ESO

European Organisation
for Astronomical
Research in the
Southern Hemisphere

Annual Report 2009

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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 14 countries: Austria, Belgium, 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 m high mountain 600 km north of Santiago de Chile. It is equipped with several optical telescopes with mirror diameters of up to 3.6 metres. The 3.5-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 m 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 km south of Antofagasta in Chile, 12 km 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.

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.

View of the La Silla Observatory from the site of the 3.6-metre telescope, which ESO operates together with the New Technology Telescope, and the MPG/ESO 2.2-metre Telescope. La Silla also hosts national telescopes, such as the Swiss 1.2-metre Leonhard Euler Telescope and the Danish 1.54-metre Telescope.

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 a 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.

Each year, about 2000 proposals are submitted for the use of ESO telescopes, requesting between four and six times

I. Bončina/ESO

The Very Large Telescope at Cerro Paranal. Located in the Atacama Desert in Chile, the site is over 2600 metres above sea level, providing incredibly dry, dark viewing conditions.

Three of the ALMA antennas face the sky on the Chajnantor plain of the Chilean Andes, 5000 m above sea level.


I. Bončina/ALMA (ESO/NAOJ/NRAO)

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 2009 alone, almost 700 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 m 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.

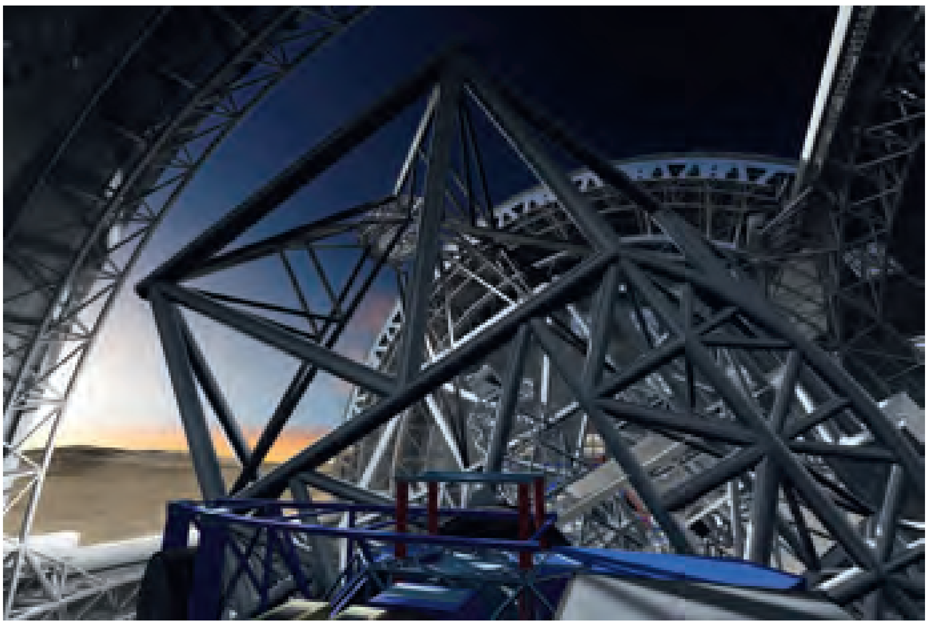
The Chajnantor site is also home to the Atacama Pathfinder Experiment (APEX) a 12-metre millimetre and submillimetre telescope, operated by ESO on behalf of the Max-Planck Institute for Radio Astronomy, the Onsala Space Observatory and ESO itself.

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 2010, with the start of operations planned for 2018.

ESO Headquarters is located in Garching, near Munich, Germany. This is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the observatories with the most advanced instruments. It is also home for the Space Telescope — European Coordinating Facility (ST-ECF), operated jointly by ESO and the European Space Agency (ESA). The ESO offices in Chile are located in Vitacura, one of the districts of Santiago. They host the local administration and support, and the ESO/Chile astronomers when they are not at the observatories. ESO Vitacura has become an active node for the training of new generations of researchers, acting as a bridge between scientists in Europe and Chile.

The Member State contributions to ESO in 2009 were approximately 140 million Euros and ESO employs around 700 staff members.

June 2009 version of the design of the 42-metre European Extremely Large Telescope in its enclosure (artist's impression).



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Foreword

The year 2009 was, as declared by the United Nations following an initiative by the International Astronomical Union and UNESCO, the International Year of Astronomy (IYA2009). As might have been expected, ESO was the leading organisation in Europe to support this worldwide event. The international success of the IYA2009 demonstrates the human capacity to share a common vision. In a world where conflicts, wars, economic crises, poverty and famine are unfortunately only too present, the IYA2009 created a worldwide interest beyond national borders, religions and economic development status. An important message was delivered: we are all part of the same Universe, we all share the same night sky and admire its natural beauty. But to unveil the Universe's mystery, we must develop education and foster scientific curiosity. Looking back at what has been achieved shows that the IYA2009 constituted a signal and took a step towards a more equitable and peaceful world. We should continue to act with energy to disseminate astronomy to the public and make use of its attractiveness to promote a scientific and technical culture. This is clearly one of ESO's missions. And we hope that ESO and the other major contributors to the IYA2009 will continue in their efforts, building on the wonderful success of 2009.

Fortuitously, 2009 was also the 40th anniversary of the La Silla Observatory. At its peak, La Silla was the world's largest astronomical observatory, and it still remains at the forefront of research in many areas, including the search for exoplanets. While informal discussions started earlier, ESO was formally launched in 1962 when five European countries signed the Convention. It is interesting to revisit the text of the Preamble to this Convention: *"The Governments of the States parties to this convention considering, …That it is urgent to install instrument in the Southern hemisphere, … but that such a project can only be accomplished through international collaboration; Desirous of jointly creating an observatory equipped with powerful instruments in the Southern hemisphere and accordingly promoting and organizing co-operation in astronomical research …"*

Every word of this text remains valid today. It was only by pooling resources for a common goal that the Member States were able to create a new observatory with capabilities far beyond what they could have achieved alone. And it is important to note that it was not done to the detriment of national programmes. On the contrary, the development of ESO has been in symbiosis with the development of astronomy in the Member States, to the mutual advantage of both. Now with 14 Member States, running the La Silla Paranal Observatory, and in charge of the European part of ALMA, ESO is a success story that has gone far beyond the expectations current when ESO was created. This can be judged by the initial programme for ESO, as stated in the Convention: "*a telescope of about 3 m aperture, a Schmidt telescope of 1.20 m, a meridian circle, and not more than 3 telescopes of maximum 1 m aperture*". This is an important lesson for the future. With the decision approaching for the construction of the European Extremely Large Telescope (E-ELT), which will be a new challenge for ESO, we should continue the collaborative spirit between the Member States within ESO, which was clearly the key to past success.

Among the numerous scientific and technical achievements described in this annual report, I will select only two, for their importance to the programme.

After many difficulties in manufacturing and integration, VISTA (the Visible and Infrared Survey Telescope for Astronomy) has started producing impressive wide field infrared images of the southern sky. Many astronomers in the ESO community were waiting for the start of the wide field surveys in the near-infrared, and it is now very satisfying to see the exquisite quality of these images. Everything is now in place for the beginning of the deep surveys, which will provide invaluable clues about galaxy formation and evolution, as well as information about the stellar population in our own galaxy. With VISTA, and, hopefully soon, the VLT Survey Telescope (VST), in addition to the VLT/VLTI, the suite of telescopes available at the Paranal Observatory will be unrivalled, with the capability to tackle major questions in all aspects of modern astrophysics.

The development of ALMA on the Chajnantor site has taken a very important step forward, with the demonstration of phase closure with three antennas on the high site. Beyond the event itself, this achievement is the first end-to-end demonstration of the validity of the ALMA design. It is not the end of the construction phase, and many difficulties still lie ahead of us. But it demonstrates that, when completed, ALMA will be able to achieve the ambitious goals set at the beginning of the project. This conclusion was also reached by the ALMA Annual Review Committee, who evaluated the project at the end of 2009. Every effort should now be made to keep this project on target within budget and schedule.

In looking to the past it is useful to understand the reasons for success, but also to understand the difficulties. We should keep these lessons in mind as we strive to maintain ESO at the forefront of astronomical observatories.

President of the ESO Council
Laurent Vigroux

Introduction

The International Year of Astronomy 2009 saw many activities at ESO, and a further increase in ESO's visibility worldwide, assisted by a very active public outreach programme.

Science

La Silla, Paranal and the Atacama Pathfinder Experiment continue to produce spectacular science and all telescopes are highly oversubscribed, together generating about 700 refereed papers per year. The number of observing proposals rose once again, and is now over 1000 per round. Highlights include the discovery of many dozens of exoplanets by HARPS, high resolution imaging of star clusters with MAD, the first VLTI images of giant stars, studies of galaxy nuclei with MIDI and SINFONI, UVES high resolution spectroscopy of quasars, and mapping of the molecular gas in the Milky Way by APEX.

Operations

X-shooter is now in routine service at Paranal and is a highly popular instrument. A new control room was inaugurated on La Silla, located in the old library, avoiding the need for night-time driving to the Ritz building. The La Silla 2010+ plan was implemented smoothly, and operations are supported by a much reduced staff complement as of 1 October. A new collective agreement with the Local Staff unions came into effect on 1 December.

Instrumentation developments

The second generation instruments (KMOS, MUSE, SPHERE, PRIMA, MATISSE and GRAVITY) for the Very Large Telescope and the VLT Interferometer are all on track. The in-house development of fibre lasers continued, and led to a total power output of over 50 W by coupling three such lasers. This provides an affordable way forward for the procurement of lasers for the Adaptive Optics Facility and for the European Extremely Large Telescope.

Survey telescopes

Integration of VISTA by the UK team continued throughout most of 2009. The activities were monitored closely by our engineers on Paranal. Science Verification in late 2009 demonstrated the power of the telescope for infrared surveys, and allowed the six survey teams to finalise their preparations for the planned public surveys. Provisional acceptance of VISTA occurred on 10 December, in the presence of many of the key people from the project.

All the parts for the VLT Survey Telescope were planned to arrive on Paranal during the first half of 2009. Unfortunately, the main mirror cell was damaged during transport and needed to be completely refurbished. L'Istituto Nazionale di Astrofisica (INAF) is putting all its efforts into the successful delivery of the VST in 2010.

ALMA

In November, the Atacama Large Millimeter/submillimeter Array achieved a major milestone by demonstrating interferometric performance with three antennas at the Array Operations Site (AOS). Most of the European deliverables for the construction of ALMA are on schedule and within specifications and cost. The European ALMA antenna consortium managed to bring the antenna production line in Europe up to speed, and started integrating the first antennas at the Operations Support Facility (OSF). Senior ESO staff have been transferred to Chile to be directly involved in monitoring the key ALMA deliverables, and helping out with solving problems across the entire project.

It has been ESO's goal to implement support of ALMA operations within the already existing operational infrastructure of user support, archive, software development and ALMA future development. This led to a distribution of the ALMA activities over several departments within ESO. To coordinate these activities and have a unique interface with the Joint ALMA Observatory, the European ALMA

Support Centre (EASC) was created in the Directorate of Operations effective 1 October, with Andreas Kaufer as acting head.

European Extremely Large Telescope

The E-ELT design effort progressed very well, and received a very positive report from the external mid-term review panel. Phase A studies for up to eight potential instruments and two post-focal stations continued. All is on track for completion of the construction proposal in the second half of 2010.

The search for the best site for the E-ELT made significant progress. The Site Selection Advisory Committee recommended shortening the original list of potential sites to five, four of which are located in Chile's Region II and the fifth on La Palma. Discussions were held with the governments of Spain and Chile concerning the possibilities for access to these sites.

A baseline funding scenario for the construction of the E-ELT was developed in close consultation with the Member States. If implemented, it will not only allow the construction of the E-ELT and continued support of operations of the La Silla Paranal Observatory, of ALMA and of the E-ELT, but will also make it possible for ESO to take on a further world-class ground-based astronomy project post 2018. The scenario foresees significant additional funding from ESO's Member States, and some of them have already pledged their share. Much effort has also gone into discussions with potential new Member States.

Organisation

The necessary revision of the Financial Rules and Regulations, under discussion since 2004, was completed. The approval by Council given in December will allow international accounting standards to be implemented in 2010. Council had already approved new financial thresholds in June. As part of the longer-term drive to update and document all ESO procedures a number of administrative procedures were clarified, including safety instructions, access rights for the Enterprise Resource Planning (ERP) system and rules governing proposals for EU funding.

Headquarters building extension

ESO was able to extend its "territory" in Garching from 24 000 m^2 to 73 500 m^2, partly by acquiring land from local owners and partly by accepting an offer from the Max-Planck Society to expand the area it leases to ESO today. This will allow the construction of the Office and Conference building and the Technical Building while leaving room for potential further expansion in the future. The architectural firm Auer+Weber will finalise the detailed design in 2010, after which a Call for Tenders for construction will be issued. Containment of cost is a key driver, and activities to raise external funds continue.

Tim de Zeeuw
ESO Director General

Astronomers obtained this portrait of Barnard's Galaxy using the Wide Field Imager attached to the MPG/ESO 2.2-metre telescope at ESO's La Silla Observatory. Also known as NGC 6822, this dwarf irregular galaxy is one of the Milky Way's galactic neighbours.

The ESO Headquarters in Garching
near Munich, Germany.

Science

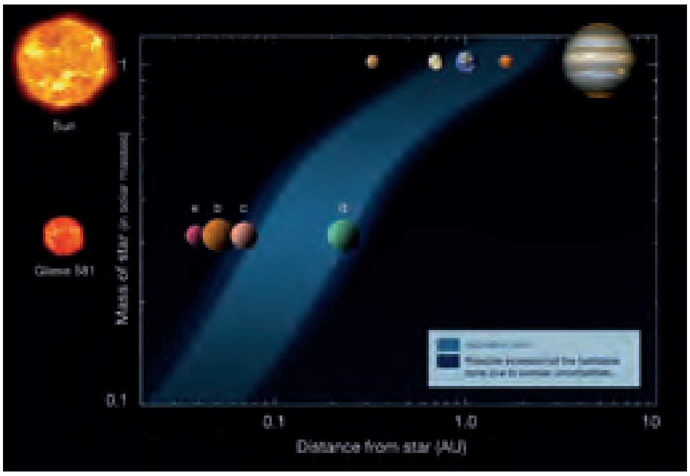
G. Hüdepohl/ESO

VISTA has a main mirror that is 4.1 metres across and is by far the largest telescope in the world dedicated to surveying the sky at near-infrared wavelengths. VISTA's operational synergy with the rest of the Paranal Observatory is beautifully illustrated in this photo.

Research Highlights

Extrasolar planets

ESO telescopes have played a key role in the discovery and characterisation of extrasolar planets. In addition to the radial velocity technique, modern planet-hunting techniques include the strong amplification of a background star by a star hosting a planet, known as microlensing, and the eclipse of the light of the parent star by the transit of the planet in front of the stellar disc. Since even the largest planets eclipse only a very small fraction of the light of the parent star, the transit technique requires very high photometric accuracies that are only achievable from the ground with large telescopes, but that are easily reached with smaller telescopes in space. Transits allow the diameters of the planets to be determined by accurately measuring the timing of the event that yields information about the inclination and period of the orbit as well as, through models, the radius of the star. By combining the planet's mass and radius it is possible to derive the planet's composition, so transits and radial velocities have opened up the new field of extrasolar planetology. The field has matured dramatically in recent years, thanks to the combination of ground-based and space-borne telescopes dedicated to measuring photometric transits, and high precision radial velocity machines, in particular HARPS on the 3.6-metre telescope at La Silla — possibly the only instrument capable of measuring stellar radial velocities with precisions better than 1 ms^{-1} over periods of time comparable to the orbiting periods of a broad class of extrasolar planets. Since many extrasolar planets occur in planetary systems with several planets, disentangling their complex orbits requires high precision monitoring over substantial periods of time to improve statistics and remove aliases introduced, for example, by stellar rotation and activity. Thus, six years after its installation, HARPS produced a veritable revolution in extrasolar planet research in 2009. Not only through the discovery of many new exoplanets, but mostly by finding an unprecedented number of systems with multiple planets and dramatically multiplying the number of known low-mass planets. Thus, extrasolar planet hunts have gone from finding mostly "hot Jupiters" (i.e. Jupiter-sized planets very close to their host stars) and "hot Neptunes", to finding increasing numbers of super-Earths, planets of masses between around two and ten times the mass of our Earth. At least one of these super-Earths (Gliese 581d) is in the habitable zone of its parent red dwarf star.



The habitable zone of Gliese 581 compared to the Solar System. Because of the lower luminosity of the star, the habitable zone of Gliese 581 is closer and one of its planets (G581d) appears to be within the zone where water could exist in liquid form.

Gliese 581

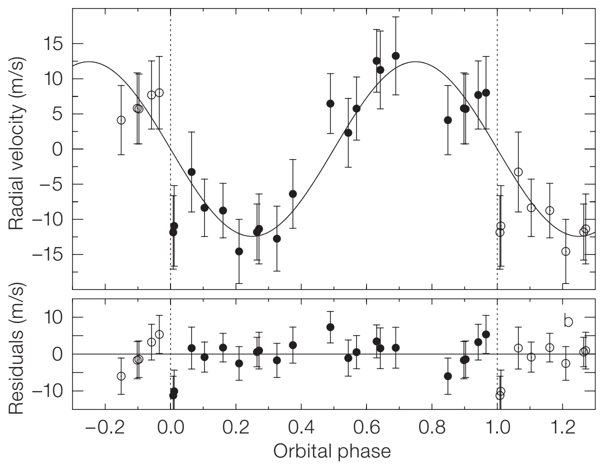
The case of Gliese 581 is a particularly good example of the power of HARPS. The superb accuracy and stability of HARPS made it possible to infer that the star was surrounded by three planets of masses ranging between 5 and 16 Earth masses. Further observations allowed the Geneva group to establish the presence of a fourth planet — Gliese 581e — that has only 1.9 Earth masses, making it the least massive extrasolar planet known. While these planets remain very different from Earth and are probably hostile to life, instruments like HARPS are bringing humanity closer to finding planets similar to our own Earth.

CoRoT-7

One of the first extrasolar planets found by CoRoT is a super-Earth orbiting an otherwise unremarkable star in the

Artist's impression of CoRoT-7b showing oceans of molten lava on the exoplanet and indications of strong activity on the star depicted by large Sun-like spots and huge flares.

constellation of Monoceros, called TYC 4799-1733-1. However, the CoRoT researchers were unable to derive a mass from their transit observations, due in part to the stellar activity that produces photometric variability with a period that is very close to the orbital period of the planet (about 20.4 hours). Since this planet promised to be one of the lowest-mass planets known, an observing campaign with HARPS was launched to determine its mass. It required more than 70 hours of observations to establish the radial velocity curve of the CoRoT-7 planet. After filtering out the stellar activity the HARPS team was able to infer that CoRoT-7 harbours not one, but two planets (b and c) of 4.8 and 8.4 Earth masses, although only CoRoT-7b transits in front of the star. Combining the mass and the radius allowed the first determination of the density of a super-Earth: 5.6 g/cm^3, similar, in fact, to the density of the Earth. Although it is a rocky planet, being 23 times closer to its star than Mercury is to the Sun, CoRoT-7b has an equilibrium temperature of about 2000 °C. Its surface is probably covered with molten lava. The result demonstrates that HARPS and CoRoT herald the beginning of the era of comparative extrasolar planetology.

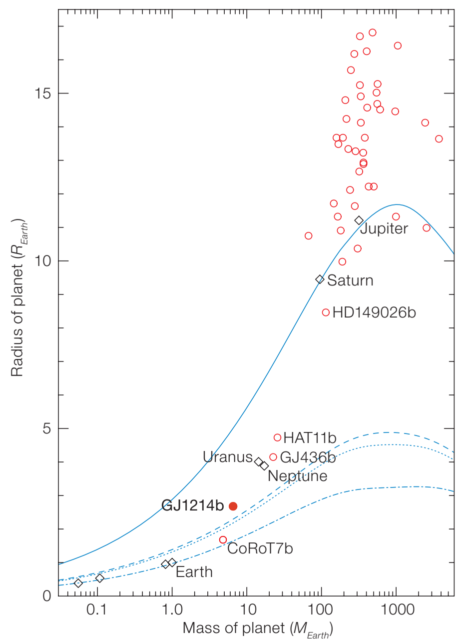


The HARPS radial velocity curve of GJ1214 that yielded a semi-amplitude of a little over 12 ms^{-1} — large by HARPS standards.

GJ1214b

CoRoT-7b is 500 light-years away from the Sun, too far to allow a direct investigation of its atmosphere with ground-based or space-borne observatories. However, another transiting super-Earth exoplanet was discovered around the nearby red dwarf star GJ1214 — only 40 light-years away from us. The planet, GJ1214b, was first discovered as a transiting object by the MEarth telescope(s) that photometrically monitor 2000 nearby M-dwarfs of masses between 0.10 and 0.35 solar masses to look for exoplanets. The photometric light curve shows flat-bottomed eclipses with a depth of 1.3%, indicative of a planetary transit. The planetary nature was confirmed by HARPS, which also provided the orbital elements required to derive an accurate value for the planet's mass and radius, measured to be 6.55 Earth masses and 2.68 Earth radii respectively. The orbital period is only 1.58 (Earth) days, but still longer than the mere 20.4 hours of CoRoT-7b. The radius is actually between that of the Earth and those of the ice giants of the Solar System, Uranus and Neptune.

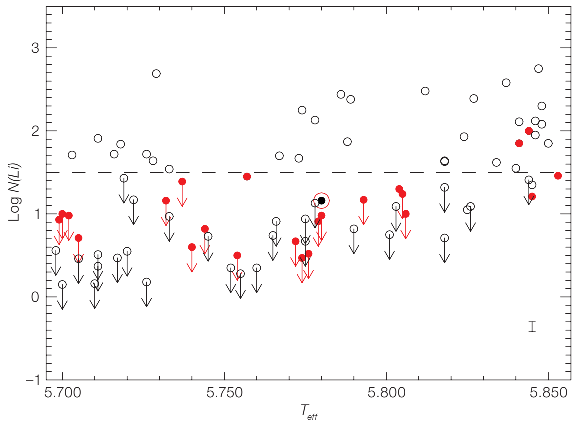
The density of GJ1214b derived by combining the mass and the radius turned out to be a factor of almost three lower than that of CoRoT-7b, indicating a very different composition: while CoRoT-7b is mostly rocky, GJ1214b is an icy world. In fact, comparison of the observations with models of planetary interiors indicates that the radius of GJ1214b is too large for its mass, even if it were entirely composed of water. Thus, the models suggest that the planet must be surrounded by a large envelope (or atmosphere), probably made mostly of hydrogen that has been removed from the surface of the planet by the ultraviolet (UV) radiation from the host star. This atmosphere could occult a sizable fraction of the stellar disc during transit and therefore could be detected spectroscopically, thus providing further insight into the structure and composition of an extrasolar super-Earth. The differences between CoRoT-7b and GJ1214b are probably due to the different degrees to which the two planets are irradiated by their parent stars. Since CoRoT-7 is much more luminous than GJ1214, it is possible that both planets formed in a similar way and have rocky cores, but the primordial gaseous envelope of CoRoT-7b was removed by the stellar radiation, leaving behind only the rocky core and thus a smaller radius. Alternatively, GJ1214b may have a water-dominated core indicating a very different formation history from that of CoRoT-7b. As the planet hunt evolves to find ever lower masses, it will be important to develop new methods to remove these kinds of degeneracies in the models that occur when only mass and radius are available. Direct observations of the planets using instruments such as the planet finder SPHERE, due to see first light on the VLT around 2011, may provide at least part of the answer.



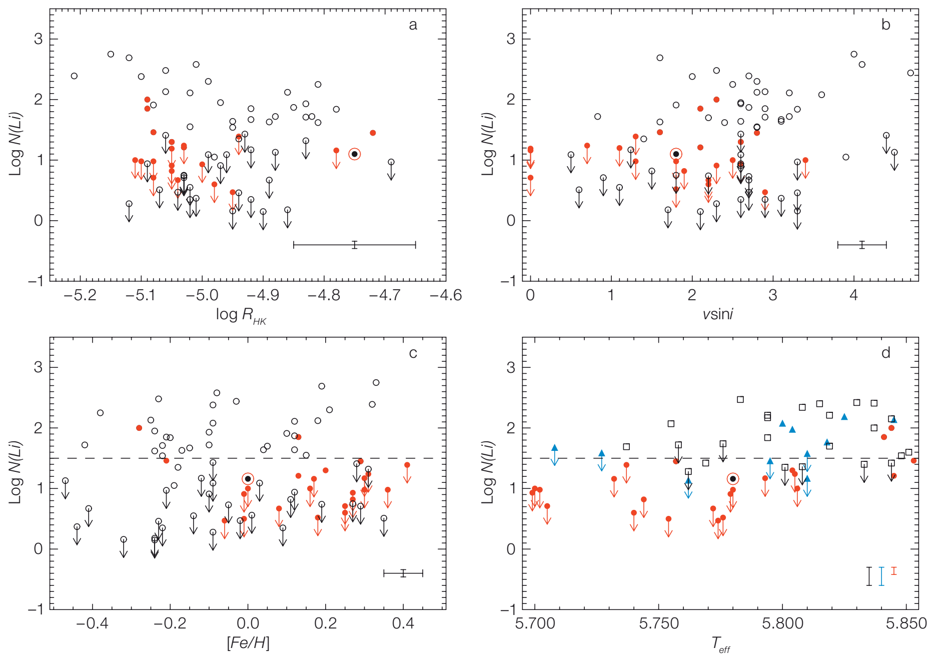
Masses and radii of transiting planets. The known transiting planets including CoRoT-7b are compared to GJ1214b. Predicted radii as a function of mass are shown for different compositions. The solid line is for an H/He composition and the dashed line shows a pure H_2O world.

Why do some stars like the Sun have planets and others don't?

The observation that solar-type stars with planets have higher metallicities than similar stars without detected planets has puzzled astronomers during the last ten years. Another seemingly unrelated puzzle is that the surface abundance of lithium in the Sun is 140 times less than the protosolar value, yet the temperature at the bottom of the convection zone is not high enough to burn (and thus destroy) lithium and hence reduce its abundance. A team of astronomers has recently put the two puzzles together through the confirmation of an early suggestion that stars with planets have lower lithium abundances, using a large sample of 451 unevolved, slowly rotating stars of effective temperatures between 4900 and 6500 K. The dichotomy is more dramatic if the sample is restricted to solar-analogue stars — stars with the same effective temperature as the Sun (5777 K) to within 80 K ($T = T_{\odot} \pm 80$ K). This is shown in the figure that plots lithium abundance log [*N(Li)*] as a function of effective temperature. About 50 % of the 60 single solar-analogue stars in this plot have abundances larger than log [*N(Li)*] = 1.5 while only two of the 24 planet-hosting stars reach these high values.



Lithium abundances of solar-analogue stars. Only two of the planet-hosting stars (shown with red symbols) have log[*N(Li)*] > 1.5, while about 50 % of the single stars have high lithium abundances.



Lithium abundance as a function the activity indicator R_{HK} that is used as a proxy for age (a); (b) rotation (*v*sin*i*); and (c) metallicity [*Fe/H*]. Panel (d) compares the Li abundances of stars in open clusters with those of stars hosting planets.

Since all these stars have similar masses, physical parameters, and internal structure, there should be some additional reason for the over-depletion of lithium in stars with planets. Possibilities include age distribution (lithium abundance is observed to decrease with age), different rotation rates, which induce enhanced circulation and/or enhanced chromospheric activity, or a different metallicity distribution that may result in small but important changes in the structure of the stars. The large size of the HARPS sample allows these hypotheses to be tested against observations. The figure to the right plots lithium abundance versus age (R_{HK}), rotation (*v*sin*i*), and metallicity [*Fe/H*] indicators. None of these plots show any significant trends indicating that high metallicity and/or age may be the main cause for the observed systematically low lithium abundances in solar-analogue planet-hosting stars. Thus, the suggestion is that the low lithium is directly associated with the presence of planets, either through effects of angular momentum that may influence stellar evolution and surface convective mixing, or through long-lasting star–disc interaction during the pre-main sequence phase. Clearly, a putative relationship between protoplanetary discs and stellar structure in the early phases of the evolution of solar-type stars poses a formidable challenge to stellar evolution models, but the rewards are certainly worth the effort.

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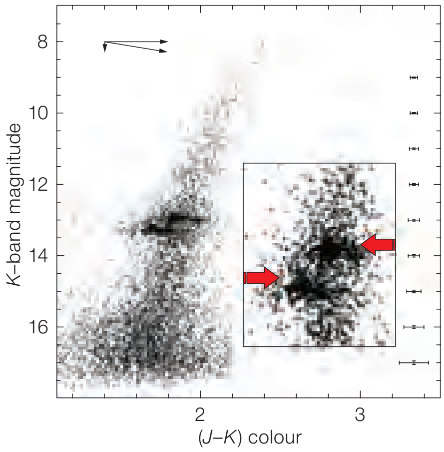
Clusters in the Milky Way Bulge

The fact that at least some globular clusters in the Milky Way halo are indeed remnants of tidally disrupted dwarf galaxies, as seems to be the case for Omega Centauri, could be interpreted as the evidence that the spheroidal component of spiral galaxies is made up (at least partially), of disrupted pieces of dwarf galaxies as predicted by the hierarchical formation scenarios. This could be also true for the Milky Way Bulge. The Bulge, however, is hidden from us behind a substantial amount of rather patchy foreground extinction that makes photometry of the accuracy required to disentangle multiple sequences in the colour-magnitude diagram (CMD) a particularly difficult enterprise. Observations at near-infrared (NIR) wavelengths, where dust extinction is much less severe, offer a solution, but conventional NIR imagers are limited by crowding in these dense stellar fields. On the other hand, adaptive optics (AO) assisted imagers lack the field of view required to cover even part of the clusters, let alone to correct for field contamination. Also, the substantial variations in the point spread function (PSF) across the field limits the photometric accuracy of most AO imagers. Thus, the advent of the first generation of Multi-Conjugate Adaptive Optics (MCAO) instruments that can image fields of over one arcminute at resolutions close to the diffraction limit of telescopes with uniform PSFs, provides optimal instruments for this kind of studies. ESO's Multi-conjugate Adaptive optics Demonstrator (MAD) was conceived as a technology demonstrator for the E-ELT, and was successfully used as such at the VLT. The demonstration of MAD was so successful that ESO was prompted to open this unique instrument to the community through a number of science demonstration runs that elicited a large number of proposals for a wide range of scientific applications. One of these applications was the observation of globular clusters, and in particular of the elusive clusters in the Milky Way Bulge. Among these, one cluster, Terzan 5, produced unexpected results.

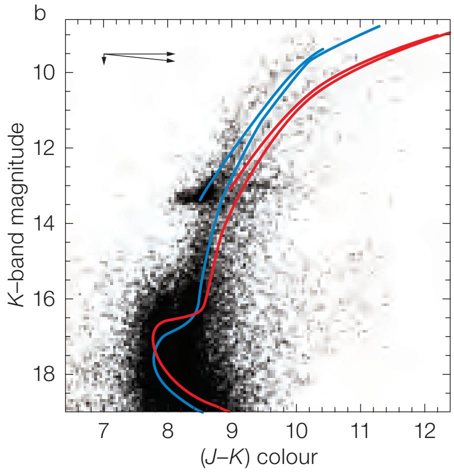
MAD *J*- and *K*-band image of the central part of the cluster Terzan 5. The field of view is 40 arcseconds across. The full corrected field of view of MAD is 2 × 2 arcminutes.

The MAD CMD of Terzan 5 shows a double horizontal branch that reveals its turbulent history. The bright horizontal branch (BHB) is much more centrally condensed than the faint branch (FHB), and in fact BHB stars are twice as abundant in the centre of the cluster. Spectroscopy of three stars in each group with the Keck telescope showed that the BHB stars have an iron abundance three times higher than that of the FHB, thus making Terzan 5 the only globular cluster other than Omega Centauri known to show a detectable spread in [*Fe/H*]. Knowing that the cluster has at least two distinct populations, it was possible to use archival Hubble Space Telescope (HST) images corrected for differential reddening to search for these features also in the optical regime. The combined MAD and HST/ACS colour-magnitude diagram of the cluster reproduced in the figure on the next page shows that the two populations can be fitted by theoretical isochrones indicating an age of 12 billion years for the metal-poor population, and only about



MAD NIR colour-magnitude diagram of Terzan 5. The two horizontal branches are clearly seen in this plot stretched by differential reddening as indicated by the reddening arrows on top of the figure.

6 billion years for the metal-rich component. While it is conceivable that the cluster formed by the merger of two independent stellar aggregates, it is difficult to reconcile this hypothesis with the fact that the younger, more metal-rich population is observed to be more centrally concentrated, and with the fact that globular clusters younger than 10 billion years are very rare in our Milky Way. Instead, it is more likely that — like the Messier 54-Sagittarius system, the Carina dwarf spheroidal galaxy, and maybe Omega Centauri — Terzan 5 is the nuclear remnant of a disrupted galaxy. In fact, a larger central concentration of metal-rich and younger stars is a commonly observed feature in the satellites of the Milky Way and Messier 31. Moreover, the strict similarity in iron abundance between Terzan 5 and the field stars in the Milky Way Bulge is consistent with the hypothesis that the partial disruption of its progenitor has contributed to the formation of the Milky Way Bulge. The sheer number of horizontal branch stars estimated from the combined MAD/ACS samples is larger than the entire horizontal branch population of 47 Tucanae, one of the most massive clusters in the halo of the Milky Way, suggesting that Terzan 5 is more massive than previously thought.



Combined MAD & HST/ACS colour-magnitude diagram showing isochrone fits to the two populations discussed in the text. The blue line is for [*Fe/H*] = −0.2 and *t* = 12 Gyr and the red line is for [*Fe/H*] = +0.3 and *t* = 6 Gyr. Only slightly different helium abundances were required for the two isochrones.

The discovery of a bi-modal stellar population in Terzan 5 could be the first direct observational evidence that the innermost spheroidal components of large spiral galaxies originate in the merging of pre-formed evolved stellar systems, and suggests that other similar objects might be hidden in the heavily obscured central regions of our Milky Way. Interestingly, and probably not coincidentally, Terzan 5 is known to contain the largest concentration of millisecond pulsars in any cluster of the Milky Way.

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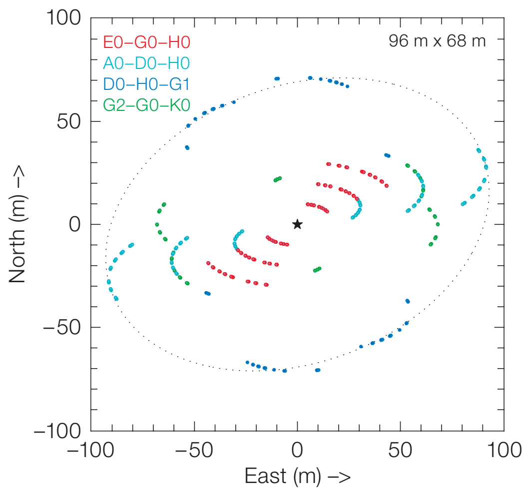
The first images with the VLTI

The ultimate goal of optical/infrared (IR) interferometers is to provide imaging spectroscopy with the highest possible spatial resolution. For single telescopes, the light of a star, containing all the information about the star, is conveyed to the detector through the optical train. The spatial resolution of a telescope is determined by the diameter of the telescope. While there is a limit on the maximum size of a telescope, interferometry allows this to be exceeded, at the expense of image fidelity when the *uv*-plane is insufficiently covered. The VLTI solves this problem by moving the Auxiliary Telescopes (ATs), or by Earth synthesis, in the same way as radio or (sub)-mm interferometers.

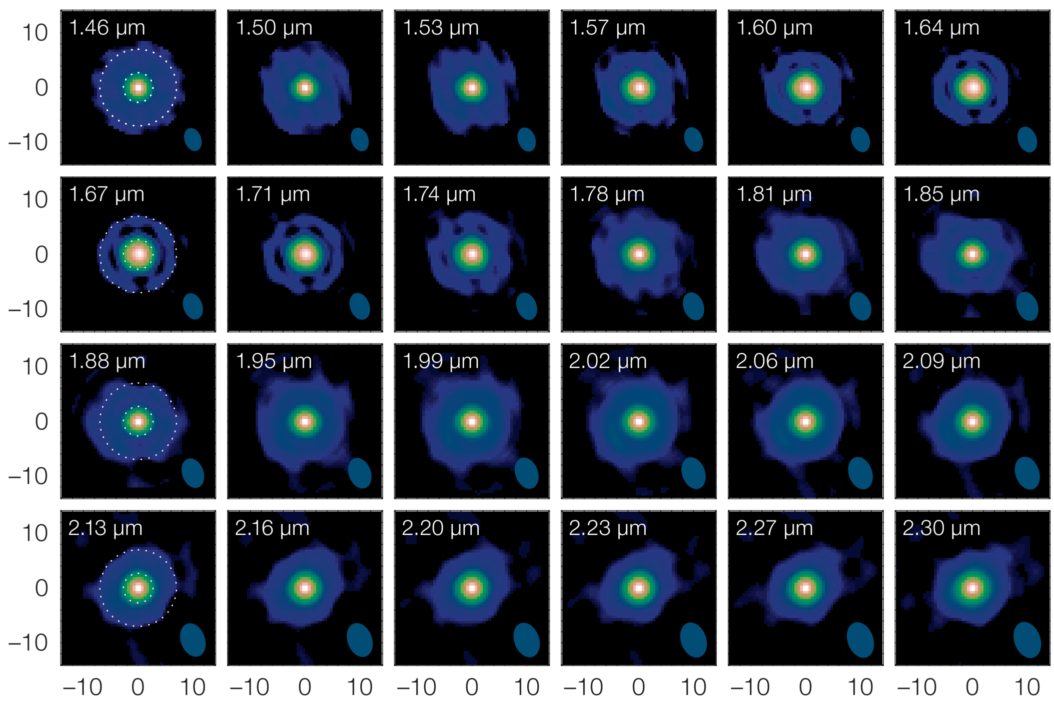
The first generation of VLTI instruments and infrastructure can combine the light of at most three telescopes (Auxiliary Telescopes or Unit Telescopes), but, as always, making images with optical/IR interferometers is a particularly challenging enterprise. Therefore, exploiting the potential of the VLTI as a high definition spectro-imager had to wait until the complete system — telescopes, delay lines, guiding systems, and instruments — was fully debugged and fine-tuned. The first high-fidelity images with the VLTI were presented in 2009 by two teams using quite different techniques. The first team exploited the option of moving the ATs over relatively short periods of time, thus acquiring a dataset taken under reasonably homogeneous atmospheric and instrumental conditions, to observe the bright Mira star T Leporis, which, in spite of having been extensively studied in the past, was still not fully understood. The second team observed the high eccentricity binary system θ^1 Orionis C, which is the brightest OB star in the central cluster of the Orion nebula (the Trapezium), in three different observing runs spanning a little more than one year. The figure on the top of next page shows the *uv*-coverage of the T Leporis observations that were obtained over a few days and also made use of some archival observations taken about one month earlier. The data were recorded using the AMBER NIR spectro-imager that can, in low resolution, record the *J*-, *H*- and *Ks*-bands simultaneously.

Mira stars are stars with masses similar to the Sun that have left the main sequence and are evolving to become planetary nebulae and/or white dwarfs. In the Mira phase the stars shed a very large amount of the products of stellar nucleosynthesis both as gas and dust, and therefore Miras are surrounded by extensive molecular shells. During their evolution Miras show very large changes in brightness associated with changes in the structure of their envelopes.

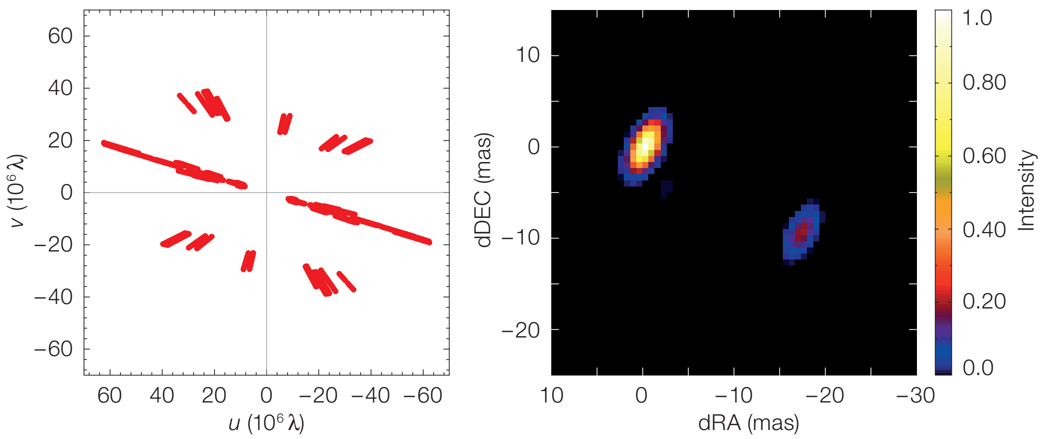


The *uv*-coverage of the complete dataset of T Leporis. Different baselines (indicated by the colours) are enabled by moving the VLTI ATs to different stations (E0, G0, G1, etc.). As the Earth rotates each station sweeps the *uv*-plane as shown by the tracks in the figure. The holes in the *uv*-plane are largely filled by the image reconstruction algorithms, but the PSF remains elongated as indicated by the dashed line.

The reconstructed images of T Leporis are shown below. The ovals in the lower right corner of each frame show the instrumental profile of the interferometer whose elongation reflects the *uv*-plane coverage seen above. These images clearly highlight two components. The brighter central component corresponds to the stellar photosphere, with a radius of 100 $R_\odot$ and the second component to a molecular layer characterised by the high spectral dependency of its morphology. Within the molecular absorption bands (1.5–1.6 μm, 1.75–2.15 μm, 2.3–2.5 μm), the shell is optically thick and appears, projected toward the observer, as a circular disc. Between these bands, absorption by molecules is not as strong and the shell becomes optically thin. It appears as a projected ring encircling the photosphere (1.6–1.75 μm). While these interferometric images confirm the broad picture of a shell-like geometry of the molecular envelope surrounding the stellar photosphere, they also show some new features. For example, the changes in the structure of the star are not due to a wavelength-dependent size of the molecular envelope as previously thought, but to changes in the molecular opacity. Also, the extensive dataset provides definitive evidence for the presence of significant asymmetries in the envelope. The highest value of these observations, the first of a Mira star with almost continuous spectral and spatial domain coverage, however, is to demonstrate that in a relatively short amount of time it is possible to obtain high-fidelity spectro-images with AMBER at the VLTI.



Reconstructed images of T Leporis for several AMBER spectral bins across the *H*- and *K*-bands. The interferometric beam size is displayed in the lower right of each image. Spatial scale is in milliarcseconds (mas). The white circles in the first column represent the average radius for the molecular layer (~ 15 mas) and for the central star (~ 5.8 mas), determined from modelling and corresponding to 2.5 and 1 astronomical units respectively.



Left: *uv*-plane coverage of the θ^1 Orionis C observations. The radial extension of the *uv*-tracks reflects the spectral coverage of the data (notice that the axis scales are in wavelength units rather than in metres). Right: Reconstructed aperture synthesis image of the system with a spatial resolution of 2 mas. The two stellar components are resolved and the extension reflects the *uv*-coverage.

The *uv*-plane coverage of the θ^1 Orionis C observations shows the wavelength dependence of the coverage as a radial extension. The resulting image of the two stars is shown in the right panel of the figure above. Because the atmospheric conditions during the rather extended period of observations were not always optimal, only differential techniques were used to reconstruct the images, techniques that are complementary to the techniques used to reconstruct the images of T Leporis. Thus, while the orbital elements derived from the high resolution VLTI data did not significantly change the already known parameters of the star, these observations again demonstrate the potential of the VLTI as a powerful spectro-imager even under variable and challenging observing conditions.

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Active galactic nuclei

The standard model of Active Galactic Nuclei (AGN) postulates that the central engine (a black hole and accretion disc) is embedded in a dusty torus. AGNs are classified as type 1 or type 2 depending on whether this torus is seen face-on (type 1: the central engine is seen directly) or edge-on (type 2: we only see the central engine through the torus). Historically this classification arises from the Seyfert galaxies that host AGN of these two types. For a long time there was only indirect evidence for the existence of these dust enshrouding tori, until VLTI observations with the Mid-infrared Interferometric Instrument (MIDI) actually resolved parsec-scale dust structures heated by the AGN of two nearby Seyfert 2 galaxies. Further snapshot observations with the VLTI have recently demonstrated the presence of parsec-sized dust structures in several Seyfert 1s, and the central premise of the standard model — that the dust structures of Seyfert 1s and Seyfert 2s only differ in orientation — has been recently successfully tested through detailed MIDI observations of the nearest Seyfert 1 galaxy, NGC 4151.

MIDI can only combine two telescopes and therefore it is more difficult and time consuming to obtain reconstructed images and thus to recover the full 2D structure of a source. Moreover, observations of even the closest AGN require using the Unit Telescopes (UTs) of the VLT that, *a fortiori*, provide only a limited range of baselines. So, in order to interpret the MIDI interferometric observations of NGC 4151, it is necessary to use an *a priori* model for the spatial structure of the source. The model consists of a point-like source surrounded by a Gaussian disc. The best-fitting parameters of the Gaussian disc are shown in the figure on the next page, which plots the correlated flux of the source as a function of the spatial resolution of the interferometer for three reference wavelengths extracted from the spectra observed with MIDI: 8.3 µm, 10.3 µm and 12.5 µm.

The models seem to be uniquely determined by the observations at the three different wavelengths and therefore provide a robust estimate of the size of the obscuring torus around the central engine of NGC 4151. The strict test of the unified model requires that, at a given far-UV luminosity, the sizes of the dust tori should be independent of the AGN type: Seyfert 1s and Seyfert 2s of similar luminosities should have similar tori. The size of the mid-IR nuclear source in NGC 4151 obtained from the Gaussian fit is 2.0 ± 0.4 pc (Full Width Half Maximum [FWHM]), which compares very well with the tori of the Seyfert 2 nuclei of the Circinus galaxy (2 pc) and of NGC 1068 (3 × 4 pc). Scaled to similar accretion luminosity these values agree well, as also do the dust temperatures, thus providing a direct test of the unified model of AGN.

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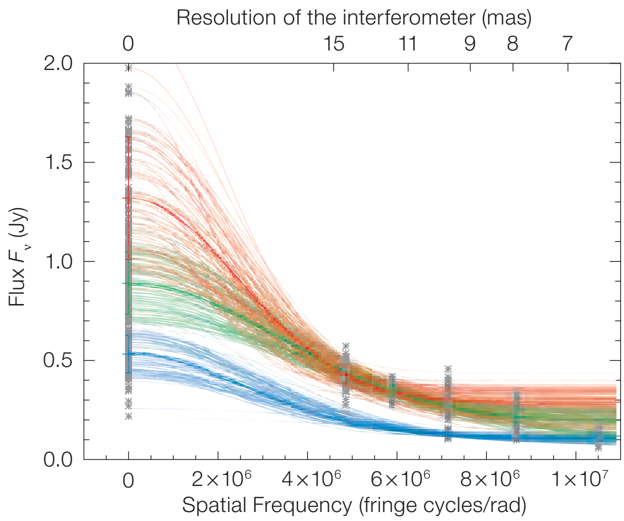


Gaussian models for NGC 4151. The upper scale shows the resolutions of the interferometer. The three curves correspond to the three reference wavelengths: 8.3 μm (red), 10.3 μm (green) and 12.5 μm (blue). The thin lines are estimates of the fitting errors. Data points and errors from single telescopes (0 resolution), and interferometric measurements (two points per wavelength) are shown.

Sizing supermassive black holes

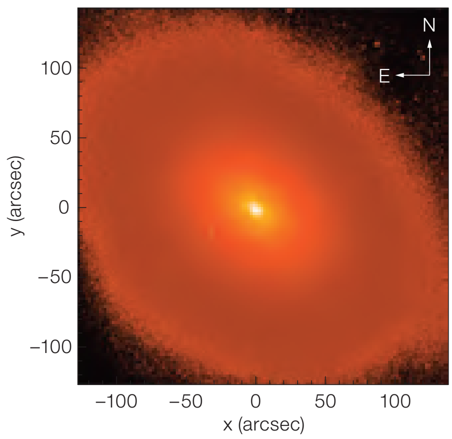
The idea that galaxies and their nuclear supermassive black holes co-evolve has matured in the last ten years since the discovery of a tight correlation between the mass of the central black hole and the galaxy luminosity (and its more recent incarnation as the correlation between black hole mass and velocity dispersion of the galaxy's bulge: the M_{BH}–σ relation). Modern galaxy formation scenarios predict that bulges evolve through mergers of smaller galaxies, while black holes grow through the active galactic nucleus phase when they are fed by massive accretion discs. Thus, testing and refining theories of bulge and black hole (co-)evolution requires detailed studies of active galactic nuclei and merger remnants in different evolutionary stages. This in turn requires powerful instruments on large telescopes and to date only two galaxies with recent major merger events have been observed with sufficient resolution: NGC 5128, the parent galaxy of the powerful radio source Centaurus A, and NGC 1316 (Fornax A), both of which have recently been observed with SINFONI on the VLT. Fornax A is also a powerful radio source located in a cluster of galaxies, and its peculiar morphology indicates that it underwent a major merger about three billion years ago. Surprisingly, the AGN in Fornax A is presently very faint, which indicates that the central engine has been dormant for the past 100 million years or so. While this provides valuable information about the life cycles of AGN, it also facilitates the determination of the black hole mass through direct observation of stellar radial velocities very close to the black hole that are otherwise impossible when the AGN is very bright and completely dominates the nuclear light. The nucleus of Centaurus A is, on the other hand, quite active, producing a substantial contamination of the stellar absorption lines by non-thermal emission that needs to be accurately modelled and subtracted to avoid biasing the kinematical information. Centaurus A has a rotating gaseous disc that allows an independent measurement of the central black hole mass through the strong emission lines from the disc. Thus, the combination of the stellar and gaseous kinematics — which can be obtained from the same SINFONI dataset — provides a robust measurement of the black hole mass.

To determine the black hole mass one needs to measure the gravitational potential of the stellar component using photometric observations with sufficient spatial resolution and radial extent. In the case of Fornax A this was achieved from a combination of HST NICMOS images, that provide the spatial resolution, with images from SOFI on the NTT that provide the spatial extent.

The stellar kinematics of both Centaurus A and Fornax A were measured using SINFONI in AO mode that provided a spatial resolution of 0.17 arcsecond. This is substantially smaller than the expected sphere of (gravitational) influence of the black holes allowing the observations to disentangle its gravitational pull from that of the dense concentration of stars in the nuclear region of each galaxy. In the case of Centaurus A, the high spatial resolution of SINFONI is also crucial to model the non-thermal emission of the AGN.

SINFONI can measure the two-dimensional kinematics of the stars near the black hole and hence allows a more precise modelling of the nuclear gravitational potential. In fact, disentangling the stellar and the black hole potential requires the use of rather sophisticated models illustrating one of the paradigms of modern astronomy: extracting the information provided by modern instruments and telescopes requires state-of-the-art computational techniques and much more time at the computer than at the telescope. The figure below shows the central part of Centaurus A seen with two different magnifications and illustrates the wealth of information provided by high-fidelity spectro-imagers like SINFONI. For example, the radial velocity diagrams shown in the left-most panels indicate that the stellar component in the nuclear region of the galaxy rotates around the nucleus in the opposite direction to the rotation of the gaseous disc. But many of the features in these plots, like the structure of the velocity dispersion maps, are very complex and a correct interpretation requires extensive modelling and simulations. The models are shown in the figure and clearly provide very good fits to the data.

Two-dimensional maps like these can test the assumptions that go into the models, and in particular the crucial assumption of axial symmetry of the gravitational potential. The end result is a reliable determination of the black hole mass and of the mass-to-light ratio of the stellar population, both critical parameters to test galaxy formation and evolution scenarios. The inferred black hole masses are 1.3×10^8 solar masses for Fornax A and 5.5×10^7 solar masses for Centaurus A, both in excellent agreement (within the uncertainties) with the values predicted by the M_{BH}–σ relation. Since both Centaurus A and Fornax A underwent major merger events fairly recently, the "normal" masses of their nuclear black holes provide substantial evidence that bulges and central supermassive black holes grow and/or evolve synchronously. Interestingly, however, neither Centaurus A nor Fornax A appear to fit the correlation between black hole mass and bulge infrared luminosity (which is a reliable indicator of bulge mass): the bulges of both galaxies are more luminous than the values for the masses of their central black holes would lead us to expect. If confirmed, this puzzle may provide important clues to help understand the processes that synchronise the growth of bulges and central black holes. More observations of galaxies in various stages of merging and bulge formation will be very important to understand how galaxies form and evolve and SINFONI and the VLT will continue to lead the way.



Dust corrected *Ks*-band image of Fornax A taken with SOFI at the NTT.

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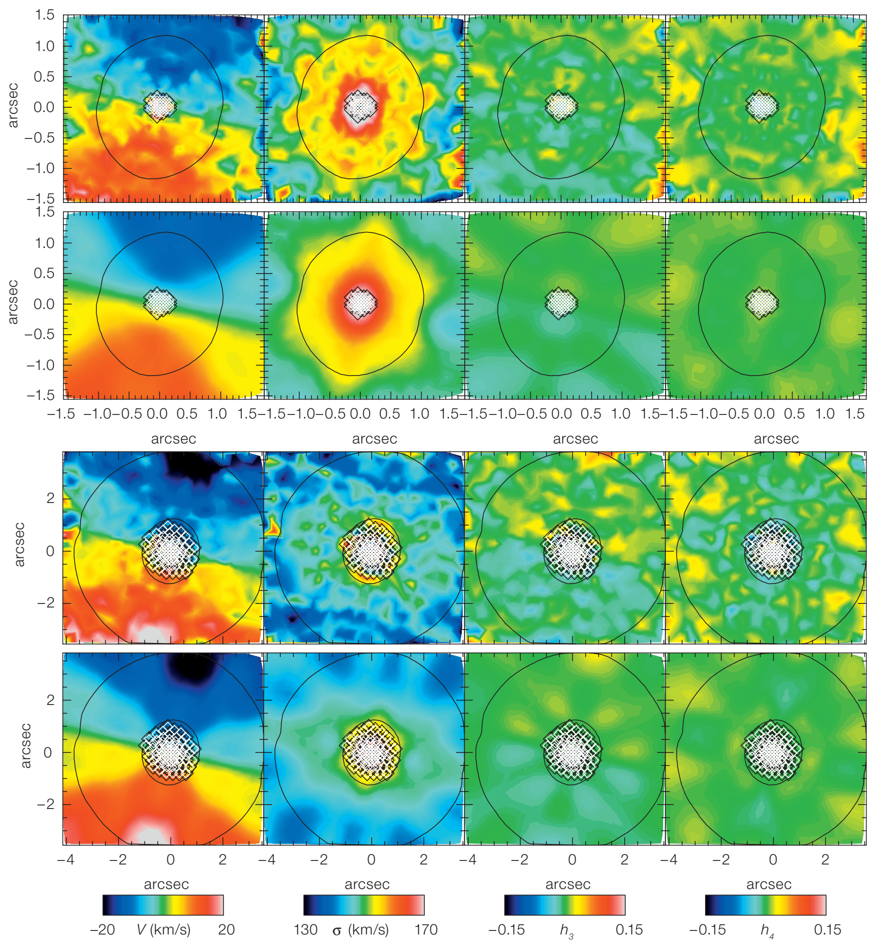
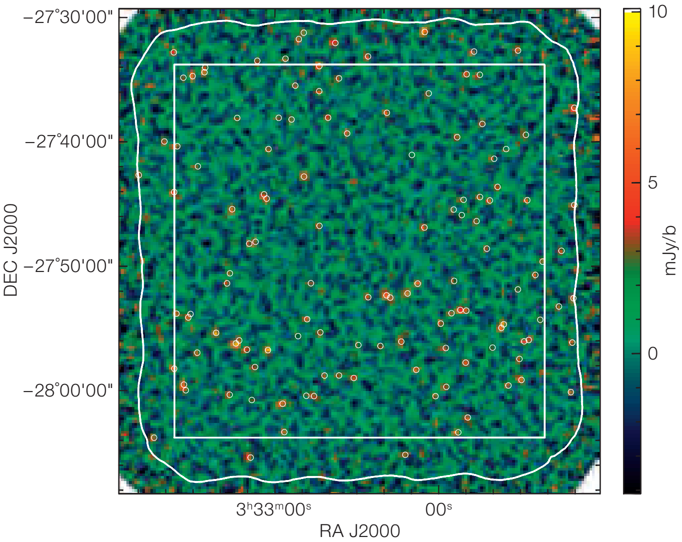


SINFONI observations of the nucleus of Centaurus A at two different spatial scales. The upper two panels show the observations (top) and the models used to interpret the data (bottom) at 100-mas resolution. The lower two panels show similar maps for observations at 250-mas resolution.

The Great Observatories Origins Deep Survey (GOODS)

GOODS is a public multi-wavelength survey that covers two 150 square arcminute fields centred around the Hubble Deep Field North and the Chandra Deep Field South (CDF-S). It was the first coordinated effort to combine the deepest survey data over the widest wavelength range (from X-ray through radio) from space and ground-based observatories. Observations were designed to promote major advances in our understanding of the mass assembly history of galaxies over a broad range of cosmic time, to obtain a census of energetic output from star formation and supermassive black holes, and to trace the star formation history of the Universe out to $z \sim 7$. Thus, nearly ten years ago ESO embarked on a public project consisting of a number of observing campaigns in the CDF-S field, primarily with the VLT, under a programme that extended over the periods P68–P77. Science-ready data products were prepared by the ESO–GOODS team that included members from the ST-ECF and the community, and was publicly released into the ESO archive in a progressive manner, within 6–12 months from the conclusion of each observing run. The ESO–GOODS programme reached the final milestone in December 2009 by completing the public release of all advanced science-ready data products consisting of: 1) deep near-IR coverage of the GOODS region in the *JHK*-bands with ISAAC; 2) very deep *U*-band imaging of the entire CDF-S area with VIMOS; and 3) an extensive spectroscopic campaign with FORS2 and VIMOS which has yielded ~ 2700 secure source redshifts. To facilitate the utilisation of such a large investment of VLT spectroscopic time (over 500 hours), an up-to-date database of all publicly available spectra obtained in the GOODS/CDF-S area has been constructed by ESO and the ST-ECF and made accessible with a search-engine interface. The ESO–GOODS public data products have remained in great demand over the last four years and have fuelled a large number of high-impact publications. They continue to stimulate several follow-up programmes with ESO facilities.



LABOCA flux map of the Extended Chandra Deep Field South at a resolution of 27 arcseconds. In addition to the 126 sources detected in this image, the uniformity of this map enables fainter source populations to be detected by using the stacking technique.

The LABOCA bolometer array on the Atacama Pathfinder Experiment complemented the ESO–GOODS multi-wavelength dataset with a 0.5 × 0.5 degree 870-μm map of the Extended Chandra Deep Field South (ECDF-S) that reaches a depth of ~ 1.2 mJy/beam. A total of over 300 hours of APEX time was invested in this project and the result is the largest and most uniform sub-mm map ever published. Both of these aspects are essential to allow the stacking of source populations such as BzK galaxies and AGN. Such stacking analysis allows the sub-mm properties of sources well below the nominal detection limit of the images to be studied, thereby providing a preview of the science ALMA will perform in this field. The large area also facilitates the discovery of rare sub-mm sources such as the most distant sub-mm galaxy known to date at $z = 4.76$.

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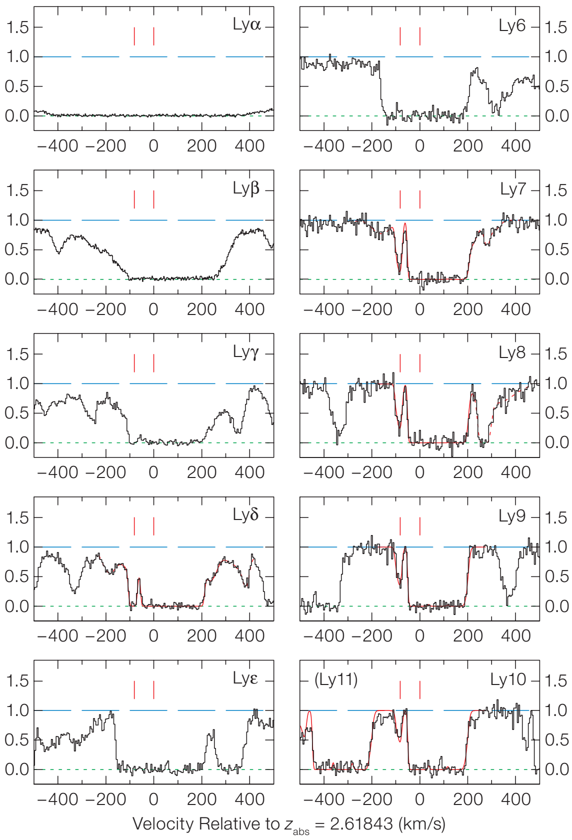
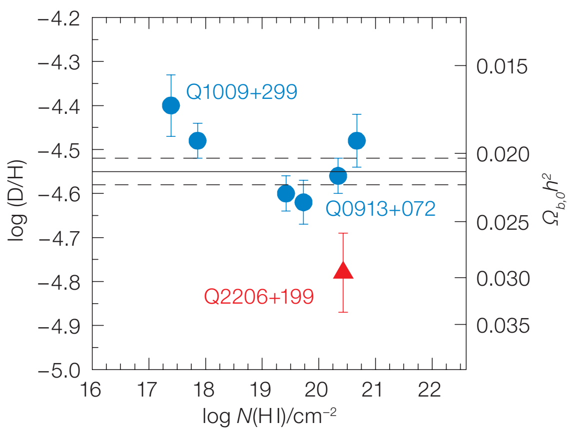
Zeroing in on the primordial deuterium abundance

The Wilkinson Microwave Anisotropy Probe (WMAP) observations of the cosmic microwave background (CMB) temperature fluctuations heralded the era of precision cosmology: the values of the fundamental cosmological parameters are now known to a precision of better than 10%. This remarkable achievement, however, should not hamper the pursuit of alternative ways of measuring these parameters, both because it is important to independently check the consistency of the standard cosmological models, and because CMB fluctuations generally constrain combinations of more than one parameter. Thus, for example, independent measurements of the cosmic acceleration through standard candles such as type I a supernovae, combined with CMB fluctuations improve substantially not only the precision of the determinations of the cosmic density of dark energy and dark matter, but also, and perhaps more importantly, the reliability of the interpretation of the observations in terms of an equation of state with negative pressure. Thus, while CMB measurements provide firm constraints on the value of the present density of baryons in the Universe, $\Omega_{b,0}$, its (CMB) value is tied to other parameters such as the spectral index of primordial fluctuations and the optical depth to reionisation. So it is very important to measure the baryon density through independent methods. A very sensitive method is provided by the primordial density of light elements whose nucleosynthesis results from physical processes that differ fundamentally from the acoustic oscillations of the photon-baryon fluid imprinted in the CMB. Among the light elements produced by primordial nucleosynthesis, deuterium is the one whose abundance relative to hydrogen (*D/H*) depends most sensitively on $\Omega_{b,0}$.

Reliable measurements of the primordial deuterium abundance $(D/H)_P$ are difficult to obtain because it requires low metallicity hydrogen-rich clouds with particular internal structures to be observed along the lines of sight to high-redshift Quasi Stellar Objects (QSOs). Thus, while the method has been known for over 30 years, reliable determinations of $(D/H)_P$ using 8–10-metre telescopes are available for only five objects. While the mean abundance from these measurements agrees within the errors with the value expected from the WMAP CMB value for $\Omega_{b,0}$, the dispersion of the values is larger than the errors of the individual measurements. This may well be due to an underestimate of the intrinsic errors of these difficult measurements, but is a cause of concern because the implied variance in the primordial deuterium abundance would be difficult to explain within the current cosmological paradigm. UVES at the VLT is an ideal instrument for this type of problem, and indeed has been extensively used to obtain high fidelity observations of absorption line systems in front of high redshift QSOs for a variety of astronomical problems. The isotopic shift between D and H is only about 81 kms^{-1},



UVES spectra of QSO Q0913+072 at the wavelengths of the strongest H I lines. The red profiles show model fits to the observations, and the red vertical lines show the expected positions of the H I lines (at 0 velocity), and the D I lines at −81.6 kms^{-1}.



Deuterium abundance relative to hydrogen for the full sample of DLA QSOs for which these measurements have been performed. Blue circles show measurements with 8–10-metre telescopes and the red triangle shows HST observations. The horizontal lines are drawn at the weighted average of the measurements and its error. The corresponding cosmic baryon density (for a particular value of the Hubble constant, $h = H_0/100$ km/s/Mpc) is shown on the righthand *y*-scale.

so high spectral purity and high signal-to-noise ratio are required to determine reliable deuterium abundances. This is beautifully illustrated in the UVES spectra of the Damped Lyman-α Absorber (DLA) QSO Q0913+072 shown at the top with a total exposure time of more than 20 hours.

The availability of a range of D I lines with a range of optical depths — from the saturated Lyδ to the optically thin Ly10 — allows a very precise determination of number of D I atoms on the line of sight *N(D I)*. The determination of the hydrogen column densities from these broad (damped) lines can be done with very good accuracy leading to a precise determination of the deuterium abundance relative to hydrogen *D/H*. The figure above plots log(*D/H*) for the now seven low metallicity DLAs where this delicate measurement has been performed.

The new UVES measurement of the most metal-poor DLA system known (QSO Q0913-072) is found to be in excellent agreement with four of the previous measurements, but disagrees with the other two. In hindsight, there are good reasons to believe the error bars of these two outliers to be significantly underestimated; if such is the case, the dispersion of the measurements becomes consistent with the observational errors thus allowing one to conclude that all objects have the same *D/H*.

All measurements shown in the figure correspond to very metal-poor systems for which galactic chemical evolution models show negligible decrease in *D/H* from the primordial value. Therefore, the weighted average provides a very accurate measurement indeed of the primordial deuterium abundance from Big-Bang nucleosynthesis constraints (BBN) $(D/H)_P\,h^2$ (BBN) = 0.0213 ± 0.0010, which is just within the errors of the CMB value. While the new long-exposure UVES observations did not appreciably change the BBN constraints on $\Omega_{b,0}$, they have led to a clearer understanding of the errors and thus the reliability of such measurements to constrain other cosmological parameters when combined with other sources of data, such as CMB fluctuations, type Ia supernova distances, and baryon wiggles in the galaxy distribution. In fact, the results of this combination are beginning to constrain even the most intimate parameters of the standard cosmological model.

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This image is a part of a 360-degree panoramic image, covering the entire southern and northern celestial sphere. It reveals the cosmic landscape that surrounds our tiny blue planet.


ESO/S. Brunier

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

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

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

D: Stellar Evolution
D1 Main-sequence stars
D2 Post-main-sequence stars, giants, supergiants, AGB stars, post-AGB stars
D3 Pulsating stars and stellar activity
D4 Mass loss and winds
D5 Supernovae, pulsars
D6 Planetary nebulae, nova remnants and supernova remnants
D7 Pre-white dwarfs and white dwarfs, neutron stars
D8 Evolved binaries, black-hole candidates, novae, X-ray binaries, CVs
D9 Gamma-ray and X-ray bursters
D10 OB associations, open and globular clusters, extragalactic star clusters
D11 Individual stars in external galaxies, resolved stellar populations
D12 Distance scale — stars

Percentage of scheduled observing time/telescope/instrument/discipline

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
UT1	CRIRES	0	0	22	9	31
	FORS2	21	13	7	19	60
	ISAAC	1	0	4	4	9
Total		22	13	33	32	100
UT2	FLAMES	0	14	4	16	34
	UVES	9	5	7	9	30
	X-SHOOTER	17	4	6	9	36
Total		26	23	17	34	100
UT3	ISAAC	4	5	8	2	19
	VIMOS	36	12	1	6	55
	VISIR	0	7	14	5	26
Total		40	24	23	13	100
UT4	HAWK-I	15	0	4	2	21
	NACO	1	3	25	4	33
	SINFONI	17	23	2	4	46
Total		33	26	31	10	100
VLTI	AMBER	0	0	31	36	67
	MIDI	0	9	11	13	33
Total		0	9	42	49	100

		Scientific Categories				
Telescope	Instrument	A	B	C	D	Total
2.2-metre	FEROS	0	9	11	34	54
	WFI	0	26	7	13	46
Total		0	35	18	47	100
3.6-metre	HARPS	0	0	74	26	100
Total		0	0	74	26	100
NTT	EFOSC2	7	8	10	28	53
	SOFI	4	5	17	9	35
	Special NTT	0	0	3	9	12
Total		11	13	30	46	100
APEX	APEX-2A	0	0	3	0	3
	LABOCA	14	10	23	3	50
	SABOCA	0	0	0	1	1
	SHFI	0	4	17	18	39
	Special APEX	0	2	5	0	7
Total		14	16	48	22	100

ESO/Y. Beletsky

Below the trails left by the stars in a dark and clear night, a laser beam shoots out from Yepun, the fourth Unit Telescope of ESO's Very Large Telescope.

Operations

ESO/Y. Beletsky

This view of ESO's La Silla Observatory shows the splendour of the Chilean night sky.

La Silla Paranal Observatory

Operations

In 2009 we celebrated the 10th anniversary of the start of science operations on the ESO Very Large Telescope with Unit Telescope 1 (UT1, Antu), and the two scientific instruments ISAAC and FORS1. For the first observing period of the VLT ten years ago, P63 in ESO's continuous count, we received 276 observing proposals from the community to use the new and exciting 8-metre telescope facility.

Today, ten years later, the VLT operates with four 8.2-metre UTs and its 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 adaptive optics supported instruments of the VLT with an artificial reference star. The VLT Interferometer combines the light of either the Unit Telesopes or the Auxiliary Telescopes to feed one of the two interferometric first generation instruments with a coherent wavefront, further stabilised by the VLTI fringe tracker. For the observing period 83, ten years after the first observing period with the VLT, we received 763 observing proposals for the VLT and the VLTI.

On La Silla, the New Technology Telescope, the 3.6-metre, and the 2.2-metre telescopes operate with an instrumentation suite of six instruments. The La Silla site further supports five national telescope projects including the latest addition of the La Silla-QUEST Variability Sky Survey at the ESO Schmidt 1-metre telescope.

The Observatory also provides operations support for the Atacama Pathfinder Experiment with its 12-metre sub-mm radio antenna and its recently completed suite of heterodyne and bolometer facility instruments located on the plateau of Chajnantor at 5100 metres altitude.

The Observatory continued its efficient operation by maintaining the high availability and low technical downtime of its telescopes and instruments — key elements for productive scientific observations. In 2009 a total of 2287 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 88% of the total number of nights theoretically available over the whole year. The remaining 12% were scheduled for planned engineering and maintenance activities to guarantee the continuous performance of the telescopes and instruments and include time slots for the commissioning of new instruments and facilities. Out of the available science time for Paranal only 3.3% was lost due to technical problems and about 7.9% due to bad weather conditions. On La Silla bad weather accounted for losses of about 10.8%, technical problems for 0.9%.

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 high scientific productivity. We have counted 466 peer-reviewed papers that were published in 2009 in different scientific journals and are at least partially based on data collected with VLT and VLTI instruments at Paranal. In the ten years since the start of science operation the VLT has now contributed to more than 3100 refereed publications. In addition, 277 refereed papers that referred to La Silla observations and 11 to APEX observations in ESO time were published.

The second generation instrument X-shooter at the UT2 Cassegrain focus.

New instruments

The first of the second generation VLT instruments, X-shooter, started its installation and commissioning in the last quarter of 2008. X-shooter was commissioned at the Cassegrain focus of the Melipal telescope (UT3), temporarily replacing VISIR in P82. At the beginning of P83, i.e. in April 2009, X-shooter was transferred to Kueyen (UT2) where regular science operation started in P84, i.e. in October 2009 after an intensive period of final commissioning and Science Verification.

X-shooter is a highly efficient, medium-resolution spectrograph providing simultaneous spectral coverage from 300 to 2450 nm, i.e., from ultraviolet to near-infrared wavelengths. The high efficiency and unprecedented simultaneous wavelength coverage combined with the ability of the VLT to rapidly acquire targets upon external triggers in the Rapid Response Mode (RRM) make X-shooter at the VLT a powerful tool to study transient phenomena in the sky where the shape and redshift of the spectra are *a priori* unknown. The fast follow-up of the quickly fading optical counterparts of gamma-ray bursts is therefore expected to be one of the most common types of observations with X-shooter.

The arrival of X-shooter at Kueyen required FORS1, the very first of the first generation VLT instruments, to be decommissioned after ten years of highly successful science operations. FORS1 alone has so far contributed to more than 750 scientific publications. Fortunately, FORS2 remains in operation for the foreseeable future. The polarimetry optics of FORS1 was transferred to its twin FORS2 at Antu to maintain this unique capability at the VLT. In addition, the high efficiency filters and grisms and the blue-sensitive CCD detector system of FORS1 are now available at FORS2.

During August we moved the ISAAC instrument from the Nasmyth B focus station on UT1 to the Nasmyth A focus station on UT3. The goal of this move was to improve the balance of the pressure on the requests for telescope time by the scientific community. UT1 with ISAAC, FORS2 and CRIRES received requests for about 550 observing nights in each observing period, i.e., for a factor of 3.5 more time than is actually available in the six-month observing period. Over the same period, for UT3 with VIMOS and VISIR, the requests summed to only 150 nights. After ISAAC's move, UT1 with FORS2 and CRIRES received requests for 400 nights, and UT3 with ISAAC, VIMOS and VISIR for 300 nights. This improvement in the distribution of time requests means that users of the popular FORS2 instrument obtain more time than before. This need for more access to the FORS2 instrument became even more important for the community after the decommissioning of FORS1. Moving a large VLT instrument facility like ISAAC from one Unit Telescope to another comes with certain risks for the sensitive cryogenic, opto-mechanical and detector systems of the instrument. However, the transfer was carefully planned and executed and ISAAC became available after a short period of re-commissioning at UT3 with the same performance as achieved before on UT1. With the move of ISAAC to UT3, the visitor focus has been relocated to UT1 until the arrival of the KMOS instrument in 2011.

Upgrades

To maintain the competitiveness of the VLT and VLTI it is not sufficient to continue to develop new instruments, but it is also necessary to follow a rigorous upgrade programme for the existing instruments. In July 2009 the first generation MIT/LL CCD detector of the red channel of the UVES high-resolution spectrograph was replaced with a deep depletion MIT/LL CCD of 40 μm nominal thickness. The new, thicker device became available after the decommissioning of the EMMI instrument in La Silla, where it had already served for many years. During commissioning of the new device in UVES, the overall efficiency of the instrument was measured to have increased by a factor of two at 900 nm, while the fringing amplitude has much reduced. This, together with very good "cosmetics" and linearity and unchanged geometry, readout noise and dark current of the detector, resulted in a substantial improvement of the red sensitivity of UVES, which is appreciated by the numerous science programmes that make extensive use of the reddest spectral region.

Paranal's new mechanical workshop.

New facilities

This year the Paranal site saw a very special new facility: the Paranal Mechanical Workshop. Covering a total area of 730 square metres, one of the — probably *the* — best-equipped workshop for precision mechanics in South America has been erected. It inherited its outstanding machine park and highly skilled staff from La Silla, where the famous *Astrotaller* closed this year. Maintaining the capabilities developed over decades to design and build precise opto-mechanical instruments and tools for the ESO observatories in Chile was identified as a high priority goal during the discussion of the restructuring of the La Silla site operations (cf. below). The new workshop in Paranal had started operation by the end of the year and provides not only a modern machine shop and storage space for materials and tools, but also design facilities and dedicated facilities for welding, painting, anodising, heat treatment and assembly of the manufactured parts.

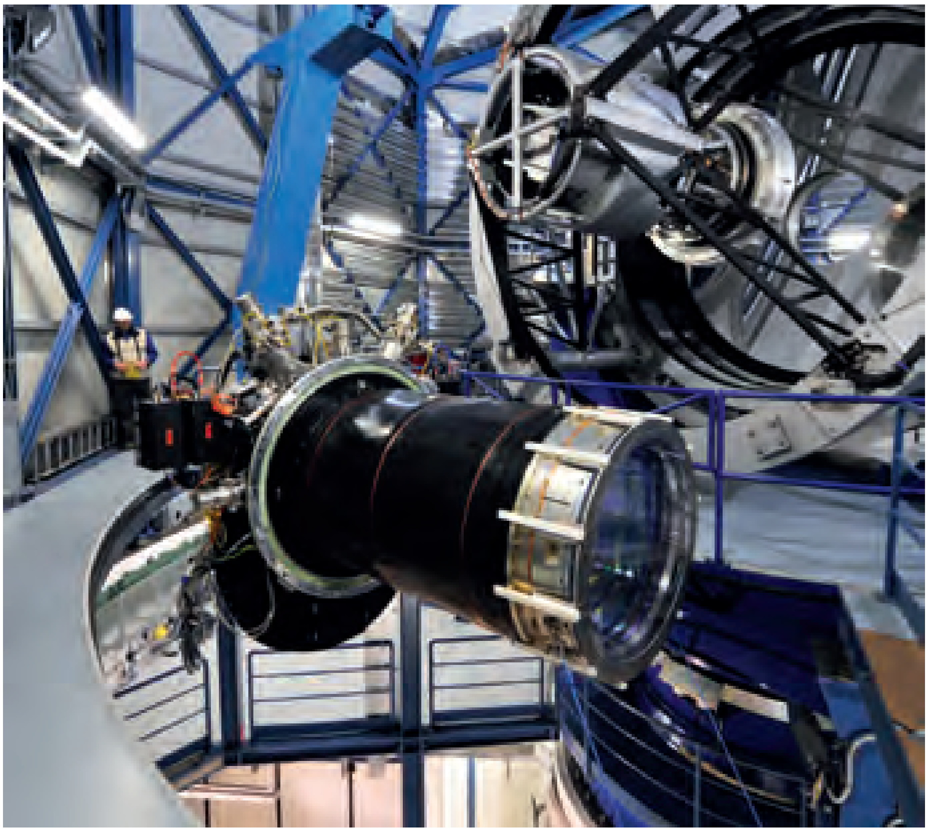
The VLT Interferometer

In 2009 the VLT Interferometer executed about 193 nights of scientific observations with MIDI and AMBER using UT and AT baselines. The remaining time was 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 70 technical nights. Out of the scheduled VLTI science time 7.7% was lost due to technical problems.

The AMBER instrument can combine up to three UT or AT beams interferometrically, supported by the FINITO fringe tracker. While AMBER operation with FINITO has become routine with the ATs, FINITO fringe tracking with the UTs remains challenging. Vibrations of the optical surfaces of the UTs transmitted to the VLTI are known to limit the performance of this mode. After a vibration-suppression system was deployed and fully commissioned to at least partially overcome the vibration problem, the hunt for the sources of the vibrations and their elimination has been one for the key activities of the VLTI team in 2009. A systematic and thorough investigation of the vibration environment of the VLTI revealed various culprits. Among those, the biggest contributors were found to be vacuum and cryogenic pumps required by some of the scientific instruments of the VLT. While sometimes simple measures like orienting the unused instruments to specific rotator positions drastically reduced the induced vibrations, in other cases a laborious replacement of the pumps by low-vibration models was found to be the only viable solution. As a consequence the overall vibration environment has been considerably improved in the course of the year. For UT1 and UT2 the measured residuals of the optical path difference were pushed below a root mean square (rms) of 200 nm. UT3 and UT4 already come close to this value, but more work is still needed.

The AMBER instrument itself was also upgraded over the year. Improved feeding optics removed unwanted spectral interference patterns previously observed, notably in the high-resolution mode of AMBER. New alignment strategies for the complex optical systems of AMBER have considerably improved the stability and maintainability of the instrument.

The four Auxiliary Telescopes that form the VLTI Sub Array (VISA) have become the workhorses of the VLT Interferometer. Several improvements to the ATs, including new STRAP tip-tilt sensors and new focusing devices have been implemented over the year, which led to improvements of the performance of the ATs. Additional upgrades are planned over the coming year to improve the reliability and maintainability of the telescopes and therefore to maximise their availability for science operations.



The three-tonne VIRCAM infrared camera on the VISTA 4.1-metre infrared survey telescope on Paranal.

As of P85, VISA is being offered to the science community in three different four-telescope configurations. For each of these quadruplets, all possible two-telescope and three-telescope configurations can be used by the scientific instruments MIDI and AMBER. During each month of science operation VISA is reconfigured so that each of the three four-telescope configurations is available for about a week. This is a considerable increase in the number of available AT baseline combinations within a given time, and, together with the opening of new AT stations, allows the VLTI to better fulfil the increasing desire of astronomers for milli-arcsecond resolution images of the surfaces and local environments of stars.

VISTA

The Visible and Infrared Survey Telescope for Astronomy is the latest addition to the telescope suite at 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 km from the four UTs. The telescope has an altitude-azimuth mount and quasi-Ritchey-Chrétien optics with a fast f/1 primary mirror giving an f/3.25 focus to the instrument at Cassegrain. VISTA's main mirror is 4.1 metres across and is the most highly curved mirror of this size and quality ever made — its deviations from a perfect surface are less than a few thousandths of the thickness of a human hair — and its construction and polishing presented formidable challenges. Shape and position of the mirrors in the telescope are actively controlled by high and low order curvature wavefront sensors (WFS) located inside the instrument focal plane. The low order

WFS can be used simultaneously with the scientific observations.

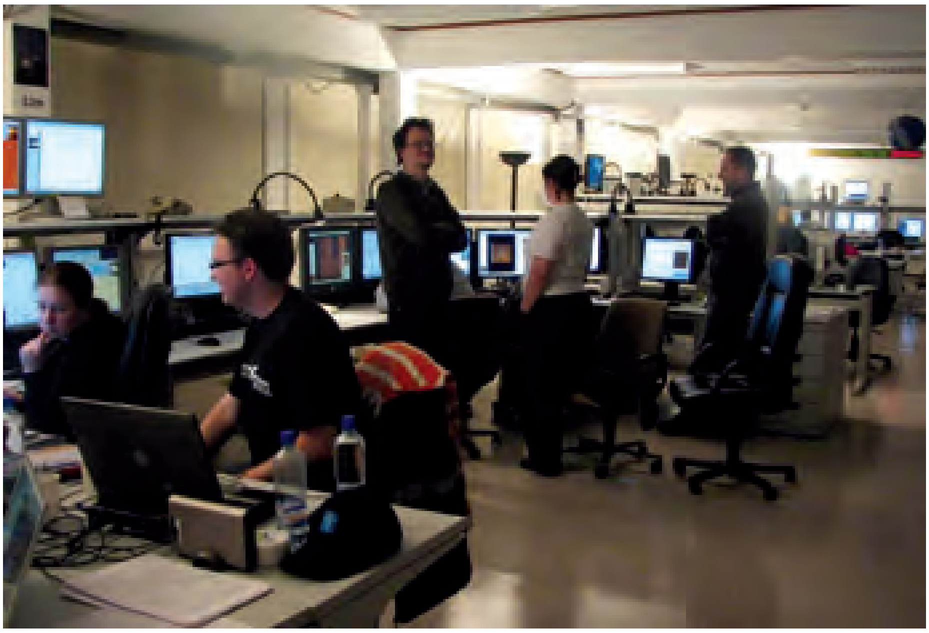
VISTA is equipped with the near infrared camera VIRCAM, which covers a 1.65-degree diameter field of view with a loosely packed detector mosaic totalling some 67 million pixels with a mean pixel size of 0.34×0.34 arcseconds^2. Each VISTA image captures a section of sky covering about ten times the area of the full Moon. This will allow the detection and cataloguing of objects over the whole southern sky with a sensitivity that is 40 times greater than that achieved with earlier infrared sky surveys such as the highly successful Two Micron All-Sky Survey (2MASS).

VISTA was conceived and developed by a consortium of 18 universities in the United Kingdom (UK) led by Queen Mary, University of London and became an in-kind contribution to ESO as part of the UK's accession agreement. The telescope design and construction were project-managed by the UK Astronomy Technology Centre of the Science and Technology Facilities Council (STFC, UK ATC). Following an intensive commissioning, verification and acceptance period carried out by the VISTA Project Office and ESO, the VISTA telescope was provisionally accepted and handed over by the STFC to ESO on 10 December 2009.

Science Verification (SV) observations were carried out on 15 nights between 15 October and 2 November 2009. SV observations are a very important check of the entire operational procedures and a verification of the scientific status of the VISTA telescope and its VIRCAM instrument. The SV observations provided the first comprehensive self-contained scientific datasets from VISTA. The data were immediately made available worldwide. In this way, the entire astronomical community was able to exploit the data scientifically and use them to plan future observations with VISTA.

The first five years of VISTA operation are dedicated primarily to the execution of six approved public surveys. Public survey operation with VISTA will formally start in April 2010 after an extended period of technical activities and so-called dry runs to resolve remaining technical issues and to exercise new science operations tools and processes, respectively. During the dry runs real science observations out of the pool of the public survey programmes are carried out. These early science data allow the Principal Investigators of the public surveys to optimise their observing strategies and data reduction techniques at this early stage.

P. Sinclaire



The new La Silla control room.

VST

The VLT Survey Telescope is the optical counterpart of VISTA. Construction of the VST by the Italian Istituto Nazionale di Astrofisica continued next to the UTs on the Paranal telescope platform. During the first half of the year the project has seen considerable progress, as the telescope structure was erected inside the enclosure. Unfortunately, the main mirror cell, with its support and actuator systems, was damaged during the transport from Italy to Chile and had to be returned for refurbishment. Integration and commissioning works are expected to continue in the second quarter of 2010.

La Silla

As of October 2009 the La Silla Observatory operates according to a new streamlined operations model labelled the *La Silla 2010+* model, as endorsed by the ESO Council in 2007. During 2009 the La Silla site and science operations have undergone the transition to the new operations mode. This included relocation of the telescope control consoles from the Ritz to a new control building, the former administration building, where now all the La Silla operation and administration have been centralised. Further, all the logistical aspects of the operation (accommodation, lodging, transport, service contracts) have been adjusted to the reduced operational needs. For ESO's visiting astronomers to La Silla the most notable change due to the new science operations model is the absence of an ESO staff astronomer to support the execution of their observations.

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 MPG/ESO 2.2-metre telescope with FEROS and WFI. As of

April 2009 the MPG/ESO 2.2-metre telescope operates according to a new agreement with the Max-Planck-Institut für Astronomie (Heidelberg, Germany). This agreement ensures the continued operation of the MPG/ESO 2.2-metre telescope until 2013, with an ESO share of 25% of the available observing time in response to the continued high pressure by the community on the FEROS and WFI instruments.

The science operation of La Silla has been further streamlined to minimise operational costs (instrument changes only for visitor instruments, visitor mode as the only operations mode) and to maximise the scientific return of the telescopes by encouraging large programmes with high impact of up to four years in duration, such as the HARPS planet search programme. The telescopes continue to be operated using the VLT Control and Data Flow System infrastructure, including the storage of all obtained data in the ESO archive.

La Silla Observatory continues to support observations on the Danish 1.54-metre, the Swiss 1.2-metre Leonhard Euler, the REM, and the TAROT telescopes. It further supports new projects that make scientific use of the available La Silla infrastructure. The ESO Schmidt 1-metre telescope has been reopened for the La Silla QUEST Variability Sky Survey (VSS) project. The principal goal of the US/French LS–QUEST consortium is to carry out a large five-year variability survey in the southern hemisphere, primarily to study a large sample of nearby type Ia supernovae to explore the nature of the recently discovered dark energy, and to search for trans-neptunian objects and dwarf planets in our Solar System. In 2009 the Schmidt 1-metre telescope was successfully modified by the consortium to carry the 10-degree-field QUEST camera and started to operate in quasi-robotic mode mid-2009.

The APEX antenna. APEX is a collaboration between the Max-Planck-Institut für Radioastronomie (MPIfR), Onsala Space Observatory (OSO) and ESO.

APEX

In 2009 APEX has reached its full complement of facility instruments. After the arrival of LABOCA in 2007, the Swedish heterodyne facility (SHFI) receivers that cover all four atmospheric windows from 200 to 1400 GHz were delivered by Onsala Space Observatory in 2008. Only Band 3 remains to be fully commissioned in early 2010.

The commissioning of the Shortwave Apex BOlometer Camera (SABOCA) developed by the Max-Planck-Institut für Radioastronomie (Bonn, Germany) was completed in 2009. SABOCA operates at a wavelength of 370 μm and provides a field of view of approximately 1 square arcminute using an array of 37 superconducting pixels allowing the efficient observation of maps of large areas of the sky.

In the course of 2009 the APEX operations team has implemented a 24-hour operation mode, which allows almost continuous scientific observations during day and night with APEX and its suite of sub-mm facility instruments. This new operations mode maximises the exploitation of the exceptional conditions available at the site of Chajnantor at 5100 metres altitude.

I. Bončina/ESO

Two Unit Telescopes of the Very Large Telescope at ESO's Cerro Paranal observing site.

Data Management and Operations Division

The Data Management and Operations (DMO) division continued to provide support to the operation of ESO facilities and to their users in the framework of an integrated end-to-end system, maintaining the archive facility and its data holdings as a powerful resource both for research and operations.

A major new facility, VISTA, has been integrated into the end-to-end system during 2009 and is getting ready to start regular operations in early 2010. This has involved the adaptation of operations procedures and their associated tools and infrastructure to the specifics of a telescope entirely devoted to survey programmes extending for several years, producing nightly data volumes nearly one order of magnitude above those produced by the other telescopes on Paranal combined. The first of the VLT second generation instruments, X-shooter, has also been integrated into end-to-end operations.

The ALMA Regional Centre (ARC), hosted at the ESO Headquarters, has continued to prepare for the support of ALMA, while also participating in activities across Europe to enable the scientific community to prepare to make the best use of ALMA as it enters operations. Operational concepts for the E-ELT era have also continued to be developed.

User Support

A new APEX operations plan, allowing up to 24 hours of continuous observing, was successfully implemented in June. Each ESO observing slot at APEX now requires the support of three ESO astronomers, who can then cover the three daily shifts. The first regular Target of Opportunity runs at APEX were scheduled and executed during Period 84.

Several astronomers from the User Support Department have played a substantial role in the coordination of the VISTA Science Verification run in October, and have stayed strongly involved in the subsequent VISTA dry runs. All documentation and tools needed by VISTA users, including new video tutorials, were released in September and the first Phase 2 call was issued just before Christmas.

The User Support Department was also deeply involved in the commissioning and Science Verification runs of X-shooter, the first of the VLT second generation instruments. The support of the first period of X-shooter operations went very smoothly.

Besides its regular support activities, the User Support Department participated in the upgrade activities for several VLT instruments (VISIR, UVES CCD Red, FORS1+2 merging, VIMOS), and also led development projects like the upgrade of the ESO User Portal and the Paranal night log tool.

European ALMA Regional Centre

ARC continued to prepare for its mission of providing the scientific and technical support services necessary for the European user community to exploit ALMA to its full scientific potential. In Europe, ARC is set up as a network of nodes throughout Europe, coordinated by a central node located at the ESO Headquarters in Garching. In this distributed network, user support and operations experience at ESO can be mixed with the millimetre-wave astronomy experience that exists in the community to create optimal science support services.

The nodes will provide face-to-face help and additional support, beyond the ARC core functions. The central ARC at ESO coordinates this network of nodes. The current activities and the people involved in the ARC nodes are described in the individual web pages of each node. Links to these pages can be found in the ESO ARC web page (www.eso.org/sci/facilities/alma/arc/).

The ARC at ESO is ramping up and is fully engaged with activities in Chile at the Joint ALMA Observatory (JAO), while organising the support for the European scientific community. ARC astronomers are participating in the commissioning and Science Verification phase. All ARC staff are testing the software (observing tool, data reduction and simulator tools, observatory operations tools, etc.), writing "cookbooks" and manuals. The first call for proposals for early science is expected to be issued towards the end of 2010 and ARC must be fully functional before that time.

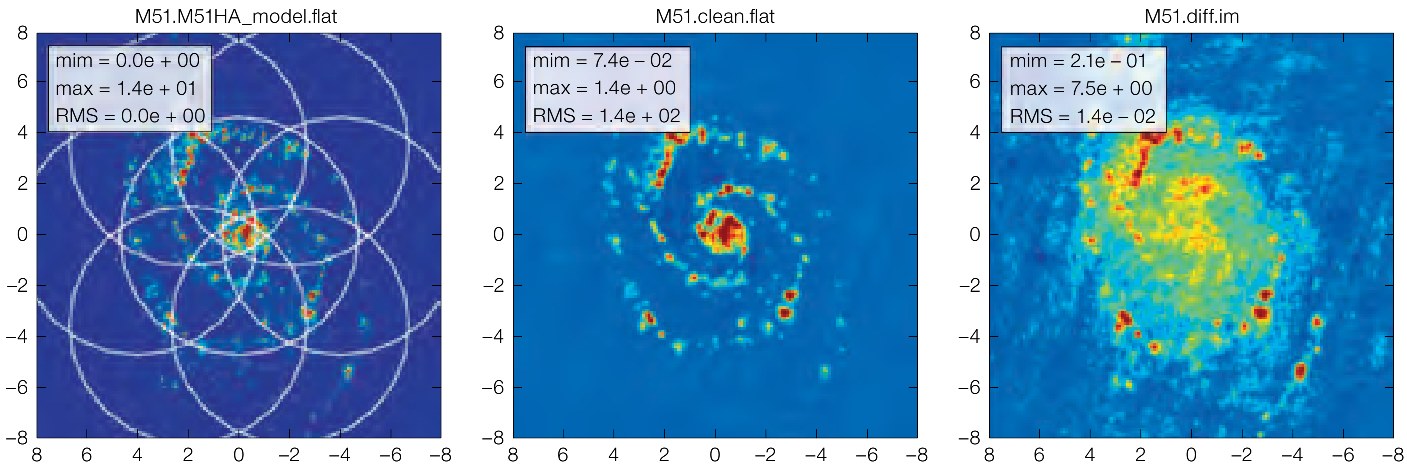
During 2009 the ESO ARC engaged in testing the observations simulations and prepared a database of simulated data. The main purpose is to have simulated ALMA data for archive, operations and pipeline testing, and to make this tool available to users to assist in proposal preparation. At the end of 2009 the ALMA simulator became available, as part of the first official CASA release (version 3.0).

The simulator generates mock ALMA observations, taking into account instrumental and atmospheric corruption of the visibilities. One of the most useful aspects of the simulator is its ability to assess quantitatively how, for example, the choice of antenna configuration, exposure time and actual weather conditions determine the quality of a specific observation. Starting from a first set of observational parameters, one can then search for a better set to optimise for the science question at hand.

Data Products

The Data Processing and Quality Control group works closely with the Paranal Science Operations department to assure that all instruments (now including the first survey instrument, the infrared VIRCAM camera on the VISTA telescope) are always performing within expected and published ranges. Taking advantage of the fast data transfer link, the quality control loop between Paranal and Garching is now routinely closed on a timescale of about one hour.

During 2009 the Data Processing and Quality Control group processed more than 10 TB of VLT/VLTI raw data in 210 000 processing jobs. 1120 service mode packages were created and distributed to their respective Principal Investigators (PIs). In addition to service mode data, as of 1 October 2009, processing also includes visitor mode science data. This is an important step



The picture on the left shows a spiral galaxy which is run through the ALMA simulator, using a relatively compact configuration for the full ALMA array and simulating a mosaic of seven pointings (as indicated by the white circles) at 668 GHz, with a total observing time of one hour. The central picture shows the resulting (cleaned) mock observation, whereas the difference between this mock and the original science model is shown in the right picture. The simulator allows the user to establish which parts of the image are going to be most reliably observed with ALMA for a given antenna configuration, frequency, exposure time, etc.

towards filling the Science Archive Facility with a complete and consistent suite of data products. The beginning of operations in the autumn of 2009 of the VIRCAM camera on the VISTA telescope marked an explosion of data production on Paranal. In the last one and half quarters of 2009, it has generated more than 8 TB of data to be processed. This constitutes 80 % of the total production of the entire suite of VLT/VLTI instruments over the full year!

The packing of service mode data from La Silla instruments was decommissioned in 2009, following the evolution of the observatory to visitor mode only.

ESO continues its efforts to improve the scientific quality of the data obtained, a task carried out by the Science Data Products group in close collaboration with the Pipeline Systems department of the Software Development Division. Projects undertaken in 2009 include the combination of data across Observing Blocks, the characterisation and correction of geometric distortions in HAWK-I data and the generation of science-grade data products from VLTI.

A science data products forum (www.eso.org/sci/data-processing/forum.html) is available to the science community as a public platform to discuss issues with data from ESO instruments.

The list of advanced data products generated by the ESO community, mainly through the execution of Large Programmes with ESO facilities, and returned to ESO for publication through the Science Archive Facility has continued to increase during 2009. At the time of writing, the ESO Science Archive Facility holds about 0.9 TB of highly processed data products, corresponding to some 1.8 million files.

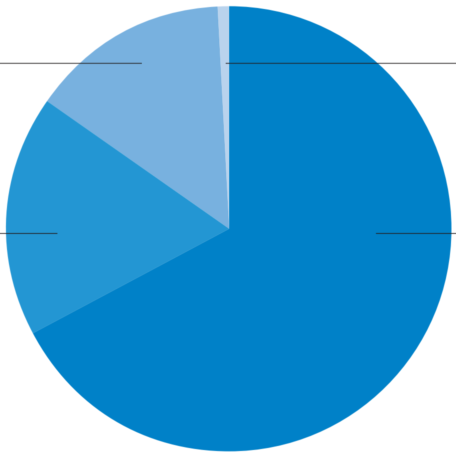
Principal Investigators are offered a standardised procedure with a unique entry point for returning their reduced data products to ESO. Work is in progress at a brisk pace to finalise the preparation for accepting the first data products from public surveys with VISTA, now that the telescope has entered science production.

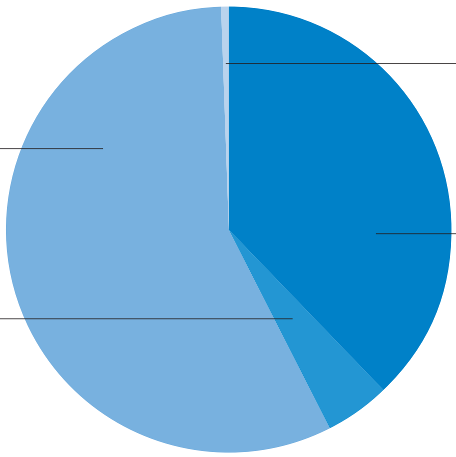
Science Archive Facility

The Science Archive Facility is physically maintained in the ESO Data Centre and continued to fulfil the long-term storage and distribution requirements for raw and processed data from the ESO La Silla Paranal Observatory (ESO LPO), as well as for data delivered from the Hubble Space Telescope, the Wide Field Infrared Camera (WFCAM) for the UK Infrared Telescope (UKIRT) and the Atacama Pathfinder Experiment. The total archive holdings now comprise some 145 TB of data distributed across 30 million files after the addition of 34 TB or approximately 6.4 million files in 2009. The distribution of the data intake in 2009 in terms of volume and file-count is illustrated in the next page.

Pivotal in the management of the archive holdings are the metadata extracted from each file and catalogued in the archive database infrastructure. In 2009 the databases ingested information covering 1.68 million raw observation frames (~ 1 400 000 LPO; ~ 300 000 WFCAM; ~ 18 000 from APEX), as well as just over 1 million pipeline processed frames (~ 370 000 master calibration, ~ 300 000 science and ~ 350 000 auxiliary frames). The FITS keyword repository database ingested the headers of ~ 2.7 million frames. The database currently holds full header information from ~ 13.6 million frames in ~ 5.7 billion database rows. The operations log database ingested ~ 700 million rows, bringing the grand total database holdings to 3.6 billion rows. A separate database system manages the HST data.

Data releases that occurred in 2009 were the GOODS/VIMOS Spectroscopy, Version 2 and Imaging Version 1, PRIMA fringe sensor unit commissioning, X-shooter commissioning and Science Verification 1 and 2, and the VISTA/VIRCAM Science Verification. Unique archive requests comprised 18 600 requests of 14 TB compressed data or 1.7 million files. A total raw data volume of 1.7 TB has been delivered to PIs following requests





The distribution of data ingested in the ESO/ST-ECF archive across the ESO LPO, HST, WFCAM and APEX collections depicted in terms of (a) data volume and (b) the number of actual files.

for their own proprietary data. In addition, 1120 VLT/VLTI PI packages and 140 requests for pre-imaging have been successfully delivered. For HST data 795 unique requests comprising 3.7 TB or 400 000 files were served.

As regards the creation of more value-added services, as of January 2009, APEX weather data can be searched by date interval, or any meteorological parameter for the Chajnantor site. The availability of ESO archival raw data through the visual archive browser VirGO is now assured operationally. We have carried out consistency checks and analysis of some archival metadata holdings. This will set the basis for a complete specification of the ESO archival data, providing information on their history and the raw files that were used in their processing. These are necessary steps to better support archive users in their identification and characterisation of data of interest for a wide range of scientific projects.

A critical function of the Science Archive Facility is to ensure the appropriate access rights to all data are maintained and updated in a timely manner. After an internal review of access policy documents and user access scenarios, an updated specification of access control for both metadata and data has been established. This is one of the critical steps in a general overhaul in the handling of all archived entities that will guide development of the archive and contribute to the re-working of external interfaces for the benefit of archive users.

The overall data flow operations have been augmented on ingestion, with La Silla data being transferred via the network from 5 May 2009. Meanwhile, PIs have been able to benefit from an online PI package service introduced since 29 June (with 76 packages delivered) and the later exploitation of Blu-ray optical disks for the postal delivery of PI packages since 10 December 2009.

At the end of the year there were 6578 registered users of the user portal.

Virtual Observatory (VO)

The Virtual Observatory Project Office (VOP) continues to increase the VO-compliant contents of the ESO archive, and coordinates ESO's involvement in the VO, namely in the Euro-VO project and the International Virtual Observatory Alliance (IVOA).

Several improvements were also made to VirGO, the visual browser to the ESO archive (http://archive.eso.org/cms/virgo/), which provides a modern and intuitive way to access ESO data by displaying on the sky the field of view of imaging detectors and slits of spectrographs. These include a new user interface, improved VO compatibility, and a User Guide.

Work on the Survey Visualisation and Monitoring Tool (SVMT) has started. The SVMT will be used by the ESO public survey teams to monitor the progress of their surveys. The initial focus has been on the definition of a list of tasks and the delivery of a preliminary architectural design document. Large changes were made to VirGO's core and graphical user interface so it could be used as a base for SVMT.

The first European "hands-on" VO school was held at ESO between 30 March and 2 April 2009, with heavy involvement of VOP staff. The aim of the school, targeted mostly at PhD students and young post-docs, was to expose European astronomers to the many available VO tools and services so that they could be used efficiently for research purposes. Real-life examples of scientific applications were given. The school involved 40 students and 15 tutors and tool developers. Based on the input received from the participants during the hands-on and feedback sessions the school was a great success. A "VO day" was also organised at ESO on 15 September.

The Euro-VO project, through its Science Advisory Committee (SAC) and the Facility Centre, selected three projects, which are making use of VO tools and applications to carry out astronomical research. The projects are receiving scientific support and will complete their work by November 2010.

VOP staff were present at the Joint European National Astronomy Meeting (JENAM) at the University of Hertfordshire, Hatfield, UK, 20–23 April, where they also manned a Euro-VO booth with astronomers from other Euro-VO partner projects, at the European Infrastructures Session of the IX Hellenic Astronomical Society Conference in Athens, 20–24 September, and at the NoviCosmo school in Croatia, 28–30 September.

VOP organised the second IVOA Interoperability meeting of 2009 at ESO on 9–12 November. These meetings represent an opportunity for the IVOA Working Groups and Interest Groups to have face-to-face discussions and for technical questions to be resolved.

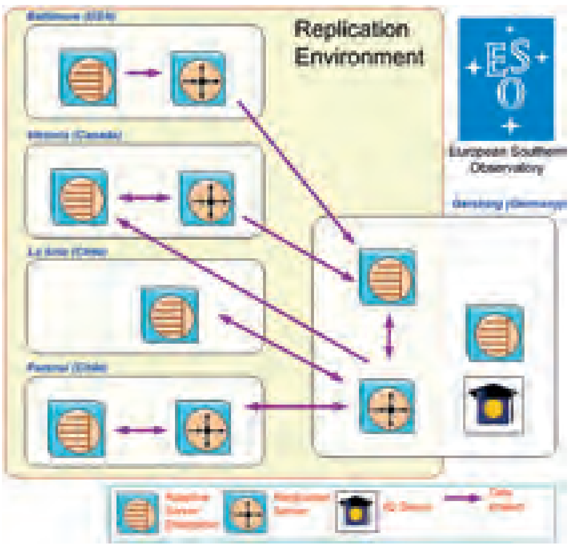
Participation is open to anyone with an interest in VO standards and technologies. The meeting attracted about 100 participants from all over the world. The meeting web page is available at www.ivoa.net/cgi-bin/twiki/bin/view/IVOA/InterOpNov2009.

The Euro-VO Science Advisory Committee, which provides scientific advice to the project, was mostly renewed after its three-year term was over. The new SAC composition is available at www.euro-vo.org/pub/fc/sac.html. The 6th meeting of the Euro-VO SAC took place at ESO on 14 December, where SAC members were presented with the current activities of the Euro-VO and its future goals, and provided input on the topics of dissemination, data publishing in the VO, and VO-enabled science.

VOP maintains the Euro-VO project website, which in 2009 served 86 GB of content resulting from 830 000 web hits in 73 000 user sessions. VOP is also in charge of the IVOA project website, which served 75 GB of web content resulting from 1.6 million web hits in 220 000 user sessions.

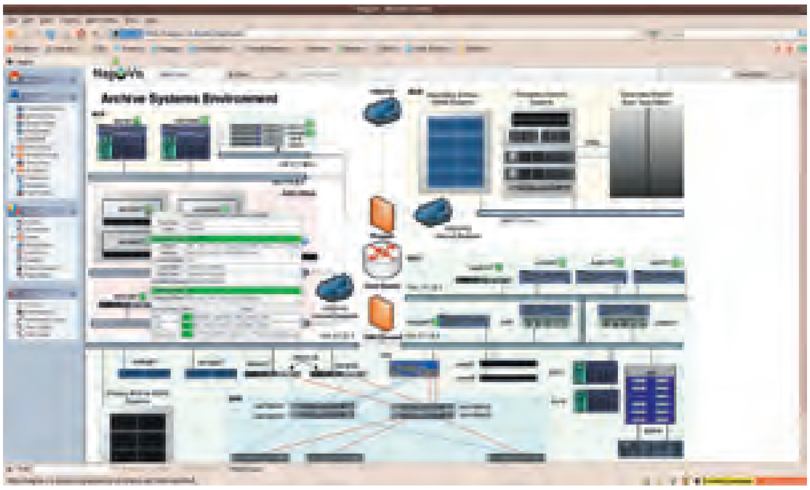
Operations Technical Support

ESO operations are heavily dependent on the use and replication of relational databases. The migration of the ESO operational database replication environment from Unix to Linux has been successfully completed. As a result of the migration, there has been a sizeable increase in the throughput of the replication service, which is critical to the provision of support to surveys. Bradmark Surveillance has been deployed to monitor database replication, the primary database servers and the data warehouse



An example of the database replication at the heart of ESO operations, sending and receiving transactions on a global scale: ESO replicates to and from collaborations at a database level with other astronomical institutes, as well as La Silla Paranal.

This is an example of Bradmark monitoring for ESO operational database servers including Sybase Adaptive Server Enterprise, Replication Server and IQ.



An example of the NAGIOS event monitoring system for the operational archive environment at ESO. This graphical overview provides real-time data, for instance for a Blu-ray production system.

Actively cooled racks installed in the ESO Data Centre for the archive and database environment of the ALMA Regional Centre within the Data Management and Operations Division.

An example of the MUNIN performance and trend monitoring system for an operational archive system at ESO.

containing 5.5 billion observational keywords. The tool allows administrators to observe the servers usage and be notified when events occur.

The efficiency of mission-critical computer systems within operations is ensured by the newly deployed NAGIOS event and MUNIN performance and trend-monitoring environment. This event-monitoring system collects and analyses event occurrences of over 250 computers and over 800 services and instantly signals the occurrence via electronic mail or a fully redundant short message service. The performance and trend monitoring system systematically collects information about the mission-critical environment and their services to monitor their performance.

The ESO Data Centre capacity has been extended in terms of actively cooled racks, redundant cooling and power supplies to host and operate the archive and database environment for the ALMA Regional Centre within the Data Management and Operations Division.

A view of the Atacama Pathfinder Experiment, with the famous sulphur mountains in the background.

European ALMA Support Centre

On 1 October 2009 ESO formally instituted the European ALMA Support Centre. EASC is the “face” of ALMA for the European scientific community and institutes and for 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 encompasses the 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 with the individual users (see page 34). This function is successfully performed for the VLT by the User Support Department in the DMO, which has many commonalities with the function of the central ARC. Other functions foreseen for the ARC correspond to other departments supporting VLT operations (e.g. 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.

The ALMA partnership foresees continuous upgrades 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 EASC’s ALMA Technical Support group. The ALMA upgrade and development programme will be funded from the ALMA operations budget through 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.

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

I. Bončina/ALMA (ESO/NAOJ/NRAO)

Four of the ALMA antennas thrust to the sky at the OSF.

ESO/S. Guisard

Part of the second of three images of ESO's GigaGalaxy Zoom project is a vista of the central parts of our galactic home. The Lagoon and the Trifid Nebulae can be seen at the top of the image and at the bottom are NGC 6357 and NGC 6334.

A close-up of astronaut John Grunsfeld shows the reflection of astronaut Andrew Feustel, perched on the Shuttle's robotic arm and taking the photo. The pair teamed up together on three of the five spacewalks during the Hubble Servicing Mission 4 in May 2009.

NASA/ESA

ST-ECF

In a collaboration between ESO and the European Space Agency, the ST-ECF continues to perform HST instrument science and archival functions in close coordination with the Space Telescope Science Institute (STScI) and, for the archive operation and legacy data products, also with the Canadian Astronomy Data Centre (CADC). The group works with ESO's education and Outreach Department (ePOD) to produce a range of public outreach materials and releases concerning Hubble.

In May 2009, the long-awaited fifth servicing mission (SM4) took place and, in 13 days — including some 37 hours of spacewalks — astronauts completed essentially all of their scheduled activities to leave the space observatory in by far its most powerful state ever. With two new instruments, a panchromatic camera WFC3 and a high efficiency ultraviolet spectrograph, COS, and repairs to the existing camera and spectrograph, ACS and STIS, Hubble now provides unprecedented capabilities for imaging and spectroscopy from the far-ultraviolet to the near-infrared. During the rest of the year, the programme of orbital verification of the observatory was completed and routine science observations begun.

One of the new capabilities provided by WFC3 is the ability to perform very high sensitivity slitless spectroscopy in the near-infrared up to 1700 nm, complementing the capabilities of ACS in the visible/red spectral range. With the low sky background in space, these modes are extremely sensitive and provide the capability to study continuum features, such as Lyman breaks, and emission lines to very high redshifts. At intermediate redshifts, the ability to detect Hα and other optical emission lines in many galaxies provides the gold standard in mapping the star formation history of the Universe during a most critical epoch. By formal agreement with STScI, the ST-ECF is responsible for providing the calibration and user support for these modes and so has been closely involved with both the ground testing and the orbital verification and calibration programmes. In the later part of the year, spectral extractions — using the aXe software developed at the ST-ECF — were provided for the Early Release Science observations and several other programmes. Other instrument science activities included continued support for the ACS grism modes and close involvement with the team making the EUCLID (dark energy mission) proposal to ESA to provide sophisticated simulations of both slit and slitless spectroscopy to evaluate mission capabilities.

As part of the Hubble Legacy Archive (HLA) initiative — to provide science-ready data products — the ST-ECF had continued its work to extract and qualify all the useable spectra contained in the pre-SM4 ACS observations with the $R \sim 100$ red grism in the wide-field channel of this instrument. This work is resulting in a set of approximately 30 000 calibrated spectra from fields amounting to coverage of some 800 square arcminutes and down to a limiting magnitude (AB) of at least 26. Public release is planned during the first half of 2010. A sampler, consisting of 1235 spectra available from the HLA and from the ST-ECF website, was released in April 2009.

The ST-ECF at ESO hosts the European copy of the complete HST science data archive which, by agreement between ESA and NASA, includes proprietary as well as publicly available data. The operation of this archive, both for serving requests and for data ingest, takes place within the overall ESO archive system and it is currently being readied for the possibility of a low-cost, low-maintenance operation after the closure of the ST-ECF at the end of 2010. With Hubble operating as it is after SM4, it is expected that both the existing and the subsequently ingested data products will be of extremely high scientific value in perpetuity. Work has centred on the task of fully integrating the HLA data products and providing more capable and convenient user interfaces, which are now available for use.

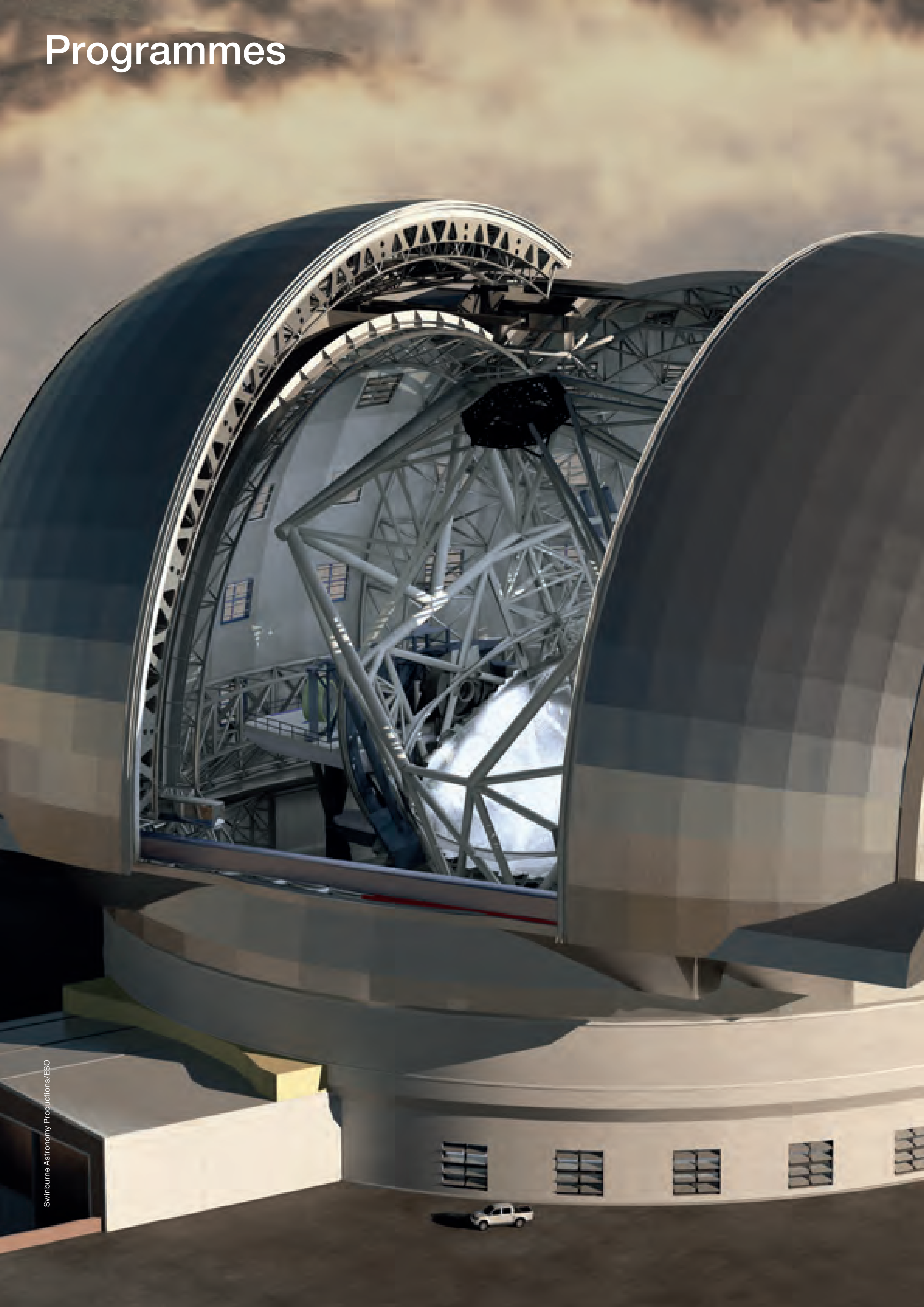
Since the initial Hubble, Spitzer and Chandra observations took place early in the decade, ST-ECF staff have been concerned with various aspects of the GOODS programme, notably with the ESO follow-up observations of the CDF-S. The last of the data papers describing the extensive spectroscopic observations with FORS2 and VIMOS was submitted at the end of the year (accepted January 2010) and the ESO–GOODS website has been updated accordingly and includes an extensive compilation of CDF-S spectroscopy.

These four images were among the first observations made by the new Wide Field Camera 3 aboard the upgraded NASA/ESA Hubble Space Telescope.

The European Hubble outreach activities, which were originally requested by ESA and NASA, are now fully integrated within ESO's outreach department. An overview of the outreach activities is given in the section about ESO outreach in this annual report (see page 94).

The ST-ECF, in collaboration with STScI, has taken the initiative of organising a high profile HST science meeting in Europe in 2010. To be held in Venice in October this meeting will, as well as celebrating Hubble's 20th anniversary, allow a mature retrospective view of Hubble's contribution to astronomy while also, after more than a year of post-SM4 operation, encourage a presentation of the observatory's current capabilities and newest discoveries. In conjunction with the conference, there will be an exhibition of Hubble hardware, including returned components, astronaut tools and a spacesuit — supplied by both NASA and ESA — and a collection of images selected from the whole mission. The venue is being provided by the Istituto Veneto di Scienze, Lettere ed Arti with support from them and the Observatory and University of Padova.

Programmes



Swinburne Astronomy Productions/ESO

European Extremely Large Telescope

The Directorate of Programmes comprises the Telescope, Instrumentation and Technology Divisions, thus covering the E-ELT project, the survey telescope projects, instrumentation development and technology.

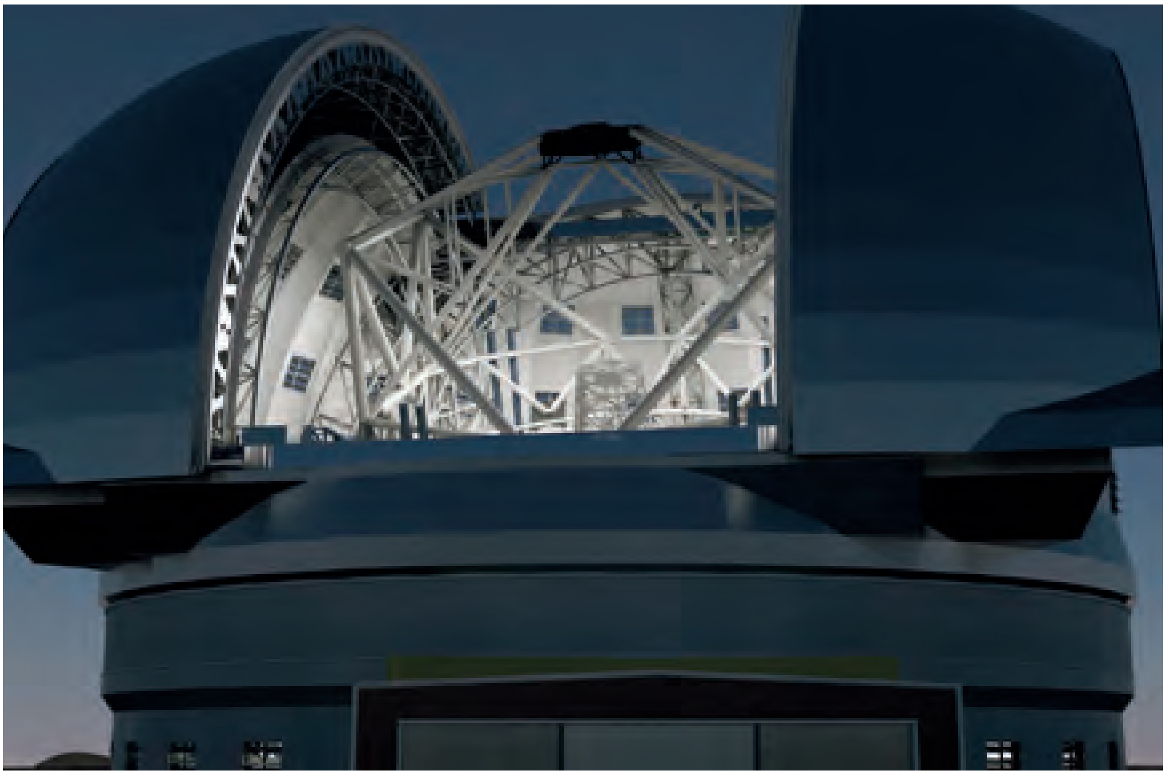
Highlights of 2009 included excellent progress of the E-ELT Phase B design study; the provisional acceptance of VISTA; installation of most of the PRIMA subsystems on the VLTI; start of science operations with X-shooter on the VLT; good progress in the assembly and test of the remaining second generation VLT instruments KMOS, MUSE, SPHERE and on the design of the second generation VLTI instruments MATISSE and GRAVITY. Work on upgrades, technology demonstrators and research and development (R&D) was also actively pursued to ensure that ESO's telescopes and instrumentation achieve and maintain state of the art performance. Particularly noteworthy was the generation of the required 25 W power at 589 nm for the Adaptive Optics Facility with a single Raman fibre laser developed at ESO.

The E-ELT Telescope Project Office had a busy year in 2009. A critical milestone was the mid-term external review in May. The review panel was given access to all the E-ELT documentation and, in a three-day meeting in Garching, a series of presentations on each activity and subsystem of the telescope were made. The recommendations of the review have been extremely useful for the project and have, to a large extent, been wholeheartedly adopted.

The detailed work on the dome and the main structure of the telescope advanced from the preliminary design phase to a more detailed design, costing and scheduling phase with the launch of parallel contracts for Front-End Engineering Designs (FEED) of these subsystems. Two dome contracts and one main structure contract are now running, consolidating the earlier work. The project has also contracted external firms to review its specifications and construction plans for these subsystems. Moreover, the midterm review has provided advice on the validation of the output from our suppliers in order to establish a high degree of confidence in the proposed concepts.

Work on the components of the primary mirror also made major steps forward in 2009. The contracts placed with industry to deliver prototype segments meeting all the requirements of the E-ELT final mirror advanced in the elaboration of the test setups and the equipment necessary for grinding and polishing the segments. The initial stages of production are well underway. With that work progressing well, the project leveraged the early preliminary design work undertaken by industry to launch two FEED contracts for the segment subunits, each to detail a design and produce three prototype whiffle-tree style supports and associated warping harnesses. This work concluded its first phase in late 2009 and is on schedule to provide the hardware in time for integration with the segments. Additionally, two prototype actuator contracts and a single edge sensor contract were launched in 2009. The project is well on the way to having complete segments, meeting the demanding specifications of the E-ELT made by industry in advance of a proposal for construction.

The secondary mirror cell preliminary design work undertaken by industry was



Swinburne Astronomy Productions/ESO

(Left and right) 3D renderings of ESO's planned European Extremely Large Telescope shows the telescope at work, with its dome open and its record-setting 42-metre primary mirror pointed to the sky.

concluded in late 2009. Additionally the project has had alternate suppliers evaluate its requirements and validate the feasibility of the secondary mirror (M2) system. Based on this work the telescope project office, at the end of 2009, launched a FEED contract for the entire M2 unit. Contracts have also been placed with glass suppliers to establish the manufacturing processes necessary to make the M2 mirror blank.

The tertiary mirror cell preliminary design work was also concluded satisfactorily in late 2009, as was the preliminary design of the pre-focal stations.

The quaternary adaptive mirror contracts that were launched very early in phase B have been progressing well. Although there have been some mishaps with the thin mirrors that are used in these technologies, the prototype systems developed under these contracts are performing well and both at ESO and in industry there is a good level of confidence that this critical subsystem is well on the way to being validated on a technical and programmatic level.

The electromechanical unit for the fifth mirror (M5) is also progressing well. At the end of 2009 the scale one prototype unit was in the final integration stages and the heavy duty, but very precise, actuators were being tested in the lab. In late 2009 parallel contracts with lightweight mirror suppliers have been initiated to further the earlier work done by the project on the production of our desired mirror. In parallel, the project has been working extensively with the electromechanical suppliers studying low risk options for the mirror.

The projected telescope performance continues to be studied, with considerable effort going into the control strategy, associated stroke and error budgets and operational scenarios.

The work on characterising sites for the telescope continued at full speed in 2009 and the Site Selection Advisory Committee was given tours of all candidate sites on La Palma and in Chile, forming a personal as well as a data-based view of the locations.

Following upon this work the infrastructure necessary for the operation of the telescope has taken a big step forwards with the consolidation of the requirements and a start on the layout work for how the observatory would look and where and how we would perform tasks such as power generation, warehousing, coating etc.

In parallel to the telescope's detailed design, the science case for the E-ELT was consolidated in 2009 with the help of ESO's user community. Scientific guidance to the E-ELT project was given through several efforts: the Design Reference Mission (DRM) intended, through detailed simulations of several key science cases, to identify critical telescope and instrument performances; the Design Reference Science Plan (DRSP) aimed at collecting a large number of use cases for the E-ELT to explore the full parameter space requested by the future users; science cases developed in the frame of the instrument concept studies focused on the science accessible by individual capabilities.

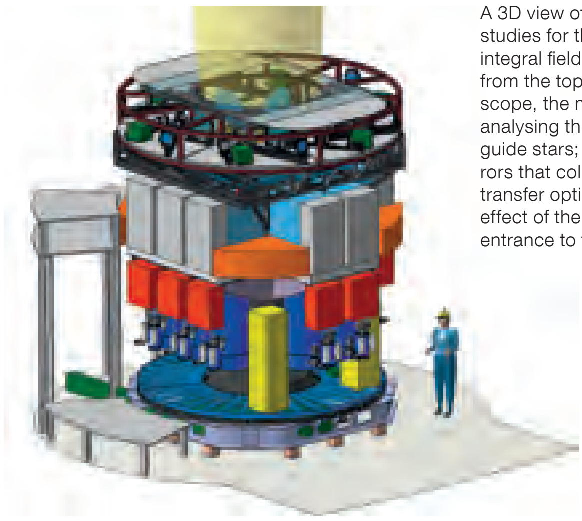
The active Science Working Group, composed of members of the ESO community, is monitoring and advising the project. With its help, the essence of the science case has been summarised in a brochure, *An Expanded View of the Universe — Science with the European Extremely Large Telescope*, that was distributed widely among the ESO user community by the end of 2009.

Throughout the year, the Design Reference Mission simulations advanced and were supported by a DRM & DRSP community workshop held in Garching in February 2009 (following the one in 2008). By the middle of the year, the Design Reference Science Plan web questionnaire was closed after the project had received nearly 200 E-ELT observing proposals from the community. These have been analysed and fed back to the project. Preliminary results were published in *The Messenger* (138, 2009).

E-ELT instrumentation

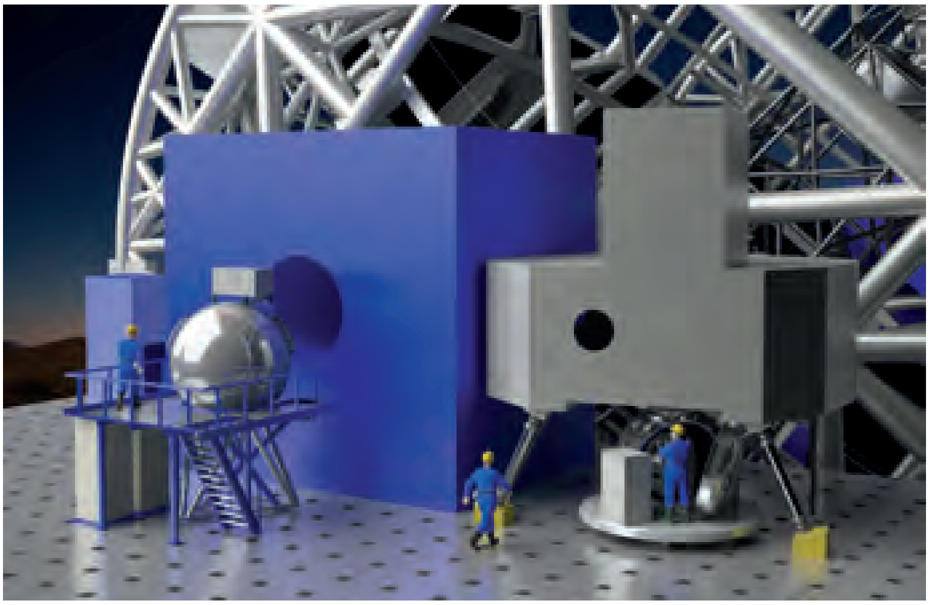
The ten Advanced Conceptual Studies for E-ELT instruments and the associated adaptive optics systems initiated in 2007 are now approaching conclusion. More than 200 astronomers and engineers in institutes of ten Member States and in Chile have contributed with their expertise, enthusiasm and dedication to the different studies. ESO staff have concentrated on the definition of the interface of instrumentation with the telescope and on the coordination, follow-up and review of the studies. The documentation of four studies has been carefully reviewed in the last quarter 2009 for the scientific case, the technical concept, the proposed management structure and for the cost and person-power estimates. The four completed studies are:

– EAGLE, a multi-object adaptive optics system with an associated near-infrared



A 3D view of EAGLE, one of the eight instruments studies for the E-ELT. The main modules of this multi integral field unit, near-infrared spectrograph are from the top, following the path of light from the telescope, the multi-object adaptive optics system analysing the light from six laser and three natural guide stars; the focal plane unit with 20 pick-off mirrors that collect the images of the targets and the transfer optics, which correct these images for the effect of the atmosphere and reformat them at the entrance to ten cryogenic spectrographs.

The ten E-ELT instrumentation studies concluded (or will conclude) with final reviews of the documentation on the scientific, technical and managerial aspects. This image shows members of the MICADO study consortium, ESO staff and external consultants at ESO at the review meeting on 1 December.



This 3D vision of the Nasmyth platform of the E-ELT shows three of the potential instruments whose studies were completed in 2009. The direct focus hosts METIS, a mid-infrared imager–spectrograph while mounted at the lateral focus are MAORY, a multi-conjugate adaptive optics system which provides correction of the atmosphere to diffraction limit over large field and, below MAORY, MICADO, a near-infrared camera for photometry and astrometry at the diffraction limit.

spectrograph fed by 20 integral field units that can be positioned over the focal plane of the E-ELT (studied by a consortium of French and British institutes);

– MICADO, an approximately 1-arcminute-field, near-infrared camera to work at diffraction-limited resolution with high astrometric and photometric accuracy (studied by a consortium of German, Italian, Dutch and French institutes);

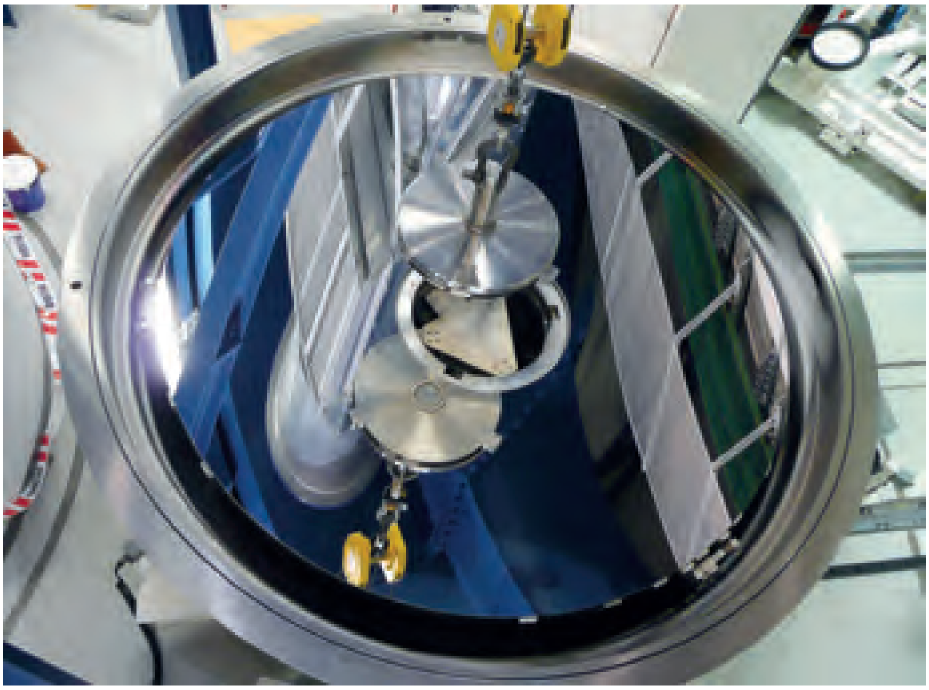
– MAORY, a module to correct for atmospheric turbulence over a field up to 2 arcminutes in diameter, with two adaptive mirrors conjugated to two atmospheric layers at different altitudes (studied by a consortium of Italian and French institutes); and finally

– METIS, a mid-infrared imager/spectrograph designed to work to the diffraction limit (studied by a consortium of Dutch, Belgian, British, French and German institutes).

The other six studies will be reviewed between January and March 2010. Based on the results of the studies and of the review process, ESO will present a first proposal of the Instrumentation Plan for the E-ELT in 2010 for review by the ESO advisory committees and eventually for inclusion in the E-ELT construction proposal to be presented to the ESO Council.

Survey Telescopes

The VISTA 4.1-metre Infrared Survey Telescope was developed by the UK and delivered to ESO as part of its in-kind membership entrance fee. Following a detailed verification and commissioning phase (including a superb recoating of the primary mirror) it was provisionally accepted at a ceremony on 10 December 2009 and will start regular survey operations in early 2010.



VISTA primary mirror after re-coating with silver in 2009.

ESO/Y. Beletsky

VISTA, the world's largest survey telescope, is shown in its dome at Cerro Paranal in the deserts of northern Chile.

This image, the first to be released publicly from VISTA, shows the spectacular star-forming region known as the Flame Nebula and its surroundings in the constellation of Orion.

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

Instrumentation for the La Silla Paranal Observatory

Instruments in commissioning

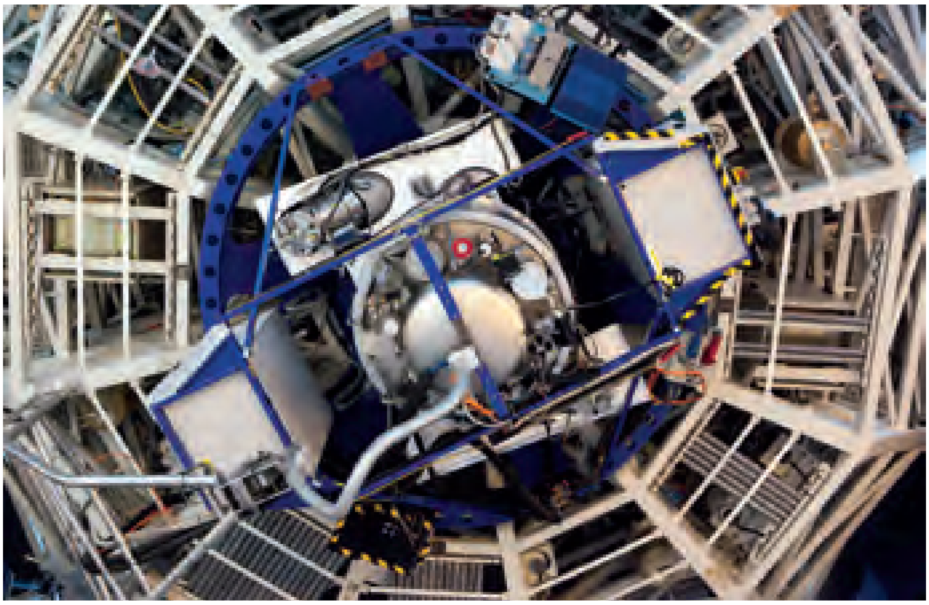
ESO's latest instrument on the VLT, X-shooter, is a spectrograph which covers almost a decade in wavelength, from the ultraviolet to the infrared (*U* to *K*). It was partially integrated on the VLT in 2008 with the installation of the ultraviolet and visible arms. The third arm, an infrared spectrograph, was delayed due to technical problems, which were ultimately solved in 2009. The necessary work included replacing the copper cooling braid in the detector with silver foil, replacing a faulty vacuum connector, and rapidly developing a new Programmable Logic Controller (PLC)-based cryocontroller at ESO. New ESO instruments are always tested on real science programmes through a Science Verification process. This was a great success with X-shooter and 95% of the projects selected were completed. Since the fourth quarter of 2009 X-shooter has been in regular operation. The instrument has been in great demand by the community of users, who are keen to exploit its unique capabilities.

Upgrades and maintenance

A number of important interventions to upgrade or repair instruments were made during 2009. Despite the fact that these represent a risk to delicate instrumentation, and that they require significant resources, this kind of work is nonetheless important to keep instruments at the cutting edge as tools for research.

– The conventional CCD in UVES, one of the most popular instruments on Paranal, was replaced with a high resistivity, low-fringing CCD. The new detector increases the sensitivity of the instrument in the red, with a gain in performance of a factor of two at 900 nm.

– A faulty CCD was successfully replaced in the OmegaCAM focal plane. OmegaCAM contains a massive focal plane consisting of 32 CCDs which will eventually be used with the VST to make vast imaging surveys of the sky. The electrostatically sensitive nature and precise position of the focal plane demanded great care, cleanliness and precision in performing the exchange.



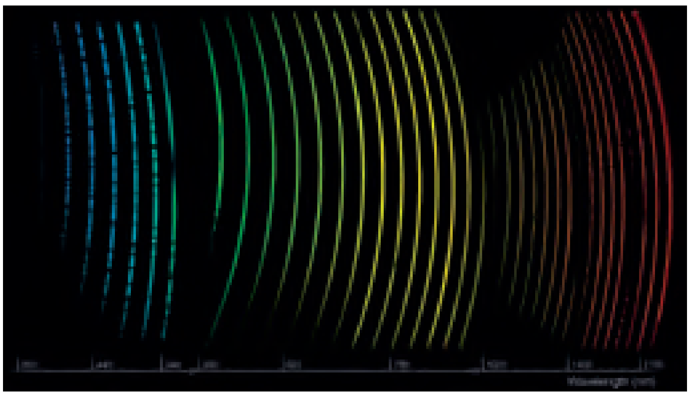
The first of the second generation Very Large Telescope instruments, X-shooter, ready to start routine observations. X-shooter is really three spectrographs in one instrument (ultraviolet, visible and infrared) and is shown mounted here at a Cassegrain focus.

– In 2009 an upgrade project was begun for the VIMOS instrument, one of ESO's visible wavelength multi-object spectrographs, first commissioned in 2002. The upgrade, in collaboration with the Instrumentation and Science Operations groups of Paranal, will seek to improve instrument reliability, calibration stability and sensitivity in the infrared — hence significantly improving its efficiency and ability to conduct large surveys.

– In 2009 an upgrade of NACO was started to improve its performance in laser guide star mode. The visible wavefront sensor lenslet arrays will be replaced by ones with a larger field of view to match better the larger than expected laser spot size. At the time of writing, the upgrade has been successfully completed and a Strehl ratio of up to 35% in the *K*-band has been obtained with the laser guide star.

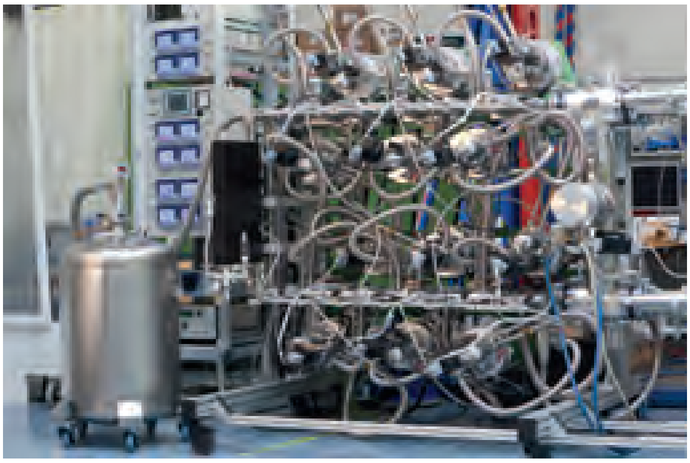
Instruments under development

ESO has an ambitious programme of second generation instrument construction for both the VLT and VLTI, all of which should be world-leading in their own different ways. These complex projects contain significant technological risks, which are handled through a combination of early prototyping, intensive design reviews, and clear specifications and acceptance milestones. Four major



X-shooter can record the spectrum (from the ultraviolet to the near-infrared) of a celestial object (in this example, a distant lensed quasar) in one shot with great sensitivity and spectral resolution.

VLT projects have now completed their detailed design phase and are in the manufacturing and subsystem assembly and test phase. KMOS, MUSE and SPHERE are all managed and constructed by external consortia of institutes, with major subsystems supplied by ESO. The Adaptive Optics Facility (AOF) is an internal ESO project with contributions from external institutes.



Twelve of the MUSE cryostats under test in the lab at ESO Headquarters, Garching.

KMOS and MUSE share a common goal — the deployment of 24 Integral Field Units (IFUs) on the sky so that spectra can be obtained for each 0.2-arcsecond pixel in the field of view. This type of 3D spectroscopy enables detailed astrophysical investigation of extended objects, velocity maps of distant galaxies and the execution of blind searches for emission lines from galaxies at high redshift. Although similar in this respect, they are in practice very different instruments. KMOS works at infrared wavelengths and uses relatively small IFUs which are deployed by cryogenic robotic arms at pre-selected locations within a 7.2-arcminute field of view. MUSE, on the other hand, works at optical wavelengths and assembles the IFUs into a giant, fixed 1-arcminute square field of view in which every 0.2-arcsecond pixel yields a spectrum. Both projects are at technically similar stages and important progress was made with subsystems in 2009. KMOS has continued with the assembly and optical alignment of the robotic arms, diamond-machining of the optics for the IFUs, and the manufacture of the first spectrograph camera. Importantly, the cryostat has been fully commissioned, providing a reliable and stable platform for further integration and testing of subsystems. MUSE issued all its major tender contracts by the end of 2009, and conducted the first IFU tests. All of the 24 (+ 1 spare) science-grade CCD devices were delivered to ESO and characterisation started. All 24 cryostats were also received, and testing and integration with detector heads started. The vacuum and cryogenic system, which will ultimately evacuate and cool all the cryostats with liquid nitrogen underwent its first successful tests.

SPHERE is a multimode instrument designed for the discovery and study of extrasolar giant planets — a topic of great current interest. The heart of SPHERE is a 1377-actuator deformable mirror (delivered 2008) with which the atmospheric turbulent distortion may be corrected with high speed and accuracy. The corrected image will then be studied using its three science subsystems for infrared dual-beam imaging (IRDIS), infrared integral field spectroscopy (IFS) and polarimetric modes (ZIMPOL). SPHERE made steady progress in 2009. The Hawaii 2RG detectors received for the two infrared subsystems are of high quality, and one has been integrated into its camera, which is now awaiting delivery of the optics. The ZIMPOL camera was integrated and tested. The challenging real-time computer, SPARTA, has been integrated and has demonstrated the low latency required by this AO-based instrument.

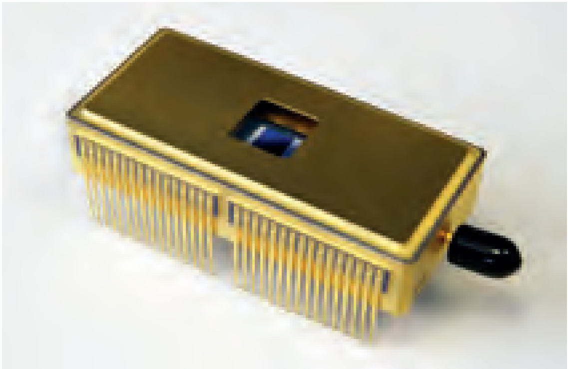
The AOF is a large project to modify Unit Telescope 4 (Yepun) to include a deformable secondary mirror, four 20 W laser guide stars, two adaptive optics wavefront sensing modules (GRAAL and GALACSI), and the fast real-time computing required to close the image-correcting control loop. GRAAL is designed to be used with the operational HAWK-I instrument, and GALACSI with the future MUSE instrument. The AOF will thereby provide improved image quality over wide fields of view or diffraction-limited performance over small fields. In addition to HAWK-I and MUSE, the AOF will be a general facility for providing high performance AO correction for any future instrument on UT4. The project took some important steps forward in 2009:

- The optical and mechanical parts for GRAAL and GALACSI entered manufacturing. An assembly readiness review for the deformable secondary mirror took place in September and was passed, allowing the integration of the complicated electromechanically actuated mirror to proceed.

- The procurement of four powerful lasers to create artificial guide stars in the 90 km-high sodium layer was always considered a risky step in the project; fortunately, the industrial procurement has gone well and two experienced companies developed satisfactory preliminary designs and prototyping, and submitted construction proposals for a design review in September. One will be selected for eventual construction of the lasers.

- The AOF will be thoroughly tested in Garching before shipment to Paranal, requiring a special test bench (ASSIST) to be constructed. The bench passed its final design review in June and is now in manufacturing.

In addition to the second generation instruments under construction for the VLT, two major instruments for interferometry at Paranal are in early design phases. MATISSE will be a general purpose imager/spectrometer operating in the 3–5 and 10-micron atmospheric windows and able to combine beams from either four 8.2-metre Unit Telescopes or 1.8-metre Auxiliary Telescopes. A sufficient number of different baselines will be measured so that MATISSE will be able to reconstruct real images from its observations. GRAVITY, on the other hand, is a more specialised instrument designed to conduct astrometry with a precision approaching 10 micro-arcseconds. Its prime use will be the study of the orbits of stars around the black hole at the centre of the Milky Way, ultimately even testing general relativity. Both MATISSE and GRAVITY are at similar early design phases, and both had preliminary design reviews in 2009. Given the ambitious specifications and challenging technologies of both instruments, it is understandable that neither review was completely successful, and delta-reviews are planned in 2010 for both.



This CCD220 high speed detector can produce up to 1500 frames per second, with very low noise.

Detector development

Detectors are the heart of any instrument in that they ultimately determine the overall performance. Although general science detectors for both the optical and infrared are readily available from manufacturers, devices with special requirements must be developed. One such special need is in the area of high readout speed, low read-noise devices for wavefront sensing, for use in both adaptive optics systems and interferometry. Opticon (an FP6 programme) and ESO have jointly funded the development of a new CCD from e2v, the CCD220. This 240 × 240 device is capable of frame rates exceeding 1 kHz. While this would normally lead to unacceptable noise, the CCD220 keeps the readout noise below 1 electron by incorporating L3Vision gain stages in its circuitry. This device will first appear in the wavefront sensor of the SPHERE instrument. The situation is more difficult in the infrared where no suitable devices yet exist. To attempt to resolve this problem, ESO has been funding the development at Selex (UK) of HgCdTe arrays with avalanche gain. Tests in 2009 with early devices have been very positive and it is hoped that real science devices will become available in one or two years.

Good quality detectors for the mid-infrared have always been difficult to obtain, despite the fact that much interesting and unique science can be done in the 10-micron atmospheric window. ESO has co-sponsored a development at Raytheon of a new 10-micron arsenic-doped silicon device, named the Aquarius. First images with a fully hybridised detector were achieved in 2009 at the manufacturer, and ESO looks forward to delivery of its full detector order in 2010.

Astronomical detectors require special driving and readout electronics, and the Next Generation detector Controller (NGC) platform has become ESO's new standard electronics for both infrared and optical detectors, and will be used in all forthcoming instruments. NGC was developed in-house and initial systems were delivered to the KMOS, MUSE, SPHERE and ZIMPOL projects in 2009. ESO continues development of its AO version of the NGC, capable of pixel rates as high as 8 Mpixels/s.

VLTI infrastructure

During 2009, the main activity was the continuation of the PRIMA (Phase-Referenced Imaging and Micro-arcsecond Astrometry) integration and the commissioning of its subsystems. PRIMA touches on all the core elements of the VLTI used in operation: the telescopes, the interferometric supervisor software, the calibration source, the controllers for fringe tracking, and the infrared tip-tilt sensor. Thus, the integration and testing has to be carefully planned and double-checked to insure proper operation of the VLTI after each commissioning run. No scientific operation time has so far been lost due to the PRIMA installation.

Seven commissioning runs took place in 2009 totalling 50 nights of tests. After the record-breaking achievement in 2008 (fringe-tracking on a K-magnitude 9 star), this year the emphasis was put on the consolidation of the various subsystems and on the understanding of their behaviour under various conditions (seeing, star magnitude, star size…). The planning was also affected by some technical problems: broken piezoelectric cables, misalignment of one beam and late delivery of critical components like the telescope field stabilisation system.

Finally, in December, all the components needed to test the dual-feed of PRIMA were delivered and installed. Two stars per telescope could be relayed to the VLTI laboratory and their light injected into the fringe sensor units. The first tests to detect the fringes on both objects simultaneously will be attempted in February 2010. By then, all subsystem functionalities necessary to perform off-axis fringe-tracking will have been demonstrated and most of the data necessary to evaluate the subsystem performance will have been taken, waiting for analysis. The general PRIMA system commissioning should then start in mid 2010.

The star separators installed on AT-3 and AT-4 feed two stars within a 120-arcsecond diameter field of view to the VLTI. They also provide image and pupil stabilisation as well as (counter-) chopping functionalities.

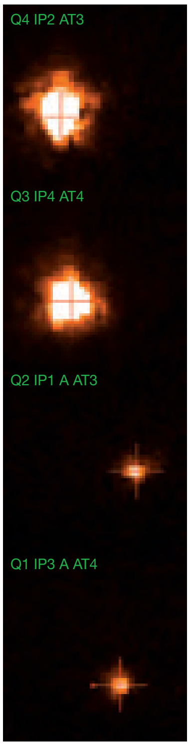
The Differential Delay Lines (DDL) introduce the necessary optical delay between both stars to compensate for their difference in position on the sky. These very precise systems are placed under vacuum to avoid air dispersion effects on the astrometric measurements. The performance of the DDLs has been fully measured in Europe and re-measured on site. They are well within the stringent specifications required for micro-arcsecond astrometry. The DDL have been used in a test as actuators for the fringe-tracking loop. This showed a significant improvement of the fringe-tracking performance (lower residuals) thanks to the faster response of this actuator compared to the main delay lines. This success encouraged Paranal to analyse the main delay line response resulting in a way to reduce the latency in the main delay line response which is now being implemented by Paranal.

The Fringe Sensor Units (FSUs) have been tested for fringe-tracking on the single-feed telescopes. A large amount of data has been collected and are being analysed. Several fringe detection algorithms have been implemented and will be compared. The FSUs have proved to be very sensitive to the polarisation of the light reaching them and to the stability of the injection of the light in their fibres. New ways of calibrating the FSUs are being developed and new health check procedures have been implemented to lower this sensitivity.

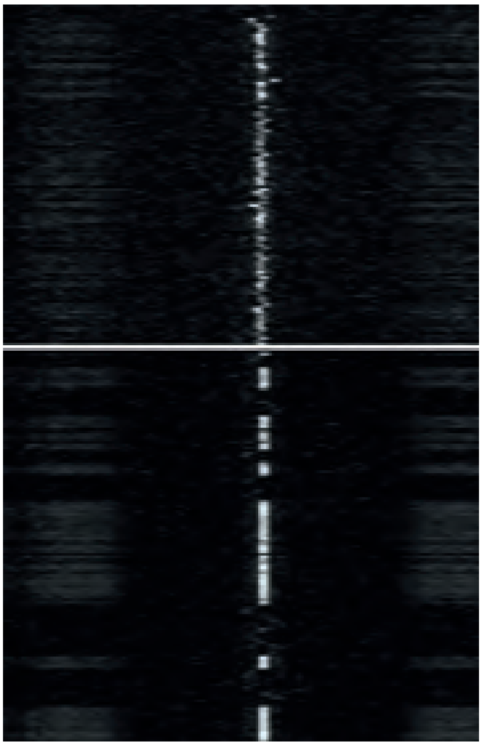
The PRIMA metrology has been tested in various configurations, unfortunately, not yet in the final configuration due to various technical problems on the star separators (broken cable, misalignments, etc…). The current results are in line with expectations and the final configuration will be tested later in 2010. The available time was used to improve and update the hardware, and to consolidate the operation of the system.

The control software of PRIMA is intricately interwoven within the operational VLTI software and great care had to be taken to guarantee stable operation of the VLTI after the PRIMA runs. This has been successful and the software is ready for the dual-feed operation. The instrument software had to be creatively adapted to the hardware availability at each run to ensure the highest possible efficiency. The alignment procedures have been optimised to improve the FSU calibrations and reduce the overheads.

The reflective memory network monitor, a system allowing the recording of real-time data at many places over the VLTI, developed originally for PRIMA, has been installed and is now routinely used by Paranal when operating with FINITO.



(Left) The four PRIMA beams (two stars per telescope) as seen in the VLTI laboratory on the infrared tip-tilt sensor IRIS.



(Right) Waterfall plot of the MIDI fringes (horizontal: fringe position, vertical: time). Above, when MIDI is used alone and does its own fringe tracking. Below, when the PRIMA fringe sensor unit is being used for on-axis fringe tracking.

Finally, taking advantage of the time freed by the unavailability of some hardware for the dual-feed, tests have been performed to prepare for the use of PRIMA with MIDI and the fringe sensor unit as an on-axis fringe tracker with MIDI. It was not a mode originally foreseen for PRIMA, but is a first step towards off-axis fringe-tracking. The tests were successful and fringes could be detected on MIDI objects never observed before.

The effect of water vapour on seeing is being explored. The data are under analysis to prove that fringes can be calibrated despite the absence of photometric signals.

It is expected that the PRIMA system commissioning, i.e. PRIMA as an astrometric machine as well as an off-axis fringe tracker for AMBER and MIDI, can start by the middle of 2010. Some hardware has still to be installed for the phase-referencing mode and for care-free, automated operation. It will be done in parallel with the system commissioning.

In parallel with the PRIMA activities, the VLTI infrastructure is also being prepared for the second generation instruments. A prototype of a metrology system to measure the UT vibrations is being developed by Jena University, and the project is progressing well. The prototype will be tested in Europe around April 2010 and at Paranal by the end of 2010. Three feasibility studies for the second generation fringe tracker for the VLTI have been launched and passed their mid-term reviews. Final results are expected for April 2010. The feasibility studies and the PRIMA FSU commissioning results will be used to specify the second generation fringe tracker to be used with MATISSE and GRAVITY. Due to the large number of activities and the lack of manpower, the development of the adaptive optics system for the Auxiliary Telescopes (NAOMI) has started very slowly. The platform for the real-time computer, the interfaces and the technical specifications have been defined, but the design work will only start in 2010. Support for the Preliminary Design Reviews of the second generation instruments MATISSE and GRAVITY has also been provided.

Technology Developments

Laser developments

Laser Guide Stars (LGS) are obtained by illuminating the natural layer of atomic sodium in the mesosphere (80–100-km altitude) with a laser operating at a wavelength of 589 nm. This artificial star is useful for adaptive optics systems as an alternative to a natural guide star.

In 2009 the main project commitment was the development of the new four laser guide star facility (4-LGSF) within the AOF, which comprises four second generation guide star beacons attached to UT4 (Yepun) of the VLT. This year saw the passing of the Preliminary Design Review milestone for the LGS system and key subsystems, including the lasers themselves.

As lasers suitable for LGS generation were not commercially available, an internal R&D programme to develop them has been carried out at ESO. The year 2009 marked a breakthrough with the completion of a narrowband Raman fibre laser emitting more than 25 W at 589 nm and greater than 50 W from three combined lasers. Fibre lasers are rugged and reliable, making them promising candidates for use in the next generation of LGS systems. This development has been made available to industry and a European consortium (Toptica Photonics) has already independently demonstrated a 20 W laser using the technology developed at ESO.

The interaction of the laser beam with mesospheric sodium has also been studied. In a collaboration with Berkeley and Princeton University, a detailed computer model has been developed to optimise guide star properties and field experiments to confirm the results are planned for the future.

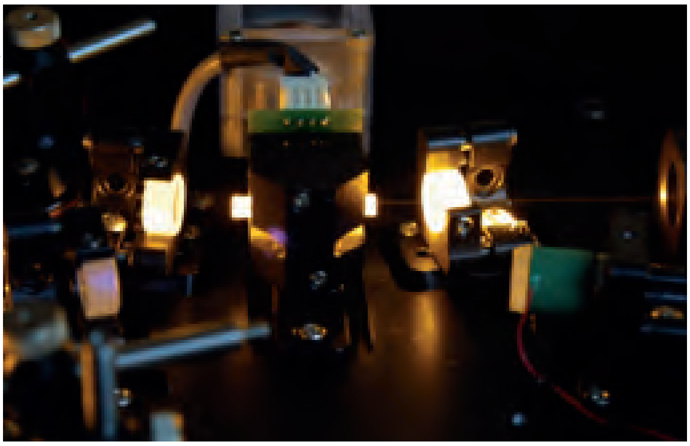
Active Phasing Experiment (APE)

The 42-metre diameter primary mirror of the E-ELT will consist of approximately 1000 segments, which poses a major problem to ensure that adjacent segments are adjusted in height to within a few nanometres to avoid phase steps at the borders, a procedure called phasing. Within an FP6 project, ESO, with four partner institutes, has studied methods for measuring these phase steps. APE was demonstrated in the laboratory and on one of the VLT UTs and has confirmed the suitability of new sensors. Some of them do not require a precise alignment of the sensor to the primary mirror. As they can work with faint stars they also offer the possibility of performing phasing measurements and therefore corrections of the errors during observations.

S. Seip/ESO

UT4 with the laser beam propagated.

L. Taylor/ESO

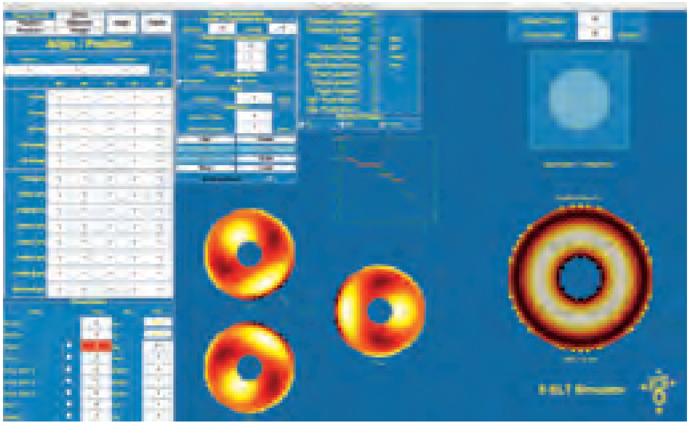


589-nm visible laser light generation.

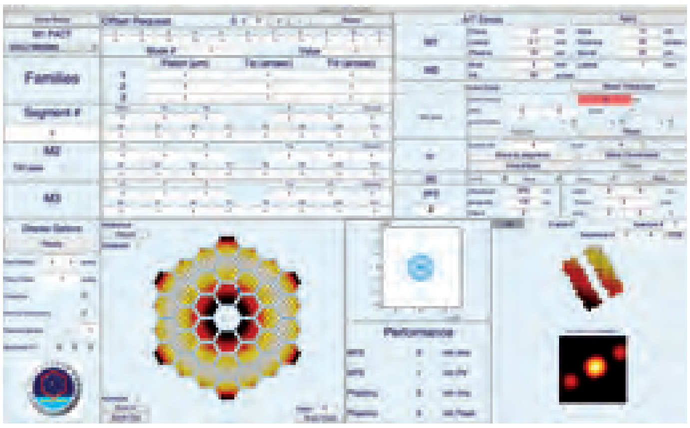
Simulating the optical properties of a segmented telescope

An optical simulator has been developed for the E-ELT to support the telescope control study. The simulator is linked to a database describing the impact on the structure of external perturbations (e.g., gravity, temperature, wind).

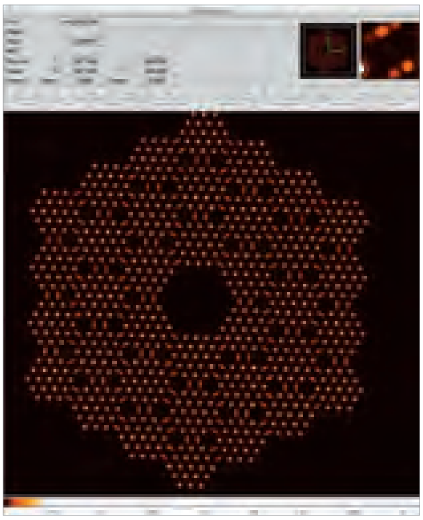
The modular architecture of the simulator allows the tool to be adapted to other designs. The first example has been the development of the GTC (Gran Telescopio Canarias) model to prepare and support tests carried out at this telescope. The simulator includes a detailed model of the control equipment used in our tests, down to the production of images in the format delivered by the telescope. This is a powerful tool to prepare and validate test procedures; minimising debugging time at the telescope itself.



E-ELT ray tracing graphical interface.



GTC ray-tracing graphical interface.



Simulated GTC phasing sensor frame.

Electronic standards

PLC safety control systems have recently been included in VLT instrumentation. These safety devices are particularly well suited to control cryogenic systems. The first system to be successfully deployed at Paranal was the X-shooter cryo-controller, followed by the PRIMA laser access control system. Most of the instruments are now using PLC as the baseline for their development, e.g., MUSE, 4-LGSF, etc.

Control system

The E-ELT technology demonstrator was created for evaluation of suitable technologies for its telescope control system. The Control Department played a leading role in defining and demonstrating the feasibility of the E-ELT interlock and safety system based entirely on PLCs. As a further proof of concept, the VLT enclosure control system is being upgraded to E-ELT standards; replacing all control units with the standard E-ELT PLC solution.

Engineers from the Control Department (in collaboration with the Mechanical Systems Department) made a detailed analysis, simulation and implementation of the vibration damping system for the ALMA antenna transporter. The new Control System Department has been consulted for assistance in other control-related issues (e.g. ALMA ACT temperature controller tuning, antenna cryogenic and monitoring system).

Mechanical systems

For the ALMA antennas to function as an interferometer, the positional stability of their azimuth rotation axis is vital. A reliable run-out measurement method suitable for the large diameter bearings is required for construction and acceptance. Classical optical measurement methods cannot be applied on the assembled system (accessibility problems) and standard 3D systems are at their accuracy limit. An alternative method using a fixed CCD camera and lasers rotating with the bearing have been developed.

ALMA's cryogenic systems provide the necessary cooling for the receivers in the front-end vacuum vessel. It is mandatory that the cryogenic system operates reliably in terms of temperature stability and robustness. The helium

Damping control of ALMA transporter.

A. Silber/ESO

An ALMA external compressor enclosure (left) and internal electronic enclosure (right) undergoing environmental performance tests.

compressors, located outside of the receiver cabin on the antenna platform, are central to these systems and the harsh environmental conditions at the operational site has required the development of protective enclosures and special high altitude qualification tests by ESO's Mechanical Systems Department. Tests are currently running on the ALMA high site (Chajnantor) at 5000-metre altitude.

I. Bončina/ESO

Inside one of the 8.2-metre Unit Telescopes of the Very Large Telescope at ESO's Cerro Paranal observing site.

ALMA

ALMA (ESO/NAOJ/NRAO)

An ALMA antenna en route from the Operations Support Facility to the plateau of Chajnantor for the first time.

ALMA, the Atacama Large Millimeter/Submillimeter Array, will be a single research instrument composed of at least 66 high-precision antennas, located on the Chajnantor plain of the Chilean Andes in the District of San Pedro de Atacama, at 5000 metres altitude. 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 of 0.3 to 9.6 millimetres, where the Earth's atmosphere above a high, dry site is largely transparent, and will provide astronomers with unprecedented sensitivity and resolution. The 12-metre antennas will have reconfigurable baselines ranging from 15 m to 18 km. Resolutions as fine as 0.005 arcseconds will be achieved at the highest frequencies, a factor of ten better than the NASA/ESA Hubble Space Telescope.

Construction is in full swing and considerable progress has been made in 2009:

- conditional acceptance of the first antenna at the beginning of 2009;
- first fringes with two antennas at the Operations Support Facility (OSF) a few months later;
- transport of three antennas to the Array Operations Site (AOS) in the autumn;
- fringes with two antennas at submillimetre wavelengths; and
- three antennas linked together at the AOS.

A very important achievement was the demonstration of interferometry with three antennas at the 5000-metre site. This was the culmination of many years of work getting ready for this crucial system test. In order to achieve this milestone, many (sub)systems and much infrastructure had to be available and operational at the AOS, including antennas, antenna foundations, front-ends, a central local oscillator, correlator, software, fibre links, power connections, power system, antenna transporters, and roads. With this milestone, a kind of "mini-ALMA", consisting of three antennas, has been established and will be continuously expanded until the full ALMA complement of 66 antennas is reached by 2012/2013.

ALMA (ESO/NAOJ/NRAO)

Transport of an ALMA antenna from the OSF (2900 m) to the AOS (5000 m).

ALMA (ESO/NAOJ/NRAO)

Site construction work

The ALMA Observatory comprises three sites: the ALMA OSF at an altitude of 2900 m near San Pedro de Atacama, the AOS, located at 5000 m altitude on the Llano de Chajnantor, 28 km from the OSF, and the Santiago Central Office (SCO) on 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 done. The Assembly, Integration and Verification (AIV) for the antennas and other advanced equipment are being completed there before they are moved to the Array Operations Site. By the end of 2009 three antennas had been moved to the AOS, installed and were operating.

Operations at the AOS are limited to an absolute minimum due to the harsh environment. The antenna foundations, together with road links and an electrical and fibre optic cable network are under construction. 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 provides the 192 antenna foundations at the AOS. In 2009 almost all the foundations were completed. The construction of roads to the 192 antenna stations at the AOS is progressing well and about 25% were completed by the end of the year.

Completed foundations need to be fitted with high accuracy mechanical interfaces, as well as electrical and fibre optic interfaces before an antenna can be

ALMA (ESO/NAOJ/NRAO)

Antenna foundations for the ALMA central cluster.

ALMA (ESO/NAOJ/NRAO)

Antenna stations at an assembly area at the OSF.

ALMA (ESO/NAOJ/NRAO)

Construction of the ALMA Santiago Central Office.

placed on them. Installation of these interfaces started in 2009 and will be completed in 2011. By the end of 2009 ten antenna foundations have been fully outfitted and are ready to receive antennas.

The ALMA sites are connected to Chilean Highway 23 by a 43 km long access road. The road from the OSF to the AOS is up to 14 metres wide, so that the antennas can be moved between the two sites by a special heavy-duty transport vehicle. During 2009 the resurfacing of the access road started and completion is foreseen for the second half of 2010.

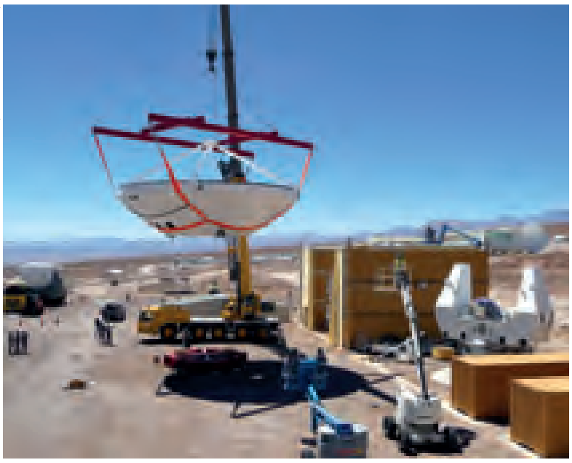
The interior outfitting of the OSF Technical Facilities building continued throughout 2009. During the year the computer room hosting the scientific data archive was equipped with a high performance cooling system and an uninterruptible power supply.

During 2009 additional antenna stations were built at the contractors' assembly areas at the OSF to allow multiple assembly operations.

Supplying electrical power to an observatory at altitudes of 2900 and 5000 m in the Chilean Atacama Desert is not a trivial task. The original strategy of connecting to the public electricity grid was abandoned due to difficulties encountered during the energy supply negotiations and the changed conditions of the fuel market, which made an island-mode solution more attractive. It was therefore decided to procure a stand-alone power generation plant based on multi-fuel turbines (similar to that at Paranal Observatory) allowing affordable operational costs and independence from a single power supplier. The procurement of the multi-fuel turbines started in 2009.

The electrical power distribution system, which includes 23 km of medium voltage underground cable connecting the AOS and OSF, as well as all the ancillary equipment, transformers, and switchgears, was subject to a tendering process. The contract was granted at the end of 2009 and work started soon after signature. The system is scheduled to be completed by mid-2011, at the same time as the power generation system at the OSF will become operational.

ALMA (ESO/NAOJ/NRAO)



ALMA (ESO/NAOJ/NRAO)

The first European antenna structure is being assembled.

After completing the design of the ALMA Santiago Central Office in 2008, the contract for construction was awarded early in 2009. During 2009 the construction progressed very well and completion is scheduled for the second quarter of 2010. The migration of all ALMA staff from the temporary offices in Santiago is scheduled for the following quarter.

ALMA antennas

ESO is providing 25 high-precision 12-metre antennas to ALMA. In 2009 the activities of the ESO ALMA Antenna group concentrated on:

– follow-up of the serial production in Europe;

– formal pre-shipment inspection; and

– the start of antenna assembly in Chile.

During 2009 the production of antenna elements in Europe and shipment to Chile progressed impressively. By the end of 2009 the integration of the first antennas at the OSF was underway.

In January 2009 the contractor, the AEM Consortium (Thales Alenia Space, European Industrial Engineering, MT Mechatronics) completed the trial assembly and testing of the first antenna steel structure. These tests were reviewed by ESO at the beginning of February. This review included the compliance verification of the hardware, the analysis of all product assurance, the test records and the workmanship of the parts prior to shipment to Chile. The first steel structure was shipped at the beginning of March and arrived at the OSF in April. Similar inspection processes have been applied by ESO for the receiver cabin and the first Back-Up Structure (BUS), which arrived at the OSF in March.

The readiness of AEM Consortium to perform the integration tasks at the OSF was reviewed by ESO in March. Whereas planning in general was judged positive, ESO identified that the facilities and activities on site, as planned by the AEM Consortium, needed some improvement. At the same time, AEM encountered difficulties with their Chilean subcontractor in charge of constructing and equipping the assembly facilities and area, providing manpower and services (tools, cranes, etc.) for assembling the antennas, and producing access platforms for the antennas. The problem escalated and in April the contract with the subcontractor was terminated by AEM.

In May AEM presented a recovery plan including a new subcontractor for services in Chile. These corrective actions were implemented, but a delay on the overall schedule could not be avoided. For safety reasons, the BUS integration building needed to be reinforced. It had to be equipped with air conditioning and heating, allowing precise alignment of the reflector panels under temperature-controlled conditions.

In June the delicate connection of the two halves of the first BUS was completed successfully. Shortly afterwards, the quadripod legs and the apex were mounted and panel installation started.

ALMA (ESO/NAOJ/NRAO)

The first two back-up structures of the European ALMA antennas at the OSF.

Approximately one month later, a second BUS was assembled and stored for further integration.

The antenna integration plan foresees that the complete antenna reflector, including panels, will be assembled on the ground and lifted onto a cabin and a steel structure once they are ready to receive it. The integration of the first steel structure started in June. In November the receiver cabin was positioned in the structure and the cabling of the antenna started. The second steel structure arrived at the OSF in summer 2009 and was positioned on the second antenna pad for integration. The steel structures of antennas 3, 4 and 5 arrived in October and were positioned on other antenna pads at the OSF. By the end of 2009 most of the insulation was mounted on the first antenna structure and the cabling was well advanced. Tests on the azimuth axis were also performed, checking that transport and integration activities had no effect on the alignment. The second structure was also made ready for the integration of the receiver cabin.

Initially, the reflector integration encountered some difficulties and so further fine-tuning of the panel adjusters was needed to achieve the precision prescribed by the technical specification. The factors that affected the precision of panel mounting were identified and have been corrected, where necessary. Furthermore a second set of tools has been procured to allow parallel installation.

Despite clearly visible progress in 2009, the serial antenna project acquired further delays and the commissioning of the first antenna slipped into 2010. Although ESO's corrective measures to recover schedule slips were effective, the change of the AEM subcontractor has had some non-recoverable effects on the schedule.

The front-end system

During the year 2009 significant progress has been made in the production of components of the Front-End (FE) system.

First European front-end delivered to Chile.

Water vapour radiometers stored at the OSF warehouse awaiting antenna integration.

Many devices and sub-assemblies were delivered to the three FE Integration Centres (FEIC) and also the deliveries to the ALMA Observatory moved ahead. ESO delivered the first European FE unit, assembled at the European FEIC to the Observatory in April.

The design of the 183 GHz Water Vapour Radiometers (WVR) was completed in early 2009 and the first two units were delivered to the OSF in March 2009. After passing the Provisional Acceptance, one of the units was installed in an antenna. Within an hour of installation, observations were made with this WVR. The key performance parameters of the third WVR were independently verified in the spring by the Onsala Space Observatory (Sweden). The verification results, published in July, confirmed that the demanding requirements have been met. Since then the production process has made substantial progress. By the end of 2009 the contractor had delivered 17 WVRs to ALMA.

Europe is providing the high frequency Band 7 and Band 9 receiver cartridges to ALMA. By the end of 2009 the supplier of Band 7 cartridges (Institut de Radioastronomie Millimétrique, IRAM) had delivered 23 units to the ALMA FE Integration Centres. The Netherlands Research School for Astronomy (NOVA), supplying the Band 9 cartridges, delivered 26 units

Components for cryostat integration at the RAL storage area. Left: Vacuum vessels. Right: Cryostat shields.

by the end of the year. These deliveries are proceeding as scheduled. Band 3 and Band 6 cartridges will be supplied by the National Radio Astronomical Observatory (NRAO), and the National Astronomical Observatory of Japan (NAOJ) will provide cartridges for Bands 4, 8 and 10.

The supply of cryostats and cartridge bodies at Rutherford Appleton Laboratory (RAL, Didcot, UK) was sufficient to keep cartridge manufacturers and FEICs running. Some issues were encountered with subcontractors, causing a slip in delivery schedule. In the meantime, RAL solved these problems and by the end of the year the storage area at RAL was full of components ready for integration. Increasing the delivery rate of cryostats and cartridge bodies has become a matter of providing sufficient manpower to assemble and verify units. RAL informed ESO that the resources necessary to complete the production in time will be provided.

Five Amplitude Calibration Devices (ACD), equipped with interim ambient and hot loads, were delivered during 2009 to the ALMA Observatory, available well before integration with the antennas. A substantial design effort was made by the FE Integrated Product Team (IPT) within the ALMA Division at ESO to complete the most challenging part of the ACDs, the calibration loads. The production design was presented at a Critical Design Review early December. The design was well received by the review panel and production of calibration loads has started.

The European FEIC passed two very important milestones in 2009. The first milestone was the delivery of the first FE assembly to the Observatory. The FE assembly delivered to the ALMA Observatory was a partially tested engineering model, as requested by the JAO. This FE assembly was the first unit to be shipped as one single, completely assembled, unit. This new approach proved to be very successful — leading to a substantially quicker delivery time — and was adapted by the FEICs in North America and Taiwan.

The second key milestone was the completion of the first part of the Operational Readiness Review, held on 27–28 October 2009 at RAL. The review panel scrutinised the readiness of the European FEIC, test equipment and organisation. Novel test solutions, such as an advanced digital fast Fourier transform spectrometer developed by the ESO ALMA Division and industry, were presented on this occasion.

ESO took over the task of providing all FE DC power supplies to the ALMA Observatory from the North American Executive in early 2009. After placing a contract with industry in June, a rapid start was made. In September three preproduction units were delivered and successfully tested at the North American FEIC, ESO Garching and at the ALMA Observatory. By October, a Critical Design Review for this custom designed power supply had been successfully passed, and production of the power supplies started.

Progress was also made on the Band 5 cartridge development and production within the ALMA Enhancement Programme, supported by the European Commission. These activities are being carried out by Chalmers University (Sweden) and RAL (United Kingdom) and six Band 5 cartridges will be delivered to the ALMA Observatory. The first part of the Critical Design Review was held in November/December 2009. As part of the ALMA Enhancement Programme, the Department of Astronomy of the University of Chile will be involved in the integration of the six Band 5 receivers into FE assemblies.

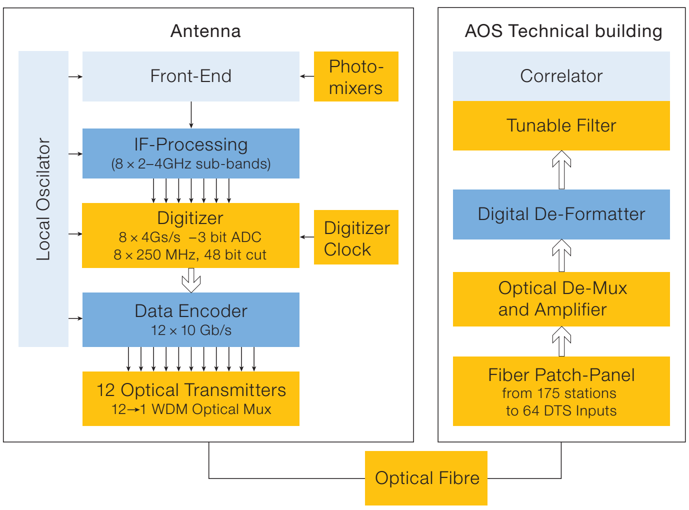
The back-end system and the correlator

The production phase of the ALMA back-end started in 2008 and progressed smoothly during 2009.

Each ALMA antenna is equipped with the elements shown in the left half of schematic overview below. Signals from the front-end 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 de-MUX/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 patch panel and associated patch cables. The table on the next page summarises the supply of back-end components by ESO.

By the end of 2009 the back-end IPT had delivered ten antenna back-end racks to the Observatory. During 2009 the validation of the system continued with tests in the field with operating antennas. These tests identified some sporadic communications problems that have been investigated and addressed with a new release of the digitiser's firmware.

In the last quarter of 2009 the first part of the Critical Design Review of the back-end was successfully concluded with the approval of the design. The Critical



The ALMA back-end system. Parts in yellow are provided by ESO.

ALMA back-end system components provided by ESO.

Component	Supplier	Total	Received
Photomixers	RAL	500	45
Digitiser	Univ. Bordeaux	281	135
Digitiser clock	IRAM	68	68
Opt. transmitters MUX	ESO	80	80
Optical fibre patch cable sets	Huber+Suhner	2	2
Fibre patch panel	Huber+Suhner	2	2
Opt. de-MUX and amplifier	ESO	80	80
Tunable filter	Univ. Bordeaux	554	554

Design Review of the rest of the back-end, which is mainly the photonic local oscillator system, is scheduled for the first quarter of 2010.

The ALMA correlator is a specialised computer, operating at the AOS at 5000 m altitude that can process data at a rate in the order of 10^{15} operations per second. The second of four correlator quadrants was installed in 2009 in the Technical Building at the AOS by the North American ALMA partner.

Testing of correlator quadrants at the AOS continued in 2009 when actual signals from the antennas became available. 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.

Each of the four correlator quadrants contains 128 Tunable Filter Bank (TFB) cards, a sophisticated high-speed digital filter processor based on state-of-the-art field programmable gate array technology. The TFB was developed and produced at the University of Bordeaux under an ESO contract. During the year 2009 all 554 units (including spares) were delivered.

ALMA computing

The ALMA software has been developed from the beginning as an end-to-end system including proposal preparation, dynamic scheduling, instrument control, data acquisition, on-line telescope calibration, data archiving and retrieval, automatic and manual data processing, and support for observatory operations. As such the ALMA software is delivered incrementally to the ALMA Observatory.

Work in Europe is organised through ESO, with some software subsystems being developed by ESO in collaboration with European institutes.

The main achievements of the computing team during 2009 include:

- Development of software for Releases R6.1 and R7.0. This software is in use at the ALMA Observatory and tests the ALMA functionality before moving from the integration to the commissioning phase.
- ESO computing staff have made a substantial contribution to the tests carried out at the OSF during last year, through various long missions and also with the temporary transfer of two staff members to Chile.

The main European development contributions have been in the area of the ALMA Common Software (ACS), archive, observing preparation tools, observatory support software and software engineering.

An important event during 2009 was the installation of the OSF archive. The installation of this system (initially consisting of 14 computers, to be increased to a total of 18) in the new OSF computer room started in August 2009. The full deployment of the archive will take place in the first quarter of 2010, when replication tests directed towards a temporary archive in Santiago are planned.

System Engineering and Integration

The ALMA System Engineering and Integration team covers a large area consisting of many different tasks, from system and subsystem design and analysis, requirement and interface management, equipment acceptance, integration and verification activities. In 2009 the Joint ALMA Office System Engineering (SE) team in Chile was established to carry out ALMA-wide SE tasks in Chile in close cooperation with the existing system engineering teams.

ALMA system block diagrams were further refined, in compliance with system, interface and general requirements and the DOORS database kept up to date. Several design reviews were chaired and SE played also a major role in the conditional acceptance of the antennas, front-ends and back-ends.

Tests at the AOS started verifying the performance of the ALMA cryogenic and vacuum system under very harsh conditions. First tests results are available and so far no major problems have been encountered. The design for the compressor enclosures was completed and ten sets manufactured. Several units have been installed on the antennas and are in operation at the AOS and the OSF.

The computerised maintenance management system was further developed and handover to ALMA operation will be done early 2010. System Engineering provided support to ALMA operation, e.g., the planning for the cryogenic labs at the OSF was done and training courses were organised.

Product Assurance (PA) continued to organise most of the acceptance reviews. Conditional acceptance for the first front-end assemblies and further antennas was granted. Product assurance audits were performed on the cryostat production, antenna subcontractors and the European Front-End Integration Centre. Processes were refined and action items and non-conformances are now tracked by a centralised tool.

The AIV team in Chile grew during 2009 to about 60 people. AIV carried out some of the on-site acceptance testing for the front-end assemblies, back-ends, antennas, calibration devices, water vapour radiometers and others. These activities included data analyses and, wherever needed, debugging of equipment. Subsequently five antennas were outfitted,

ALMA (ESO/NAOJ/NRAO)

Three ALMA antennas at the AOS working as an interferometer.

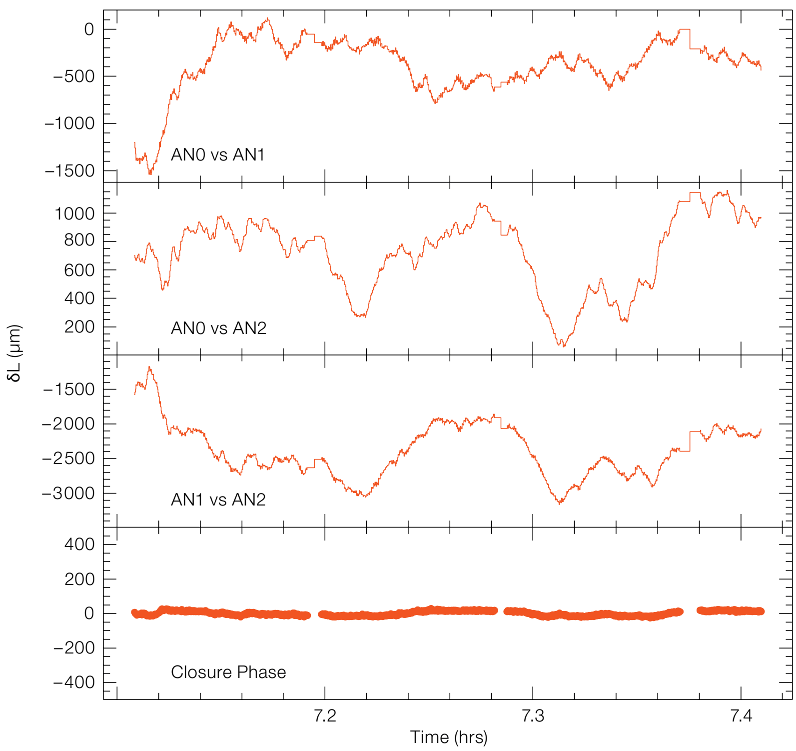
of which three were transported to the AOS. Significant progress was also made on the documentation.

ALMA science activities

After the ALMA Test Facility in Socorro (USA) closed, activities moved to the OSF at the end of 2008. During the year 2009 remarkable progress has been made in many aspects of the project. In particular, the linking of three antennas at the AOS marked the readiness for CSV (commissioning and Science Verification).

Stable fringes and closure phase were achieved in December by the ALMA AIV and CSV teams (see also ESO press release, eso1001).

After the successful checks on the three-antenna interferometer and the deployment of the latest version of the ALMA software system, ALMA will start the CSV phase in January 2010. The goals for 2010 are to commission the hardware and software and to perform the necessary tests, to be followed by the first call for proposals for early science observations with ALMA.



Test of closure phase with three antennas at the AOS. The data were obtained in very poor phase stability conditions (as can be seen from the large variation of the delays), but the achieved closure phase is still relatively good. The three top panels show the phases of the individual baselines between the three antennas. These are varying quite a lot due to a combination of atmospheric fluctuations and baseline errors while the closure phase (the sum of these three, shown in the lowest panel) is almost zero, as it should be.

Scientific studies and analyses for the ALMA development plan were carried out. A working group of the ALMA Science Advisory Committee, jointly with the ALMA Project Scientists, prepared and presented a document outlining the scientific priorities for ALMA development in the coming decade to the ALMA Board.

ALMA (ESO/NAOJ/NRAO)

An ALMA antenna meets the first rays of sunlight of the day.

Software Development

SDD CIS Department laboratory for testing technologies for E-ELT and second generation VLT instruments.

The task of the Software Development Division is to provide software resources and products to the VLT, ALMA and E-ELT projects and to maintain a high level of quality while containing the costs. Therefore it is clear that the division has to be more than a "body shop" and must create an environment in which resources are optimised and synergies promoted and encouraged where possible.

The division is organised around three major development departments, a systems engineering department, which provides services to all development units and the IT Department.

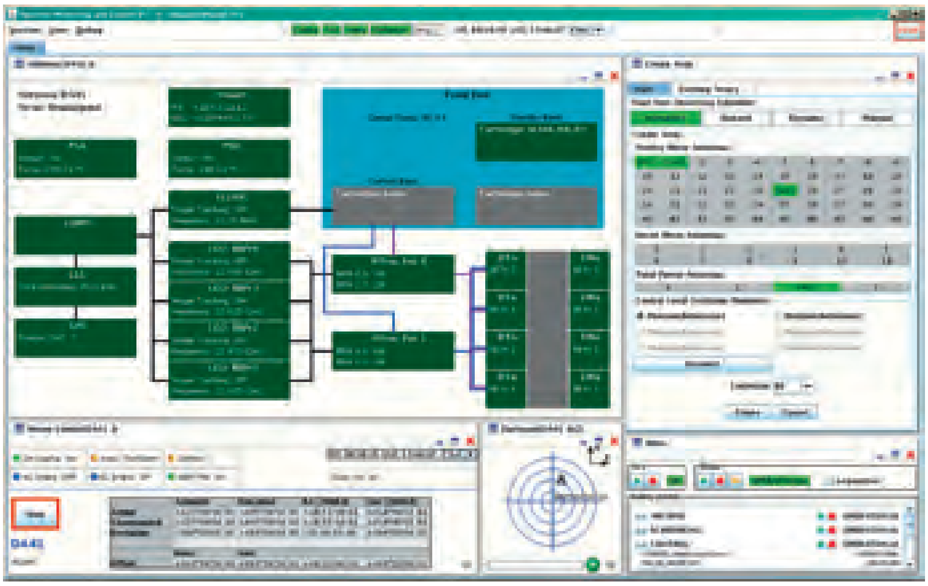
One challenge for 2009 was to provide each project and operation team with the requested resources. While ALMA is being commissioned, necessitating a thorough testing of the related software, much work was also done to support the E-ELT Phase B.

The IT Department

The IT department consists of two groups, one in Chile and one in Garching and is responsible for providing general IT services to the whole organisation, including support for network and communication, general servers and desktop/laptops and applications as well as helpdesk. IT specifies provisions, maintains and supports a secure, high performance and reliable IT infrastructure while ensuring cost-effectiveness and compliance with ESO rules. IT provides effective and friendly support to all users, whatever the standard platform or operating system they use.

One of the first foci of the new IT department was, and will continue to be, the improvement of the service quality and user satisfaction. The incident management process was optimised, in particular by reducing the time-to-escalation and better prioritising the incidents. The impact of these changes has been assessed via two User Satisfaction Surveys.

In consultation with the IT User Group, the department defined a procedure for managing and enforcing standards that was endorsed by the ESO Management team. Standards for the Windows, Linux and Mac hardware equipment used by the ESO staff were put in place. While users are required to use supported operating systems, the IT strategy aims at letting them build and manage their own tools from secure and reliable building blocks.



The ALMA operator's console, as used at the Operations Support Facility for the antenna tests in Chile. Out of the many available panels normally displayed on three screens, the focus in this screenshot is on status and position of one antenna (left), the creation of antenna arrays (upper right), and the overall software status (bottom right).

The IT department developed a concept and architecture for a unified Collaboration and Messaging system. The architecture will be based on MS Exchange. All features will be made available to users of Linux and MacOS through virtualisation. In that way, users will keep the flexibility of using the operating system of their choice whilst having access to a well integrated IT infrastructure providing Enterprise Resource Planning, e-mail, messaging, collaboration, unified communication and document management system functionalities.

The Systems Engineering Department

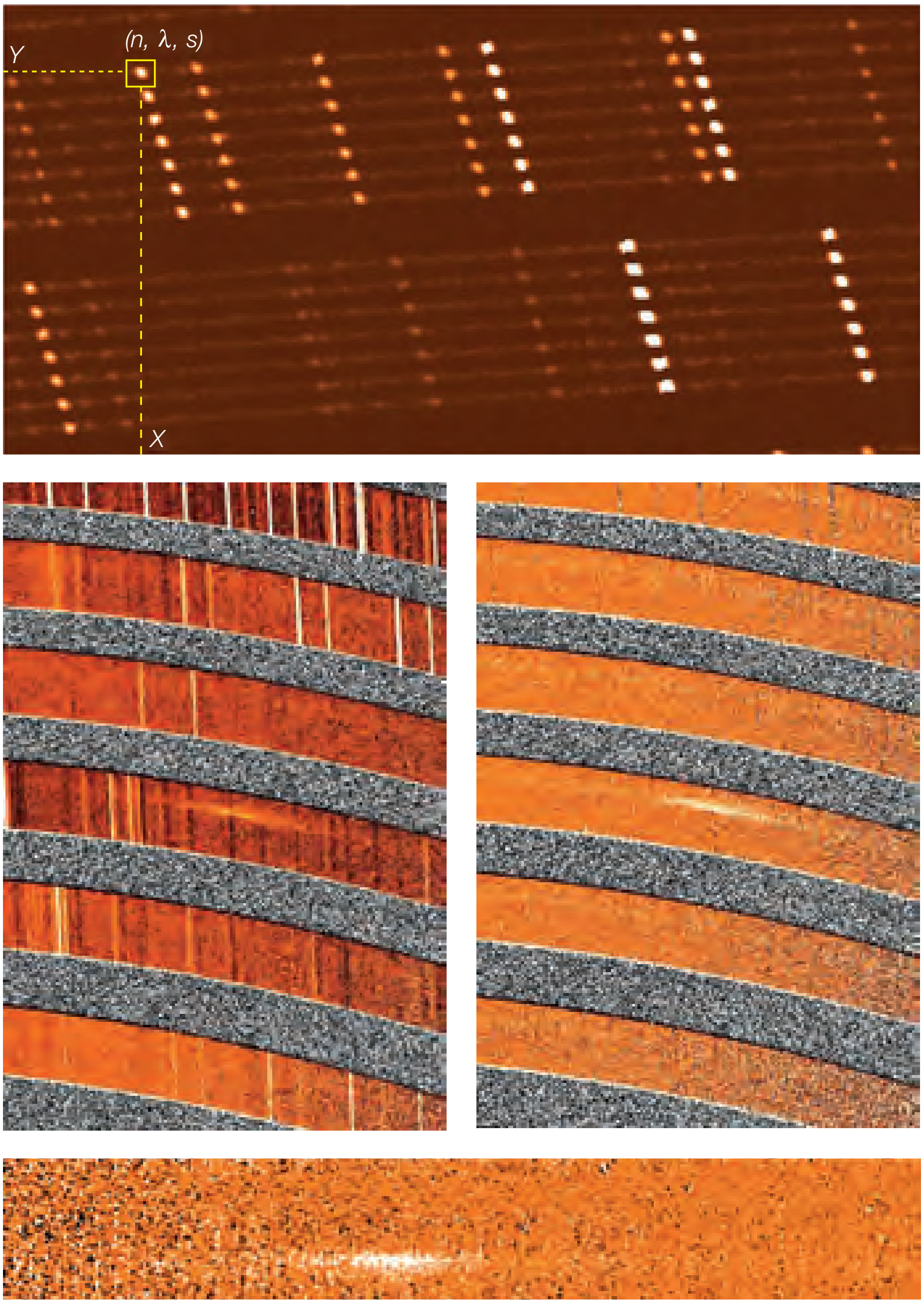
The Systems Engineering Department (SED) provides the development teams with software engineering services such as the environment and tools to support the software life cycle, software quality assurance and control. The department is also in charge of integrating software modules, preparing and validating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

Some of the tasks performed by engineers in this department (e.g., maintenance of the control model and of the development tools) could be described as routine work. They are, however, critical to the success of our projects and operation teams.

Large software systems consist of components that are developed by different development teams and must be integrated to form the system. This integration task falls under the responsibility of the department that, in 2009, integrated a new release of the VLT software and delivered it to the La Silla Paranal Observatory. It also delivered two releases of the ALMA software to all sites.

To strengthen synergies and improve knowledge sharing, the department coordinates working groups, each dealing with one specific software engineering topic, such as testing, platform virtualisation, change and configuration control and automatic code inspection.

The Test Engineering Working Group has defined standards applicable to all projects, e.g., a QF-Test for automatic tests of graphical user interfaces (GUIs), templates for test plans and reports and criteria for acceptance.



Main steps of the X-shooter data reduction: 1) the two-dimensional mapping of the spectral format is determined using multi-pinhole exposures of an arc calibration lamp (top); 2) the science data are corrected for detector contributions and flat-field illumination (left), and the very strong sky emission lines and sky continuum are subtracted from the data (right); 3) the sky-subtracted spectrum of the faint radio-galaxy object is resampled into wavelength and slit coordinates (bottom).

The Virtualisation Working Group has evaluated several technologies and tools, recommended a standard product (VMware ESX) and introduced that standard into the VLT development, integration and test environments, including the VLT Control Model.

The Software Engineering Working Group, which is comprised of staff from the ESO groups involved in software development and is chaired by the head of the department, released a few documents (e.g., software engineering process and standards recommendations), which will be essential for the desired improvements to our software process.

Software verification and validation takes two thirds of the resources dedicated to software quality. This effort has proven to be very successful, as shown by the deployment of the survey tools at the La Silla Paranal Observatory.

As a part of the E-ELT Phase B work, the department evaluated and reported on a version control system (SVN), software engineering practices for non-text based programming languages and virtualisation.

The Control and Instrument Software Department (CIS)

The Control and Instrument Software Department is responsible for the design, implementation and maintenance of control software for the VLT, VLTI and their instruments as well as ALMA and the E-ELT. Most of the time spent on VLT/VLTI software is dedicated to the development of control software for the new facilities being added to the telescopes. In 2009, the department was heavily involved in the various phases of the commissioning of PRIMA and all its subsystems, including the fringe sensor unit, fringe tracking, the metrology system and the astrometric instrument.

The ALMA software (from the low-level ALMA Common Software to the high-level Executive, which is the interface of the ALMA system to the operators) was heavily used in 2009 for the commissioning of the antennas at the OSF. As expected, this intense period of field usage and testing of the software has allowed us to bring to the surface many problems that are hard to discover off-site and has allowed us to identify new and changing requirements that can be understood only by means of real usage of the system. This has confirmed the notion that it takes a lot of effort and energy to bring software to an operational state.

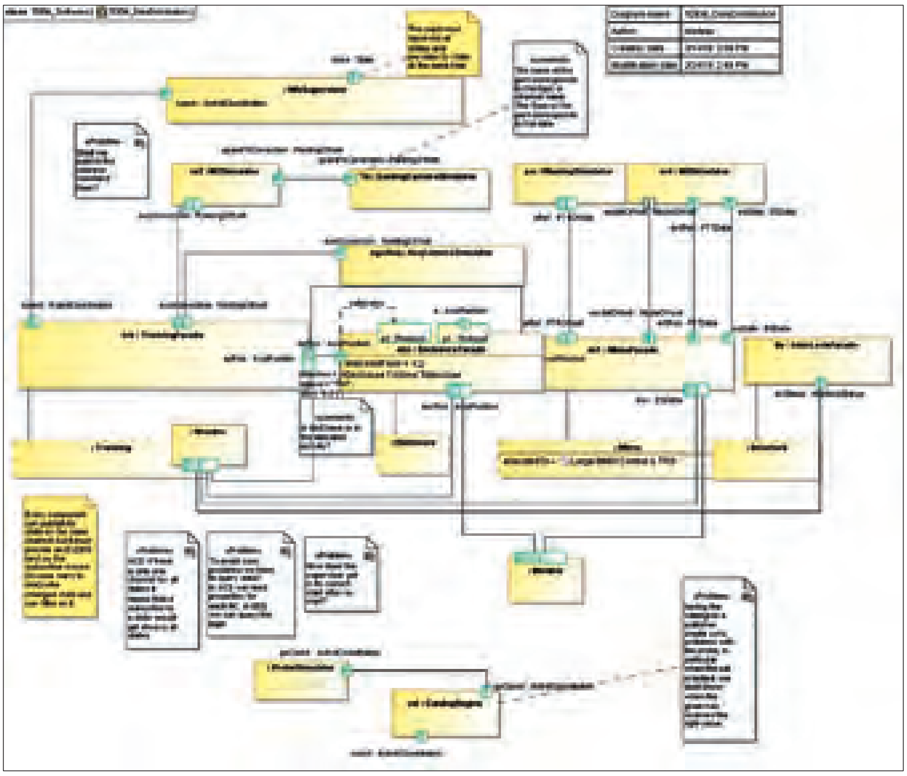
The control system for the E-ELT will be a complex entity that requires a systems approach to build. The Control and Instrument Software Department, in collaboration with the E-ELT Project Office, continued to work hard on Phase B of the project. This included a detailed requirement analysis, the design of the system and testing of technologies such as PLCs and LabView. In addition, studies were made to select the most appropriate middleware for the project. A project was initiated to test these technologies in the field at one of the VLT subsystems in 2010. This project will also demonstrate whether such a system could represent an evolutionary path for the VLT software.

The Data Flow Infrastructure Department

Astronomical survey programmes that will be carried out by VISTA and the VST introduce a paradigm shift with respect to classic service mode observing. Programmes are very few but massive and identical observations are carried out on a large set of targets or a large set of very similar Observation Blocks (OBs) is executed. The complete survey tool chain was released to the Observatory in October and used successfully for the VISTA Science Verification. The Phase II tools used by astronomers to prepare their Observation Blocks were upgraded to support the concept of scheduling containers while the Observing Tool generates a priority list of OBs taking into consideration all possible scheduling information. The ranking algorithm was developed in collaboration with the telescope scientist and is based on probability distributions of various observing constraints. As a result, observations can be conducted almost without human intervention. Monthly incremental deliveries to the Software Engineering Department and iterative testing have improved the software quality significantly.

The online Principal Investigator pack service was developed to allow PIs to access their service mode data, including reduced data and quality control information, as soon as the Quality Control Group processes the data.

The department has also concentrated its efforts on delivering a processing infrastructure that can sustain the amount of data generated by VISTA. This includes the new Reduction Block Scheduler, which provides a parallel execution environment for data reduction pipelines, and it is able to take full advantage of multi-core hardware. Finally the department took over the development of Reflex, a front-end interface to pipelines by adopting Kepler as the underlying workflow engine.



E-ELT Technology Demonstrator: SysML model of the software components implemented and of the publisher/subscriber relations using a data driver architecture.

The Pipeline Systems Department

The Pipeline Systems Department (PSD) is responsible for designing, implementing and maintaining data reduction pipelines for the VLT and VLTI instruments. The department also develops Exposure Time Calculators, which are used by the scientific community to prepare observations. In addition, since the autumn of 2008, the PSD has participated in the development of the ALMA data reduction system CASA.

First priority is always given to the support of the new instruments. The integration, development and verification of the X-shooter pipeline continued throughout the instrument Science Verification and the beginning of science operations, while the VIRCAM pipeline delivered by the consortium was integrated within the infrastructure and delivered for commissioning and Science Verification of the instrument.

Part of the PSD task is to improve the quality of the science products generated by existing pipelines on a one-to-one basis. In 2009 science-grade product developments for the FORS Absolute Photometry project were delivered to the operation teams and improvements to the HAWK-I recipes for the illumination correction and the background subtraction were implemented.

All ESO pipelines are based on the ESO Common Pipeline Library in order to facilitate maintenance and sharing of functionalities. They are released for public use (www.eso.org/pipelines) when they have reached an acceptable level of quality and stability.

Administration

In 2009, the Finance Department gave high priority to specific tasks, such as reviewing ESO's long-term financial planning and financing scenarios for the E-ELT, besides the regular accounting and budget control activities. The new Financial Rules and Regulations were adopted by ESO Council in December 2009, following the Finance Committee's recommendation. Some preparatory work was done to allow for the implementation of new accounting norms in 2010, as prescribed by the new Financial Rules and Regulations.

The main focus of the Contracts and Procurement Department was directed towards ALMA. Major civil engineering and power generation contracts were especially demanding. Another important achievement was the awarding of the architect's contract for the ESO Headquarters extension. Major contracts for engineering and design studies for the E-ELT structure and dome were concluded in 2009. The share of single source procurements was significantly reduced and the industrial return was considerably improved for some Member States that had registered imbalances in the past in that respect. The involvement of the Industrial Liaison Officers has been enhanced and the communication flow was improved. Work has also started to review and update internal procedures. ESO Council approved new procurement thresholds.

Within the scope of the 7th Framework Programme (FP7) ESO signed seven Grant Agreements with the EU Commission and submitted four further applications. The EU funding is limited to certain activities such as fellowships, networking and infrastructure. To support the ALMA communities in its Member States, ESO, for the first time, offers EU Marie Curie co-funded fellowships. ESO participates in European-wide networks of astronomical institutes, such ASTRONET, RadioNet and OPTICON, to discuss the potential future development of astronomical research in Europe. The EVALSO (Enabling Virtual Access to Latin-american Southern Observatories) project will construct a high-speed data infrastructure between the astronomical sites in Chile and ESO Headquarters in Europe.

In 2009 ESO Management decided to provide more support towards Technology Transfer (TT) activities to maximise the benefit on the investment by Member States and initiated the drafting of a formal TT policy document. The trigger was the successful licensing of a technology developed at ESO and the submission of a patent application in 2008 (patent expected in 2010). ESO is planning to strengthen its position as a centre of technological excellence via the TT activities supported by the TT policy document. To that end, ESO also participated in a major TT conference in Heidelberg in November, organised by the EIROforum partnership, of which ESO is a member.

The projects regarding the extension of the Headquarters building as well as on the new temporary offices have been progressing well and the new Site Safety Engineer started to be closely involved. An additional piece of land was acquired, the conceptual design phase of the Headquarters building extension was completed and the temporary offices will be installed in spring 2010.

Several procedures on safety issues have been updated. The administrative information systems (ERP) implemented new applications such as the central Document Management System, the time allocation of staff, etc. Finally, an access policy and a Software Change Management procedure were put in place.

The new ESO Headquarters building in an architect's rendering.

Auer + Weber

Finance and Budget

Financial Statements 2009
(in € 1000)

Balance Sheet	31.12.2009	31.12.2008
Assets		
Cash and short-term deposits	115 537	149 415
Claims, advances, refundable taxes and other assets	4 109	3 095
Total assets	119 646	152 510
Liabilities and equity		
Dues	6 646	7 007
Advance payments received and other liabilities	18 890	19 538
Total liabilities	25 536	26 545
Cumulated result previous years	125 964	122 034
Annual result	–31 854	3 931
Total equity	94 110	125 965
Total liabilities and equity	119 646	152 510

Statement of Income and Expenditure	01.01.–31.12.2009	01.01.–31.12.2008
Income		
Contributions from Member States	140 807	133 583
Contributions from third parties and partners	13 738	8 465
Income from sales and other income	13 291	12 400
Total income	167 836	154 448
Expenditure		
Expenditure for staff	61 513	56 410
Operating and other expenditure	138 177	94 107
Total expenditure	199 690	150 517
Annual Result	–31 854	3 931

Statement of cash flow	01.01.–31.12.2009	01.01.–31.12.2008
Cash flow from operating activities		
Receipts		
Income	167 836	154 448
Net movements on accounts receivable	–1 032	1 414
Total	166 804	155 862
Payments		
Expenditure	–199 690	–150 516
Net movements on accounts payable	195	–6 127
Total	–199 495	–156 643
Net cash flow from operating activities	–32 691	–781
Net cash flow from financing activities	–1 187	5 652
Net cash flow = net increase/decrease in cash and short-term deposits	–33 878	4 871

Budget for 2010
(in € 1000)

Income budget	2010
Contributions from Member States	131 105
Other income from Member States	11 814
Income from third parties	13 427
Various income	4 536
Total income budget	160 882

Payment budget	2010
Personnel cost	62 059
Other cost	180 183
Total payment budget	242 242

Commitment budget	2010
Personnel cost	62 059
Projects commitments w/o personnel	68 816
Operations commitments w/o personnel	67 981
Total commitment budget	198 856

In 2009, as a result of the spending profile of the ALMA construction budget, the ESO expenditure exceeded the annual income by 31.9 million euros. The 2009 cash flow reflected the same trend after several years of positive balances, with the annual payments exceeding the receipts by 33.9 million euros.

The cash and short-term deposits as of 31 December 2009 amounted to 115.5 million euros, part of which will be used to cover the planned difference between income and expenditure in 2010.

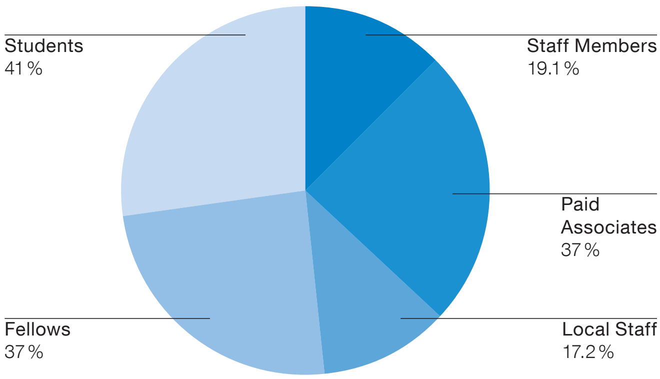
The budget for 2010 was approved by the ESO Council in December 2009. The 2010 income budget amounts to 160.9 million euros. The 2010 commitment budget (for contracts to be placed in 2010) amounts to 198.9 million euros. The payment budget (including open commitments from preceding years) amounts to 242.2 million euros and covers in particular the next annual tranche of the ALMA construction cost and the last part of the E-ELT design phase.

ESO/Y. Beletsky

In the night sky over ESO's Very Large Telescope observatory at Paranal, the Moon shines along with two bright companions: already aloft in the heavens and glowing in the centre of the image is Venus, Earth's closest planetary neighbour, and, to its right, the giant, though more distant planet, Jupiter.

Human Resources

The Human Resources Division (HR) is responsible for the administration of all personnel matters concerning ESO International and Local Staff Members, Fellows, Students, Associates and temporary manpower.



Breakdown of female staff by category.

Recruitment and selection

During 2009 ESO published vacancy notices for 97 positions and received in total 2442 applications:

Contract Type	No. of Campaigns	No. of Applications
Staff Member	51	1398
Local Staff	16	733
Paid Associates	6	81
Fellows	12	186
Students	12	144

All positions were advertised on the ESO homepage. In addition, the international positions were sent out to all members of Council, the Finance Committee and delegates of other ESO Committees, as well as to national and international research centres and observatories. High priority advertising in appropriate specialist publications/recruitment web pages was used for selected positions, with the aim of increasing the awareness of vacancies across all Member States throughout the campaigns.

Policy and measures to increase recruitment of women

All advertisements contain a statement on our commitment to equal opportunities. In the last year the number of female staff has risen from 148 to 163, an increase of 10 % and about equal to the general growth in staff. The number of female staff represents 23 % of the overall count. The breakdown by staff category is shown above.

It is important to note that over the past five years more women are occupying higher qualified positions (starting in Grades 7 and B1) in science, engineering and administration. This positive development is not yet evident in senior and management positions. Nevertheless, it remains one of our main objectives to improve the attractiveness of ESO further for female applicants, to increase the percentage of women in higher qualified positions and to foster internal career development for female staff in general.

Work/life balance

Since 1 July 2009 ESO has offered revised maternity and paternity benefits, giving flexibility within the maternity arrangements to extend the maternity leave period up to three months. ESO continues to support mothers who return to work by offering options for flexible and part-time working. Alongside maternity benefits, the benefits to those mothers who adopt a child have been extended. In addition, due to urgent demand, the number of secured places at the local IPP Kinderkrippe/Kindergarten — a daycare facility for children — has been slightly increased temporarily.

A flexible approach to maternity/paternity benefits will enable ESO to compete with similar organisations, thus potentially widening the pool of applicants, and enabling parents to take a flexible approach to meeting parenting and work commitments.

Policy on fair treatment, courtesy and respect

Although the culture of ESO is not to tolerate any harassment, it is important that staff understand what action they can take, and are aware of any support available, should they feel they are subject to harassment and/or bullying in the workplace. In this respect a policy paper was presented and discussed by the management and the Standing Advisory Committee. Implementation is imminent. Initial training activities for the unions, the Staff Association, Human Resources and contact persons in Garching and Chile have already started.

La Silla 2010+

The reorganisation of activities at La Silla and the resulting staff allocation was successfully and finally settled throughout 2009. From 1 October 2009, La Silla will be operated by 20 staff. Over the last three years the staff complement has been reduced from 60 positions by reassignments to other sites in Chile and/or by offering an early retirement plan.

Collective bargaining with local staff

Collective bargaining took place during the period 3–20 November 2009. The new collective contract for the period December 2009 to November 2012 was signed on 25 November 2009. The key aspects of the outcome of this collective bargaining process are a validity of three years, salary adjustments by 1 % for the years 2010 and 2011, as well as reviews and adjustments regarding flexible working time, overtime, emergency work, special conditions for Telescope and Instrument Operators, special leave, temporary reassignments after maternity, commuting to the sites, communication costs and amendments in the area of sick leave.

Indefinite appointments

Twelve Staff Members were considered at the Indefinite Appointments Advisory Board, chaired by the Director of Programmes. Following its recommendation, the Director General granted ten Staff Members indefinite appointments with effect from 1 August 2009.

In 2009 11 Local Staff Members in Chile were granted an indefinite contract.

Temporary transfers

In order to maximise knowledge management and skills transfer, an exchange programme between the Observatories/ the Administration in Chile and the Headquarters in Garching is being implemented, affecting a small number of staff. In addition five transfers started in autumn 2009, supporting the various commissioning activities of ALMA, which will be further increased over the next twelve months.

Training and professional development

The year 2009 also saw the introduction of a coordinated, transparent approach to the planning, organisation and delivery of tailored training across ESO, as described below. Some corporate training activities were undertaken to improve soft skills and create a fruitful environment to implement and embed ESO policies.

The Management Development Programme, introduced in 2008 to support managers in their role, was applied in parallel in Chile and Garching and completed by the end of the year. About 60 supervisors went successfully through four key training areas: managing styles and managing change; performance management; interviewing skills; and managing teams in a multi-cultural environment. The training is now integral to the training of all new and future managers. To supplement this training, we also delivered training on internal procedural matters in the area of Annual Performance Reviews.

In addition, the division coordinated, planned, organised and delivered tailored and corporate training sessions and workshops across ESO (approx. 270 people) in the areas of:

- project management;
- teambuilding;
- MS Office and Dreamweaver;
- time management;
- individual coaching;
- staff induction courses;
- language courses for German, English and Spanish;
- e-learning platforms;
- fair treatment, courtesy and respect; and
- pre-retirement.

As part of the ESO Fellowship Symposium 2009 held in Garching, training in time management and interview and presentation skills was provided for 28 Fellows.

As mentioned there are few women in management positions. While the need for leadership and management training is not exclusive to women, there are skills that can support women in their development in a male-dominated environment/sector. The development of such training programmes and seminars are currently being evaluated and designed together with our partner organisations in the Human Resources Thematic Working Group of the EIROforum.

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 through 2009. In total, 26 meetings were held in in Garching and Vitacura, as well as on the sites in Chile, to inform, and allow for discussion and an exchange of opinions about organisational developments, amendments in policies, regulations, training and individual cases. The meetings took place in a constructive and open atmosphere and a shared wish to find mutually satisfactory solutions to the various matters.

In the course of the year two Rehabilitation Boards were appointed to examine a case concerning the nature of an accident/ illnesses and a case regarding incapacity. In both Boards well-supported recommendations were received and followed by the Director General. Two meetings of the Standing Advisory Committee (STAC) took place to evaluate proposed amendments in the Staff Regulations and specific guidelines.

Collaborations and representation of Human Resources

As a member of the ALMA Human Resources Advisory Group and involved in the recruitment of International Staff for the Joint ALMA Office/Observatory, the ESO Human Resources Division has participated in monthly meetings and contributed decisively to the implementation in the following areas: HR procedures; conversions of staff positions; unique performance evaluation for all Local Staff; provision of a Supervisor's Guide as part of the Local Staff Regulations; salary surveys/ adjustments; promotion procedures, as well as in the unionisation process. The Deputy of Human Resources was seconded to the JAO for a period of two months and successfully developed and implemented procedures and guidelines for JAO International Staff concerning recruitment and selection; relocation services; annual performance review; learning and development, as well as contract administration.

Since 1 July 2008 the Head of Human Resources has been Chair of the HR Thematic Working Group of EIROforum. Two meetings were held during the year and the main subjects were:

- common training events for researchers;
- further developments/exchanges on equal opportunities in particular career and management development for women; and
- possible short-term secondments/staff exchanges among the EIROforum Organisations.

Human Resources also organised and participated in two meetings of the ESO Tripartite Group related, in particular to the matters concerning the development of the CERN Pension Fund, salary adjustment 2010, La Silla 2010+, changes in Staff Regulations as well as in Administrative Circulars.

HR administration

Beside a comprehensive and 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, full-time equivalent (FTE) allocation, budget preparation and control, statistics, the settlement of about 3900 travel claims, special services for international staff in Chile (accreditation, schooling, accommodation and relocation, insurances etc.), review and update of the HR internet web pages, organising formal induction days for new staff members in Chile and Garching, coordination with the European School Munich, organising regular medical examinations and many other tasks. In 2009 the following documents were developed, reviewed or issued:

- Temporary Transfer to Chile;
- Professional Training;
- Policy on Alcohol and Drug Misuse;
- Policy on Fair Treatment, Courtesy and Respect;
- Working hours for Astronomers, Fellow and Students in Chile;
- Revised Performance Review form;
- Guidelines for the Application of the Probation Period;
- Agreement between ESO and MICINN-Training of Graduates from Spain;
- FTE Allocation Process;
- IT Policy on P2P, in close interaction with the Software Development Division;
- ESO Safety Organisation, in close interaction with the related working group;
- Processes in cases of serious occupational or work-related accidents in Chile and Garching;
- Unemployment Scheme;
- Adoption and Special Leave;
- Information on German Income Tax; and
- ESO People Policy Guidelines.

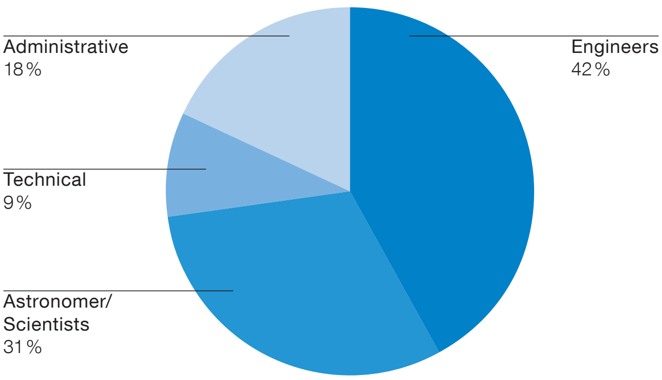
In September 2009 Jorge Moreno left HR Administration in Vitacura after 33 years of reliable and dedicated service to his colleagues in Chile.

ESO staff development

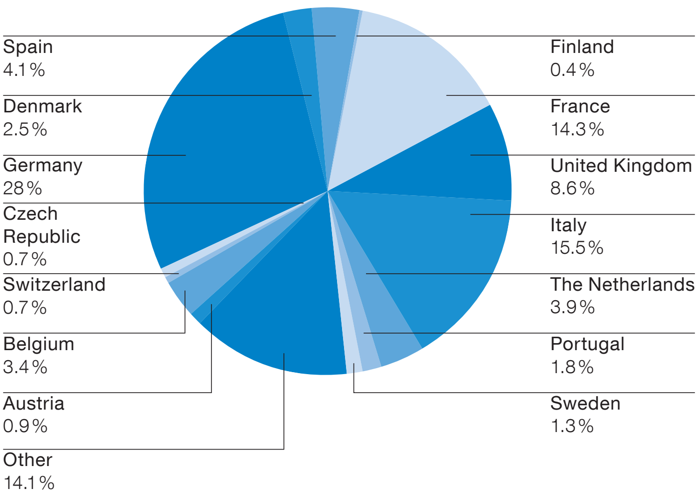
The departure of staff members in 2009 is due to:

Reasons	Staff Member	Local Staff
Resignation	5	4
Expiry of contract	3	3
Retirement	3	5
Mutual agreement		1
Dismissal		1
Death	1	1
Total	12	15

This leads to an average annual fluctuation rate of 3% for Staff Members and 8% for Local Staff. Four out of the twelve departures of Staff Members were in Chile.



(Left) Distribution of staff by job category — 31 December 2009.



(Right) Staff Members by nationality — 31 December 2009.

List of Staff

As of 31 December 2009

Office of the Director General

Tim de Zeeuw

Isabelle Baginski
Mary Bauerle
Laura Comendador Frutos
Mary Dinjens-D'Lazarus
Jörg Eschwey
Gabriela Gajardo
Nikolaj Gube
Karin Horn
Isolde Kreutle
Anna Krüger
Milla Laaksonen
Luis Felipe Lira
Claus Madsen
Thomas Naets
Valérie Saint-Hilaire
Rowena Sirey
Massimo Tarenghi

Administration Division

Patrick Geeraert

Patricia Adriazola
Maria Soledad Amira
Andrés Arias
Juan Carlo Avanti
Jean-Michel Bonneau
Renate Brunner
Marcela Campos
Karina Celedon
Claudia Silvina Cerda
Joana Correia
Malcolm De Silva
Tommaso Di Dio
Andrea Dinkel
Günther Dremel
Sabine Eisenbraun
Willem Arie Dirk Eng
Rebonto Guha
Leonardo Guzman
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
Hélène Neuville
Christine Nieuwenkamp
Ester Oliveras
Oscar Orrego
Enikő Patkós
Thomas Penker
Rolando Quintana
Andre Ritz
Elke Rose
Johannes Schimpelsberger
Sandra Schmidt
Guido Serrano
Erich Siml
Alexandra Specht
Albert Triat
Maritza Vicencio
Elisabeth Völk
Michael Weigand
Yves Wesse
Gerd Wieland

Human Resources

Roland Block

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

Software Development Division

Michèle Péron

Roberto Abuter
Luigi Andolfato
Javier Argomedo
Andrea Balestra
Pascal Ballester
Klaus Banse
Thierry Beniflah
Thomas Bierwirth
Reynald Bourtembourg
Blanca Camucet
Alessandro Caproni
Sandra María Castro
Maurizio Chavan
Gianluca Chiozzi
Mauro Comin
Livio Condorelli
Paulo Correia Nunes
Dario Dorigo
Philippe Duhoux
Neil Ferguson
Sylvie Feyrin
Vincenzo Forchi
Robert Frahm
Bruno Gilli
Percy Glaves
Carlos Guirao Sánchez
Florian Heissenhuber
Carlo Izzo
Bogdan Jeram
Francesc Julbe Lopez
Yves Jung
Robert Karban
Mario Kiekebusch
Maurice klein Gebbinck
Jens Knudstrup
Uwe Lange
Jonas Larsen
Antonio Longinotti
Simon Lowery
Lars Kristian Lundin
Holger Meuss
Andrea Modigliani
Christophe Moins
Michael Naumann
Ralf Palsa
Moreno Pasquato
Martine Peltzer
Werther Pirani
Dan Popovic
Eszter Pozna
Marcus Schilling
Diego Sforna
Paola Sivera
Fabio Sogni
Heiko Andreas Sommer
Helmut Tischer
Stefano Turolla
Jakob Vinther
Rein Warmels
Michèle Zamparelli
Stefano Zampieri
William Zinsmeyer

ALMA Construction Division

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Gareth Aspinall
Fabio Biancat Marchet
Claudio Cabrera
Massimiliano Camuri
Alessio Checcucci
Emanuela Ciattaglia
Petrus Gerhardus Fourie
Preben Grosbøl
Christoph Haupt
Pieter Klaas Hekman
Jennifer Hewitson
Andreas Kempf
Hervé Kurlandczyk
Robert Alexander Laing
Paul Lilley
Robert Lucas
Massimiliano Marchesi
Pascal Martinez
Rainer Mauersberger
Ferdinand Patt
Gianni Raffi
Silvio Rossi
Hans Rykaczewski
Joseph Schwarz
Stefano Stanghellini
Donald Tait
Gie Han Tan
Eugenio Ureta
Gianluca Verzichelli
Pavel Yagoubov
Elena Zuffanelli

Directorate of Programmes

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Georg Igl
Josef Strasser

Telescope Division

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Emmanuel Aller Carpentier
Mustafa Basbilir
Bertrand Bauvir
Alex Böhnert
Annalisa Calamida
Marc Cayrel
Françoise Delplancke-Ströbele
Frédéric Derie
Philippe Dierickx
Giorgio Filippi
Francesca Gerlin
Szymon Gladysz
Bertrand Koehler
Aybüke Küpcü Yoldaş
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Jochen Liske
Gianluca Lombardi
Serge Menardi
Samantha Milligan
Katia Montironi
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Duc Thanh Phan
Marc Sarazin
Christian Schmid
Michael Schneermann
Dominik Schneller
Jason Spyromilio
Gerard van Belle
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Nataliya Yaitskova

Directorate of Operations

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Iris Bronnert
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Reinhold Dorn
Mark Desmond Downing
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Siegfried Eschbaumer
Enrico Fedrigo
Gert Finger
Christoph Geimer
Andreas Glindemann
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Norbert Hubin
Derek James Ives
Olaf Iwert
Gerd Jakob
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Jean Paul Kirchbauer
Johann Kolb
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Jean-Louis Lizon à L'Allemand
Gaspare Lo Curto
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Antonio Ramon Manescau Hernandez
Enrico Marchetti
Patrice Martínez
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Jean-François Pirard
Suzanne Ramsay
Roland Reiss
Javier Reyes
Andrea Richichi
Gero Rupprecht
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Ralf Siebenmorgen
Paul Singh
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Stefan Ströbele
Marcos Suárez Valles
Mirko Todorovic
Sebastien Tordo
Elise Vernet
Joël Daniel Roger Vernet

Technology Division

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Dina Arbogast
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Roland Brast
Enzo Brunetto
Bernard Buzzoni
Ralf Dieter Conzelmann
Bernard-Alexis Delabre
Nicola Di Lieto
Canio Dichirico
Martin Dimmler
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Marco Quattri
Jutta Quentin
Babak Sedghi
Armin Silber
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Arkadiusz Swat
Luke Taylor
Arno Van Kesteren
Veronique Ziegler

La Silla Paranal Observatory

Andreas Kaufer

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Claudio Agurto
Bernardo Ahumada
Yazan Al Momany
Jaime Alonso
Nilso Alquinta
José Luis Alvarez
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Ernesto Araya
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Oriel Alberto Arriagada
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Guillaume Blanchard
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Mauricio Cárdenas
Giovanni Carraro
Duncan Castex
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Mónica Castillo
Jorge Castizaga
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Cecilia Ceron
Claudia Cid
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Michael Dumke
Carlos Durán
Carlos Ebensperger
Cristian Elao
Alejandra Emmerich
Cristian Esparza
Matthew Evatt
Lorena Faundez
José Figueroa
Erito Flores
Juan Carlos Fluxa
Eloy Fuenteseca
Sergio Gaete
Leonardo Gallegos
Rodrigo Gesswein
Gordon Gillet
Alain Gilliotte
Julien H. V. Girard
Philippe Gitton
Leonardo González
Andrés González
Sergio González
Javier Andres González
Patricia Guajardo
Carlos Guerra
Stéphane Guisard
Serge Guniat
Flavio Gutiérrez
Fernando Gutiérrez
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Juan Pablo Haddad
Pierre Haguenauer
Juan Pablo Henriquez
Cristian Herrera
Gerhard Hüdepohl
Rodrigo Huerta
Nicolas Huerta
Ramón Huidobro
Gerardo Ihle
Valentin Ivanov
Nestor Jimenez
Ismo Kastinen
Nicholas Charles Kornweibel
Carlos La Fuente
Francisco Labraña
Octavio Lavin
Paul Le Saux
Cedric Ledoux
Alfredo Leiva
Gino Leon
Ignacio López
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Paul Lynam
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Agustin Macchino
Gianni Marconi
Pedro Mardones
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Mauricio Martínez
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Steffen Mieske
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Juan Pineda
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Aldo Pizarro
Andrés Pizarro
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Christian Ramírez
Claudio Reinero
Sridharan Rengaswamy
Claudia Reyes
Mauricio Ribes
Miguel Riquelme
Leonel Rivas
Thomas Rivinius
Pascal Robert
Chester Rojas
Pascual Rojas
Cristian Romero
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Francisco G. Ruseler
Claudio Saguez
Fernando Salgado
Ariel Sanchez
Stefan Sandrock
Roberto Sanhueza
Pierre Sansgasset
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Ivo Saviane
Linda Schmidtobreick
Ricardo Schmutzer
Nicolas Schuhler
Alex Segovia
Fernando Selman
Waldo Siclari
Peter Sinclaire
Giorgio Siringo
Nicolas Slusarenko
Alain Smette
Jonathan Smoker
Christian Spille
Stanislav Stefl
Michael Fritz Sterzik
Sandra Strunk
Thomas Szeifert
Richard Tamblay
Mario Tapia
Alexis Thomas
Manuel Torres
Josefina Urrutia
Guillermo Valdés
Jose Javier Valenzuela
Karen Vallejo
Pierre Vanderheyden
Oscar Varas
Enrique Vera
Jorge Vilaza
Stefan Wehner
Ueli Weilenmann
Luis Wendegass
Gundolf Wieching
Andrew Wright

Directorate for Science

Bruno Leibundgut

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Pedro Viana Almeida
Alvaro Alvarez Candal
Gonzalo Argandoña
Daniel Asmus
Giuseppina Battaglia
Amelia Maria Bayo
Yuri Beletsky
Thomas Lennart Bensby
Stephane Blondin
Henri Boffin
Maxime Bois
Jutta Boxheimer
Pamela Bristow
Claudio Cáceres
Lars Lindberg Christensen
Blair Campbell Conn
Arianna Cortesi
Silvia Cristiani
Joana Mafalda da Cruz Carmo Martins
Sebastian Daemgen
Itziar De Gregorio Monsalvo
Gayandhi Manomala De Silva
Michaela Döllinger
Eric Emsellem
Christopher Erdmann
Lu Feng
Francesco Fontani
Andrew Fox
Matthias Frank
Dimitri Gadotti
Alexandre Gallenne
Diego Alex Garcia-Appadoo
Mark Gieles
Carla Gil
Ciriaco Goddi
María Eugenia Gómez
Luis Gonçalves Calçada
Oscar Gonzalez
Juan Esteban González Gutiérrez
Uta Grothkopf
Daria Guidetti
Olivier Hainaut
Camilla Juul Hansen
Hans Hermann Heyer
Frank Heymann
Renate Hoppe-Lentner
Gaitee Hussain
Behrang Jalali
Gaël James
Edmund Janssen
Lucie Jilkova
Paulina Jiron
Benedikt Justen
Petr Kabath
Iva Karovicova
Pamela Klaassen
Heidi Helena Korhonen
Martin Kornmesser
Davor Krajnovic
Daniel Kubas
Eric Lagadec
Jean Baptiste Le Bouquin
Karin Lind
Sergio Martin
Reneé Cecilia Mateluna
Gautier Mathys
Anaelle Maury
Jorge Melnick
Ingo Misgeld
Margaret Moerchen
Guillaume Montagnier
André Müller
Nadine Neumayer
Lars Holm Nielsen
Carolina Andrea Nunez Santelices
Olja Panic
Fabien Patru
Tania Marcela Penuela
Douglas Pierce-Price
Magaretha Pretorius
Anna Raiter
Luca Ricci
Paula Valentina Rodriguez
Alma Ruiz Velasco
Jan Ruppert
Pedro Miguel Russo
Ricardo Salinas
Hugues Sana
Rubén Sánchez-Janssen
Gina Santangelo
Dominik Schleicher
Ulf Seemann
Colleen Sharkey
Raquel Yumi Shida
Rodolfo Smiljanic
Colin Snodgrass
Christina Stoffer
Cezary Szyszka
Masayuki Tanaka
Paula Stella Teixeira
Leonardo Testi
Svea Teupke
Francesco Trotta
Stefanie Unterguggenberger
Elena Valenti
Mathieu Van Der Swaelmen
Bram Venemans
Laura Ventura
Jeffrey Franklin Wagg
Michael West
Michael Williams
Iryna Yegorova
Herbert Zodet
Monica Zorotovic

Data Management/ Operation

Fernando Comerón

Paola Andreani
Angelika Beller
Andrew Biggs
Daniel Bramich
Andrew Burrows
Stella-Maria Chasiotis
Fabien Chereau
Thomas Dall
Carlos De Breuck
Claudio De Figueiredo Melo
Nausicaa Delmotte
Danuta Dobrzycka
Adam Dobrzycki
Paul Eglitis
Nathalie Fourniol
Wolfram Freudling
Monika Gotzens
Reinhard Hanuschik
Evanthia Hatziminaoglou
Michael Hilker
Wolfgang Hummel
Christian Hummel
Elizabeth Humphreys
John Lockhart
Vincenzo Mainieri
Stéphane Marteau
Alberto Micol
Sabine Moehler
Palle Møller
Sangeeta Mysore
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Paolo Padovani
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Dirk Petry
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Jörg Retzlaff
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Martino Romaniello
Juan de Dios Santander Vela
Remco Slijkhuis
Thomas Stanke
Dieter Suchar
Lowell Tacconi-Garman
Mario Van Den Ancker
Eelco van Kampen
Ignacio Vera Sequeiros
Andreas Wicenec
Markus Wittkowski
Burkhard Wolff
Bodo Ziegler
Martin Zwaan

Space Telescope-ECF

Robert Fosbury

Jonas Haase
Richard Hook
Martin Kümmel
Harald Kuntschner
Marco Lombardi
Kim Nilsson
Piero Rosati
Britt Sjöberg
Felix Stöhr
Jeremy Walsh

ALMA Joint Office

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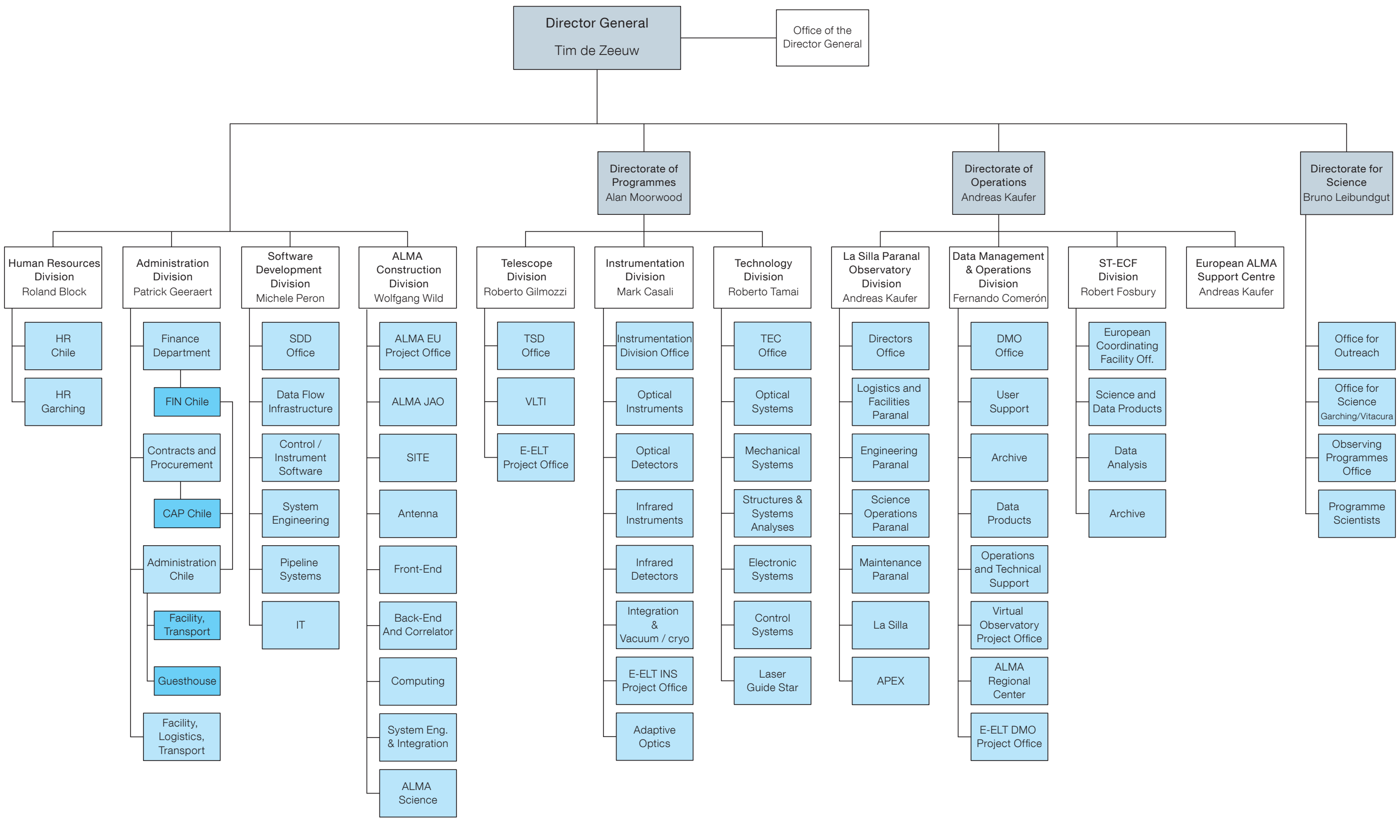
Ravinder Bhatia
Paulina Bocaz
Javier Marti Canales
William Dent
Richard Hills
Jorge Ibsen
Rüdiger Kneissl
Richard John Kurz
Jacques Lassalle
Lars Åke Nyman
Martin Oestreich
Pere Planesas
Mark Rawlings
Russell Smeback
William Snow
Baltasar Vila Vilaro
Nicholas Whyborn

The building currently housing the ALMA "El Golf" offices in Santiago, Chile.

Organigram



The main organisational and managerial units of ESO are the Directorates which currently include: the Directorate of Programmes, Operations and Science. The Directorates are organised in Divisions. The Divisions Software Development, Administration, ALMA Construction and Human Resources have a special status. (Status of the Organisation as of December 2009.)

The Residencia at Paranal, temporary "home" for many scientists and technicians from all over the globe.

Committees

Council

The ESO Convention designates the ESO Council as the supreme organ of the Organisation. It determines the policy of the Organisation with respect to scientific, technical and administrative matters, while delegating the responsibility for the day-to-day operation to the Director General. Normally, the Council convenes twice each year and twice in its Committee of Council configuration. In 2009, Council held its ordinary meetings in Vienna on 3 and 4 June and in Garching on 8 and 9 December. Committee of Council met at ESO Headquarters on 2 and 3 March and at the ALMA OSF in Chile on 5 and 6 October. All meetings were chaired by the President, Laurent Vigroux.

For the June meeting (114th Council Meeting), Council met at the Austrian Federal Ministry for Science and Research in Vienna commemorating the recent accession of Austria to ESO. At the meeting, Minister Johannes Hahn, the Austrian Minister for Science and Research, welcomed the Council President, the Council delegates and the ESO management to Vienna. He expressed his satisfaction at Austria finally joining ESO after discussions that had lasted some 35 years and was keen to assist in developing ESO further. To this end he pledged Austria's full support to contribute its share towards the E-ELT project.

Council heard reports on all aspects of the ESO programme. New financial thresholds including some for procurement were approved, as well as a new agreement between CERN and ESO concerning the admission of ESO staff to the CERN Pension Fund. Furthermore, Council approved the acquisition of the land known as "Plot B" next to the Headquarters building, approved the Financial Statements for the year 2008 as well as the External Audit Report 2008 and granted discharge to the Director General.

At the 115th meeting, held in December, Council approved new Financial Rules and Regulations as well as the new Rules of Procedure both for Council and the Finance Committee. Laurent Vigroux and Thomas Henning were re-elected President and Vice-President of Council respectively until the end of 2010. Laurent Vigroux, as President of Council, and the Director General were re-elected to serve as ex-officio members of the ALMA Board, also until the end of 2010. For the same period, Alain Heynen and Johan Holmberg were reelected Chair and Vice-chair respectively of the Finance Committee, while Willy Benz was reappointed Chair of the STC. Further reappointments (until the end of 2011) included the Chair of the Tri-partite Group, Patricia Laplaud. Appointments included Ralf Bender as Chair and Eileen Friel as Vice-chair of the OPC for the OPC periods 86 and 87. At the meeting, Council heard reports about the various ESO activities including the status of the E-ELT Design Phase and from the E-ELT Standing Review Committee, chaired by Roger Davies.

Council approved the appointments and the terms of reference of the members of the 2010 Visiting Committee. Finally, Council approved the budget for 2010 and the scale of contributions of 2010.

Following the Council meeting, on 10 December, Provisional Acceptance of VISTA was marked with a ceremony where the Council President, the UK Council delegation, as well as members of other delegations attended.

Council and Committee of Council 2009

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

Finance Committee

Finance Committee 2009	
Chair	Alain Heynen
Austria	Daniel Weselka (from November on)
Belgium	Robert Renier
Czech Republic	Jiri Toifl
Denmark	Cecilie Tornøe
Finland	Jaana Aalto
France	Patricia Laplaud
Germany	Matthias Nagel
Italy	Germana Di Domenico
The Netherlands	Coen van Riel
Portugal	Fernando Bello
Spain	Luis Ruiz López
Sweden	Johan Holmberg (Vice-chair)
Switzerland	Maurizio Toneatto
United Kingdom	Colin Vincent

In 2009, the Finance Committee held two ordinary meetings and one extraordinary meeting (February) chaired by Alain Heynen. The meetings took place at ESO Headquarters in Garching. Starting with the last ordinary meeting of the Finance Committee in November, Austria was represented officially by a delegate.

New financial thresholds for submitting requests to the Finance Committee for the awarding of contracts have been decided. Thus, the Finance Committee approved 17 contracts exceeding € 300 000 (February, May) and 14 contracts exceeding € 500 000 (November) as well as seven single-source procurements exceeding € 150 000 (February, May) and two single-source procurements exceeding € 250 000 (November). Ten amendments to existing contracts have been approved by the Finance Committee. Four contracts, one of them being the purchase of the "Plot B" piece of land for the extension of the Headquarters building, were approved by written procedure. Also, following thorough discussions in the meetings and two revisions, the Financial Rules and Regulations were recommended to Council for approval n written procedure. Finance Committee received information concerning procurement statistics, forthcoming calls for tenders and price enquiries exceeding € 150 000.

Furthermore, the Finance Committee dealt with financial issues (such as annual accounts, budget, cash-flow situation, financial statements, Member State contributions, financing of the E-ELT) and general personnel subjects, concerning International and Local Staff as well as the Pension Fund. These themes were discussed in detail and recommendations were made to Council.

This image beautifully captures the zodiacal light, a triangular glow seen best in night skies free of overpowering moonlight and light pollution.

ESO/Y. Beletsky

Scientific Technical Committee

The Scientific Technical Committee 2009

Chair	Willy Benz
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 (LSP)
The Netherlands	Marco de Vos (LSP)
Portugal	José Afonso (ESAC)
Spain	Rafael Bachiller
Sweden	Göran Olofsson (ESE)
Switzerland	Didier Queloz (ESE)
United Kingdom	Rob Ivison (ESAC, STC Vice-chair)
Chile	Leonardo Bronfman

Members at Large

David Crampton (ESE)
Elaine Sadler (ESAC)
Linda Tacconi (ESAC Chair)

New structure with STC subcommittees

Following Council approval of the new structure of the STC with members from each Member State, a member from Chile and members at large as well as subcommittees dedicated to the discussion of specifics of the individual ESO programmes, the STC was newly constituted. The STC members were appointed by Council in its December 2008 meeting. The subcommittees for the La Silla Paranal Observatory (LSP), the ALMA European Science Advisory Committee (ESAC) and the E-ELT Science and Engineering Committee (ESE) were organised closely with the STC itself. The new structure was presented at an STC teleconference in January.

The regular subcommittee meetings were organised so as to take place before the STC itself and a full report with preliminary conclusions was delivered at the STC meetings for discussion. Over the year the separation of work between the STC and its subcommittees was further refined. In addition, ESAC does not only advise the ESO STC, but also provides input to the ALMA Science Advisory Committee (ASAC).

A good practice for the subcommittees appears to be to have teleconferences with updates on the programmes at about three month intervals between the face-to-face meetings.

70th STC meeting

The STC met in its new composition for its 70th meeting on 22 and 23 April in Garching. The La Silla Paranal and the E-ELT Science and Engineering subcommittees had all met the week before. The ESAC meeting took place several weeks earlier in preparation for the ALMA Science Advisory Committee. The STC received presentations of the ongoing ESO programmes and in addition discussed the proposal for a VLTI visitor instrument.

The STC stressed the importance of developing a plan for the future VLT workhorse instruments and asked ESO to work out a strategy as an essential ingredient to maintaining the scientific eminence of the VLT into the ELT era.

It further discussed the scientific value of spectroscopic surveys following an ESO workshop, requested during the 69th STC meeting, that took place in March. The workshop demonstrated a strong interest by the European astronomical community in such surveys and led to the following STC recommendations:

- current instruments should be used for public spectroscopic surveys as rapidly as possible;
- ESO should issue a call for public spectroscopic surveys; and
- ESO should issue a call for instrument concepts and associated science for large-scale public spectroscopic surveys with dedicated instrumentation.

The STC discussion on the proposed VLTI visitor instrument PIONIER, a four-beam combiner, concentrated on the feasibility, in particular the rapid implementation of the instrument (by 2010) and the requirements on ESO to provide four operating auxiliary telescopes. This is a condition for the operations of the second generation VLTI instruments as well, but will require an accelerated implementation for PIONIER. It was further clarified that the observing proposals submitted to the Observing Programmes Committee for evaluation of the scientific value of such observations were rated very highly. The STC appreciated the enhancement PIONIER provides on a short timescale and in particular the imaging capabilities it brings to the VLTI. The STC hence recommended:

- a speedy implementation of PIONIER conditional that PIONIER does not interfere with the commissioning of PRIMA or the schedule of the second generation instruments; and that
- ESO develops a roadmap leading to the commissioning of the Adaptive Optics Facility. In particular, the impact on the operations of UT4 should be evaluated and documented.

Concerning ALMA the STC stressed the importance of keeping the specification of the antennas and the receivers and not relax them to recover the accumulated delays. It further stated its resolve that Early Science with ALMA should begin with no less than 16 antennas. The efforts by ESO for a solution for the ESO prototype antenna at Socorro were supported by the STC. Recognising the need for adequate information on the pertinent identification of molecular emission lines, frequencies, collision strengths and chemical reaction rates for a proper scientific exploitation of ALMA data, the STC suggested organising the efforts within the ALMA Regional Centre framework to enable a timely science return. In response to the proposal for the creation of a Czech ARC node at Ondřejov the STC expected to receive an evaluation from the ARC coordination committee and ESAC before issuing a recommendation. Finally, the STC enthusiastically noted the excellent sensitivity levels reached for most ALMA receiver bands, exceeding the specification in several cases.

The discussion on the E-ELT design study progress resulted in a request to have information on the site characterisation process as it was developed by the Site Selection Advisory Committee. The STC was fully aware of the issues of confidentiality involved in these matters. The missing expertise on telescopes and optics should be filled in the E-ELT Science and Engineering Committee as soon as possible. In addition, the STC recommended several changes concerning the presentation of the project. Two aspects of particular attention were the tradeoffs a high site would provide and the water vapour characteristics above candidate sites as they would affect the science as presented in the design reference mission.

71st STC

On 21 and 22 October the STC met for its 71st meeting in Garching. The subcommittees had again met the week before. Reports on those subcommittee meetings were given verbally at the STC in cases where there was insufficient time to prepare documents and slides. In addition to the regular update reports on ESO's major projects, the STC also heard a presentation on the future of general-purpose observing modes on the VLT. The STC appreciated the overview on this topic. It endorsed ESO's plans to complete a study of the available options to ensure the availability of near-infrared diffraction-limited imaging in light of the planned decommissioning of NACO in 2012. The lack of such an imaging camera would present a significant scientific loss and impact a number of high profile science areas. The STC recommended investigating whether moving NACO to another UT would be a viable alternative to decommissioning. The steady progress at the VLTI was highly appreciated by the STC. The importance of PRIMA for the existing VLTI instruments AMBER and MIDI was stressed as much as the improvements needed for the Auxiliary Telescope performance and the reduction of the vibrations in the overall telescope system. A complete and timely commissioning of PRIMA was urged. A reassessment of the science goals of the public surveys planned for the much delayed VST was requested by the STC. The surveys had been approved several years ago and a confirmation — and maybe slight re-adjustments — of the surveys appears reasonable.

The Committee was concerned by the lack of significant time contingencies in many major components of ALMA. It stressed again that the original scientific capabilities of ALMA be preserved despite the pressures arising from the requirement to stay within the approved cost to completion of the project. Given that Early Science with ALMA would be only one year away, the STC recommended that a proper time allocation process be completed quickly. It urged that the matter needed to be addressed without further delay. The STC considered a continuation of APEX operations beyond 2012 and even after ALMA inauguration as highly desirable. The planning for ALMA development during the operations phase should be widely advertised in the ESO community.

The proposed selection criteria for the capabilities of the first E-ELT instruments were considered appropriate and sufficient by the STC. The STC was strongly of the opinion that a full set of first generation instruments should be identified and not only the first light instruments be included in the E-ELT construction proposal. This would ensure a coherent programme, while ensuring a maximal involvement by the community, which the STC considered essential for the success of the project. The selection process for the instruments should be transparent for the community. The STC in particular would like to be able to discuss the selection of instrument capabilities as a whole as early as possible and to receive brief summaries of the instrument concepts, the capabilities, options, costs and relevant comments from the review process.

The 2010 ESO budget proposal was discussed and the STC re-iterated the importance of keeping the VLT performance level as high as possible for the future.

Observing Programmes Committee

The Observing Programmes Committee 2009

Elias Brinks (Chair)

Maria Teresa Beltrán (P84)
Jacqueline Bergeron
François Boulanger
Enrico Cappellaro
Cathie Clarke
Sofia Feltzing (P84)
Natascha Förster-Schreiber (P84)
Adriano Fontana
Eileen Friel (P85)
Armando Gil de Paz (P84)
Rosa González-Delgado (P85)
Philip James (P85)
Leon Koopmans (P84)
Claes-Ingvar Lagerkvist
Henny Lamers (P84)
John Landstreet (Acting Vice-chair in P85)
Ari Laor (P84)
Diego Mardones
Michael Merrifield
Hermann-Josef Röser (P84)
Huub Röttgering
Regina Schulte-Ladbeck (P85)
Esko Valtaoja
Paul van der Werf
Kim Venn (P84, Vice-chair)
Werner Weiss
Simon White

The two annual meetings of the Observing Programmes Committee took place in May and November, for evaluation of the proposals submitted for observations to be executed, respectively, in Periods 84 (P84; 1 October 2009 to 31 March 2010) and 85 (P85; 1 April 2010 to 30 September 2010). A record number of 1094 proposals for observation with the ESO telescopes were received in P84, which represents an increase of 133 proposals over the previous record (P83). In addition, in P84, the OPC also had to review 18 Large Programme proposals for usage of the GTC within the framework of the accession agreement of Spain into ESO. In P85, 988 proposals were submitted. While considerably less than in P84, this still represents the second-highest number of proposals for a given semester in ESO's history. The distribution of proposals across the different scientific areas remained similar to recent periods, with about twice as many dealing with Galactic science — OPC categories C (interstellar medium, star formation and planetary systems) and D (stellar evolution) — as with extragalactic topics — categories A (cosmology) and B (galaxies and galactic nuclei).

The dramatic increase in the total number of submitted proposals from P83 to P84 was to a large extent due to X-shooter, which was offered to the community for the first time in P84, attracting 148 proposals. This immediately placed it in second position in the ranking of the VLT instruments by amount of requested time, behind FORS2 — with a demand twice the average, making it by far the most popular VLT instrument — but well ahead of all others. The arrival of X-shooter also made Kueyen (UT2) the most popular Unit Telescope of the VLT, pushing it ahead of Antu (UT1) in terms of pressure factor, i.e. the ratio of the requested to the available time. For UT2, the latter rose to an unprecedented value of 8.5 in P84.

On La Silla, HARPS and EFOSC2 remain in high demand. The community shows a strong interest in the option to mount visitor instruments at the NTT. Between P84 and P85, a total of 28 proposals were submitted for observations with four different visitor instruments at this telescope. Three (AstraLux, IQuEye and ULTRACAM) were mounted on the telescope with 74 nights allocated for programmes using them.

Under the 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 sixth time, in 2009. ESO received two joint applications in P85, neither of which qualified for allocation of telescope time. Time at both facilities was granted to one joint proposal evaluated by the XMM Observing Time Allocation Committee.

Targets of Opportunity

As in 2008, a high number of proposals for observations of Targets of Opportunity (ToO) were submitted for evaluation by the OPC: 51 in P84 and 52 in P85, of which respectively 20 and 17 were approved. After several years during which studies of gamma-ray bursts (GRBs) accounted for the largest fraction of the successful ToO proposals, there was a shift of focus in 2010, where 40% of these proposals dealt with supernovae and approximately 20% were dedicated to GRB science.

Calibration Programmes

Calibration Programmes 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 usage of the same resources. One Calibration Programme (CP) proposal was accepted in P84 (out of six submitted), and three in P85 (from four submissions).

Large Programmes

Large Programmes (LPs) are projects requiring a minimum of 100 hours of observing time and that have the potential to lead to a major advance or breakthrough in the considered 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 VLTI and on APEX. Respectively 28 and 21 LP proposals were received in P84 and P85, of which six and five were scheduled. The user community responded positively to our encouragement to make more use of the La Silla telescopes for the execution of LPs and to the increase from two to four years for the maximum duration of such programmes to be carried out on La Silla. In P85, there were five LPs scheduled on the 3.6-metre telescope, with a combined time allocation of 93 nights in this period — more than 50% of the total science time; on the NTT, 26 nights were assigned to three LPs. Of the nine La Silla LP proposals approved since the increase of the maximum LP duration in P83, seven have a total duration of three to four years.

ESO/GTC Programmes

At the time of publication of the Call for Proposals for observations with ESO telescopes in P84, ESO also opened the second cycle of submission of ESO/GTC proposals. As part of the latter, Principal Investigators from ESO Member States were invited to submit Large Programme proposals for usage of the observing time offered on the GTC. These proposals were evaluated by the OPC in the same way as regular ESO Large Programme proposals. Two members-at-large appointed by Spain assisted the OPC in this task. The proposals deemed suitable for implementation by the OPC were subsequently reviewed by the ESO–Spain Liaison Committee with respect to the relevant technical and operational constraints. As an outcome of this process, three programmes were approved.

OPC procedures

Period 84 saw the introduction of triage in the ESO proposal evaluation process. The 30% lowest-ranked proposals, identified on the basis of the preliminary grades assigned by the referees in preparation of the OPC meeting, are no longer discussed during the meeting. This allows more time to be available for evaluation of those proposals that show the greatest scientific promise. OPC and panel members concurred almost unanimously that triage allowed them to perform the evaluation work better. Also for the first time in P84, the OPC chair was not part of any panel, in order to allow him/her to dedicate more of his time to his/her specific responsibilities.

Following the major increase in the number of received proposals in P84, and the resulting excessive workload for the panel members of OPC category A, a third panel was created in this category for P85. This raised the total number of OPC members to 79, distributed in thirteen specialised panels, each with an independent chair.

The steps described above are only first measures to address the most urgent issues resulting from the ever-increasing number of proposals. In order to tackle the challenge that this represents on a more fundamental and longer term basis, the Director General created an advisory Working Group in 2009. Its mission is to review the strengths and the weaknesses of the current proposal selection process and to assess possible alternative scenarios for the future.

Director's Discretionary Time

The biannual proposal selection process carried out by the OPC involves a long lead time. The elapsed time between the submission and the execution of a programme may exceed one year. However, for urgent projects such as observations of unpredictable transient sources, users can apply for Director's Discretionary Time (DDT) at any time. Using this channel, the delay between proposal submission and execution can, if necessary, be as short as a few hours. In 2009, 126 DDT proposals were received by ESO. After taking advice from an internal committee composed of ESO staff astronomers, the Director General approved about half of them for implementation.

I. Bončina/ESO

Star trails around the celestial south pole during a night at ESO's La Silla Observatory in northern Chile's Atacama Desert.

Users Committee

The Users Committee 2009	
Austria	Werner Zeilinger
Belgium	Martin Groenewegen
Czech Republic	Jiří Grygar
Denmark	Frank Grundahl
Finland	Seppo Katajainen
France	Vanessa Hill
Germany	Jochen Heidt
Italy	Bianca Poggianti
The Netherlands	Walter Jaffe
Portugal	Jorge Meléndez
Spain	Ignacio Negueruela
Sweden	Nils Ryde
Switzerland	Frédéric Courbin (Vice-chair)
United Kingdom	Jacco van Loon (Chair)
Chile	Manuela Zoccali

The annual meeting of the Users Committee (UC) took place at ESO Headquarters in Garching on 27 and 28 April, now officially including Austria. This was also the first UC meeting organised by the User Support Department within the Operations Directorate.

The Director General opened the meeting with a presentation on ESO's long-term strategies and priorities, which was then followed by several reports on specific areas of ESO activities. These presentations ranged from updates on the La Silla Paranal Observatory and APEX, on the current status and future plans of ALMA, the Instrumentation Division, and the E-ELT Project Office, to reviews on telescope time statistics and ESO's scientific outcome.

The UC provided a detailed report on various operational matters regarding ESO facilities, based on feedback by users provided through a questionnaire that all UC members distribute to their respective communities. In general, users confirmed their satisfaction with the level of support received during the implementation and execution of observations at the La Silla Paranal Observatory (including APEX), both in service mode and in visitor mode. With the increasing complexities of future second generation VLT instruments, they emphasised the importance of delivering stable and robust data reduction pipelines and tools, so that the users will be able to fully exploit their datasets. Other areas of concern were the over-subscription rates on some specific instruments/telescopes and the coordination of the ALMA Regional Centre nodes, including the type of user support these nodes will be able to provide to the astronomical community.

The special topic this year was devoted to "Target of Opportunity (ToO) and Rapid Response Mode (RRM), from beginning to end". After a brief introduction by ESO, two frequent users (Stefano Covino and Elena Pian), representing different (large) collaborations, shared their experiences with both the ToO and RRM observing modes. Their reports were very positive on all steps involved in the support of these modes: from input to be provided in the Phase 1 proposal, to the preparation of observing material (Phase 2), triggering procedures, observations follow-up with access to the data in real time.

I. Bončina/ESO

Sunset over the Very Large Telescope at ESO's Cerro Paranal.

Outreach

Three-colour composite mosaic image of the Eagle Nebula obtained with the Wide-Field Imager camera on the MPG/ESO 2.2-metre telescope at the La Silla Observatory. At the centre, the "Pillars of Creation" can be seen.

The ESO education and Public Outreach Department (ePOD) continues to serve ESO, the ST-ECF (ESA/Hubble), the International Year of Astronomy 2009 and the International Astronomical Union (IAU) with products and services to increase awareness of the projects, to promote astronomy and the scientific process and to propagate the awareness that Europe is a major player in ground-based astronomy with ESO and in space-based astronomy with ESA.

ePOD had an extremely eventful and challenging year. ESO has played a major role in the organisation of the International Year of Astronomy. One of the outcomes of IYA2009 was an increased visibility for astronomy, and hence also an increased visibility for ESO.

The year 2009 also saw the implementation of a new outreach strategy aimed at increasing the effectiveness of ESO's outreach by merging the existing outreach efforts at ESO and consolidating comprehensive changes in the department. ePOD workflows and structures, including computing equipment, file structures, web processes, inventories, evaluation processes, budget follow-up, procurement procedures, personnel planning and audiovisual copyrights, were re-organised and documented with comprehensive guidelines.

The highlights of the year were the global coordination of the IYA2009 through the IYA2009 Secretariat embedded within ePOD, and the ESO-led IYA2009 Cornerstone activities, especially Around the World in 80 Telescopes, the Cosmic Diary, Portal to the Universe and Gigagalaxy-Zoom. The highlight for ESA/Hubble was the Hubble Servicing Mission 4 (SM4) and the subsequent Early Release Observations (EROs). For the International Astronomical Union, ePOD successfully set up and operated the 2009 General Assembly Press Office in Rio de Janeiro.

ePOD's work was recognised by the Special Jury Award at the 2009 MEDEA Awards for the production quality of the movie *Eyes on the Skies*, chosen from a field of over 254 entries from 39 countries. Around the World in 80 Telescopes received the first runner-up IYA2009/Mani Bhaumik Prize for Excellence in Astronomy Education and Public Outreach.

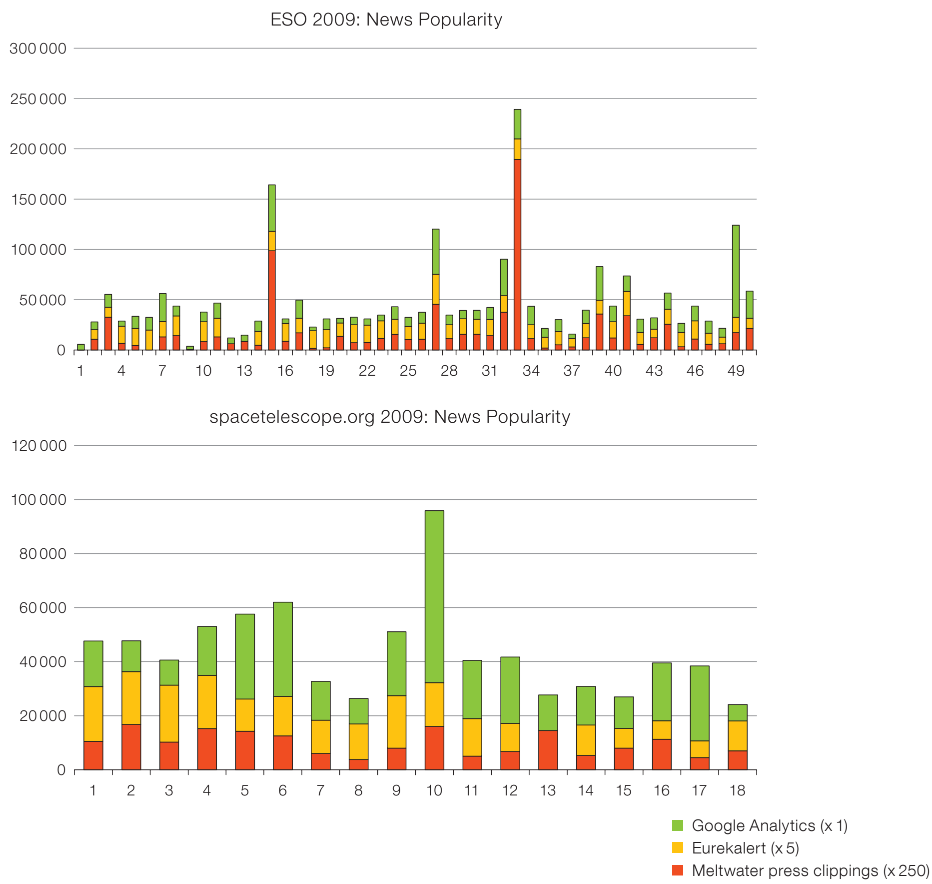
Press activities

Helped both by the high level of press activities at ESO and the high visibility of astronomy in 2009 the ESO science, photo and organisation releases created significant resonance with the media.

ESO published 50 press releases (up 2 % from 2008), ESA/Hubble 18 releases (down 22 %) and the IAU had 23 releases (up 130 %), combining into a record high of more than 90 ePOD press releases, almost all with high quality visuals. In Chile 15 additional press releases were produced in Spanish and distributed locally. 45 ESO announcements and 14 Hubble updates were distributed. IYA2009 press activities are listed below in the IYA2009 section.

Press conferences were held in Finland, UK, France, Santiago de Chile and a system for virtual press conferences was implemented and used for one press conference.

The first release of VISTA images occurred in late 2009 and was accompanied by a large and popular press release including three spectacular images, an ESOcast and a video news release. This was coordinated with the many involved parties in the UK.



Popularity of news 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 is the number of online newspaper articles about the news release. The 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. ESO press release 15 is the Lightest Exoplanet release, 33 is the First Rocky Exoplanet release. Hubble release 10 is the SM4 EROs.

Publications and audiovisuals

The production of print products continued, with several highly visible publications.

Seven three to five minute trailers were produced: for ESO, VLT, La Silla, ALMA, APEX, E-ELT and for the ALMA planetarium show.

The ESOcast video podcasts, launched in late 2008 continued during 2009. Nine episodes were published during the year, covering topics such as La Silla's 40th anniversary, the latest exoplanet research and the first images from VISTA.

The very popular Hubblecasts also continued with seven episodes (down 46 %, partly due to the SM4 "black-out").

ESO had two video news releases during 2009, photography and high definition filming was carried out on site in Chile for inclusion in the ESO image and video archive.

Models of the VLT were produced for Google Earth and distributed to the online community. New E-ELT and ALMA computer renderings and animations were added to the archives.

ESO, in collaboration with ESA and the IAU, produced a book and movie celebrating the 400th anniversary of the telescope. *Eyes on the Skies* explores the story of the telescope — its history, the scientific and technical advances and the people involved. The hardcover book is available in several languages, as is the movie on DVD and Blu-ray. Over 300 000 copies of the movie have been distributed, and it has also been broadcast numerous times on television. 20 000 copies of the Blu-ray version have been produced. All versions include narration in seven languages and subtitles in 32 languages.

In close cooperation with ESO, as part of its IYA2009 activities, the production companies parallax raumprojektion and fact&film have produced a unique 3D documentary about the VLT. The film, *The EYE 3D — Life and Research on Cerro Paranal*, stars the ESOcast host, Joe Liske, who was accompanied by

Periodicals	*The Messenger*: 4 issues
	ST-ECF Newsletter: 2 issues
	Capjournal: 3 issues
	Science in School: 3 issues (jointly with EIROforum)
Books	*Cosmic Collisions* (Springer New York)
	Eyes on the Skies in Finnish, Korean, Japanese, German and Chinese
	Hidden Universe in Finnish, Japanese, German and Chinese
	Blaauw's *ESO's Early History* (reprint)
Brochures	E-ELT (for decision makers)
	E-ELT (for the general public)
	IYA2009 brochure v.4
	Astronomy for the Developing World (IAU)
Other	Paranal Safety Flyer
	ESO Annual Report 2008
	7 handouts
	11 conference posters
	13 picture posters
	1 exoplanet media kit
	1 postcard set
	ESO Calendar 2010
	1 multi-latitude planisphere for Chile
Electronic publications	ESO Christmas card
	ALMA educational sheets
	User's Guide for FITS Liberator v2.3
	Electronic ESO Christmas Card

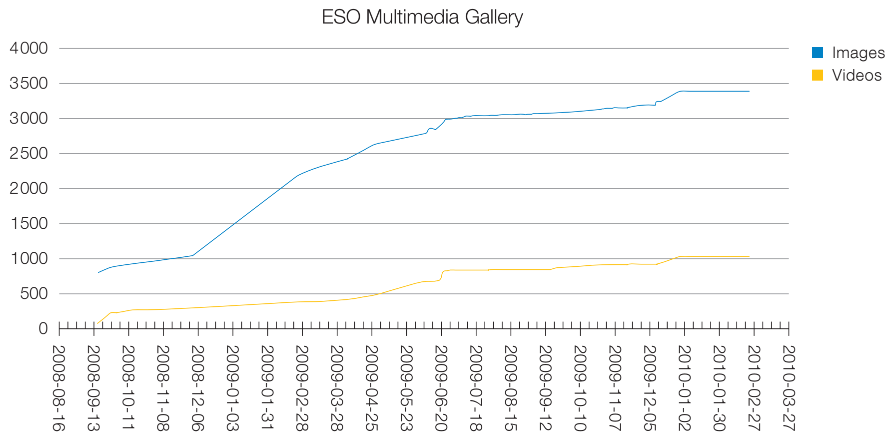
ePOD's publications in 2009.

a German 3D-film crew on a trip to the VLT in June 2009. In partnership with ARKAB productions ESO assisted in the production of the movie *Tours du Monde, Tours du Ciel*.

In search of our Cosmic Origins is a planetarium show about ALMA. The show, produced by ESO and the Association of French Language Planetariums in collaboration with the Planetarium of Augsburg, is available in six languages and in formats for fulldome video and standard planetariums. Almost 40 planetariums have the show in their programming and more have shown interest.

Events and exhibitions

The ESO exhibitions concept was streamlined and merged with that of ePOD/Chile, new panels were produced and a major overhaul was made (see www.eso.org/public/outreach/products/exhibitions/). New panels were designed to include light pollution and information about ESO in Chile.



A new online media archive improved the functionality and increased the visibility of ESO's audiovisual assets. The volume of resources available on the ESO website has roughly tripled.

ESO had a presence at 83 exhibitions in Europe, Chile and USA during 2009, representing a fivefold increase on previous years. Among the exhibitions were the global opening ceremony for IYA2009 at UNESCO in Paris, the opening of IYA2009 in Chile and the German ceremony in Berlin. Audiences in Paris and Berlin were "transported" to the Paranal observatory site, thanks to live video-conferencing question-and-answer sessions. ESO had a major presence at the IAU General Assembly in Rio de Janeiro, where the ESO stand also hosted the ESO-hour — a social event designed to promote networking and discussion among delegates. At the General Assembly, the IAU Press Office and the office for IYA2009 were partially staffed by ESO personnel. Some of these exhibitions involved multiple sites, like the 60 exhibits in Europe and Chile arranged for the GigaGalaxyZoom project in collaboration with science centres and planetariums. In many cases the exhibitions were carried out in partnership with local organisers.

On 24 October ESO Headquarters welcomed the public as part of the annual campus-wide Open House event in Garching. This year's event attracted a record-breaking 4000 visitors. La Silla had Open Door days on 1 and 6 October and Paranal on 10 and 17 October.

Our eight permanent exhibitions continue to draw crowds. They are *Ruinas de Huanchaca* (Antofagasta, opened 2009), Museo Interactivo Mirador, Santiago (MIM) Santiago, *Science Tunnel* (Chilean version opened in 2009), Sci & Tech Museum Santiago (refurbished in 2009), Taltal (close to Paranal), the ALMA site museum at the ALMA Operations Support Facility, Deutsches Museum (opened 2009) and at Paranal.

Distribution and other products

Many print products were distributed in 2009, including three IYA2009 infopacks, several periodicals and brochures sent to VIPs, policy-makers and educators. A special ESO info-pack including several brochures and hand-outs was sent out to 3500 of the most important educators, science centres, planetariums and freelancers.

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

Image processing

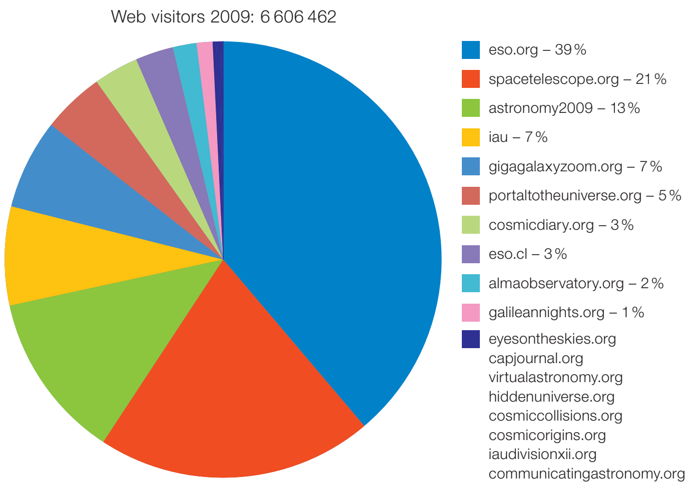
The systematic mining of the ESO and HST science archives continued to yield spectacular results. VISTA's huge field of view and high image quality give it a high "photogenic resolution" (area divided by size of the typical star images) and make it a gold mine for spectacular datasets.

Web and software development

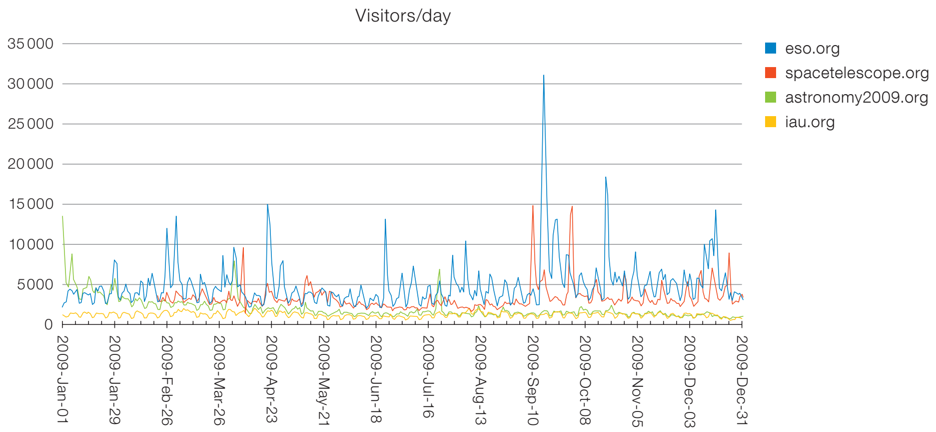
Eighteen different websites of varying complexity and importance are maintained by ePOD (three other sites were passed on to partners). The ePOD's own media archive software was further developed and moved to a more contemporary development platform. The new system has passed all tests under real operating conditions and is now serving iau.org, astronomy2009.org (IYA2009) and image and video archives on eso.org.

In collaboration with the Information Technology Department several important improvements were made to the infrastructure of the web servers and IT's Content Management System (CMS) project for the static web pages was supported.

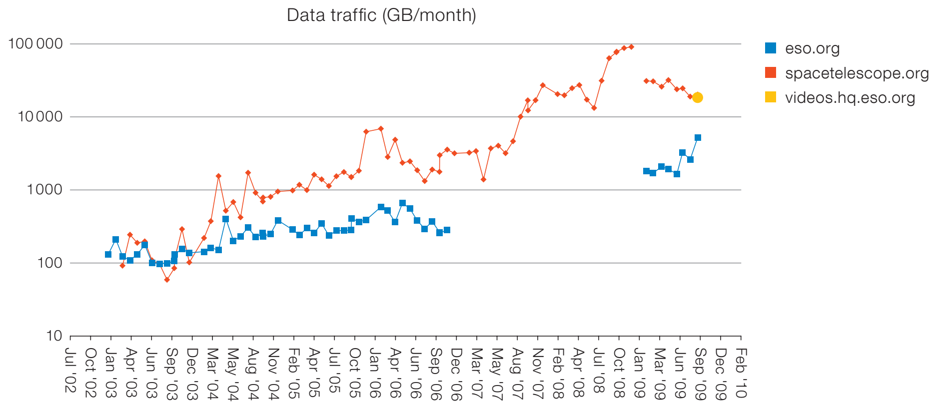
Images and video material are key to ESO's outreach activities. During 2009,



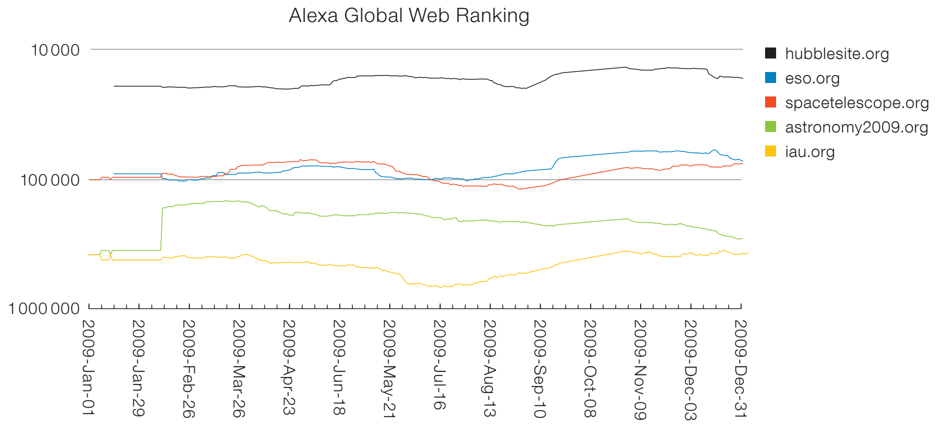
The total number of web visitors to our 18 websites in 2009. eso.org had the most visitors. eso.org and spacetelescope.org together represent almost two-thirds (60 %) of the total number of visitors.



Number of visitors per day for the four main sites in 2009 (blue is eso.org, red is spacetelescope.org, green is the IYA2009 site, yellow iau.org). The highest ESO peak for the period (16 September) is the release of the first GigaGalaxy Zoom episode, followed by two smaller peaks for the second and third episodes. The 19 October peak was caused by the announcement of 32 new exoplanets and the last group of peaks by VISTA, and the exoplanet GJ1214b. The spacetelescope.org peaks on 9 September and 1 October follow the release of the first images after Hubble SM4 (the long-awaited EROs) and the ram-pressure stripping photo release.



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 websites is negligible. As of September 2009, a separate server, videos.hq.eso.org, serves the Hubble and ESO videos as well as gigagalaxyzoom.org. The top of the box indicates 100 TB. The accumulated traffic from all sites corresponds to 0.34 PB/year.



Alexa global rank for the four main websites, together with NASA's hubblesite.org as a benchmark site. This ranking measures the popularity of websites among a pool of web users registered with Alexa (1 is Google, 2 Yahoo, 3 YouTube, etc.).

the volume of resources available on the ESO website has roughly tripled, largely due to a considerable effort in digitising historical media and re-organising workflows. The new online media archive has made the online image and video galleries searchable, and significantly improved their appearance and performance.

Several of the websites received major overhauls, including eso.org, where the public content is now more attractive and visible. eso.org now includes a comprehensive timeline of over 100 of the most important milestones in ESO's history, a list of the top ten scientific discoveries with ESO telescopes, and various factboxes and PowerPoint presentations. The public was also provided with as much information as possible on the E-ELT through a set of comprehensive web pages. These pages are also part of all the national mini-sites, and are available in 12 languages.

Chilean students, accompanied by their teacher, enjoying their weekend tour at Paranal.

A TV crew from Europe shooting a production for the BBC at the Paranal Residencia. A wide variety of documentaries, news stories and media projects were filmed at Paranal, reaching millions of people worldwide.

The total number of web visitors this year was 6.6 million and the total number of pageviews was 26 million. eso.org had 2.6 million visitors (up 68% from 2008), spacetelescope.org 1.3 million visitors (down 70%, partly due to the SM4 “black-out”).

ESO’s and ESA/Hubble’s presence on social networking sites such as Facebook, Twitter, YouTube, MySpace, and Dailymotion continues to flourish. Thousands of fans learn about our latest press releases, pictures of the week, vodcasts and announcements through these sites, and often share and republish the news in their own profiles.

Wikipedia and Wikimedia Commons were also used to promote ESO and Hubble results and attract visitors to the websites.

Version 2.3 of the ESA/ESO/NASA FITS Liberator plug-in for Photoshop was completed and released. This version includes full support for Photoshop CS4, significant performance (speed) enhancement achieved by using multiple Central Processing Units (CPUs) and CPU cores and an improved memory management strategy (for large images). The PDS image format for planetary images is now supported and minor improvements were made to the user interface.

The web-based GigaGalaxyZoom project consists of three giant images on different scales, the first reveals the full sky as seen with the unaided eye from one of the darkest deserts on Earth, the second zooms in on a rich region of the Milky Way using an amateur telescope, and the final image uses the power of a professional telescope to reveal the details of an iconic nebula. Serge Brunier and Stéphane Guisard captured two of the images, taking advantage of the excellent skies above ESO’s La Silla and Paranal sites. The third was obtained with the Wide Field Imager attached to the MPG/ESO 2.2-metre telescope at La Silla. In total the project attracted 440 000 visitors in 2009 and promoted ESO to new segments of the public.

Activities in Chile

ESO organised a wide range of outreach activities and projects for 2009 in Chile. These include the distribution of a special multi-latitude southern hemisphere planisphere, running a series of Science Cafés, promoting a network of schools, an annual meeting/workshop with the educational publisher PROED, revisiting classic science experiments such as the determination of the size of the Earth, opening the permanent astronomical exhibition at the Huanchaca Museum of the Desert in Antofagasta, and hosting an Open House at Paranal and La Silla. ESO is also a partner in the GalileoMobile IYA2009 Special Project, has supported the 5th Summer Astronomy School for Teachers (with the participation of 61 teachers from different regions in Chile), and has arranged several exhibitions of images in Chile including TWAN (The World at Night), ESO Heritage and From the Earth to the Universe.

This year 130 person-days were spent on-site with media and VIPs. During the regular weekend visits more than 7000 tourists visited the sites.

ESO Science Outreach Network

Early in the year steps were taken to reinvigorate the existing ESO Science Outreach Network (ESON), and this culminated on 1 July with a fully functioning ESON, making ESO's press releases available in 12 different languages on 17 different mini-sites under eso.org. 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 and more. They promote ESO in various ways in their home countries and add significantly to the visibility of the organisation.

Hubble EPO

During 2009, there were 18 press releases, seven Hubblecasts, and 14 Hubble updates (shorter announcements). The Servicing Mission to Hubble allowed the rare opportunity to communicate with the public in near real-time during a very exciting period. A Servicing Mission blog was updated several times per day, first from the launch at Kennedy Space Center in Florida, USA, and then from NASA's Goddard Space Flight Center in Maryland, USA. Nearly 5000 people visited the blog during the 13-day mission. Following SM4, the ST-ECF prepared a three-colour image of the Abell cluster 370, one of the finest illustrations of gravitational lensing by a cluster of galaxies, as one of the Early Release images.

Education

The 2008 Catch a Star programme was concluded with visits of prizewinners to Königsleiten, Germany.

A booklet of educational sheets about ALMA was published. The worksheets, intended for use in secondary education, cover topics such as "What is submillimetre astronomy?", "Why build ALMA in the high Andes?", and "Why is ALMA an interferometer?".

The first of a series of teacher schools organised by EIROforum was held at CERN in November. ESO, together with other EIROforum partners, provided speakers for a one-week course on the evolution of the Universe. The course was well received by the 35 participating teachers, from 18 different countries.

ESO continued to support *Science in School*, the European science education journal published by EIROforum.

EIROforum EPO

The EIROforum Outreach and Education Working Group was chaired by ESO until 1 July 2009. ESO participated in the EIROforum Teacher School at CERN, called Evolution of the Universe, in the 2009 EU Contest for Young Scientists, as well as provided assistance for the EIROforum Stand at the European Career Fair at the Massachusetts Institute of Technology (MIT).

International Year of Astronomy 2009

As IYA2009 comes to a close, the true scope of the venture has become clear. The final count of countries involved stands at 148, confirming that the IYA2009 network is the largest ever in science. More than 70 international organisations participated in the IYA2009 activities, along with 12 Cornerstone projects and 16 Special projects. Since 2007 the IYA2009 Secretariat, in collaboration with the IAU Press Office, has issued 28 press releases, 227 online features, 750 online updates, and 128 weekly newsletters.

ESO has been heavily involved in IYA2009 and hosted the IYA2009 Secretariat on behalf of the IAU since 2007. The Secretariat is the central hub for the preparation, implementation, coordination and evaluation of the global activities.

ePOD played a leading role in several global Cornerstone projects, and also organised a range of other ESO-specific activities on scales from local to global.

ESO led four of the 12 IYA2009 Cornerstones. As part of the 100 Hours of Astronomy Global Cornerstone project, Around the World in 80 Telescopes was a live 24-hour public webcast, attracting an estimated 200 000 viewers and featuring most of the research astronomical observatories both on and off the planet. During the webcast, hosted from the ESO Headquarters in Garching, astronomers at observatories around the world (including Paranal, La Silla, ALMA and APEX) talked about their work and presented exclusive images and video.

The Galilean Nights, which ran from 22–24 October 2009, and were also coordinated from ESO Garching, encouraged people everywhere to participate in stargazing events, and to experience the same sense of awe and wonder that Galileo felt when he first turned a telescope skywards 400 years ago.

The Portal to the Universe, launched in April, is a global, one-stop portal for online astronomy content, for content providers, laypeople, press, educators, decision-makers and scientists. It indexes and aggregates content including news, blogs, video and audio podcasts, images, and videos, as well as widgets showing live or near-live astronomy-related data. ESO, together with ESA/Hubble, provides the portal infrastructure. The site has attracted more than 300 000 visitors.

In the Cosmic Diary, professional scientists put a human face on astronomy through blogs, talking about not just the latest astronomical news, but what it is like to be an astronomer. The project is coordinated from the IYA2009 Secretariat at ESO, and 14 ESO researchers participated in the project. In total, 58 bloggers contributed from 30 different countries. In 2009 there were 1500 individual blog posts that attracted more than 220 000 visitors.

IYA2009/IAU/L. Pullen

Top: ESO Open House Day during IYA2009 Galilean Nights Cornerstone project. Bottom: The backstage of Around the World in 80 Telescopes, part of the 100 Hours of Astronomy, an IYA2009 Cornerstone project.

International Relations

Tim de Zeeuw in a live videoconference with Christophe Dumas at the Very Large Telescope in Paranal at the International Year of Astronomy 2009 Opening Ceremony in Paris.

IAU/L. Pullen

2009 has seen the International Relations Office (IRO) continue to develop its activities and provide support for the Director General and the Organisation more widely.

EMBL/M. Schupp

On 19 November 2009 the EIROforum Assembly took place at the EMBL headquarters in Heidelberg.

EIROforum

The ESO Director General finished his term of office as Chair of the EIROforum, completing the review of activities and reaching agreement on a new strategy and work programme, and new terms of reference for the Thematic Working Groups (TWGs), before handing over the Chairmanship to Iain Mattaj, Director General of the European Molecular Biology Laboratory (EMBL) by the end of June. ESO continued to play an active part in the implementation of the work plan through participation in the EIROforum Assembly, the Coordination Group and the various TWGs. EIROforum activities with IRO involvement also included support for a major conference on Technology Transfer, held at EMBL in Heidelberg.

E-ELT

The IRO has held a series of discussions with Member States concerning the evolution of the funding scenarios for the E-ELT, seeking to develop a better understanding of the Member States' requirements and constraints and to provide any information and support required by the Member States.

The IRO participated in the ESO–Spain Technical Working Group set up to act as the forum for clarification of factual technical (including legal) queries regarding the potential site requirements for location of the E-ELT, and the unique contact point for any technical queries.

A number of enquiries from non-Member States have been received regarding involvement with E-ELT, and the IRO has continued to support the DG in discussions with the interested parties. There has been a steady flow of enquiries about the costs and implications of membership of ESO, in response to which the IRO has provided information and answered questions. Also, in support of the E-ELT project, the IRO organised successful industry days in Berlin and Vienna.

During the year, several groups developing the new research infrastructures on the ESFRI list (and beyond) approached ESO seeking advice on developing their organisational frameworks. The IRO organised and coordinated four visits from three such projects, with contributions internally from the Administration Division and the Legal Service.

Relations with international organisations and networks

The IRO also continued to be active in a variety of interactions with international organisations and activities across Europe, including participation in the European Conference on Research Infrastructures in Prague; the RAMIRI conferences and strategy retreat; JENAM (held in Hatfield, UK); OPTICON; The second European Research Area (ERA) Stakeholder Conference in Brussels and two conferences in Lund held under the auspices of the Swedish Presidency of the European Council in July and October, respectively. IRO also represented ESO at the meetings of the UN Committee for Peaceful Uses of Outer Space, where ESO is a permanent observer. In December, the IRO took part in a preparatory meeting in Brussels for the first Asia–Europe Physics Summit, to be held in Japan in 2010.

IYA2009

A number of activities in 2009 revolved around the International Year of Astronomy. The IRO supported the DG at the launch of IYA2009 in Paris in January and represented ESO at selected IYA-related events throughout the year at meetings and events in Berlin, Brussels, Dublin and Madrid, among others.

Lord Drayson, the British Minister of Science and Innovation, takes a closer look at the E-ELT and receives an explanation of its pivotal role for raising the European scientific, technological and industrial profile by ESO Director General Tim de Zeeuw, at the JENAM meeting at Hatfield, UK.

Chile Relations

As in previous years, relations with Chile — with the authorities as well with academia and the commercial world — remained most cordial and constructive in 2009.

Due to security related incidents that had occurred in the area of the Chajnantor Plateau, the Chilean Government took important steps, through the Ministries of Foreign Affairs, the Ministry of the Interior, as well as the Carabineros, to safeguard our operations, particularly in the Paso de Jama area, near the ALMA site.

The La Silla and Paranal Observatory areas, as well as the possible future sites for the E-ELT, must also be protected against mining activities or water rights claims from third parties, who are mainly mining companies interested in establishing rights within the "area of scientific interest". In order to avoid potential conflicts, these activities are being permanently monitored by ESO and the appropriate Chilean authorities are kept informed.

Negotiations were initiated with the Chilean Government to obtain access to possible sites for the E-ELT. Several meetings were held with Ministry of Foreign Affairs officials, discussing legal and political issues.

The ESO/Government of Chile Joint Committee for the Development of Astronomy in Chile, an important component of ESO's Cooperation Programme with Chile, continued its work during 2009. This Committee was established according to the Supplementary Agreement with the Government in 1996 and has played a crucial role in establishing and strengthening astronomy in Chile. In 2009, funds worth 346 000 000 Chilean pesos (the equivalent of € 490 000) were allocated to several postdoctoral programmes and research groups. The selection process involved representatives from the Chilean Government and ESO.

A *Window to the Universe* is one of the five permanent exhibitions installed at the Museum of the Atacama Desert, in Antofagasta (II Region).

Galileomobile/ESO

The astronomers and educators in the Galileomobile team visited numerous schools and villages during their expedition, engaged young students in educational activities about astronomy and science, and offered amazing stargazing opportunities to the local communities in a region with one of the clearest skies on Earth.

Likewise, the annual meeting at CONICYT to allocate funding provided by ESO/AUI and NAOJ on behalf of ALMA for astronomy in Chile took place. Approximately US$ 500 000 is allocated annually by the Committee to Chilean universities who submit their projects for consideration.

The town of Taltal, the neighbouring town to the Paranal Observatory, celebrated its 151st anniversary. The ESO Representative in Chile participated in the celebrations. Thanks to ESO, the Galileo-mobile exhibition was also displayed in the town. Furthermore, ESO offers a scholarship programme for schoolchildren and university students, which greatly benefits low-income families.

The Office of the ESO Representative collaborated in producing and printing the book *Voces del Universo*, featuring images from galaxies with explanatory texts.

Finally, together with the education and Public Outreach Department the ESO Representative prepared a permanent astronomy exhibit to be placed within the Universidad Católica del Norte's grounds at the refurbished Ruinas de Huanchaca complex. This is a national monument in Antofagasta created in a former silver refinery that operated about 150 years ago, and was later abandoned. The project, which, with ESO participation, had been underway for several years, was inaugurated in 2009 and has already become a great attraction in the region.

As in previous years, many high-level visitors from throughout the world were received at ESO in Chile, including the delegation of the German Ministry of Research and Education (to ESO Vitacura), Vincenzo Scotti, Undersecretary for Foreign Affairs of Italy, the Italian Vice Minister of Economic Development, Adolfo Urso, Ambassadors of the ESO Member States, India and Japan, Air Force Commanders-in-Chief from Europe, USA and Latin American countries and many others. Visits by science agencies included a delegation from the Netherlands Organisation for Scientific Research (NWO), the Commissariat à l'énergie atomique et aux énergies alternatives (CEA, France) and CONICYT.

A present is handed over to the Italian Vice Minister for Economic Development, Adolfo Urso, during his visit.

ESO's Director General with the delegation of the German Ministry of Research and Education.

Four Seasons at a Glance

January

The International Year of Astronomy 2009 starts.

The ESO-led Cosmic Diary blog starts.

Start of *Ojos al Universo*, a five-month long exhibition in Valparaiso, Chile.

ESO is present at the winter American Astronomical Society (AAS) meeting in Long Beach, CA, USA.

IYA2009 opens at UNESCO, Paris, France.

ESO participates in the International Year of Astronomy 2009 German Opening Ceremony, Berlin.

A German E-ELT Industry Day takes place in Berlin.

ESO participates in the British Telecon Young Scientist of the Year event in Dublin, Ireland.

An Astroday, with ESO's presence, takes place in La Serena, Chile, attracting 10 000 visitors.

February

Using the VLTI, astronomers capture one of the sharpest colour images ever made.

Conditional acceptance of the first ALMA antenna.

The E-ELT Design Reference Mission and Design Reference Science Plan Workshop is held in Garching.

124th meeting of the Finance Committee.

ESO is present at the annual American Association for the Advancement of Science (AAAS) meeting in Chicago, USA.

ESO exhibits at the UNCOPUOS meeting in the United Nations Office in Vienna, Austria.

EIROforum participates in the MIT European Career Fair in Boston, USA.

On 20 January, the International Year of Astronomy 2009 officially kicked off in Germany at the Museum of Communication in Berlin.

March

First light for the X-shooter instrument on the VLT.

Decommissioning of FORS1 instrument at the VLT.

ESO's La Silla Observatory celebrates its 40th anniversary.

The first water vapour radiometer is delivered to ALMA and successfully tested at the site.

The first European ALMA front-end delivered to Chile.

The meeting, The Interferometric View on Hot Stars, co-organised by ESO, takes place in Viña del Mar, Chile.

The conference, ALMA and ELTs: A Deeper, Finer View of the Universe, is held at ESO.

The first European "hands-on" Virtual Observatory School is held.

The ESO Spectroscopic Survey Workshop takes place at ESO.

ESO's La Silla Observatory celebrates its 40th anniversary, became the largest astronomical observatory of its time.

A meeting on Star Clusters is organised by ESO Santiago.

Committee of Council meets in Garching.

The ALMA planetarium show, *In Search of our Cosmic Origins*, has its official premiere.

The live 24-hour free public video webcast, Around the World in 80 Telescopes, is broadcast from ESO Headquarters.

Opening event of the IYA2009 in Chile.

April

Thanks to HARPS, astronomers discover the lightest exoplanet found so far, only about twice the mass of our Earth.

The VLT shows that a faint gamma-ray burst is the signature of the explosion of the earliest, most distant known object in the Universe (a redshift of 8.2).

First astronomical fringes with two ALMA antennas are obtained at the OSF.

The construction of the ALMA Santiago Central Office is started.

ESO is present at the Joint European National Astronomy Meeting at the University of Hertfordshire, Hatfield, UK.

33rd Meeting of the Users Committee.

Scientific Technical Committee meets for its 70th session in Garching.

A record 1095 observing proposals are received for Period 84.

Launch of the ESO-led Portal to the Universe

Start of the Austrian Space Forum in Melk, with ESO's participation.

May

E-ELT mid-term external review.

First steel structure of the European ALMA antennas delivered to Chile.

ALMA (ESO/NAOJ/NRAO)

The two ALMA antennas used in the project's successful test observation of "first astronomical fringes", at the OSF.

Laboratory readout of avalanche photodiode array.

E-ELT Design Reference Mission workshop, ESO Garching, Germany.

One day workshop on Imaging at the E-ELT held in Garching.

125th meeting of the Finance Committee.

84th meeting of the Observing Programme Committee.

June

The first 240 × 240 pixel images with the world's fastest, high precision, faint light camera are obtained thanks to a collaborative effort between ESO and three French laboratories.

A new APEX operations plan, allowing up to 24 hours of continuous observing, is successfully implemented.

ESO workshop on MAD and Beyond: Science with Multi-Conjugate Adaptive Optics Instruments held in Garching.

114th Council Meeting in Vienna, Austria.

ESO Fellows Symposium, in Garching.

An ESO Austrian Industry Day takes place in Vienna, Austria.

ESO is present at the six-month-long COSMOS exhibition which starts in Paris, France.

ESO participates in the Seagate Young Innovators event in Dublin, Ireland.

ESO participates in the Astrozelt Bonn event, Germany.

ESO is present at the Munich Laser World of Photonics, Germany.

ESO joins the Expo Ciencia fair in Antofagasta, Chile.

July

Using the VLTI, astronomers obtain the sharpest observations of any kind ever made of the supergiant star Betelgeuse.

Astronomers unveil a new atlas of the inner regions of the Milky Way, using APEX.

First submillimetre observations with ALMA.

Successful joining of the back-up structure for the first European ALMA antenna.

Upgrade of the UVES instrument's red CCD detector.

ESO participates in the *The World at Night* photographic exhibition in Santiago, Chile.

August

Successful joining of the back-up structure for the second European ALMA antenna.

XXVII IAU General Assembly takes place in Rio de Janeiro, Brazil, with a major ESO presence.

The ISAAC instrument is moved from UT1 to UT3 on the VLT.

September

HARPS measurements establish the nature of the smallest and fastest-orbiting exoplanet known, CoRoT-7b.

The first of three images of ESO's Giga-Galaxy Zoom project is released.

The ESO website is now available in twelve languages.

Transport of the first ALMA antenna to the 5000-metre site.

First 7-metre ALMA antenna shipped from the port of Kobe, Japan, to Chile.

AOF's four laser guide star preliminary design completed.

A VO day is organised at ESO.

EIROforum is a partner at the European Contest of Young Scientists (EUCYS), Paris, France.

ESO participates in the 3rd Swiss Astronomy Day, held in Zug, Switzerland.

ESO is present at the 50 Plus Beurs, in Utrecht, the Netherlands, at the Highlights der Physik 2009 in Cologne, Germany, and at the Forskningstorget, University Plaza, Oslo, Norway.

Artist Tim Otto Roth spends a week at ESO, researching bridges between astronomy and art.

October

At an international ESO/CAUP conference in Porto, astronomers report on the discovery of 32 new exoplanets with HARPS.

IAU

ESO-hour during the IAU General Assembly 2009 in Rio de Janeiro, Brazil.

The VLT X-shooter spectrograph starts regular operation.

Start of the new La Silla operations model.

VISTA Science Verification run.

Transport of the second ALMA antenna to the 5000-metre site.

Operational Readiness Review held for the European ALMA Front-End Integration Centre.

First delivery of the ALMA central local oscillator system.

The laser research programme reaches 50 W output power.

Final review of the EAGLE E-ELT instrument study.

ESO workshop on Detectors for Astronomy held in Garching.

Committee of Council meets in Chile.

Scientific Technical Committee meets for its 71st session in Garching.

988 observing proposals are received for Period 85.

The ESO-led Galilean Nights IYA2009 project is organised all over the world.

The Galileomobile Project, supported by ESO and partners, starts its two-month expedition to bring the wonder and excitement of astronomy to young people in Chile, Bolivia and Peru.

ESO participates in the ANUGA major event in Cologne and at the Frankfurter Buchmesse, in Germany.

Joe Liske in the Atacama Desert in the movie *The EYE 3D*.

Representatives from industry and the European Commission, the European Investment Bank, the European Patent Office as well as government industrial liaison officers gathered in Heidelberg with technology transfer experts and decision makers in the EIROforum organisations for the two-day conference on technology transfer.


EMBL/M. Schupp

ESO plays a major role in the Chilean National Science & Technology Week. (ESO participates in the *Túnel de la Ciencia* event in Valparaiso, the *Fiesta de la Ciencia* and the *Noticias del Universo* events in Santiago, all in Chile.)

Opening of a 3D Movie Featuring ESO's Paranal Observatory, *The Eye 3D*.

Open House at ESO Headquarters attracts a record number of visitors.

EIROforum Technology Transfer Conference at EMBL in Heidelberg.

November

Astronomers make the first time-lapse movie of a rather unusual shell ejected by a "vampire star".

Transport of the third ALMA antenna to the 5000-metre site.

First fringes with two antennas are measured at the AOS. ALMA first fringes at submillimetre wavelengths.

Annual ALMA External Review is held in Chile.

Start of the construction of the ALMA Power Supply System.

Start of assembly of the third European ALMA antenna.

Final review of the MICADO E-ELT instrument study.

The first EIROforum Teacher School on the Evolution of the Universe takes place at CERN.

A Workshop Jointly organised by the Center for Astrophysics, University of Porto (CAUP) and ESO, Towards Other Earths: perspectives and limitations in the ELT era, is held in Porto, Portugal.

The ESO–MPE–MPA–USM 2009 Joint Workshop, From Circumstellar Disks to Planetary Systems, is organised in Garching.

ESO workshop on Galaxy Clusters in the Early Universe takes place in Pucón, Chile.

A workshop celebrating 20 years of AO at ESO is held in Garching.

An IVOA interoperability meeting takes place at ESO.

126th meeting of the Finance Committee.

85th meeting of the Observing Programme Committee.

ESO participates in the Lange Nacht der Forschung, Vienna, Austria.

ALMA Public Event at the Chilean Embassy in Berlin.

ESO is represented at the IYA Event in Dublin, Images of the Universe.

Successful measurements of the first phase closure with three ALMA antennas are made at the AOS.

ESO is present at the public event in Cork City, Ireland.

December

Using HARPS, astronomers discover the first super-Earth with an atmosphere.

The VISTA 4.1-metre Infrared Survey Telescope is provisionally accepted at a ceremony in Garching.

The Critical Design Review of the ALMA Amplitude Calibration Device is successfully held at ESO.

Final review of the MAORY E-ELT Adaptive Optics study and of the METIS E-ELT Instrument study.

Preliminary design reviews for the VLT AOF lasers.

115th Council Meeting in Garching.

New Financial Rules and Regulations are adopted by ESO Council.

Cosmic Evolution, a new exhibition at the Deutsches Museum featuring ESO, opens in Munich.

A collective view of the E-ELT Science cases is presented to the community.

ESO is present at the General Assembly of the EAAE.

Close-up of the dome of the Swiss 1.2-metre Leonhard Euler Telescope at La Silla. This telescope is named after the Swiss mathematician Leonhard Euler (1707–1783).

The third image of ESO's GigaGalaxy Zoom project is an amazing mosaic of the Lagoon Nebula taken with the Wide Field Imager attached to the MPG/ESO 2.2-metre telescope at the La Silla Observatory in Chile.

Publications

Publications in refereed journals based on ESO data (2009)

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Absil, O., Mennesson, B., Le Bouquin, J.B., Di Folco, E., Kervella, P. & Augereau, J.C. 2009, *An Interferometric Study of the Fomalhaut Inner Debris Disk. I. Near-Infrared Detection of Hot Dust with VLTI/VINCI*, ApJ, 704, 150

Adami, C., Le Brun, V., Biviano, A., Durret, F., Lamareille, F., Pelló, R., Ilbert, O., Mazure, A., Trilling, R. & Ulmer, M.P. 2009, *Very deep spectroscopy of the Coma cluster line of sight: exploring new territories*, A&A, 507, 1225

Ádámkovics, M., de Pater, I., Hartung, M. & Barnes, J.W. 2009, *Evidence for condazensed-phase methane enhancement over Xanadu on Titan*, P&SS, 57, 1586

Adén, D., Feltzing, S., Koch, A., Wilkinson, M.I., Grebel, E.K., Lundström, I., Gilmore, G.F., Zucker, D.B., Belokurov, V., Evans, N.W. & Faria, D. 2009, *A photometric and spectroscopic study of the new dwarf spheroidal galaxy in Hercules. Metallicity, velocities, and a clean list of RGB members*, A&A, 506, 1147

Alecian, G., Gebran, M., Auvergne, M., Richard, O., Samadi, R., Weiss, W.W. & Baglin, A. 2009, *Looking for pulsations in HgMn stars through CoRoT lightcurves*, A&A, 506, 69

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Glossary of Acronyms

2MASS	Two Micron All Sky Survey
4-LGSF	Four-Laser Guide Star Facility
AAAS	American Association for the Advancement of Science
A&A	Journal, Astronomy & Astrophysics
AAS	American Astronomical Society
ACD	Amplitude Calibration Device (ALMA)
ACS	ALMA Common Software
ACS	Advanced Camera for Surveys (Hubble)
ACT	ALMA temperature control system
AEM	ALMA construction consortium
AGB	Asymptotic Giant Branch
AGN	Active Galactic Nucleus
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)
APE	Active Phasing Experiment (E-ELT)
APEX	Atacama Pathfinder Experiment
APEX2a	APEX-2A heterodyne receiver
Aquarius	Mid-infrared array
ARC	ALMA Regional Centre
ASAC	ALMA Science Advisory Committee
ASSIST	Adaptive Secondary Setup and Instrument Simulator (AOF)
AstraLux	Lucky Imaging camera
ASTRONET	European consortium developing long-term strategic plan for European astronomy
AT	Auxiliary Telescope for the VLTI
ATC	Astronomy Technology Centre (United Kingdom)
AUI	Associated Universities Inc. (NRAO)
BAL	Broad Absorption Line
BBN	Big Bang Nucleosynthesis
BHB	Bright Horizontal Branch
BUS	Back-Up Structure (ALMA)
CADC	Canadian Astronomy Data Centre
CAPj	Journal, Communicating Astronomy with the Public
CASA	Offline data reduction system (ALMA)
CCD	Charge Coupled Device
CDF-S	Chandra Deep Field South
CEA	Commissariat à l'énergie atomique et aux énergies alternatives
CERN	European Organization for Nuclear Research
CIS	Control and Instrument Software Department
CMB	Cosmic Microwave Background
CMD	Colour-Magnitude Diagram
CMS	Content Management System
CONICA	COudé Near-Infrared CAmera (VLT)
CONICYT	Comisión Nacional de Investigación Científica y Tecnológica
CoRoT	COnvection ROtation and planetary Transits (French Satellite)
COS	Cosmic Origins Spectrograph (HST)
CP	Calibration Programme
CPU	Central Processing Unit
CRIRES	Cryogenic InfraRed Echelle Spectrometer (VLT)
CSV	Commissioning and Science Verification
CV	Cataclysmic Variable
DC	Direct Current
DDL	Differential Delay Line (VLTI)
DDT	Director's Discretionary Time
DG	Director General
DLA	Damped Lyman Alpha Absorber
DMO	Data Management and Operations Division
DOORS	Requirement management software (ALMA)
DRM	Design Reference Mission (E-ELT)
DRSP	Design Reference Science Plan (E-ELT & ALMA)
DTS	Data Transmission System (ALMA)
EAAE	European Association for Astronomy Education
EAGLE	Multi-object NIR spectrograph (E-ELT)
EASC	European ALMA Support Centre
EC	European Commission
ECDF-S	Extended Chandra Deep Field South
E-ELT	European Extremely Large Telescope
EFOSC2	ESO Faint Object Spectrograph and Camera (v.2)
EIB	European Investment Bank
EIROforum	Organisation consisting of the seven largest scientific European international organisations devoted to fostering mutual activities
EMBL	European Molecular Biology Laboratory (Germany)
EMMI	ESO Multi-Mode Instrument (NTT)
EPO	Education and Public Outreach
ePOD	education and Public Outreach Department
ERA	European Research Area
ERO	Early Release Observations (Hubble)
ERP	Enterprise Resource Planning
ESA	European Space Agency
ESAC	European Science Advisory Committee (for ALMA)
ESE	ELT Science and Engineering
ESFRI	European Strategy Forum on Research Infrastructures
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
ESON	ESO Science Outreach Network
EU	European Union
EUCLID	ESA dark energy mission
EUCYS	EU Contest for Young Scientists
Euro-VO	European Virtual Observatory
EVALSO	Enabling Virtual Access to Latin-american Southern Observatoies
FE	Front-End
FEED	Front-End Engineering Design (E-ELT)
FEIC	Front-End Integration Centres (ALMA)
FEROS	Fibre-fed, Extended Range, Échelle Spectrograph (2.2-metre)
FHB	Faint Horizontal Branch
FINITO	Fringe Tracking Instrument Nice Torino (VLTI)
FITS	Flexible Image Transport System
FLAMES	Fibre Large Array Multi Element Spectrograph (VLT)
FORS1	FOcal Reducer/low dispersion Spectrograph (VLT)-1
FORS2	FOcal Reducer/low dispersion Spectrograph (VLT)-2
FP6	Sixth EC Framework Programme
FP7	Seventh EC Framework Programme
FSUs	Fringe Sensor Units (VLTI)
FTE	Full Time Equivalent
FWHM	Full Width Half Maximum
GALACSI	Ground Atmospheric Layer Adaptive Optics for Spectroscopic Imaging (AOF)
GB	Gigabyte
GHz	Gigahertz
GOODS	Great Observatories Optical Deep Survey
GRAAL	GRound-layer Adaptive optics Assisted by Lasers (AOF)
GRAVITY	AO assisted, two-object, multiple-beam-combiner (VLTI)
GRB	Gamma-Ray Burst
GTC	Gran Telescopio Canarias
GUI	Graphical User Interface
HARPS	High Accuracy Radial Velocity Planetary Searcher (3.6-metre)
HAWK-I	High Acuity Wide field *K*-band Imager (VLT)
HLA	Hubble Legacy Archive
HR	Human Resources
HST	Hubble Space Telescope
IAU	International Astronomical Union
IFS	Integral Field Spectrograph (SPHERE, E-ELT)
IFU	Integral Field Unit
INAF	Istituto Nazionale di Astrofisica (Italy)
IPP	Max-Planck Institute for plasma Physics (Germany)
IPT	Integrated Product Team (ALMA)
IQ	Server system
IQuEye	Italian Quantum Eye (NTT)
IR	Infrared
IRDIS	InfraRed Dual-beam Imager and Spectrograph (SPHERE, E-ELT)
IRIS	VLTI Infrared Image Sensor
IRO	International Relations Office
IRAM	Institut de Radioastronomie Millimétrique
ISAAC	Infrared Spectrometer And Array Camera (VLT)
ISM	InterStellar Medium
IT	Information Technology
IVOA	International Virtual Observatory Alliance
IYA2009	International Year of Astronomy 2009
JAO	Joint ALMA Observatory
JENAM	Joint European and National Astronomy Meeting
JSM	Joint Statistical Meetings
KMOS	*K*-band Multi-Object Spectrograph (VLT)
Kueyen	VLT Unit Telescope 2
LABOCA	Large APEX Bolometer CAmera
LGS	Laser Guide Star
LGSF	Laser Guide Star Facility
LINER	Low-ionisation nuclear emission-line region galaxy
LP	Large Programme
LPO	La Silla Paranal Observatory
LS-QUEST	La Silla QUEST survey
LSP	La Silla Paranal Committee
M2	Mirror #2 in E-ELT AO unit
M5	Mirror #5 in E-ELT AO unit
MAD	Multi-conjugate Adaptive optics Demonstrator
MAORY	Multi-conjugate Adaptive Optics RelaY (E-ELT)
mas	milliarcseconds
MATISSE	Multi AperTure mid-Infrared SpectroScopic Experiment (VLTI)

MCAO	Multi-Conjugate Adaptive Optics
Melipal	VLT Unit Telescope 3
METIS	Mid-infrared imager-spectrograph (E-ELT)
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)
MUNIN	Networked resource monitoring tool
MUSE	Multi Unit Spectroscopic Explorer (VLT)
MUX	Multiplexer (ALMA)
NACO	NAOS-CONICA (VLT)
NAGIOS	IT infrastructure monitoring system
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
NICMOS	Near Infrared Camera and Multi-Object Spectrometer (Hubble)
NIR	Near-Infrared
NOVA	The Netherlands Research School for Astronomy (Nederlandse Onderzoekschool voor Astronomie)
NRAO	National Radio Astronomical Observatory
NTT	New Technology Telescope
NWO	Netherlands Organisation for Scientific Research
OB	Observation Block
ODG	Office of the Director General
OmegaCAM	Optical Camera for the VST
OPC	Observing Programmes Committee
OPTICON	Optical Infrared Coordination Network for Astronomy
OSF	ALMA Operations Support Facility
OSO	Onsala Space Observatory
P2P	Peer to Peer
P84	Observing Period 84
P85	Observing Period 85
PA	Product Assurance (ALMA)
PB	Petabyte
Pc	Parsecs
PDS	Planetary Data System image format
PI	Principal Investigator
PIONIER	Proposed VLTI visitor instrument
PLC	Programmable Logic Controllers (E-ELT)
PMS	Pre-Main Sequence
PRIMA	Phase-Referenced Imaging and Micro-arcsecond Astrometry facility (VLTI)
PSD	Pipeline Systems Department
PSF	Point Spread Function
QSO	Quasi Stellar Object
QSR	Quasi-Stellar Radio-source
R&D	Research and Development
RadioNet	EC-wide activity for European radio observatories funded under FP7
RAL	Rutherford Appleton Laboratory, Didcot (UK)
RAMIRI	Realising and Managing International Research Infrastructures
REM	Rapid Eye Movement Telescope (La Silla)
rms	Root mean square
RRM	Rapid Response Mode
SABOCA	Shortwave Apex BOlometer Camera
SAC	Euro-VO Science Advisory Committee
SCO	Santiago Central Office (ALMA/ESO Vitacura)
SDD	Software Development Division
SE	System Engineering (ALMA)
SED	System Engineering Department
SHFI	Swedish Heterodyne Facility Instrument (APEX)
SINFONI	Spectrograph for INtegral Field Observations in the Near Infrared (VLT)
SM4	Servicing Mission 4 (HST)
SOFI	SOn oF Isaac (NTT)
SPARTA	Real-time computer platform for AOF and SPHERE
SPHERE	Spectro-Polarimetric High-contrast Exoplanet Research instrument
SSAC	Site Selection Advisory Committee
SSWG	Science Strategy Working Group
STAC	Standing Advisory Committee
STC	Scientific Technical Committee
ST-ECF	Space Telescope European Coordination Facility
STFC	Science and Technology Facilities Council (UK)
STIS	Slit spectrograph (HST)
STRAP	Tip-tilt sensors (VLTI)
STScI	Space Telescope Science Institute (USA)
SV	Science Verification
SVMT	Survey Visualisation and Monitoring Tool
TAROT	Télescope à Action Rapide pour les Objets Transitoires
TB	Terabyte
TFB	Tunable Filter Bank (ALMA)
ToO	Target of Opportunity
TT	Technology Transfer
TWAN	The World At Night
TWG	Thematic Working Group
UC	Users Committee
UK	United Kingdom
UKIRT	UK Infrared Telescope
ULTRACAM	High-speed camera (NTT)
UN	United Nations
UT	Unit Telescope of the VLT
UT1–4	VLT Unit Telescopes 1–4: Antu, Kueyen, Melipal and Yepun
UV	Ultraviolet
uv-plane	Fourier Transform plane of the sky brightness distribution, as measured by interferometers
UVES	UV-Visual Echelle Spectrograph (VLT)
VIMOS	VIsible MultiObject Spectrograph (VLT)
VIRCAM	VISTA IR Camera
VirGO	Visual Archive Browser
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
WDM	Wavelength Division Multiplexing
WFC3	Wide Field Camera 3 (Hubble)
WFCAM	Infrared wide field camera for the UK Infrared Telescope on Mauna Kea
WFI	Wide Field Imager (2.2-metre)
WFS	WaveFront Sensors
WMAP	Wilkinson Microwave Anisotropy Probe
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)

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ESO is a partner in the international ALMA project

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Cover: This wide-field near-infrared view of the Orion Nebula lying about 1350 light-years from Earth, was taken with the VISTA infrared survey telescope at ESO's Paranal Observatory in Chile.
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