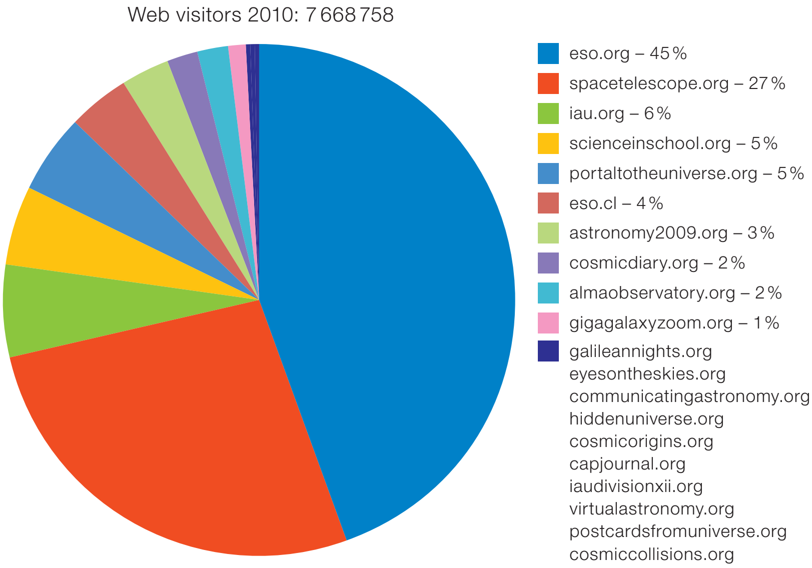
The project to tag all the ESO and the ESA/Hubble outreach images with Astronomy Visualisation Metadata (AVM) started and is now well underway.

At ESO Headquarters, a prototype for an information kiosk that displays staff information and pictures was introduced. The

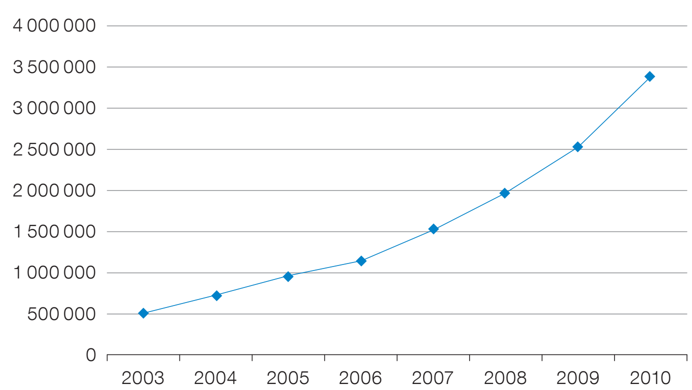
The main entrance of the Museum of the Atacama Desert (MDA), in Antofagasta (Chile's Region II).



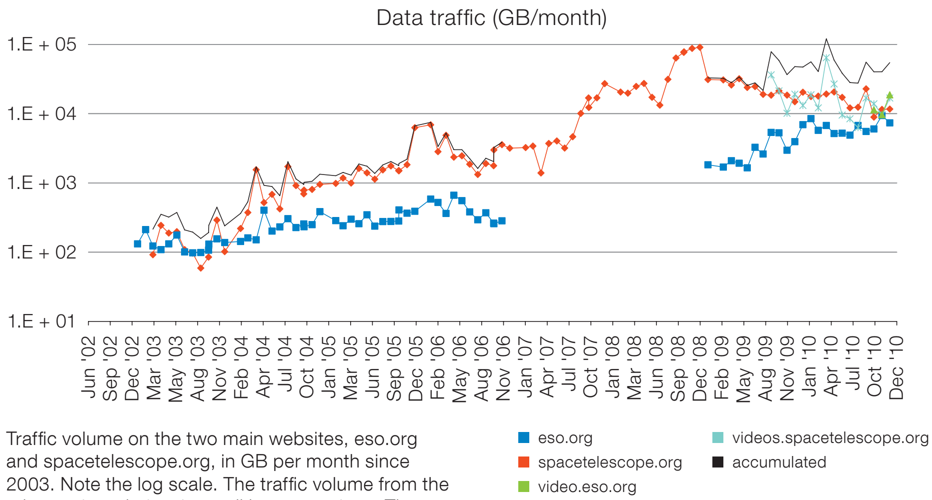
Images and video material are key to ESO's outreach activities. During this year the volume of images available on the ESO website increased by 30% and videos by 60%.



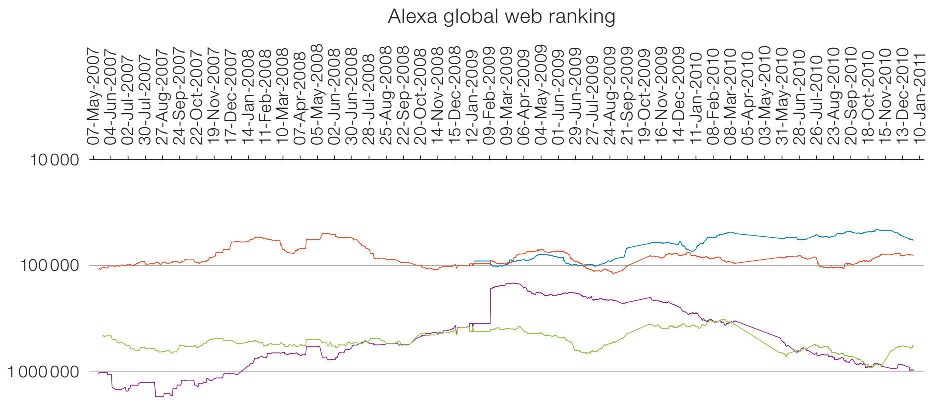
Regarding the total number of visits to our websites and our 20 partner websites this year, eso.org had the most visits. eso.org and spacetelescope.org together represent more than 70% of the total number of visits. The total number of web visits this year was 7.7 million. eso.org had 3.4 million visits (up 33% from 2009), and spacetelescope.org had 2.1 million visits (up 54%).



The increasing number of visits per year to eso.org.



Traffic volume on the two main websites, eso.org and spacetelescope.org, in GB per month since 2003. Note the log scale. The traffic volume from the other main websites is small by comparison. The top of the box indicates 0.1 PB (petabyte). The accumulated traffic from all sites corresponds to 0.6 PB/year.



Alexa website rankings indicating the popularity ranking among websites in the world (Google is ranked 1). eso.org improved its ranking significantly over the period.

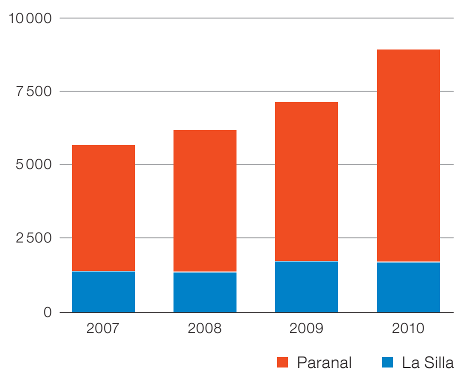
kiosk system also has additional capabilities that will be rolled out during the next period.

The web content on eso.org was subject to a continuous process of improvement during the period and expanded to include the new ESO Virtual Tours.

Several search engine optimisation actions were taken in order to generate more traffic on eso.org. Among these were: adding social media sharable buttons, the embedding of videos and cross advertisements on ePOD's mini-websites.

Activities in Chile

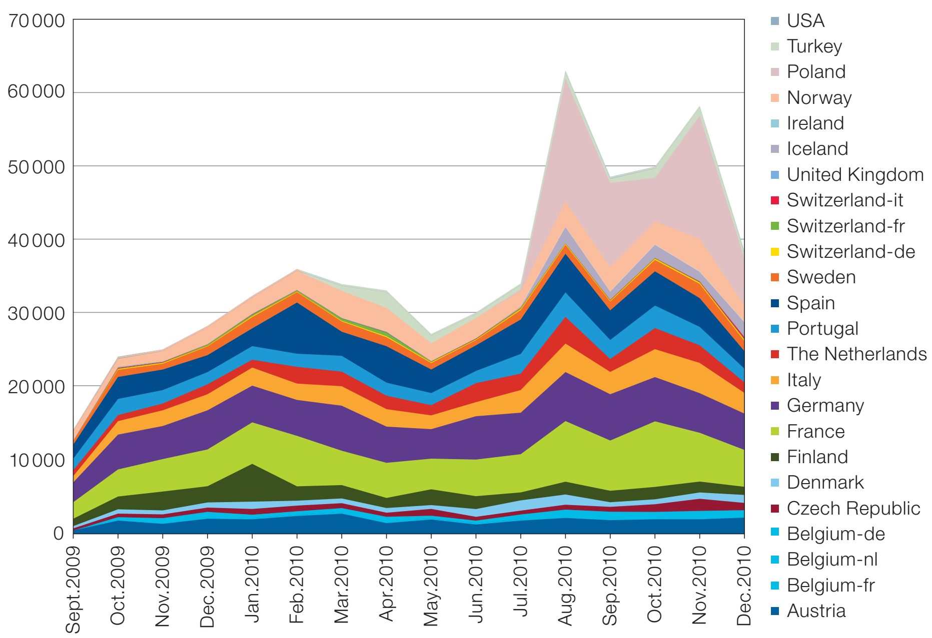
A renewed focus was placed on the Chile community outreach projects funded by ESO and new ways were sought to initiate win-win partnerships.



This year more than 350 VIPs and representatives of the media visited the ESO sites, spread over 158 days throughout the year. During the regular weekend visits (run by Operations) around 9000 tourists visited the sites — a 24 % increase over 2009).

ESO Science Outreach Network

The ESO Science Outreach Network's (ESON) prototype phase has transformed into a standard operation with 15 different languages and 18 different mini-sites. In addition to providing the translations, the ESON representatives serve as local contacts for the media and the general public in connection with ESO developments, press releases, exhibitions etc. They promote ESO in various ways in the Member States and add significantly to the visibility of the organisation.



The visits per ESON country on eso.org.

Hubble education and public outreach

During 2009, there were 19 press releases from ESA/Hubble (up 6% from 2009), 9 Hubblecasts (up 29% from 2009), and 16 Hubble updates (shorter announcements, up 14% from 2009). The Hubblecasts remain very popular and have received international recognition.

A website redesign of spacetelescope.org was launched which led to more than 50% increased visibility.

A limited but effective Hubble 20th anniversary campaign was carried out with almost 100 partners. Each received outreach materials to support the organisation of a local event that promoted Hubble 20th anniversary.

As a new initiative, ePOD now issues the series called Hubble Pictures of the Week. In total 36 images have been produced and published since its inception in April. This project has been well received by our various communities.

Following the closure of the Space Telescope - European Coordinating Facility, it was decided to continue the ESA/Hubble outreach operations at ESO ePOD as an ESA-funded service. The operational changes have been minor, but some of the more costly activities have been reduced or discontinued.

Education

ESO continued to support *Science in School*, the European science education journal published by EIROforum. *Science in School* featured articles about ALMA, and ESO's Joe Liske and his role in *Das Auge 3D*, the 3D film about the VLT. In collaboration with our partners, a school screening programme of *Das Auge 3D* was set up. ESO participated in the nationwide German Girls' Day activities designed to give female school students an insight into science and technology professions and to encourage more of them to choose such careers in the future.

EIROforum education and public outreach

ESO participated in the The EIROforum Outreach and Education Thematic Working Group.

ESO awarded its special EIROforum prizes at the 2010 EU Contest for Young Scientists to student Julian Petrasch who visited the ESO sites at La Silla, Paranal and Santiago in Chile.

Jury assistance for the magazine *Science on Stage* writing competition rounds 1 and 2 was provided.

IYA2009 and the IAU

The year 2010 was the final year of operations for the International Year of Astronomy 2009 project. ESO continued its leading role in the project with the goal of ensuring a proper close-out by transferring the knowledge to ESO and other appropriate legacy partners.

It was only at the conclusion of IYA2009 that the true scope of the venture became clear. A total of 148 countries participated, confirming that the IYA2009 network was (and still is) the largest ever in science. More than 70 international organisations participated in the IYA2009 activities, along with 13 Cornerstone projects and 16 Special projects.

ESO led four of the twelve IYA2009 Cornerstones: part of the 100 Hours of Astronomy Global Cornerstone project, Around the World in 80 Telescopes; the Galilean Nights — which ran from 22–24 October 2009; the Portal to the Universe — launched in April 2009; and the Cosmic Diary blog portal. The two latter projects remain in full operation, with the Portal to the Universe being operated by ePOD and having more than 350 000 visits per year: a number that continues to increase.

For the IYA2009, ePOD produced eight press releases (down 42% from 2009). The full story of IYA2009 was written up in a 1450-page Final Report available on astronomy2009.org. This experience represents a remarkable era in ePOD's history and has left a rich legacy.

For the IAU, ePOD produced nine press releases (down 61% from 2009).

IYA2009 Secretariat/IAU/Lee Pullen

IYA2009 closing ceremony took place in January 2010 in Padua, Italy.

Community coordination, social media, promotion and distribution

The new community coordination and promotion strategies were implemented in mid-year. The community coordination component is designed to bring ESO closer to its stakeholders, especially by exploiting the social media channels.

The ESO and ESA/Hubble presence on social networking sites such as Facebook, Twitter and YouTube continued to flourish, with the result that the public see the two brands as being closely associated. Tens of thousands of fans learnt about our latest press releases, pictures of the week, vodcasts and announcements through these sites. They often shared and republished the news in their own profiles.

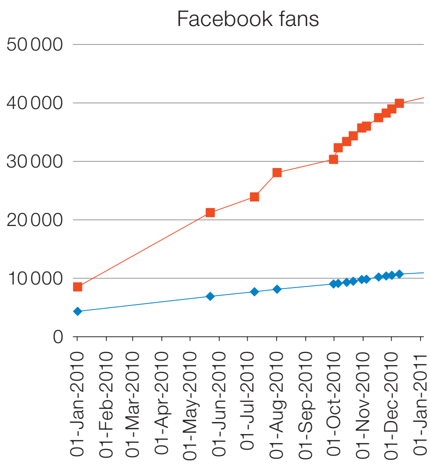
This more focused social media activity raised ESO's popularity and the visibility of its ESO news, positively influencing the traffic on eso.org. Facebook took third place amongst the top traffic-generating websites accessing eso.org; coming after eso.org itself and google.com. Wikipedia and Wikimedia Commons were also used to promote ESO and Hubble results and attract visitors to the websites.

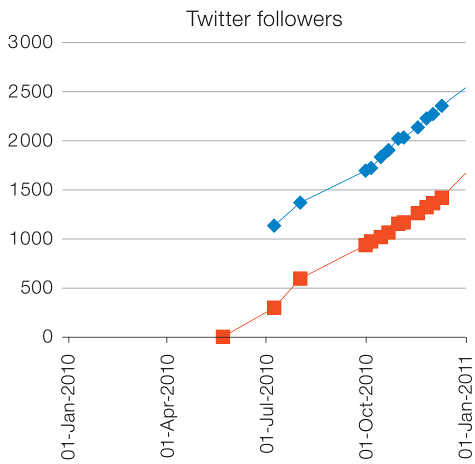
ePOD also started engaging with bloggers and social media influencers, which produced an immediate impact on brand popularity. In the same vein, several types of partnerships and collaborations were set up, including a network of Photo Ambassadors and a network of Outreach Partner Organisations.

The promotion component was designed to increase the visibility of each ePOD product as well as improving the target reach. Several promotion strategies were developed for products such as: *Postcards from the Edge of the Universe*, the ESO 2011 calendar and competitions such as ESO's Hidden Treasures. Distribution was also given special attention and handled more than 750 ticketed requests in addition to smaller tasks, shop orders etc. The ESOshop is now fully operational.

In addition to paper products, ESO-branded merchandise such as pens, caps, and mugs were produced and distributed at events and exhibitions, as well as to visiting groups.

As a result of reaching out more to its community, ESO received significantly more interest from "the real world", in the form of many unconventional outreach requests, which are likely to form an important component of our near future activity.





The social media stats for ESO and ESA/Hubble. Social media were integrated into ePOD's Strategy in 2010 and became a focus area.

- ESO Facebook fans
- Hubble Facebook fans
- ESO Twitter followers
- Hubble Twitter followers

This photograph shows three of the four Unit Telescopes that make up the VLT. The two distinct bright patches seen here in the night sky are the Large and Small Magellanic clouds, which are neighbouring galaxies to the Milky Way.

This dramatic infrared image shows the nearby star formation region Monoceros R2, located some 2700 light-years away in the constellation of Monoceros (the Unicorn).

Publications

Publications in refereed journals based on ESO data (2010)

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Glossary of Acronyms

4-LGSF	Four-Laser Guide Star Facility
4T	Four Telescope (VLTI mode)
A&A	Journal, Astronomy & Astrophysics
ACD	Amplitude Calibration Device (ALMA)
AEM	ALMA construction consortium
AIDA	Astronomical Infrastructure for Data Access
AIV	Assembly, Integration and Verification
ALMA	Atacama Large Millimeter/submillimeter Array
AMBER	Astronomical Multi-BEam combineR (VLTI Instrument)
Antu	VLT Unit Telescope 1
AO	Adaptive Optics
AOF	Adaptive Optics Facility
AOS	Array Operations Site (ALMA)
APEX	Atacama Pathfinder Experiment
Aquarius	Mid-infrared detector array (VISIR)
ARAL	Alignment facility for the VLTI
ARC	ALMA Regional Centre
ASIC	Application Specific Integrated Circuit
ASSIST	Adaptive Secondary Setup and Instrument Simulator (AOF)
AstraLux	Lucky Imaging camera for the Calar Alto 2.2-metre telescope
AT	Auxiliary Telescope for the VLTI
ATC	Astronomy Technology Centre (United Kingdom)
ATILO	Administrative Tribunal of the InternationalLabour Organisation
AU	Astronomical Unit
AVM	Astronomical Visualisation Metadata
BE	Back-End (ALMA)
CADC	Canadian Astronomy Data Centre
CAPj	Communicating Astronomy with the Public Journal
CCD	Charge Coupled Device
CDR	Critical Design Review
CERN	European Organization for Nuclear Research
CES	Coude Echelle Spectrometer
CMB	Cosmic Microwave Background
CMOS	Complementary metal–oxide–semiconductor
CNAM	Conservatoire National des Arts et Métiers
CONICA	COudé Near-Infrared CAmera (VLT)
CORALIE	Echelle Spectrograph on the 1.2-metre Leonard Euler Swiss telescope
CoRoT	COnvection ROtation and planetary Transits (French Satellite)
CP	Calibration Programme
CRIRES	Cryogenic InfraRed Echelle Spectrometer (VLT)
CSV	Commissioning and Science Verification
DC	Direct Current
DDS	Data Distribution middleware for SPARTA
DDT	Director's Discretionary Time
DG	Director General
DL	Delay Line (VLTI)
DMO	Data Management and Operations Division
DSM	Deformable Secondary Mirror
DSO	Department of Science Operations (ALMA)
EASC	European ALMA Support Centre
EC	European Commission
ECRI	European Conference on Research Infrastructures
E-ELT	European Extremely Large Telescope
EFOSC2	ESO Faint Object Spectrograph and Camera (v.2)
EIROforum	Organisation consisting of the eight largest scientific European international organisations devoted to fostering mutual activities
EMBL	European Molecular Biology Laboratory (Germany)
EMMI	ESO Multi-Mode Instrument (NTT)
ePOD	education and Public Outreach Department
ERP	Enterprise Resource Planning
ESA	European Space Agency
ESAC	European Science Advisory Committee (for ALMA)
ESE	ELT Science and Engineering
ESPRESSO	Echelle SPectrograph for Rocky Exoplanet- and Stable Spectroscopic Observations
ESM	European School Munich
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
ESOF	Euroscience Open Forum
ESON	ESO Science Outreach Network
ESRC	E-ELT Standing Review Committee
EU	European Union
EVALSO	Enabling Virtual Access to Latin-american Southern Observatories
FC	Finance Committee
FE	Front End
FEA	Finite Element Analysis
FEED	Front-End Engineering Design (E-ELT)
FEIC	Front-End Integration Centres (ALMA)
FE IPT	Front-End Integrated Project Team (ALMA)
FEROS	Fibre-fed, Extended Range, Échelle Spectrograph (2.2-metre)
FITS	Flexible Image Transport System
FORS1	FOcal Reducer/low dispersion Spectrograph (VLT)-1
FORS2	FOcal Reducer/low dispersion Spectrograph (VLT)-2
FOS	Faint Object Spectrograph (HST)
FP	Fabry-Perot
FP6	Sixth EC Framework Programme
FP7	Seventh EC Framework Programme
FTE	Full Time Equivalent
FWHM	Full Width at Half Maximum
GALACSI	Ground Atmospheric Layer Adaptive Optics for Spectroscopic Imaging (AOF)
GB	Gigabyte
GÉANT	European multi-gigabit computer network for research and education purposes
GHz	Gigahertz
GIRAFFE	Medium-high resolution (R = 7500–30000) spectrograph (VLT)
GRAAL	GRound-layer Adaptive optics Assisted by Lasers (AOF)
GRAVITY	AO assisted, two-object, multiple-beam-combiner (VLTI)
GTC	Gran Telescopio Canarias
GUI	Graphical User Interface
HARMONI	Visible and near-infrared integral field spectrograph (E-ELT)
HARPS	High Accuracy Radial Velocity Planetary Searcher (3.6-metre)
HAWK-I	High Acuity Wide field *K*-band Imager (VLT)
HCI	Human Computer Interface
HIA	Herzberg Institute of Astrophysics (Canada)
HR	Human Resources
HST	Hubble Space Telescope
HVAC	Heating, Ventilation and Air Conditioning
IAU	International Astronomical Union
IFS	Integral Field Spectrograph (SPHERE, E-ELT)
IFU	Integral Field Unit
INAF	Istituto Nazionale di Astrofisica (Italy)
INRIA	Institut National de Recherche en Informatique et en Automatique
IPP	Max-Planck Institute for Plasma Physics (Germany)
IPSAS	International Public Sector Accounting Standards
IPT	Integrated Product Team (ALMA)
IR	InfraRed
IRAM	Institut de Radioastronomie Millimétrique
IRDIS	InfraRed Dual-beam Imager and Spectrograph (SPHERE, E-ELT)
IRIS	VLTI Infrared Image Sensor
IRO	International Relations Office
ISAAC	Infrared Spectrometer And Array Camera (VLT)
IT	Information Technology
ITER	International Thermonuclear Experimental Reactor
IVOA	International Virtual Observatory Alliance
IVSLA	Istituto Veneto di Scienze ed Arti
IYA2009	International Year of Astronomy 2009
JAO	Joint ALMA Observatory
JENAM	Joint European and National Astronomy Meeting

JWST	James Webb Space Telescope
KMOS	*K*-band Multi-Object Spectrograph (VLT)
Kueyan	VLT Unit Telescope 2
LABOCA	Large APEX Bolometer CAmera
LAOG	Laboratoire d'Astrophysique de l'Observatoire de Grenoble
LGS	Laser Guide Star
LGSF	Laser Guide Star Facility
LMC	Large Magellanic Cloud
LOFAR	Low Frequency Array
LP	Large Programme
LSP	La Silla Paranal Committee
Mn	Mirror #n
MAD	Multi-conjugate Adaptive optics Demonstrator
mas	milliarcseconds
MASCOT	Mini All-Sky Cloud Observation Tool (Paranal)
MATISSE	Multi AperTure mid-Infrared SpectroScopic Experiment (VLTI)
Melipal	VLT Unit Telescope 3
MERIL	Mapping the European Research Infrastructure Landscape
MICADO	Diffraction-limited camera (E-ELT)
MIDI	Mid-infrared Interferometric Instrument (VLTI)
MIM	Museo Interactivo Mirador, Santiago
MIT	Massachusetts Institute of Technology
MPA	Max-Planck Institute for Astrophysics
MPE	Max-Planck Institute for Extraterrestrial Physics (Germany)
MPG	Max-Planck-Gesellschaft
MPIfR	Max-Planck Institute for Radioastronomy (Germany)
MUSE	Multi Unit Spectroscopic Explorer (VLT)
NACO	NAOS–CONICA (VLT)
NAOJ	National Astronomical Observatory of Japan
NAOMI	Adaptive optics system for the Ats (VLTI)
NAOS	Nasmyth Adaptive Optics System (VLT)
NASA	National Aeronautics and Space Administration
NGC	New General detector Controller
NOVA	The Netherlands Research School for Astronomy (Nederlandse Onderzoek-school voor Astronomie)
NRAO	National Radio Astronomical Observatory
NTT	New Technology Telescope
OBAMA	Optical Bidule for Aberration Measurement on the ATs
OmegaCAM	Optical Camera for the VST
OPC	Observing Programmes Committee
OPO	Observing Programmes Office
OPTICON	Optical Infrared Coordination Network for Astronomy
OSF	ALMA Operations Support Facilities
OSO	Onsala Space Observatory
OT	Observing Tool
OTS	Operations Technical Support
P2PP	Peer to Peer Protocol
P86	Observing Period 86
P87	Observing Period 87
PACMAN	Fringe tracker for PRIMA (VLTI)
PB	Petabyte
PI	Principal Investigator
PIONIER	VLTI visitor instrument
PLC	Programmable Logic Controllers (E-ELT)
PRIMA	Phase-Referenced Imaging and Micro-arcsecond Astrometry facility (VLTI)
QUEST	QUasar Equatorial Survey Team
R&D	Research and Development
RAB	Reflector Assembly Building
RAL	Rutherford Appleton Laboratory, Didcot (UK)
RedCLARA	Latin American Advanced Networks Cooperation (Academic data network in Latin America)
REM	Rapid Eye Movement Telescope (La Silla)
REUNA	Red Universitaria Nacional (Academic data network in Chile)
RM	Rossiter–McClaughlin (effect)
RMN	Reflective Memory Network (VLTI)
rms	Root mean square
SABOCA	Shortwave Apex BOlometer Camera
SAC	EURO-VO Science Advisory Committee
SAF	Science Archive Facility
SCAO	Single-Conjugated Adaptive Optics
SCO	Santiago Central Office (ALMA/ESO Vitacura)
SDD	Software Development Division
SE	System Engineering (ALMA)
SEO	Search Engine Operations
SHFI	Swedish Heterodyne Facility Instrument (APEX)
SINFONI	Spectrograph for INtegral Field Observations in the Near Infrared (VLT)
SKA	Square Kilometer Array
SM4	Servicing Mission 4 (HST)
SOFI	SOn oF Isaac (NTT)
SOPHIE	Spectrographe pour l'Observation des Phénomènes des Intérieurs stellaires et des Exoplanètes
SPARTA	Real-time computer platform for AOF and SPHERE
SPHERE	Spectro-Polarimetric High-contrast Exoplanet Research instrument (VLT)
SSED	Software System Engineering Department
SSWG	Science Strategy Working Group
STC	Scientific Technical Committee
ST-ECF	Space Telescope European Coordination Facility
STFC	Science and Technology Facilities Council (UK)
STRAP	Tip-tilt sensors (VLTI)
STScI	Space Telescope Science Institute (USA)
SUSI2	Superb Seeing Imager 2 (NTT)
TAROT	Télescope à Action Rapide pour les Objets Transitoires
TB	Terabyte
TEC	Technology Division
TFB	Tunable Filter Bank (ALMA)
TIMMI	TIMMI far-infrared camera (ESO 3.6-metre telescope)
ToO	Target of Opportunity
TRAPPIST	TRAnsiting Planets and PlanetesImals Small Telescope
TRR	Test Readiness Review
UC	Users Committee
UK	United Kingdom
ULTRACAM	High-speed camera (NTT)
UN	United Nations
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Spac
USD	User Support Department
USM	University Observatory Munich
UT	Unit Telescope of the VLT
UT1–4	VLT Unit Telescopes 1–4: Antu, Kueyen, Melipal and Yepun
UV	UltraViolet
UVES	UV-Visual Echelle Spectrograph (VLT)
VIMOS	VIsible MultiObject Spectrograph (VLT)
VINCI	VLT INterferometer Commissioning Instrument (VLTI)
VIRCAM	VISTA IR Camera
VISA	VLTI Sub-Array
VISIR	VLT Mid-Infrared Imager Spectrometer
VISTA	Visible and Infrared Survey Telescope for Astronomy
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer
VO	Virtual Observatory
VOP	Virtual Observatory Project Office
VSS	Variability Sky Survey
VST	VLT Survey Telescope
WASP	Wide Angle Search for Planets survey
WFCAM	Infrared wide field camera for the UK Infrared Telescope on Mauna Kea
WFI	Wide Field Imager (2.2-metre)
WVR	Water Vapour Radiometer (ALMA)
XMM-Newton	X-ray Multi-Mirror satellite (ESA)
X-shooter	Wideband ultraviolet-infrared single target spectrograph (VLT)
Yepun	VLT Unit Telescope 4
ZIMPOL	Zurich Imaging Polarimeter (SPHERE, E-ELT)
Z-Spec	Millimetre-wave spectrograph (APEX visitor instrument)

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Cover: This spectacular image of the reflection nebula Messier 78 was captured using the Wide Field Imager camera on the MPG/ESO 2.2-metre telescope at the La Silla Observatory, Chile. Credit: ESO/Igor Chekalin

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