ESO

European Organisation
for Astronomical
Research in the
Southern Hemisphere

Annual Report 2015

ESO

European Organisation
for Astronomical
Research in the
Southern Hemisphere

Annual Report 2015

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 16 countries: Austria, Belgium, Brazil[1], the Czech Republic, Denmark, France, Finland, Germany, Italy, the Netherlands, Poland, 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 world-class observing sites in the Atacama Desert region of Chile: La Silla, Paranal and Chajnantor. ESO's first site is at La Silla, located 2400 metres above sea level and 600 kilometres north of Santiago de Chile. It is equipped with several optical telescopes with mirror diameters of up to 3.6 metres.

The 3.5-metre New Technology Telescope (NTT) broke new ground in the 1980s 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. La Silla remains at the forefront of astronomy, and is the second-most scientifically productive observatory in ground-based astronomy (after Paranal). The Paranal site is located at 2600 metres above sea level and is home to the Very Large Telescope (VLT), the Visible and Infrared Survey Telescope for Astronomy (VISTA), the world's largest survey telescope and the VLT Survey Telescope (VST), the largest telescope designed to exclusively survey the skies in visible light. Paranal is situated about 130 kilometres south of Antofagasta in Chile, 12 kilometres inland from the Pacific coast in one of the driest areas in the world. Scientific operations began in 1999 and have resulted in many extremely successful research programmes.

ESO/G. Hüdepohl (atacamaphoto.com)

Paranal and the Pacific Ocean at sunset.

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 8.2 metres in diameter. With one such telescope, images of celestial objects as faint as magnitude 30 have been obtained in a one-hour exposure. This corresponds to seeing objects that are four billion times fainter than those seen with the naked eye.

One of the most exciting features of the VLT is the option to use it as a giant optical interferometer (VLT Interferometer or VLTI). This is done by combining the light from two or more of the 8.2-metre telescopes or two or more of the four 1.8-metre movable Auxiliary Telescopes. In this interferometric mode, the telescope has vision as sharp as that of a telescope the size of the separation between the most distant mirrors. For the VLTI, this is 200 metres.

ESO/A. Ghizzi Panizza (www.albertoghizzipanizza.com)

Part of the Atacama Large Millimeter/submillimeter Array.

[1] Brazil has already signed an Accession Agreement and will officially become the 16th Member State of ESO on completion of the requisite ratification process.

ESO/B. Tafreshi (twanight.org)

Panorama view of the La Silla Observatory.

Each year, almost 2000 proposals are submitted for the use of ESO telescopes, requesting between three and six times more nights than are available. ESO is the most productive ground-based observatory in the world whose operation yields many peer-reviewed publications: in 2015 alone, 860 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 comprises an array of 66 antennas of 12- and 7-metre diameter observing at millimetre and submillimetre wavelengths. ALMA started scientific observations in 2011 and was inaugurated in 2013. ALMA is located on the high-altitude Chajnantor Plateau, at 5000 metres above sea level — one of the highest astronomical observatories in the world. The ALMA project is a partnership between ESO, East Asia and North America, in cooperation with the Republic of Chile.

The Chajnantor site is also home to the Atacama Pathfinder Experiment (APEX) a 12-metre diameter 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 the construction of the European Extremely Large optical/infrared Telescope (E-ELT) with a primary mirror 39 metres in diameter. The E-ELT will be "the world's biggest eye on the sky" — the largest optical/near-infrared telescope in the world. When complete 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. Construction work has already begun: the site on Cerro Armazones has been prepared and major contracts have been signed. The start of E-ELT operations is expected around 2024.

ESO Headquarters are located in Garching, near Munich, Germany. This is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the observatories with the most advanced instruments. ESO's offices in Chile are located in Vitacura, Santiago. They host the local administration and support groups, and are home to ESO/Chile astronomers when they are not at the observatories. This site also contains the ALMA Santiago Central Office. ESO Vitacura is an active node for training new generations of researchers, acting as a bridge between scientists in Europe and Chile.

The total regular Member State contributions to ESO in 2015 were approximately 198 million euros and ESO employs around 680 staff.

ESO/L. Calçada/ACe Consortium

Artist's rendering of the European Extremely Large Telescope on top of Cerro Armazones.

Contents

Foreword by the President of Council	6
Introduction by the Director General	7
Science	10
Research Highlights	11
Offices for Science	20
Allocation of Telescope Time	24
Publication Digest	27
Operations	32
La Silla Paranal Observatory	33
Data Management and Operations	42
ALMA and the ESO ALMA Support Centre	46
Programmes	54
Instrumentation for the La Silla Paranal Observatory	55
Technology Development	62
European Extremely Large Telescope	64
Engineering	70
Administration	80
Finance and Budget	82
Human Resources	86
List of Staff	90
Organigram	94
Director General Support	96
Committees	104
Council	105
Finance Committee	106
Scientific Technical Committee	107
Observing Programmes Committee	109
Users Committee	111
Outreach	112
Calendar of Events	118
Glossary of Acronyms	122

Foreword by the President of Council

ESO's observatories in Chile are located in some of the driest regions on the planet. The clear, dark skies and dry atmospheric conditions that are characteristic of the Atacama Desert enable astronomers to make very sensitive observations of the cosmos. At least, that is the normal state of affairs. In March 2015, a very unusual weather pattern developed off the west coast. This led to rainstorms in northern Chile, which produced floods, mudslides and substantial damage and loss of life. These tragic events greatly affected many people in the desert towns, and naturally also raised real concerns amongst the staff at the observatories. Thankfully, none of the ESO staff or their immediate families were directly impacted by this severe weather. It is, however, a reminder that we are vulnerable to extreme events in nature. The observatories are built to the highest engineering standards to withstand such events, and on this occasion, were quickly brought back into operation once communications had been restored.

ESO's scientific output relies on the ingenuity, dedication and support provided by the ESO staff in Chile and Europe, working with institutes and industry in the Member States and the Republic of Chile. On behalf of Council, I wish to express my thanks to everyone for their contributions, which continue to ensure the success of the ESO programme.

Delegates to ESO Council met in Leiden in March, where we witnessed the unveiling of a plaque containing the 1954 Declaration resulting from the first discussions between astronomers from six European countries that eventually led to the formation of ESO in 1962. In June, we met in Lisbon, and celebrated 15 years of Portuguese contributions to ESO, and in October we met at the ESO Office in Santiago and visited the observatory sites. It was especially impressive to stand on the newly flattened summit of Cerro Armazones, the site of the E-ELT and also to witness the antenna transporters reconfiguring the ALMA array on the Chajnantor Plateau.

Commissioning of ALMA continues, with more modes becoming available and results from the long-baseline campaign published to wide acclaim. The high resolution images of planet-forming discs, lensed galaxies, stellar envelopes and Solar System objects demonstrate that ALMA is achieving its design goals, which will further increase the demand from the scientific community. The number of proposals for ALMA observations is expected to continue to rise in the next few cycles. With data on actual ALMA operations now available for a number of years, a review of ALMA operations was conducted in April. This will inform future maintenance, overhaul requirements and improve planning in the future. Council welcomed the new Trilateral Agreement governing ALMA operations and development, which was signed in Tokyo in December.

Twenty years have elapsed since the first exoplanet in orbit around a solar-type star was identified. ESO facilities are central to the discoveries that continue to challenge our ideas on planet formation and evolution. The role of the HARPS spectrograph, which has led the way in high-precision radial velocity measurements of exoplanet host star reflex motion, has been strengthened by the approval of new instruments for both the ESO 3.6-metre and NTT telescopes on La Silla. These new instruments will enhance the exoplanet instrumentation suite and extend coverage of transient object science, complementing the smaller robotic telescopes that are used for monitoring programmes for planet detection.

Further instrumentation developments to support exoplanet and other high profile science topics are underway for Paranal. These include the ESPRESSO spectrograph for the VLT combined focus and the interferometric instrument GRAVITY, which achieved first light with its beam combiner instrument. Given the scale of the necessary modifications to the VLT/VLTI infrastructure to enable these instrument developments, it was very gratifying to see how smoothly the resumption of operations proceeded.

The road to Armazones and the work to prepare the mountaintop for the construction of the E-ELT have been completed. Contracts for some of the longest lead-time optics have been placed, and planning and review of tenders for major components of the telescope continued throughout 2015. Contracts for the first instruments were signed between ESO and consortia in the Member States between September and December. The science capabilities of the world's most powerful optical/infrared telescope when it achieves first light are now agreed, and the project remains on track. A consultation process to review ESO's capabilities in the era of the E-ELT has been initiated and a vision for the 2020s is being formulated. It will certainly be an exciting time, with ESO continuing to play a leading role in astronomical discovery.

Introduction by the Director General

ESO's programme made exciting progress on all fronts this year. Poland ratified the Accession Agreement and formally became the 15th Member State on 8 July 2015. Brazilian accession made decisive progress through ratification by both the House and the Senate, but still requires the final signature of the President. A number of other countries are considering membership, including Ireland and Norway.

The VLT continues to produce spectacular scientific discoveries, in particular with the second generation instruments KMOS, MUSE and SPHERE. The VLTI was taken offline for six months, and the massive joint efforts of the teams on Paranal and at ESO Headquarters led to a full reorganisation of the VLTI laboratory and construction of the required extra infrastructure for the second generation instruments GRAVITY and MATISSE, solving a number of unexpected problems along the way. All this took place while the infrastructure upgrades required for placing ESPRESSO at the incoherent combined focus, as well as the commissioning of further components for the Adaptive Optics Facility (including the first 22 watt laser of the 4 Laser Guide Star Facility and the GRAAL module) were being carried out. The VLTI was successfully recommissioned in September with AMBER and the relocated PIONIER-3D, and the GRAVITY instrument saw first fringes in October, on track to observe the passage of the Galactic Centre black hole by the celebrated S2 star in 2018.

High-level visitors to Paranal included His Excellency Matteo Renzi, Prime Minister of Italy, the Spanish Secretary of State, Her Excellency Carmen Vela, and the Director General of the European Space Agency (ESA), Johann-Dietrich Wörner, as well as many ambassadors and other dignitaries.

New instrumentation was selected for both the NTT and the ESO 3.6-metre telescope on La Silla, to be built by external consortia. This enables the NTT to focus on following up transients, and the ESO 3.6-metre telescope to cover a larger range of stars hosting exoplanets, positioning it perfectly to provide critical complementary observations for the CHaracterising ExOPlanets Satellite (CHEOPS) and PLAnetary Transits and Oscillations of stars (PLATO) space missions. Anti-obsolescence work has to be done to keep these venerable telescopes running for at least another decade, but is worthwhile given the scientific return. This development also makes it possible to keep La Silla open as a site for national and robotic telescopes, which is welcomed by the community.

ESO's team, operating APEX on behalf of the partnership with the Max Planck Institute for Radio Astronomy in Bonn and the Onsala Space Observatory, topped last year's record number of hours on sky. The antenna received new instrumentation and the scientific output remains high.

The number of observing proposals in the annual cycle for ALMA again increased, with the oversubscription factor and publication rate remaining the highest for the ESO community. Many scientific discoveries have been made, including ultrasharp studies of star formation in the early Universe, protoplanetary discs in the Milky Way, mass-losing stars and objects in the Solar System. The ESO ALMA Regional Centre and its nodes in various Member States provide timely user support. An external review of ALMA operations highlighted areas requiring attention, in particular the need to improve the observing efficiency and effective maintenance of the facility, while new observing modes are being added. The set of bilateral agreements which governed ALMA construction and early operations was replaced by a single Trilateral Agreement between the National Institute for Natural Sciences in Japan, the National Science Foundation of the United States and ESO. It went into force after signature in Tokyo on 15 December. The construction of the ALMA Residencia is on track for hand-over to the Joint ALMA Observatory in the second half of 2016.

The construction of E-ELT Phase 1 is on schedule. The new road to Armazones and the platform on the summit were completed. Contracts for the shell and unit of the adaptive quaternary mirror are running. Agreements are in place with all the consortia building the Phase 1 instruments: MICADO, HARMONI and METIS, as well as the adaptive optics module

Y. Beletsky (LCO)/ESO

MAORY. This not only commits ESO funding for the hardware, but also secures much external funding for staff effort in Member State institutions. The carefully designed multi-year process to place a contract for the dome and telescope structure was completed by the end of the year, and the contract was awarded in a special Finance Committee meeting early in 2016, with very broad support from the Member States. It may well be the largest contract in ground-based astronomy placed to date. Work on the various optomechanical components is also proceeding well. The unexpected drop in value of the euro in January 2015 put additional pressure on the budget for future years, but steps are being taken to stay on track for first light in 2024.

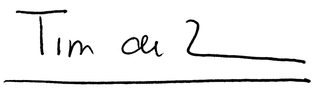
ESO has long-standing collaborations with its sister organisations, ESA and CERN (the European Organization for Nuclear Research), and these have now been put into a more solid framework by the signature of formal cooperation agreements blessed by Council. This move enables new initiatives to be effectively implemented.

The Cherenkov Telescope Array partnership selected the Paranal area as the preferred location for Cherenkov Telescope Array-South, an array of 99 optical telescopes of three different sizes that would observe the brief flashes of light generated in the upper atmosphere by very high energy gamma radiation from objects in the Universe. It is foreseen that ESO would operate the facility, and negotiations towards a partnership agreement have started.

On 24 February the groundbreaking ceremony took place for the ESO Supernova Planetarium & Visitor Centre, a state-of-the-art facility to showcase astronomy to the general public, donated by the Klaus Tschira Foundation. The construction requires innovative techniques and is advancing on schedule for completion in mid-2017. Klaus Tschira sadly passed away at the end of March 2015. He was a strong supporter of science education in general, and astronomy in particular, and a friend of ESO.

A poll early in the year demonstrated that the user community is generally very happy with the instrumentation and support offered by ESO. The workshop entitled ESO in the 2020s, which took place in January, resulted in the creation of various working groups to study possible future facilities.

All these achievements are possible because of the dedication and skills of ESO's staff, across all sites, disciplines and nationalities. As a result, ESO is now poised to take world-leadership in ground-based astronomy.



Time-lapse sequence of the total lunar eclipse of 27 September 2015 over ESO Headquarters.

ESO/M. Zamani

Science

Research Highlights

The Directorate for Science provides scientific guidance to all science-related projects at ESO. To remain adequately informed about the activities that ESO should support, directorate scientists interact closely with the scientific community through committees, workshops, seminars, individual contacts, and joint personal research projects. Broad strategic conferences, rather than just topical workshops, are especially important.

One such conference, with strong community attendance, was ESO in the 2020s, held in Garching from 19–22 January 2015. For the first time, this workshop was accompanied by a web-based community poll. There were 2517 registered ESO users who shared their views about expected shifts in scientific emphasis. Most importantly, they indicated which current and future facilities and services ESO should prioritise in order to put its community into the best possible position to be leaders of the new developments. After careful analysis, ESO scientists and representatives of the community prepared an extensive public report on scientific prioritisation to the Scientific Technical Committee (STC), available as document STC-551. Directorate scientists are now propagating the conclusions into the forward planning.

During the course of the year, we welcomed Michele Cirasuolo (formerly of the UK Astronomy Technology Centre [UK-ATC] in Edinburgh) as the new E-ELT Programme Scientist. He is replacing Jochen Liske, who accepted a professorship at the University of Hamburg.

Dust particles in the vast clouds that surround the star HD 97300 diffuse its light and create the reflection nebula IC 2631.

Assessing the scientific impact of research facilities is notoriously difficult, as no established standards exist. In addition, only modern observatories have the tools in place to collect the relevant data (programme and observing statistics, publications, citations, etc.). Two in-depth studies of the scientific impact of the VLT after 15 years (Sterzik et al., 2015) and of the first years of ALMA (Stoehr et al., 2015) demonstrate the high level of acceptance and usage of these facilities by the community. Separately, the impact of the ESO Large Programmes and Public Surveys was presented at the 2015 workshop Rainbows on the Southern Sky (see the summary by Arnaboldi et al., 2015). Scientific highlights of some of the Public Surveys were presented in the Annual Report 2014.

Research facilities must be continually renewed to improve their instrumentation and operational models. The VLT second generation instruments, the *K*-band Multi-Object Spectrograph (KMOS), Multi Unit Spectroscopic Explorer (MUSE) and Spectro-Polarimetric High-contrast Exoplanet Research instrument (SPHERE), completed their commissioning during 2014 and 2015. We present here some exciting first results from these instruments.

For ALMA, 2015 was the year when the first glimpse of the scientific promise of the long baselines was revealed. In addition, initial science results from Cycles 1 and 2 projects using intermediate baselines and with an overall collecting area close to that of the final construction project were published. We highlight some of the most impressive results coming from these new capabilities.

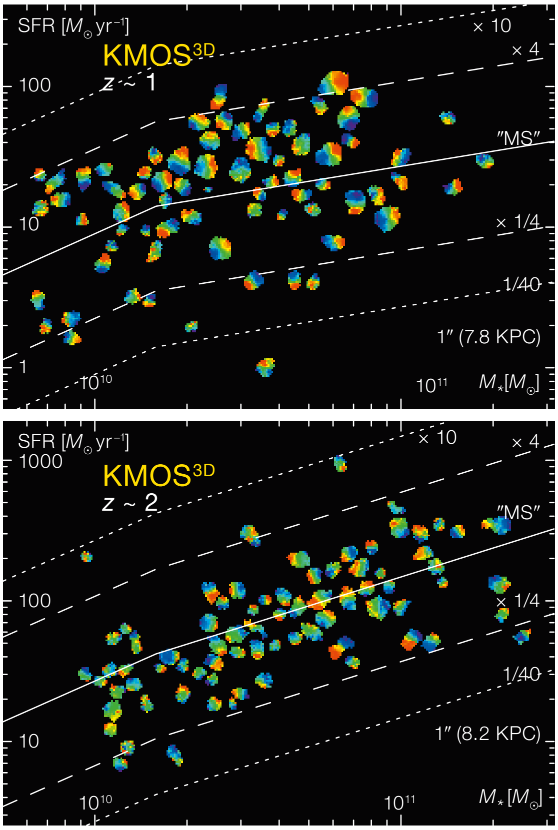
Sampling star-forming galaxies during their most active phase

The growth of stellar mass through the conversion of gas into stars in galaxies can be followed throughout the observable history of the Universe. The most intense phase of star formation was between redshifts 1 and 2.5 (i.e., between 7.7 and 10.9 billion years ago). Star formation is a balance between gas inflow from the cosmic web and the merging of smaller galaxies into bigger ones, and the recycling of gas back into the environment through outflows (referred to as feedback), driven by the star formation itself or by active galactic nuclei. A relation between the star formation rate and the mass of galaxies, referred to as the "main sequence", has been established, with larger mass galaxies showing higher star formation rates. Only at the most massive end, at stellar masses $M_* > 10^{11}\,M_\odot$, does the star formation of a galaxy appear to be suppressed (quenched).

While star-forming galaxies at redshifts greater than one have been observed for some time, spatially resolved spectroscopy through the use of integral-field instruments such as the Spectrograph for INtegral Field Observations in the Near Infrared (SINFONI), provides much additional information — on the mass, spatially resolved kinematics, star formation rate, gas excitation, metallicity and outflows. The KMOS spectrograph has been used to extend these studies to hundreds of galaxies and thus expand the collection of statistically significant samples. One programme aims to assemble a sample of about 600 mass-selected star-forming disc galaxies with $M_* > 10^{9.5}\,M_\odot$ at redshifts between 0.7 and 2.7, in order to probe the kinematics, metallicities and physical conditions of the interstellar medium within the galaxies through the peak of cosmic star formation towards the current epoch of low activity.

The first analyses with more than 200 galaxies in the sample have already yielded interesting results. Star formation generally appears to be dominated by rotating disc galaxies at all redshifts. The build-up of mass, central mass concentration and ordered rotation as a function of stellar mass can be followed. Galaxies with strongly enhanced rates of star formation for their mass, i.e., starbursts, located above the main sequence, are typically unresolved and do not show rotation. The galaxies below the main sequence, i.e., with reduced star formation at a given mass, are all rotating. From redshift $z = 2$ to $z = 1$, the velocity dispersion of the ionised gas decreases by a factor of two, which is consistent with a picture where the balance between star formation and fuelling by gas initiates turbulent motions in the discs.

Spectral analysis of galaxies in the same redshift range, which display a large ratio of the [N II] to Hα emission lines, reveals centrally concentrated broad lines for some objects. These are interpreted as outflows of gas from the nuclear region, presumably due to the presence of an active galactic nucleus (AGN). This kind of feedback has been predicted to quench the conversion of baryons into stars at high galaxy masses ($M_\star > 10^{10.9}\ M_\odot$). Combining data from several 8-metre telescopes, including the instruments SINFONI and KMOS on the VLT, the diagnostic emission lines of Hα, [N II] and [S II] were analysed in a sample of 110 galaxies (the largest currently available). A broad circumnuclear emission component (with half-peak line widths from 450 to 5300 km s^{-1}) could be found in most massive galaxies (more than half of the galaxies with $M_\star > 10^{10.9}\ M_\odot$) across the complete redshift range (0.8–2.6). The gas in the outflow cannot be gravitationally bound and a substantial fraction of the baryons must be lost from the galaxy, which leads to the quenching of the star formation. The diagnostic line ratios indicate that the outflow most probably emerges from a powerful AGN. Compared to the fraction of AGNs identified through X-ray, optical, infrared and radio data, the inferred fraction from this sample is a factor of two larger. A possible explanation is that the duty cycle, the time during which an AGN is active, is fairly short and direct detection is no longer possible, while the outflowing gas still reflects past activity.



Rotation of disc galaxies at redshifts 1 (upper) and 2 (lower), colour-coded by velocity, is shown in a diagram of star formation rate (SFR) *vs.* stellar mass ($M_\star$). From Wisnioski et al. (2015).

Stellar environments revealed

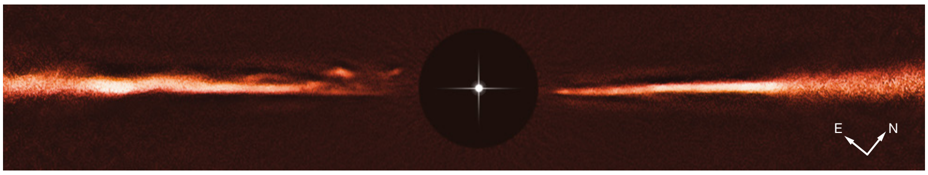
With the advent of adaptive optics and interferometry, stars other than the Sun are no longer simple balls of plasma. Regions close to other stars have become observable through the high angular resolution achieved by modern instruments. It is now common to observe the close neighbourhood of stars on the scale of the inner Solar System, i.e., a few astronomical units (au). The extreme adaptive optics capabilities of SPHERE have allowed astronomers to detect the dynamical changes in disc outflows around a young dwarf star, the structure of a dust disc around an evolved low-mass star and the sources of dust ejection around a supergiant star.

The young (~ 23 Myr old) M-type star AU Microscopii is surrounded by a debris disc largely consisting of dust left over from the formation of the star. SPHERE commissioning data revealed a knotty structure in the nearly edge-on disc, with several brighter regions above the disc plane to the southeast of the star and visible at near-infrared (1.25 μm) and optical (~ 800 nm) wavelengths. The inner features are about 10 to 20 au from the star.

Comparison with images taken by the NASA/ESA Hubble Space Telescope (HST) from 2010 and 2011 has revealed a radially outward movement of the disc features at projected speeds of 4 to 10 km s^{-1}. For a stellar mass of about 0.6 $M_\odot$, material in the outer features should not be gravitationally bound to the star. It is difficult to understand what drives these knots, given the apparent lack of similar features in the northwest part of the disc. Future observations with SPHERE will be able to follow the evolution of the dust in the disc. ALMA can also provide information on the gas distribution, and optical Hα imaging with SPHERE may detect gas accretion onto protoplanets.

The evolved star L_2 Puppis shows a prominent disc seen nearly edge-on, which has previously been extensively observed with the high-resolution near-infrared camera (NAOS-CONICA). The three-dimensional structure of the disc can now be assessed at optical wavelengths through polarimetric observations with SPHERE. These optical data uncovered a companion star with a separation of about 33 milliarcseconds or 2 au and a suspected orbital period in the range of one to five years. The polarised image displays several features that indicate that the binary star creates streamers orthogonal to the disc. Dust plumes emerging from the disc are also observed and hint at complicated interactions between the winds of the two stars and the dust disc itself. Future observations will show whether this system will develop into a bipolar planetary nebula.

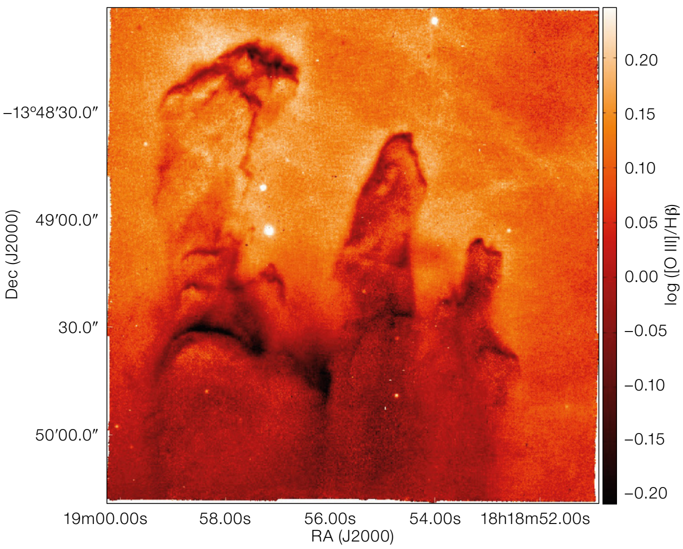
Massive stars lose a large fraction of their mass during their short lifetimes. Near the ends of their lives they become red supergiant stars with expanded, cool atmospheres. The mechanisms driving the winds during this phase are not understood and depend strongly on the size of the dust grains formed in the outer envelopes. VY Canis Majoris is a prime example of such a star and SPHERE obtained optical polarimetry of the inner region, resolving the ejecta in unprecedented detail. The polarisation reveals the scattering properties of dust clumps and provides evidence for the size of the dust grains. The grains are substantially larger than those typically found in the interstellar medium and they are large enough to be subjected to significant radiation pressure due to photon scattering. This mechanism could eject a significant amount of dust (~ 0.2 $M_\odot$) from this single star into the interstellar medium.

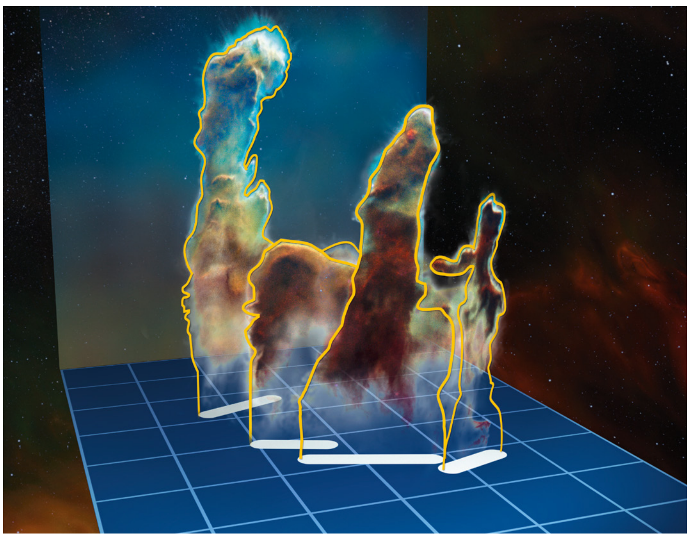


SPHERE *J*-band (1.25 µm) image of the debris disc of AU Mic. The direct starlight has been blocked by a coronagraph, enabling the disc to be imaged with high sensitivity.

The Universe in three dimensions

Massive stars shape their environment. Their intense radiation ionises large regions around them and the stellar winds destroy denser structures from the natal giant molecular cloud. The denser regions evaporate more slowly and can result in towering pillars that are eroded with time. The most prominent examples of such interactions are the iconic Pillars of Creation in the Eagle Nebula (M17).





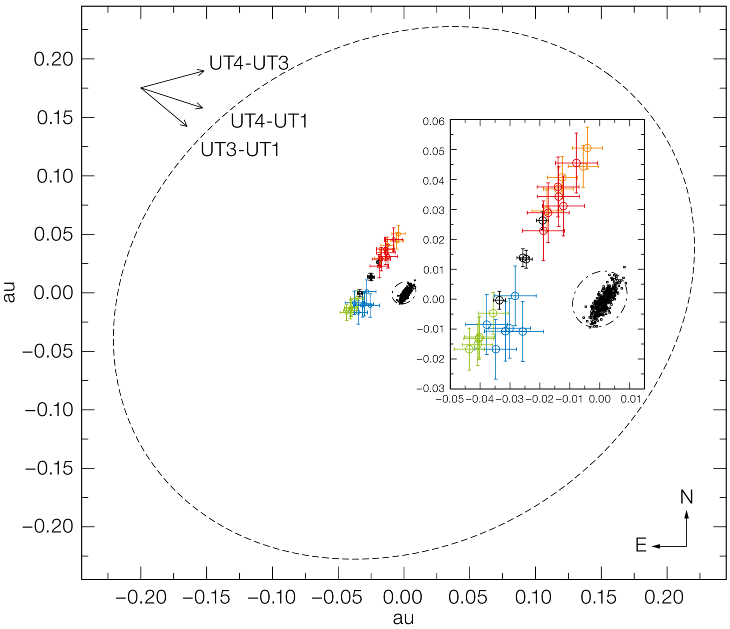
Left: Line ratio image of [O III] to Hβ, sensitive to the ionisation state of the gas, over the Pillars of Creation in M17 derived from MUSE data. From McLeod et al. (2015). Right: Visualisation of the three-dimensional structure of the Pillars of Creation (the relative distance between the pillars along the line of sight not to scale).

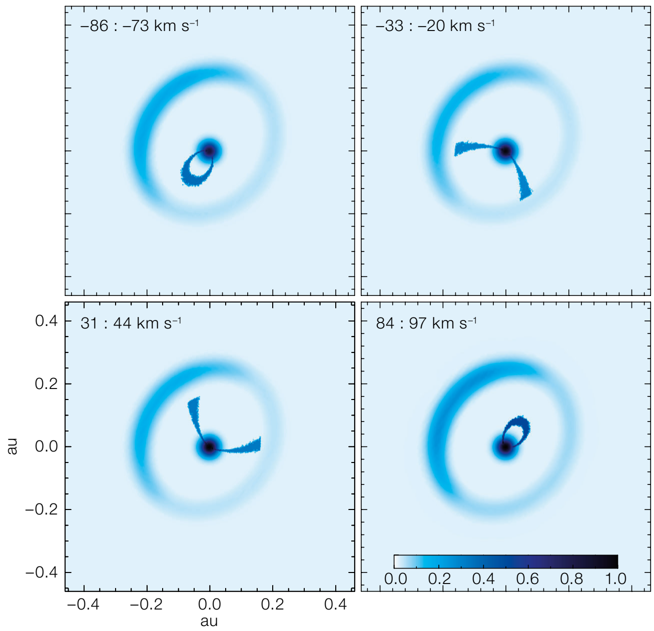
Integral-field observations with MUSE have, for the first time, mapped the whole region in emission lines. The extinction, ionisation structure, electron density and temperature could be determined for many picture elements over the pillars, hence separating the different emission regions. As a result, the geometry of the pillars could be determined and their position relative to the ionising stars mapped. There are four pillars, with one probably positioned at a larger distance from us than the ionising stars and the other three in front of the stars, and inclined towards them. At the current rate of erosion, the lifetime of the pillars is estimated to be about 3 million years. The MUSE velocity map also indicates a bipolar outflow of material, presumably from a protostar, near the tip of the central pillar.

Observing the distant Universe requires data on faint sources. Spectroscopy of faint galaxies with conventional spectrographs is difficult and time-consuming. The integral field spectrograph MUSE obtains medium-resolution spectra of every source within its 1 by 1 arcminute field of view. A deep observation (27 hours integration) of the Hubble Deep Field South containing ~ 90 000 spectra has been obtained and is among the deepest spectroscopic observations in the optical. Analysis of the spectra of objects identified by HST in the same field has yielded 181 redshifts, a tenfold increase over the known redshifts in the field and, for the first time, redshifts of faint sources (I > 25 mag). Lyman-α emission from 26 previously unknown objects (I > 29.5 mag) was also detected. The observed redshift distribution is rather flat and extends to higher redshifts than known before. Among the secure redshifts only 28% are from isolated galaxies, while 43% of the galaxies reside in 17 groups with at least three members and 29% are in galaxy pairs. The unique capability of MUSE to blindly detect faint emission lines and obtain spatially resolved spectroscopy with high angular resolution will be used in many astrophysical applications in the future.

Accretion in a planet-forming disc

Protoplanetary discs are the structures where planetary systems form. They are the natural outcome of the star formation process and consist of gas and dust distributed in a disc-like shape orbiting the central star. Over a period of a few million years they evolve under the influence of several physical processes, such as photo-evaporation, dust processing, evolution, migration and planet formation. Protoplanetary discs that are actively forming planets are thought to be revealed by the presence of narrow or large gaps in their structure. Massive planets are believed to be responsible for





Left: Detection of a photocentre shift across the hydrogen Br-γ line, attributed to a hot gaseous disc rotating around the central star HD 100546 within the sublimation radius (dashed line).

Right: Modelling of the AMBER data showing the disc dust-sublimation rim, the central star and the kinematic signature of the rotating inner gaseous disc. From Mendigutia et al. (2015).

these cavities since they sweep up and accrete material along their orbits.

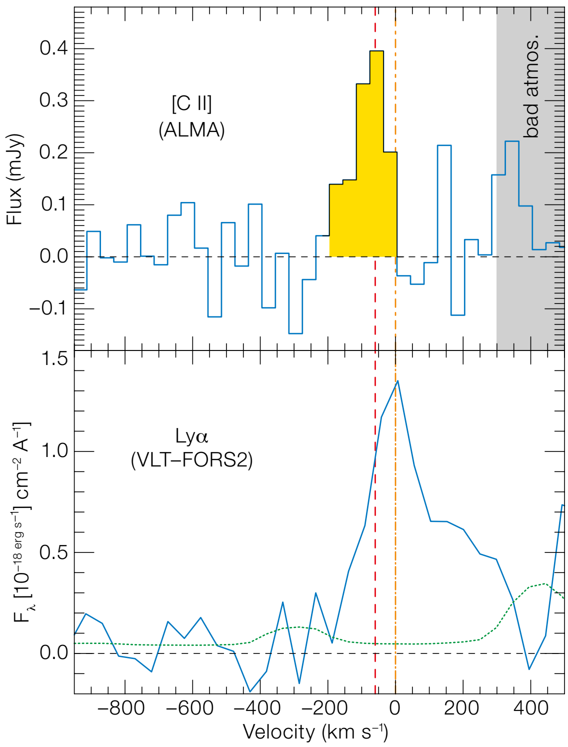
The Herbig Ae/Be star HD 100546 is one of the best-studied planet-forming stars. Its gaseous and dusty disc displays strong signs of planet formation, earning it the name "transitional disc". High-contrast adaptive optics imaging has revealed the presence of a massive planet at 50 au. Closer to the star, the same techniques have shown the presence of a large cavity with a radius of approximately 15 au. This wide gap has been confirmed by millimetre-wave observations, although in that wavelength regime the cavity is twice as large. HD 100546 is therefore an ideal laboratory for the study of planet formation.

The exquisite angular resolution of the VLTI has already been applied to HD 100546 and demonstrated that a narrow inner disc of dust and gas is still present, despite the existence of the wide gap that alters the accretion. The inner boundary of this disc is set by the intense flux from the central star, which sublimates the dust. The Astronomical Multi-BEam combineR (AMBER) was used to explore the nature of such a transitional disc within the dust sublimation front. The new observations not only resolve the dust sublimation front, but also reveal the presence of hot gas emission much closer to the star. Using spectro-astrometry, a method that can allow spatial information to be extracted at resolutions better than the diffraction limit, AMBER pushes the VLTI's angular resolution to its limit by comparing the distribution of the continuum with hot hydrogen emission. With this method, shifts in position of the order of few tens of microarcseconds are measured, corresponding to a few hundredths of an au at the distance of HD 100546 (100 pc). This observation shows that the hot gas emission arises very close to the central star. Moreover, an analysis of the hydrogen kinematics seems to indicate the presence of a flared rotating gaseous disc.

This observation raises interesting questions about the existence of this inner disc. How can it survive the accretion onto the star? The presence of a wide gap further out should alter significantly the flow of gas, but still maintain a sufficient rate to allow the inner disc to be replenished. This promising observation paves the way for the newly commissioned GRAVITY instrument to expand the study of accretion properties in such planet-forming discs.

The interstellar medium at high redshift

A major theme for ALMA, with its sensitivity and frequency coverage, is the study of the interstellar medium of star-forming galaxies at very high redshift. The [C II] line at 158 μm has long been thought to be the prime probe of the interstellar medium of such galaxies. Several studies have been dedicated to observing this line with ALMA in galaxies within and immediately after the epoch of reionisation, in the redshift range from ~ 5 to 7.5. Initial results have shown that [C II] is less bright than originally thought in galaxies at redshift $z \gtrsim 7$, with the gas possibly confined in relatively small clumps or satellites accreting onto the main star-forming galaxy. At lower redshifts ($z \sim 3$–5), ALMA observations reveal a possible population of galaxies with strong [C II] emission, but very low dust content. How these results can be reconciled is still heavily debated. Future surveys with ALMA and optical/infrared telescopes will be essential for our understanding of the assembly of early galaxies and the chemical enrichment of the Universe.



The Lyman-break galaxy BDF3299 at redshift 7.107 detected in the [C II] 158 μm line by ALMA (upper) and at Lyman-α in the optical with FOcal Reducer/low dispersion Spectrograph 2 (FORS2; lower). From Maiolino et al. (2015).

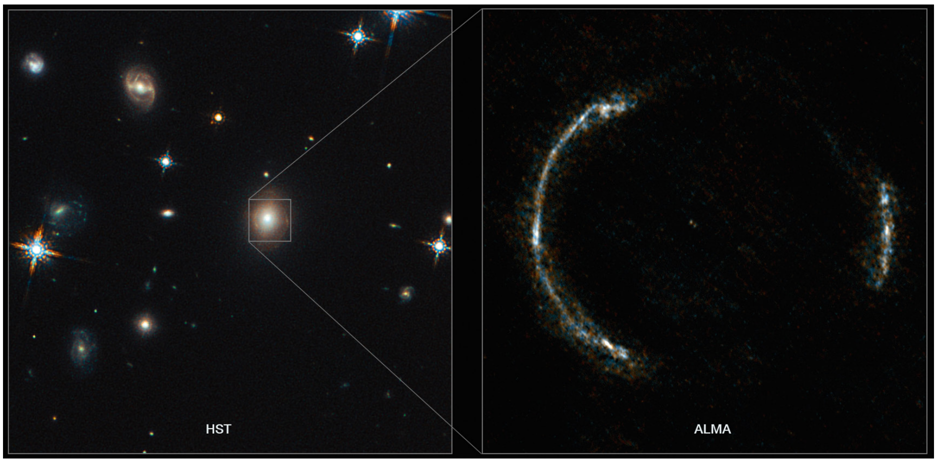
The submillimetre Universe imaged at high angular resolution

The results from the initial tests of ALMA using long baselines were presented in a series of papers in early 2015. The Science Verification tests were conducted as part of a two-month campaign in October–November 2014, using baselines up to ~ 15 kilometres, delivering an angular resolution approaching 10 milliarcseconds, in the frequency bands used in the campaign. Here we highlight the results on the lensed submillimetre galaxy SDP.81, the asteroid Juno, and the protoplanetary disc around the young solar-mass star HL Tauri, demonstrating the range of science achievable with long-baseline ALMA observations.

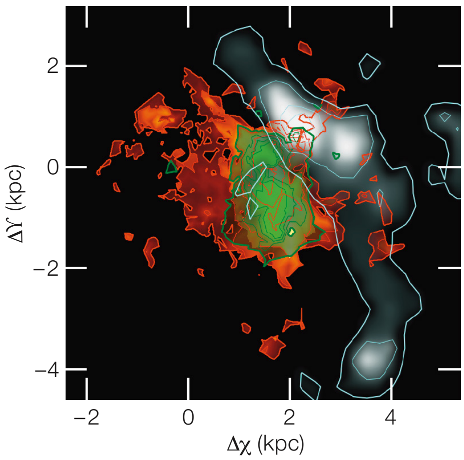
The lensed submillimetre galaxy HATLAS J090311.6+003906 (SDP.81) at redshift z ~ 3.042 was observed with ALMA in continuum and molecular lines. The gravitationally distorted and magnified image of the galaxy was detected in the submillimetre continuum (restframe far-infrared emission) and in molecular gas (carbon monoxide [CO] and H_2O). The detailed analysis of the lens system allows the source plane images of the galaxy to be reconstructed with a linear resolution better than ~ 100 pc, revealing a complex and disturbed morphology for this star-forming galaxy. The analysis is consistent with starburst activity in a merging system, possibly in a post-coalescence perturbed disc.

Asteroid 3 Juno was the third main belt asteroid to be discovered and has an estimated average diameter of ~ 300 kilometres, with high ellipticity. ALMA observed the asteroid at 1.3 millimetres in the long-baseline configuration, yielding an angular resolution of 0.04 arcseconds (~ 60 kilometres at the asteroid distance at the time of observation). The observations spanned a total of 4.4 hours, covering approximately 60% of the rotational period of the asteroid. The ALMA data, combined with SPHERE adaptive optics

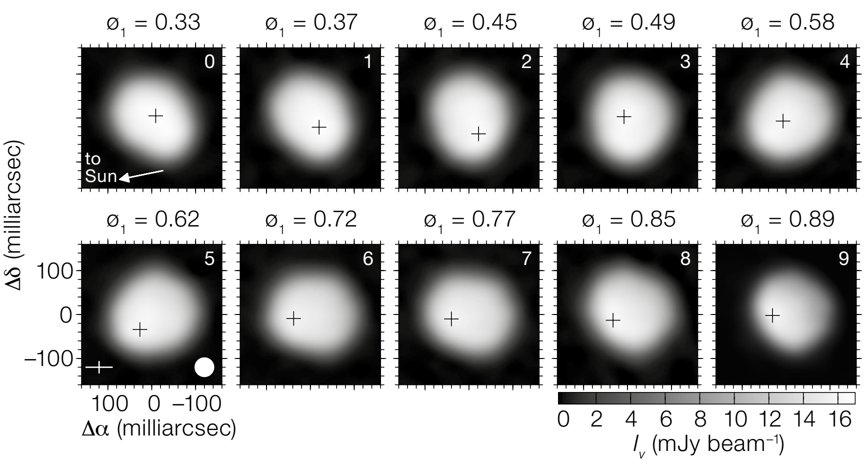
ALMA (NRAO/ESO/NAOJ)/Y. Tamura/NASA/ESA Hubble Space Telescope



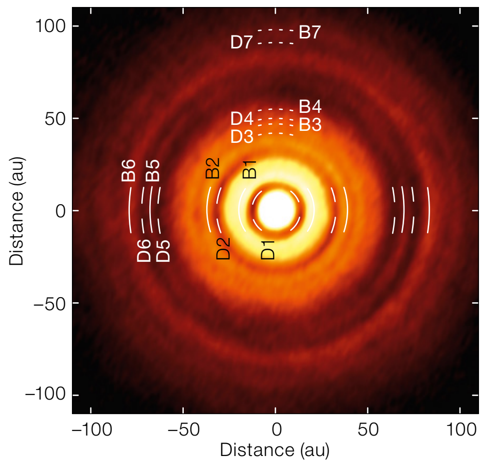
HST and ALMA images of the lensed submillimetre galaxy SDP.81.



Source plane reconstruction of the restframe ultraviolet and far-infrared emission (grey and green respectively) and warm molecular gas (CO, red) of the lensed starburst galaxy. From Rybak et al. (2015).



Asteroid 3 Juno observed at 1.3 millimetres with ALMA with ~ 0.04 arcsecond (~ 60 kilometres) resolution. Sequence of images over 4.4 hours, labelled by rotational phase. Cross marks the position of peak intensity. From ALMA Partnership, Hunter et al. (2015).



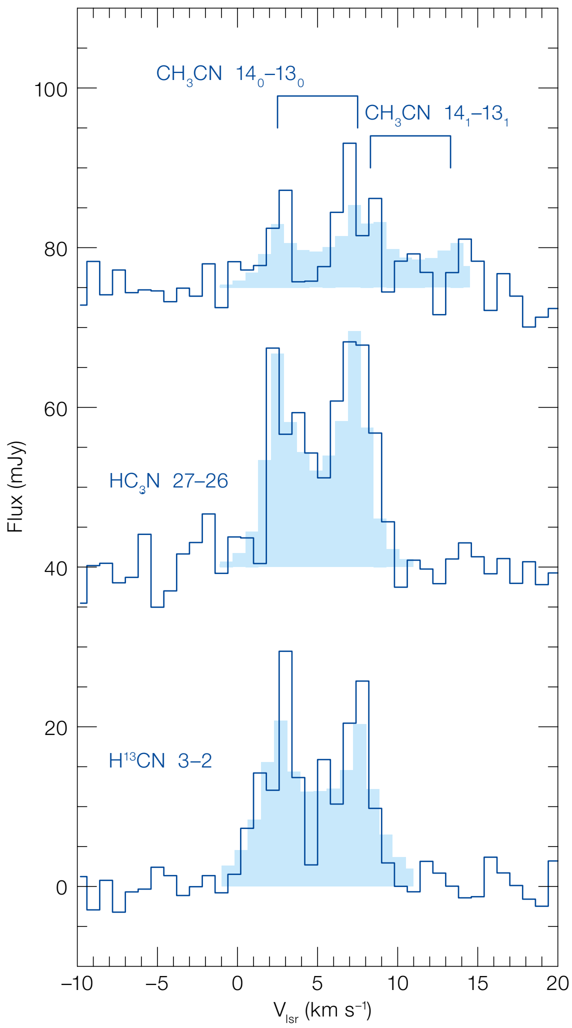
De-projected ALMA 1.3 millimetre continuum image of the protoplanetary disc around the young star HL Tauri. From ALMA Partnership, Brogen et al. (2015).

images, has allowed a detailed model of the asteroid surface to be derived, suggesting the presence of significant features on the surface, probably resulting from impact events.

ALMA observations at 5 au resolution of the protoplanetary disc surrounding the young solar analogue HL Tauri revealed a series of eccentric bright and dark rings. The observations allowed the distribution of the millimetre-sized dust grains around the star to be characterised in detail. This discovery has stimulated extensive follow-up modelling and observational work, aimed at understanding the implications for the processes of planet formation and the physics of disc evolution. The most favoured explanation seems to be that the disc morphology in the millimetre continuum is shaped by the interaction between dust grains, gas and relatively small planetary-mass bodies. In this view, the formation of planetary cores would be a much faster process than previously thought, since HL Tauri has an estimated age of less than one million years.

The chemistry of planet formation

During 2015, ALMA started to provide detailed information on the chemistry of complex molecular species in planet-forming discs. Several new datasets and analyses of the position and characteristics of the major snowlines in protoplanetary discs have been published, as well as observations of the gas content of the inner dust-depleted regions of transition discs. These studies trace the major volatiles in discs, whose presence or absence in the gas phase drives the chemistry of less abundant species. In particular, the chemistry of several deuterated and nitrogen-bearing molecules has been traced in molecules composed of up to six atoms with the detection of methyl cyanide (CH_3CN) in the protoplanetary disc MWC 480 (along with other, simpler, N-, C- and O-bearing molecules). Interestingly, while the precursor species, formaldehyde (H_2CO), has been detected and studied in some detail, in spite of several attempts, methanol (CH_3OH) still eludes detection in the gas phase of discs. This finding is at odds with methanol being one of the main species known to be present in the ices of pre-protoplanetary discs and its role as a fundamental step in the chemical pathways to produce complex organic molecules.

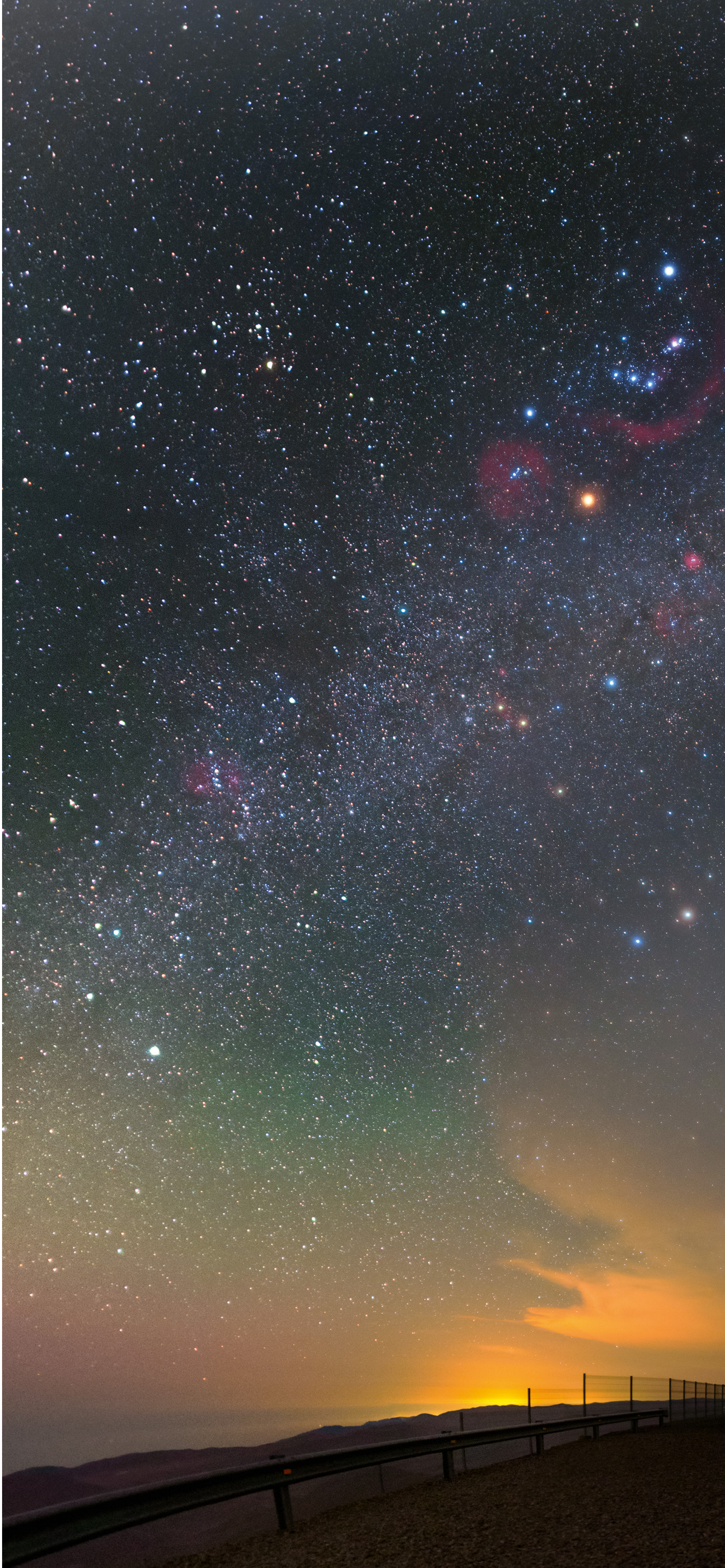


Detection of methyl cyanide in the protoplanetary disc of MWC 480 with ALMA. From Öberg et al. (2015).

References

The following papers were used as sources for the research highlights.

ALMA Partnership, Brogan, C. L. et al. 2015, ApJ, 808, L2
ALMA Partnership, Fomalont, E. B. et al. 2015, ApJ, 808, L1
ALMA Partnership, Hunter, T. R. et al. 2015, ApJ, 808, L2
ALMA Partnership, Vlahakis, C. et al. 2015, ApJ, 808, L4
Arnaboldi, M. et al. 2015, The Messenger, 162, 57
Bacon, R. et al. 2015, A&A, 575, A75
Boccaletti, A. et al. 2015, Nature, 526, 230
Capak, P. L. et al. 2015, Nature, 522, 455
Genzel, R. et al. 2015, ApJ, 796, 7
Guzmán, V. V. et al. 2015, ApJ, 814, 53
Kervella, P. et al. 2015, A&A, 578, A77
Maiolino, R. et al. 2015, MNRAS, 452, 54
McLeod, A. F. et al. 2015, MNRAS, 450, 1057
Mendigutía, I. et al. 2015, MNRAS, 453, 2126
Öberg, K. I. et al. 2015, Nature, 520, 198
Rybak, M. et al. 2015, MNRAS, 453, L30
Scicluna, P. et al. 2015, A&A, 584, L10
Sterzik, M. et al. 2015, The Messenger, 162, 2
Stoehr, F. et al. 2015, The Messenger, 162, 30
Viikinkoski, M. et al. 2015, A&A, 581, L3
Watson, D. et al. 2015, Nature, 519, 327
Wisnioski, E. et al. 2015, ApJ, 799, 209



Airglow phenomena and the Galactic Plane above one of the VLT Unit Telescopes at the Paranal Observatory.

P. Horálek/ESO

Offices for Science

The ESO Faculty

There has been a strong wish for the ESO Faculty to be engaged further as a consulting body, working with the Offices for Science to strengthen science programmes and reinforce internal science activities. The faculty has now gained momentum in this regard by leading discussions on specific topics. Working groups have been set up and discussions have been organised, sometimes triggered by the results of ESO internal polls. These working groups concluded with the formulation of sets of recommendations and formal reports that were delivered to the Director for Science and the Heads of the Offices for Science. For example, a working group that examined the ESO Studentship programme proposed that the student recruitment phase should be more flexible so as to adapt to the different procedural timescales in the Member States. This proposal resulted in the introduction of a second annual selection round. Another working group is reviewing the ESO Fellowship programme and its report will be delivered soon. Thanks are due to the Faculty Chair, Francesca Primas, and to the dedication of the faculty, fellows and students whose participation in these discussions has benefited the science programme as a whole.

Addressing diversity and gender issues

Several activities have taken place in this important area. Francesca Primas is also the Chair of the International Astronomical Union (IAU) Executive Committee Working Group for Women in Astronomy. In this capacity Francesca, together with the rest of the organising committee of this working group, arranged a highly visible and well-received programme at the IAU General Assembly (held in Hawaii in August). In addition to the well-attended Women's Lunch, the organising committee set up 12 mentoring sessions, thus reaching twice the number of students and young astronomers as at the previous IAU General Assembly in Beijing. In addition, three lunch talks addressed specific topics: results from a recent American Astronomical Society climate study in the workplace, a report from the first Inclusive Astronomy conference and the subject of "unconscious bias".

Andrea Mehner and Joe Anderson

Gaitee Hussain and other faculty members followed up with specific activities at ESO. They focused not only on issues such as diversity and gender, but also on understanding better how to prevent potential harassment situations, thus ensuring that ESO is at the forefront of efforts to foster an open and welcoming working environment in which a diversity of opinions and approaches is valued. These activities will help to reinforce existing ESO practice, as outlined in several documents (for example, People Policy, the ESO Code of Conduct, the Code of Good Scientific Practice), and allow the present generation of ESO scientists to examine their own attitudes to these issues more closely.

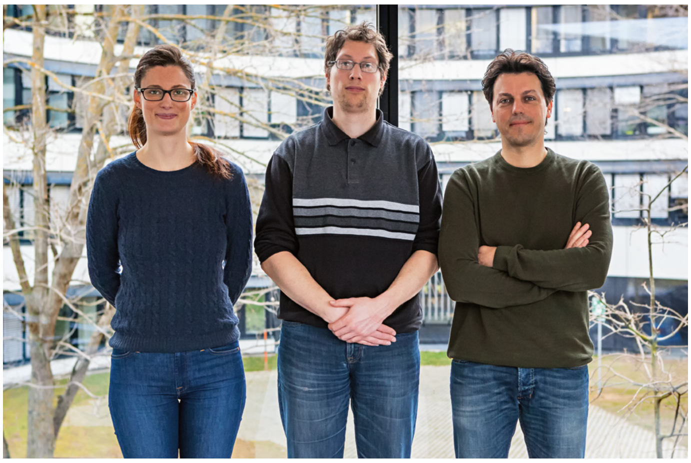
Science highlights

As in previous Annual Reports, we emphasise the achievements over the past year of two students, two fellows and two faculty members.

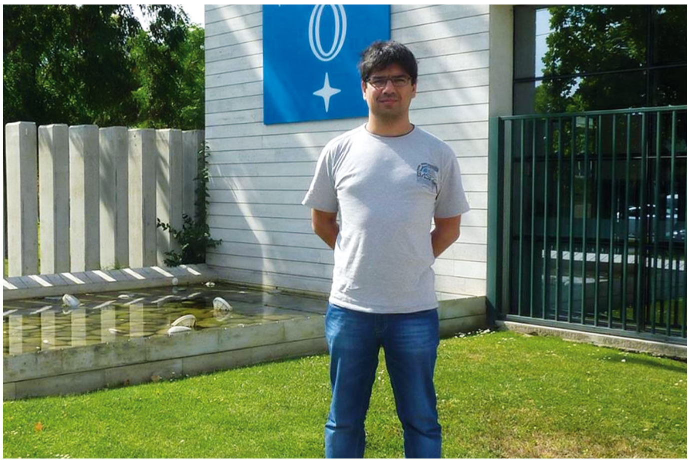
Andrea Mehner started as an ESO Chile Fellow in 2011, after obtaining a PhD from the University of Minnesota. She supports Unit Telescope 2 operations and is strongly involved in the X-shooter instrument operations team. Andrea has been appointed as staff astronomer in the Science Operations Department at the La Silla Paranal Observatory. Formerly the instrument scientist for the VIsible MultiObject Spectrograph (VIMOS), she is now in charge of X-shooter, and is currently the project scientist for the GuideCam tool, which aims to provide a unified target acquisition preparation tool for all ESO instruments.

Her scientific interests lie with evolved massive stars as the progenitors of supernovae. The enigmatic star Eta Carinae, one of the most massive and luminous stars in the Galaxy, thus plays a central role in her work. Eta Carinae underwent a giant eruption some 170 years ago, which it survived, creating its famous circumstellar nebula in the process. The star shows other intriguing variabilities on several time and magnitude scales and has remained a mystery to researchers. Andrea's scientific work combines optimally with her observatory activities. Last year, in collaboration with several ESO astronomers, Andrea published a comprehensive spectroscopic analysis of the peculiar 2014 Eta Carinae event, combining data from both the UV-Visual Echelle Spectrograph (UVES) and the Space Telescope Imaging Spectrograph (STIS, HST). Their analysis seems to indicate that the wind-wind shock may not have completely collapsed as has been proposed for previous events. Andrea is also leading a MUSE programme that looks in detail at several evolved massive stars in order to pinpoint their evolutionary stages. Andrea is a key member of the Fellowships and Studentships Selection Committee.

Bernd Husemann joined ESO in 2013 as a fellow after a two-year postdoc at the Leibniz Institute for Astrophysics in Potsdam. Bernd is an expert on integral field spectroscopy and joined the MUSE instrument team to support its commis-



Anna McLeod, Bernd Husemann and Vincenzo Mainieri



Jorge Martins

sioning. His contributions have been essential in verifying and improving the performance of the instrument, bringing it to the current state of stable operations.

Bernd's main scientific interest is in understanding the link between active galactic nuclei and their host galaxies. He is a co-organiser of the Garching campus bi-weekly AGN club. Based on MUSE's commissioning data, Bernd has shown that its high sensitivity, spatial resolution and large field of view are sufficient to measure stellar velocity dispersions, even for luminous AGN that vastly outshine their host galaxies.

Bernd is currently leading the Close AGN Reference Survey (CARS, www.cars-survey.org), an international collaboration of more than 20 scientists conducting a unique multi-wavelength campaign covering about 40 nearby luminous AGN. This survey includes MUSE spectroscopy complemented with data from the Jansky Very Large Array (VLA, in the radio), the NOrthern Extended Millimetre Array (NOEMA, submillimetre), the Stratospheric Observatory for Infrared Astronomy (SOFIA, far-infrared), Gemini-North (near-infrared), the Southern Astrophysical Research (SOAR) 4-metre telescope (near-infrared and optical), Chandra and X-ray Multi-Mirror Mission (XMM-Newton). The CARS survey will certainly set the reference standard for future AGN surveys at low and high redshifts.

Joe Anderson arrived at ESO Chile in October 2013 after completing a Fondo Nacional de Desarrollo Científico y Technológico fellowship at the Universidad de Chile in Santiago. Joe is the instrument fellow for KMOS at Paranal. His scientific interests involve the study of supernovae, and in particular attempting to understand their progenitors and explosion mechanisms. Joe has recently concentrated his research efforts on obtaining observations that explore the possibility of using Type II supernovae (massive stars that explode with their hydrogen envelope intact) as extragalactic metallicity indicators. Such a technique may provide independent constraints on the chemical enrichment of galaxies in both the near and far Universe.

In 2015, Joe also initiated the All-weather MUse Integral field Nearby Galaxies (AMUSING) survey with multiple research aims, such as providing constraints on supernova progenitors, refining the use of supernovae as probes of the Universe and constraining galaxy formation and evolution. Joe presented two talks at the IAU General Assembly in Hawaii, including an invited review on the diversity of Type II supernovae and their red supergiant progenitors.

Anna McLeod is part of the star formation group at ESO, working on feedback in massive star-forming regions. She is Principal Investigator (PI) of four MUSE programmes which target feedback-driven structures both in Galactic and extragalactic environments, as well as PI of a KMOS programme to analyse feedback in three Galactic molecular cloud clumps. By combining these datasets and simulations, Anna is working towards quantifying mechanical and radiative feedback. In Anna's first first-author paper, she and her collaborators presented MUSE observations of the iconic Pillars of Creation in the Eagle Nebula (NGC 6611), detecting an outflow from a young star forming at the tip of one of the pillars for the first time. The publication was accompanied by a joint ESO/Royal Astronomical Society press release in April, gained international media attention, and was presented at several international conferences, including the European Week of Astronomy and Space Science (EWASS) 2015 in Tenerife.

Anna is a member of the scientific organising committee of a MUSE symposium at EWASS 2016, as well as one of the organisers of a Leiden Lorentz Center Workshop (August 2016). In February she was awarded the Christiane Nüsslein-Volhard Foundation grant. Furthermore, Anna has served on the Student Selection Committee for two terms, was involved in the ESO Girls' Day, in 2014, and is one of two organisers of the weekly star formation coffee meetings.

Jorge Martins is a PhD student from the Institute of Astrophysics and Space Sciences and the Faculty of Sciences of the University of Porto, both in Portugal. At his home institute, he is co-supervised by Nuno Santos and Pedro Figueira, and while in Chile as an ESO Student he is working under the supervision of Claudio Melo. The main focus of his work is the challenging detection of the optical

Group photo of participants at the ESO Workshop on Satellites and Streams in Santiago on the lawn at the ESO Offices in Vitacura.

reflected spectrum of exoplanets, a signal with an amplitude about 10 000 times smaller than the stellar one. In this search, Jorge and collaborators were able to recover the minute reflected spectral signature of the prototypical planet 51 Pegasi b from High Accuracy Radial Velocity Planetary Searcher (HARPS) spectroscopy.

The detection of reflected light from exoplanets is of great importance as it allows the wavelength dependence of the planet's albedo to be reconstructed and enables insights into the composition of the exoplanetary atmosphere. Jorge's impressive results were highlighted in an ESO Press Release (eso1517), received the International Prize Admiral Gago Coutinho 2015, awarded by the Geographical Society of Lisbon, and was listed among the Top 10 breakthroughs of 2015 by *Physics World* magazine.

Vincenzo Mainieri arrived at ESO in 2000 with an ESO Studentship, returned as a fellow in Garching in 2006 and became a staff astronomer in 2008 in the User Support Department. Vincenzo assists our community in the use of several VLT instruments (SINFONI, MUSE, X-shooter, VIMOS) that he also uses extensively in his own research. In 2015 Vincenzo became multi-object spectroscopy project scientist, where he will work on ESO's future multi-object spectrographs. This new role is directly linked to Vincenzo's decade-long involvement in large surveys, which clearly need follow-up with high multiplexing facilities. Vincenzo is also a member of the Fellowships Selection Committee and of the Research Board of the Excellence Cluster.

Vincenzo's research focuses on the study of AGN, spanning a wide wavelength range from X-ray to radio, trying to understand how the central supermassive black hole and its host galaxy influence each other. Vincenzo leads a SINFONI Large Programme employing the highest angular resolution to study the impact of AGN-driven outflows, and to link the properties of these outflows with those of the central supermassive black hole. The collaboration includes Darshan Kakkad, an ESO Student supervised by Vincenzo and another faculty member, Paolo Padovani.

Fostering collaboration

Strengthening collaborations between ESO Chile and the Joint ALMA Observatory (JAO) is a key goal for both institutes. The Office for Science in Chile warmly welcomes John Carpenter, the new ALMA Observatory Scientist. Among a myriad of tasks, John is working closely with the Office for Science in Chile to enhance collaboration between the institutes.

During one of the Coffee with the Director General events held in Chile this year, non-astronomer colleagues proposed a regular series of lectures about astronomy aimed at informing the whole ESO community working in Vitacura about the science done with our telescopes. This is a series similar to the very successful Astronomy for Non-Astronomers series held in Garching. In its first year, Astronomy for Everyone in Vitacura has been received with great enthusiasm.

The year again saw a number of ESO-organised workshops and schools at both Garching and Vitacura, and elsewhere, including:

- In Vitacura:
  - Exoplanet Focus Meeting for the Chilean Scientific Community;
  - Astrobiology and Planetary Atmospheres, Santiago;
  - Ground and Space Observatories: A Joint Venture to Planetary Science;
- In Garching:
  - ESO in the 2020s;
  - Baryons at Low Densities: The Stellar Halos around Galaxies;
  - ALMA Community Days 2015: Preparation for Cycle 3;
  - Joint ALMA-Herschel Archival Workshop;
  - 4th EIROforum School on Instrumentation — ESI 2015 (hosted by ESO and Eurofusion);
  - Let's Group. The Life Cycle of Galaxies in their Favorite Environment (at MPA);
  - Stellar End Products: The Low Mass–High Mass Connection;
  - Theoretical and Observational Progress on Large-scale Structure of the Universe. Joint workshop with MPA/MPE/LMU/TUM/Excellence Cluster Universe;
  - European Radio Interferometry School 2015;
  - Rainbows on the Southern Sky: Science and Legacy Value of the ESO Public Surveys and Large Programmes;
  - Science Operations 2015: Science Data Management. An ESO/ESA Workshop;
- Co-sponsored by ESO: in Oxford, UK (Early E-ELT Science: Spectroscopy with HARMONI) and in Erice, Italy (Science and Technology with E-ELT).

A. Tudorica/ESO

The VLT Survey Telescope, in the foreground, is sited on Paranal. In the background a VLT Unit Telescope and an Auxiliary Telescope are visible.

Allocation of Telescope Time

The table shows the requested and scheduled observational resources allocated in 2015 for Periods 96 and 97 (October 2015–March 2016, April 2016–September 2016, respectively P96 and P97) for the La Silla Paranal Observatory and APEX. These are specified as the length of run in nights, the usual allocation unit for the La Silla Paranal Observatory and APEX.

The La Silla Paranal Observatory and APEX statistics include only proposals submitted during the two periods (P96 and P97). Current Large Programme runs approved in previous periods, Guaranteed Time runs and Public Survey runs are not included. The pressure is computed as the ratio between the requested and the allocated time. The last two columns show the total telescope time allocations and the fraction of time per instrument.

The ALMA Proposal Review Committee for the allocation of time in Early Science Cycle 3 (covering October 2015–September 2016) met in Osaka, Japan on 22–26 June 2015. The table shows the requested and scheduled resources for the ALMA Observatory in Cycle 3. The request and allocation statistics, listed by ALMA frequency band, for ESO and the world (including North America, East Asia, ESO and the host country Chile) are both included. The scheduling unit for ALMA is hours of array time.

The little-known planetary nebula ESO 378-1 captured by VLT FORS2.

Telescope	Instrument	Requested runs	Scheduled runs	Requested time	%	Scheduled time	%	Pressure	Total allocation	%
UT1	NACO	150	33	114	14.9%	20	15.5%	5.63	45	20.8%
	FORS2	489	109	473	62.2%	68	51.8%	7.00	83	38.7%
	KMOS	122	30	174	22.9%	43	32.8%	4.07	87	40.5%
Total		761	172	761		131		5.83	214	
UT2	FLAMES	113	32	243	26.3%	47	22.2%	5.19	107	39.3%
	UVES	196	53	268	29.1%	65	31.0%	4.11	66	24.2%
	X-shooter	377	97	411	44.6%	99	46.8%	4.16	99	36.5%
Total		686	182	922		211		4.37	272	
UT3	SPHERE	267	96	259	49.4%	54	49.5%	4.84	120	49.0%
	VIMOS	95	20	140	26.7%	18	16.9%	7.64	89	36.2%
	VISIR	124	44	126	24.0%	36	33.6%	3.46	36	14.8%
Total		486	160	524		108		4.85	245	
UT4	SINFONI	141	32	195	27.8%	44	33.4%	4.47	59	29.1%
	MUSE	322	57	416	59.2%	73	55.7%	5.71	120	59.3%
	HAWK-I	125	19	91	13.0%	14	10.9%	6.38	23	11.6%
Total		588	108	702		131		5.37	202	
VLTI	AMBER	93	24	61	29.6%	17	24.3%	3.66	17	23.3%
	PIONIER	160	59	146	70.4%	52	75.7%	2.80	55	76.7%
Total		253	83	207		69		3.01	72	

3.6-metre	HARPS	93	98	497	100.0%	183	100.0%	2.72	341	100.0%
Total		93	98	497		183		2.72	341	
NTT	EFOSC2	79	23	297	64.7%	69	57.5%	4.33	175	58.0%
	SOFI	46	19	162	35.3%	51	42.5%	3.20	127	42.0%
Total		125	42	459		119		3.85	301	

APEX	ArTeMiS	5	4	11	7.3%	6	7.3%	1.91	10	12.4%
	LABOCA	13	3	38	25.3%	9	12.2%	4.08	9	11.4%
	SEPIA	16	12	47	31.3%	39	52.3%	1.20	40	50.0%
	SHFI	21	11	54	36.1%	21	28.2%	2.60	21	26.2%
Total		55	30	150		75		2.00	80	

ALMA	Band	Requested proposals All/ESO	Requested hours All/ESO	Scheduled proposals (A+B) All/ESO	Scheduled hours (A+B) All/ESO	Pressure (by hours)) All/ESO
	3	488/206	2462/1138	91/39	397/164	6.20/6.94
	4	145/59	548/300	27/8	57/12	9.61/24.1
	6	713/299	3260/1425	184/55	807/243	4.04/5.86
	7	632/256	2911/1218	168/61	715/246	4.07/4.95
	8	88/43	252/135	36/12	97/28	2.60/4.82
	9	86/37	229/93	24/10	67/29	3.42/3.21
	10	23/6	70/22	7/2	23/4	3.04/5.50
Total		1589/657	9732/4331	537/187	2163/726	4.50/5.97

Relaxing in front of the Atacama Large Millimeter/submillimeter Array sits a culpeo, an Andean fox.

ESO/A. Ghizzi Panizza (www.albertoghizzipanizza.com)

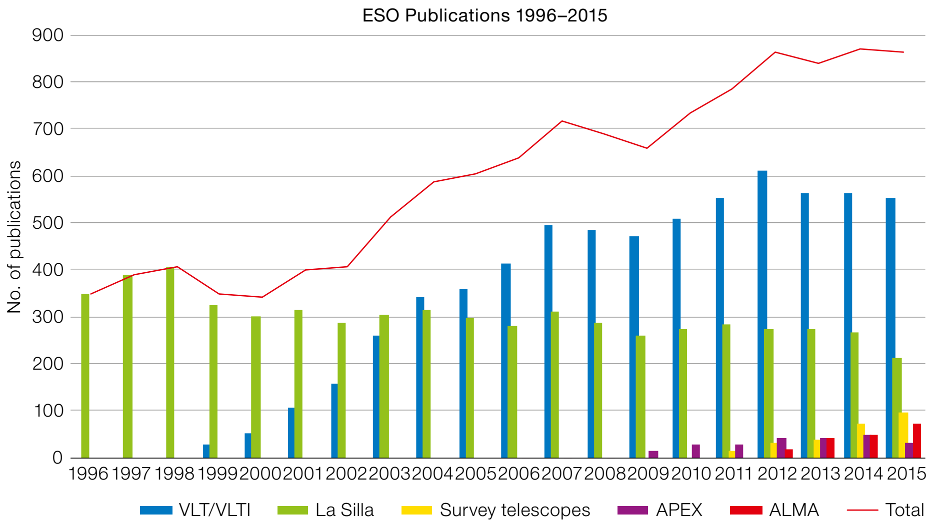
Publication Digest

By the end of 2015, the ESO telescope bibliography (*telbib*) contained almost exactly 12 000 papers that use data from ESO's observing facilities and have appeared in refereed journals since 1996. In 2015 alone, 860 of these articles were published, making this year the third most productive in terms of refereed papers in the history of ESO.

The number of papers resulting from the individual observing sites, as well as the total number per year are shown in the figure to the right. An overview of the publication statistics is available on a dedicated webpage at telbib.eso.org/pubstats_overview.php, including links to the corresponding records in the *telbib* database.

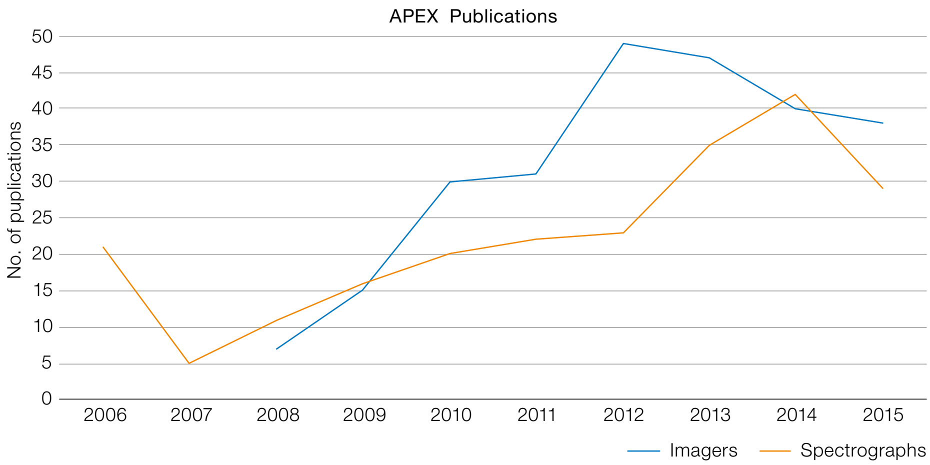
The VLT and VLTI provided data for 550 refereed papers in 2015. This number is similar to those recorded for previous years and might suggest that a plateau regarding VLT/VLTI papers has been reached. X-shooter, the first of the second generation instruments, is still increasing its productivity, generating a large number of papers (78) in its sixth year of operation. The new planet-finder instrument, SPHERE, has produced its first papers, immediately leading to the impressive number of 16 in 2015. As in previous years, UVES and FORS2 were the most productive instruments in 2015 with 144 and 91 papers, respectively. Further statistics relating to the individual instruments can be found in the *Basic ESO Publication Statistics* report.

After many years of operation, La Silla also continues to be a steady producer of data that lead to scientific publications. More than 200 papers used data that was either exclusively or partly from facilities located at this site. Once again, HARPS, mounted at the ESO 3.6-metre telescope, has shown an extraordinary performance in 2015 by producing over 80 papers. The ESO Faint Object Spectrograph and Camera 2 (EFOSC2), an instrument that was originally installed at the NTT and later transferred to the MPG/ESO 2.2-metre and then to the ESO 3.6-metre telescope, and is now once again mounted at the NTT, has provided observations that resulted in almost 50 papers in the past year.



Refereed papers using ESO data, 1996–2015. Papers can use data from more than one facility. VLT/VLTI: Papers using data generated by VLT and VLTI instruments, including visitor instruments for which observing time is recommended by the ESO OPC, for example, VLT ULTRACAM, VLTI PIONIER. La Silla: Papers using data generated by facilities on La Silla, including visitor instruments for which observing time is recommended by the OPC, for example, NTT ULTRACAM. Papers based on data from non-ESO telescopes or observations obtained during reserved periods (for example, national allocations of time) are not included.

Survey telescopes: Papers using data generated by ESO's survey telescopes VISTA and VST. APEX: Papers using data generated by APEX, including visitor instruments for which observing time is recommended by the OPC, for example, Z-Spec. Only papers based (entirely or partly) on ESO APEX time are included. ALMA: Papers using data generated by ALMA. Only papers based (entirely or partly) on ESO ALMA time are included.



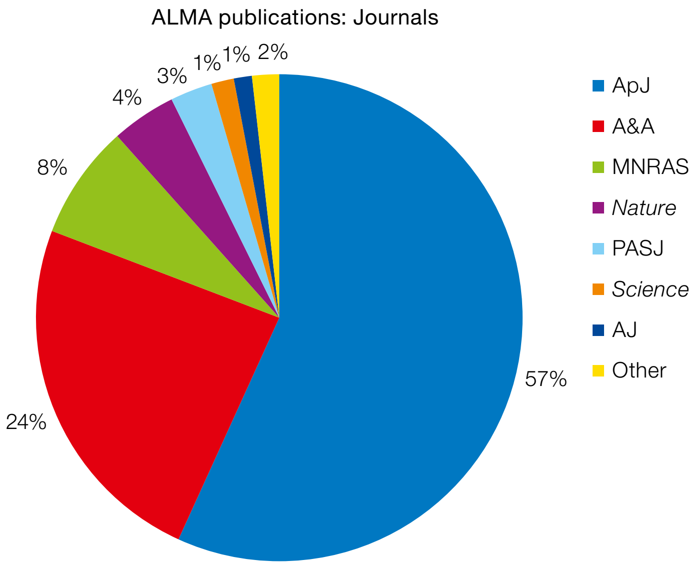
Number of refereed publications per year produced using APEX imagers and spectrographs. Data are from observations by all APEX partners.

Note that non-ESO telescopes (for instance the Swiss 1.2-metre Leonhard Euler Telescope) and other facilities located on La Silla, for which observing time is not evaluated by the Observing Programmes Committee (OPC), are not included in the ESO statistics. It is impressive that the FEROS spectrograph and the Wide Field Imager (WFI) still achieve a noteworthy number of papers (40 and 26, respectively, in 2015) even though these instruments have not been operating under ESO time since October 2013.

The ESO survey telescopes, VISTA and the VST, have increased their production of papers remarkably in 2015 (73 and

24 refereed publications, respectively). The vast majority of VISTA papers (93%, i.e., 68 out of 73 papers) were based on data from one of the six Public Surveys carried out at this telescope. The number of papers using data from the VST has tripled in 2015 in comparison with the previous year.

Data from the APEX telescope (all partners) led to 63 papers in 2015, bringing the total number of papers using APEX data to 451 by the end of the year. More than half of the 2015 papers used ESO observing time: 32 out of 63 in 2015 (51%), and 253 out of 451 papers for all years (56%). Since the first publication in 2006, the APEX imagers (APEX-SZ, LABOCA [the Large APEX BOlometer CAmera], P-ArTeMiS [Prototype Architectures de Bolometres pour des Telescopes a grand champ de vue dans la domaine sub-Millimetrique au Sol], SABOCA [Sub-millimetre APEX BOlometer CAmera]) and spectrographs (APEX-2A, CHAMP+ [Carbon Heterodyne Array of the Max Planck Institute for Radio Astronomy (MPIfR)], CONDOR [CO N$^+$ Deuterium Observations Receiver], FLASH [First Light APEX Submillimetre Heterodyne receiver], MPI 1.1 THz, SHFI [Swedish Heterodyne Facility Instrument], Z-Spec millimetre-wave spectrograph and the Redshift (*z*) Early Universe Spectrometer [ZEUS]) have led to almost the same number of papers (spectrographs: 228, imagers: 256). The distribution of publications per year is shown in the lower figure on the previous page.



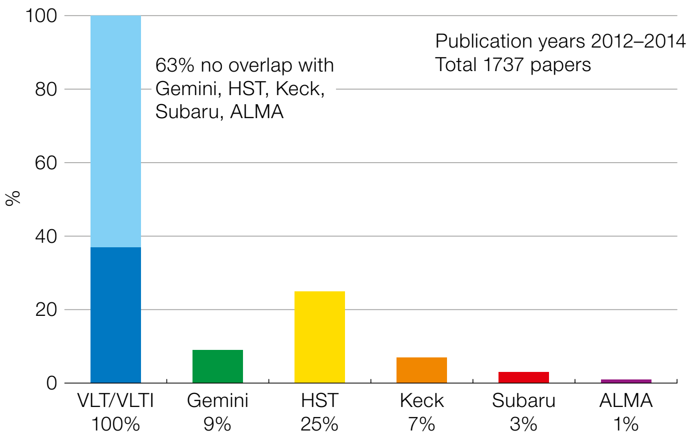
Journal distribution of ALMA papers, 2012–2015. Data are from observations by all ALMA partners.

ALMA has seen a large increase in paper productivity in 2015. In comparison with the previous year, the number of papers based on ESO ALMA time, as well as the papers resulting from the observing time assigned to all ALMA partners, has increased by approximately 55%, namely from 47 papers in 2014 to 73 in 2015 for ESO ALMA time, and from 97 to 147 for all ALMA partners. The total number of ALMA papers was 328 by the end of the year. As shown in the figure above, 57% of these publications appeared in ApJ, 24% in A&A, and 8% in MNRAS. *Nature* and *Science* papers account for 4% and 1%, respectively.

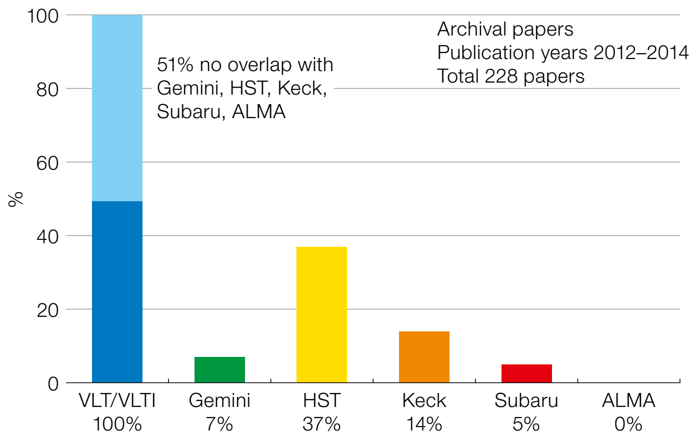
The ALMA bibliography is maintained jointly by the librarians at ESO and the National Radio Astronomy Observatory (NRAO) in the USA as well as by the National Astronomical Observatory of Japan (NAOJ). Publications based on data from all ALMA partners are recorded in *telbib*, but only those based on European observing time are counted in the ESO statistics.

The ESO Science Archive continues to be an important facility for the ESO user community. In 2015, 21% of the VLT/VLTI papers (118 out of 550) used partly or exclusively archival data. More than 6%

Overlap of VLT/VLTI proprietary and archival data with papers using Gemini, HST, Keck, Subaru or ALMA data in refereed articles for publications in the years 2012–2014.



Overlap of VLT/VLTI archival-only data with papers using Gemini, HST, Keck, Subaru, or ALMA data for refereed articles in years 2012–2014.



(34 out of 550) of all VLT/VLTI papers employed Science Data Products, i.e., pre-reduced data provided by the Science Archive Facility; this fraction corresponds to almost 29% of all papers that used archival data (34 out of 118).

It is not uncommon for VLT/VLTI data to be complemented in scientific papers by data from other large facilities, for instance in publications that deal with multi-wavelength studies. The ESO Library carried out a study for the publication years 2012–2014 to investigate the overlap of VLT/VLTI papers with those that use Gemini, HST, Keck, Subaru, or ALMA data. (The bibcodes of papers that use Gemini, HST, Keck, and Subaru data were obtained from the Astronomical Data System by selecting the respective filters. ALMA bibcodes for all ALMA partner publications are available in *telbib*.) The total number of VLT/VLTI papers published during these years was 1737. It was found that 9%, 7% and 3% of these papers also used Gemini, Keck, and Subaru data, respectively. The largest overlap, however, was found with HST papers: 25% of the publications included in this study used both VLT/VLTI and HST data. With 2012 being the first year of ALMA papers, 1% of the ALMA papers published from 2012 to 2014 also discussed VLT/VLTI observations. Some of these papers might even use data from more than one other facility. In contrast, the study also revealed that 63% of the VLT/VLTI papers did not have any overlap with Gemini, HST, Keck, Subaru, or ALMA.

Interestingly, this trend is even more pronounced in papers that use exclusively archival VLT/VLTI data, i.e., observations for which none of the authors were among the team of observers. For this set of papers (total number 228), the overlap with HST papers rises to a remarkable 37%. Also Keck and Subaru share a higher percentage with VLT/VLTI archive-only papers (14% instead of previously 7% for Keck, 5% instead of 3% for Subaru papers), while the percentage of papers shared with Gemini declines slightly (from 9% to 7%). Due to the low number of publications that use both VLT/VLTI and ALMA data, there are no papers in common when only archival VLT/VLTI data papers are taken into account (see lower plots on the previous page). Only 51% of the archival VLT/VLTI papers do not use any Gemini, HST, Keck, Subaru, or ALMA data.

The statistics presented here are derived from the ESO Telescope Bibliography (*telbib*), a database of refereed papers published by the ESO user community that links publications with the data in the ESO Science Archive. *telbib* is developed and maintained by the ESO Library. It is compiled by scanning articles published in the major astronomical journals for ESO-related keywords (for example, telescope and instrument names). Journals routinely screened for ESO-related keywords are: A&A, A&ARv, AJ, ApJ, ApJS, AN, ARA&A, EM&P, ExA, Icar, MNRAS, *Nature*, NewA, NewAR, PASJ, PASP, P&SS and *Science*. All papers included in the database have been inspected visually by the curators to ensure that they directly use ESO observational data. Further information about *telbib* and various statistics and reports can be found on the web (www.eso.org/sci/libraries/telbib_info.html).

The complete list of all 2015 papers is available at www.eso.org/libraries/telbib_info/AR/ESO_AnnualReport_publications2015.pdf. The file includes papers written by the ESO user community based on data generated by ESO facilities, followed by a separate listing of refereed publications by ESO scientists with or without use of ESO data.

View of the library at ESO Headquarters in Garching.

The Chajnantor Plateau, home of the Atacama Large Millimeter/submillimeter Array, at sunset.

P. Horálek/ESO

Operations

La Silla Paranal Observatory

The Directorate of Operations is responsible for all activities related to science operations, including the preparation and execution of observing programmes, the operation of the La Silla Paranal Observatory with its La Silla, Paranal and Chajnantor sites, and the delivery of raw and calibrated data. This mission involves user support, dataflow management, operations technical support and the development and maintenance of a science archive provided by the Data Management and Operations Division. The Science Archive Facility stores all the data obtained with ESO telescopes, as well as derived advanced products. In addition the Directorate of Operations includes ESO's contribution to ALMA operations and development through the ESO ALMA Support Centre (EASC).

The highlights of this year are the high-resolution millimetre-wave image of the planet-forming disc around the young star HL Tauri produced by ALMA in its long-baseline configuration, the record number of 1582 ALMA proposals and the start of the installation of the new Band 5 receiver by ESO. APEX was used for a new record of more than 4471 hours of on-sky science time. Two new science instruments have been selected for the La Silla Observatory. At the Paranal Observatory the start of science operations of SPHERE and the arrival of the GRAVITY instrument for the VLT Interferometer have both been exciting developments. The Data Management and Operations Division has also reported that the one millionth reduced 1D spectrum ready for science analysis was downloaded from the Science Archive Facility.

The powerful laser on VLT Unit Telescope 4 is beamed into the sky to produce an artificial star, used to correct for the effects of atmospheric turbulence.

Operations

The ESO Very Large Telescope at Paranal operates four 8.2-metre Unit Telescopes (UTs) with a suite of ten first-generation instruments and three of the four second-generation instruments. The Laser Guide Star Facility (LGSF) provides one of the three adaptive-optics-supported instruments of the VLT with an artificial reference star. The VLT Interferometer combines the light of either the UTs or the Auxiliary Telescopes (ATs) to feed either one of the two interferometric first-generation instruments or the VLTI visitor instrument focus. VISTA and the VST are in regular survey operation.

On La Silla the 3.58-metre New Technology Telescope and the ESO 3.6-metre telescope operate with a complement of three instruments. The La Silla site further supports eight hosted telescope projects.

The observatory further provides operations support for the Atacama Pathfinder Experiment on the Chajnantor Plateau at 5100 metres above sea level. APEX comprises a 12-metre submillimetre radio antenna with a suite of heterodyne and bolometer facility instruments and a number of visitor instruments.

For Periods 95 and 96 the scientific community submitted respectively 932 and 959 Phase 1 observing proposals for the La Silla Paranal Observatory, including APEX. These proposal numbers represent an increase after a short decline in previous years, attesting to the continued high demand for ESO's observing facilities. Some 80% of the proposals are for the Paranal site with the VLT, VLTI and VISTA.

The observatory continued to operate efficiently by maintaining a high level of availability and a low level of technical downtime for its telescopes and instruments — key elements for productive scientific observations. In 2015 a total of 1970 nights were scheduled for scientific observations with the four UTs at the VLT and with the two major telescopes at La Silla. This is equivalent to about 90% of the total number of nights theoretically available over the whole year. The remaining 10% of nights were scheduled for planned engineering and maintenance activities to guarantee the continued performance of the telescopes and instruments. Time slots for the commissioning of new instruments and facilities were also included in this scheduled downtime. There were 50 nights of commissioning time on the UTs in 2015, primarily to complete the commissioning of the second generation instruments MUSE and SPHERE. Out of the available science time for the VLT, 3.6% was lost as a result of technical problems and about 18.1% as a result of adverse weather conditions. On La Silla bad weather accounted for losses of about 19.6%, technical problems for about 1%.

VISTA delivered 261 nights of survey observations out of 350 scheduled nights. Of 356 scheduled nights on the VST, 260 nights of survey observations were delivered. Both survey telescopes were affected by about 20% weather losses. The technical losses of VISTA were, at 5.5%, noticeably higher than at the UTs. For the VST, the technical losses amounted to 6.7%, which is still higher than the target, but only half the value of the previous year.

Complementing regular VLT operations, the VLTI was scheduled for an additional 79 nights to execute scientific observations using baselines with either the UTs or the ATs. Of the scheduled VLTI science time, 2.2% was lost to technical problems and 14.8% to bad weather.

In preparation for the arrival of the second generation VLTI instruments GRAVITY and the Multi AperTure mid-Infrared Spectroscopic Experiment (MATISSE), the VLTI was closed for scientific operation from March to October 2015 to allow the VLTI infrastructure to be upgraded efficiently. This amounted to 225 engineering nights and 36 commissioning nights. Scientific operations resumed successfully in November with AMBER and the Precision Integrated Optics Near-infrared Imaging ExpeRiment (PIONIER), the latter having been relocated to the VLTI laboratory.

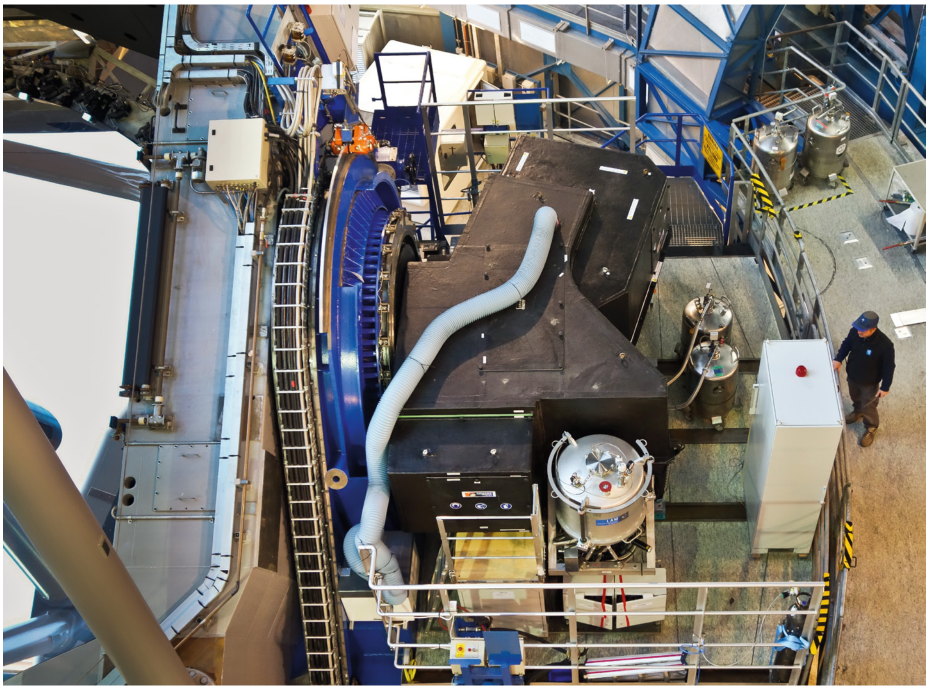
The combination of high operational efficiency, system reliability and availability of the La Silla and Paranal telescopes and instruments for scientific observations has again resulted in high scientific productivity. In 2015 (figures for 2014 shown in brackets), 550 (562) peer-reviewed papers were published wholly or partially based on data collected with the VLT and VLTI instruments at Paranal. In addition, 95 (73) refereed papers referring to observations with VISTA and the VST and 211 (267) referring to ESO-operated telescopes at La Silla were published. There were 63 (74) papers based on APEX observations, out of which 32 (47) used observations during ESO's 24% share of the time.

Since the start of operations in 1999, the VLT and the VLTI have produced a total of 6522 publications and typically added a dozen every week. Interestingly, the veteran workhorse instruments UVES and FORS2 — both commissioned at the beginning of VLT operations — still lead the publications statistics for all ESO instruments in 2015 (2014) with 144 (137) and 91 (105) publications, respectively. The first second-generation instrument, X-shooter, follows with 78 (68) publications in its sixth (fifth) year of operation. The number of publications based on UVES amounts to 1576 over the last 15 years.

Paranal Observatory

Instrumentation

After a successful commissioning period lasting less than ten months, SPHERE started science operations on 2 April 2015. SPHERE's primary scientific aim is to image and characterise giant exoplanets orbiting nearby stars. The star could be up to a million times brighter than the orbiting planets and SPHERE employs three novel techniques to achieve the highest possible imaging contrast and tease out faint exoplanetary signatures: extreme adaptive optics corrects for the effects of the Earth's atmosphere; a coronagraph blocks out the light from the star; and differential imaging exploits differences between the planetary and stellar light in terms of its colour or polarisation. Obviously these high-contrast imaging techniques have other applications beyond the detection of exoplanets, as they allow any close environment around stars to be studied at the highest spatial resolution.

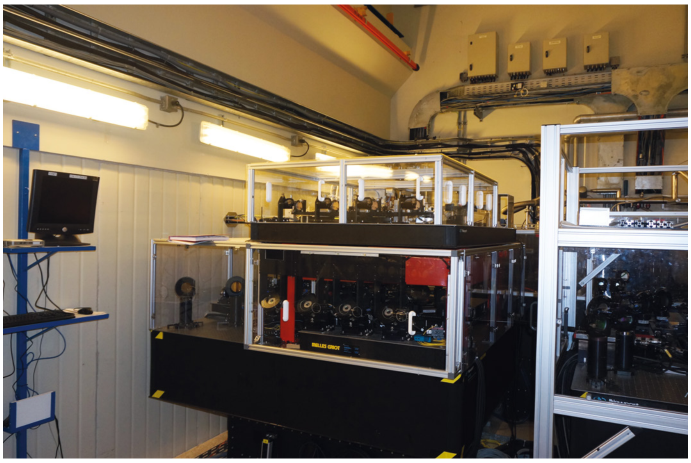

ESO/J. Girard (djulik.com)

The SPHERE instrument at the Nasmyth focus of VLT UT3.

The VLTI Mid-infrared interferometric instrument (MIDI) was decommissioned in March after 11 years of operation to make room in the VLTI laboratory for the second generation instruments GRAVITY and MATISSE. As a mid-infrared (*N*-band, 8–13 μm) two-beam combiner and spectrometer, MIDI was a VLTI first-generation workhorse instrument and produced 134 refereed publications over its operational lifetime, with more publications to be expected in the coming years. Owing to its sensitivity at mid-infrared wavelengths and a spatial resolution of some 10 milliarcseconds, MIDI was able to make major scientific contributions to a number of topics, such as resolving the complex structure of dust tori in active galactic nuclei and characterising circumstellar discs around stars.

The VLTI visitor instrument PIONIER, which was developed by the Laboratoire d'Astrophysique de Grenoble (LAOG) in France, was successfully relocated to its new position, where it will operate as a VLTI facility instrument, and the VLTI visitor focus is now discontinued. The acronym PIONIER stands for Precision Integrated Optics Near-infrared Imaging ExpeRiment and encapsulates the instrument's primary goal to make model-independent milliarcsecond-resolution images of the surfaces and close environments of stars, including their planets, and to better understand the powerful engines associated with black holes found at the centres of galaxies. The heart of the instrument is an integrated optical circuit that interferes the light from four telescopes. The resultant resolving power of the telescope array is that of a much bigger virtual telescope some 100 to 200 metres across — limited only by how far apart the telescopes are positioned. PIONIER can combine the *H*- or *K*-band light of four telescopes on six simultaneous baselines, making it the first VLTI instrument to provide real imaging capabilities.

PIONIER had already been successfully used by its Principal Investigators from Grenoble, in collaboration with the astronomical community, for the past five years as a VLTI visitor instrument. As a result of its scientific success and the continued interest of the community, ESO and LAOG developed an agreement to continue PIONIER as a facility instrument operated by ESO with technical and data-processing support from LAOG. However, since the original plan for the introduction of the VLTI second generation instruments did not envisage that



PIONIER is now located in “3D” on top of FINITO in the VLTI laboratory.

The second generation VLTI instrument GRAVITY under test at the Paranal Observatory.

PIONIER would remain in the VLTI laboratory when the second-generation VLTI instruments arrived, a new location had to be identified. Eventually, PIONIER had to be placed on top of the Fringe-tracking Instrument of NIce and TOrino (FINITO) with a periscope-type pick-up for the four telescope beams. Since this relocation in the third (vertical) dimension, the instrument is now frequently referred to as PIONIER-3D.

GRAVITY is the first second-generation VLTI instrument to arrive at Paranal. It is a four-beam combiner for the VLTI working in the *K*-band. Its main operation mode uses beams from all four UTs to measure astrometric distances between objects located within the 2-arcsecond VLTI field of view. By exploiting the sensitivity of the UTs with 4-milliarcsecond imaging resolution and 10-microarcsecond astrometric precision, GRAVITY will revolutionise the dynamical measurements of celestial objects. It will probe the physics close to the event horizon of the black hole at the Galactic Centre; unambiguously detect and measure the masses of black holes in massive star clusters throughout the Milky Way; uncover the details of mass accretion and jets in young stellar objects and active galactic nuclei; and probe the motion of binary stars, exoplanets and young stellar discs.

Major upgrades to the VLTI infrastructure were required before the second generation VLTI instruments GRAVITY and MATISSE, and the second generation VLT instrument, the Echelle SPectrograph for Rocky Exoplanet- and Stable Spectroscopic Observations (ESPRESSO), could be installed. These upgrades affected the VLTI laboratory, as well as the UTs and their coudé focus stations and the ATs. Science operation of the VLTI was paused on 5 March 2015 so that these many major interventions to the VLTI infrastructure could be implemented efficiently.

A crucial component of the upgraded infrastructure is a new maintenance station for the ATs. This new station is located next to the VLTI building and allows the relay optics of the AT placed on the station to be easily accessed. The AT maintenance station is fully integrated into the interferometer so that the AT optics can be precisely aligned with the interferometer. Construction of the maintenance station began in September 2014 and involved heavy earth works, which continued while the interferometer was still in operation. The station was delivered in April 2015, just in time for the installation and commissioning of a star separator at each AT.

A star separator is an opto-mechanical system, designed to separate the light from two astronomical objects and feed the separated signal into the interferometer in such a way so as to allow two objects to be simultaneously observed interferometrically or to use one of the two objects as a reference source. Eight star separators had to be installed at the VLTI, four on the ATs and four on the UTs. Each star separator compensates for field rotation, stabilises the beam tip-tilt and adjusts the lateral and axial alignment of the pupil. Chopping and counter-chopping on the science object or the guide star have also been implemented. Two AT star separators were upgraded and commissioned in April and May and the second pair were installed and commissioned in June and August. In addition, four new technical charged coupled device (CCD) detectors, four STRAP (System for Tip-tilt Removal with Avalanche Photodiodes) tip-tilt sensor heads, and metrology devices for GRAVITY were installed at the ATs during the same period.

At the UT coudé focus stations, installation and commissioning of the four star separators continued, together with upgrades to the existing four MACAO (Multiple Application Curvature Adaptive Optics Instrument) modules. Preparations were also made for the installation of the Coudé Infrared Adaptive Optics system (CIAO) for GRAVITY and each UT was equipped with a metrology device that is required for GRAVITY. Preparations for the installation of the coudé mirror train at the incoherent combined focus in the combined coudé laboratory (CCL), required for the ESPRESSO, continued at the four UTs.

The upgrades to the VLTI building itself were primarily dedicated to housekeeping, i.e., increased cooling, power, and network capacities and a new cryogenic distribution system for the VLTI laboratory

Images from the VLTI upgrade.

and the combined coudé laboratory. A new, dedicated and highly temperature-stabilised room had already been erected earlier in the year in the combined coudé laboratory to receive the ultra-stable ESPRESSO spectrograph in 2016. Inside the VLTI laboratory the feed optics for GRAVITY were installed and aligned between March and August in preparation for the arrival of GRAVITY.

The infrastructure upgrade period was also used to qualify the AT stations to create new quadruplets that are optimised for the new imaging capabilities of the VLTI with the four-beam combiner instruments PIONIER and GRAVITY. Three new quadruplets are now available, a "large" quadruplet A0-G1-J2-J3 with baselines between 60 and 135 metres, a "medium" quadruplet D0-G2-J3-K0 with baselines between 40 and 105 metres, and a "small" quadruplet A0-B2-C1-D0 with baselines between 10 and 35 metres.

By September 2015 most of the VLTI infrastructure work had been successfully completed. The VLTI was re-tested with the untouched AMBER instrument and the relocated PIONIER-3D instrument. It was a great relief to all the teams who had worked so hard and under intense time pressure to learn that the recommissioning of the VLTI had been completed successfully. Science operations at the VLTI resumed with AMBER and PIONIER-3D observing in mid-November as planned.

The heart of GRAVITY, the beam combiner instrument, was moved into the VLTI laboratory in early October after an intense three-month integration and testing phase in the new integration hall at Paranal. First fringes with four ATs were obtained during the night of 12 October 2015 — a splendid reward not only for the GRAVITY team, but also the ESO team from Garching and Paranal who had worked hard to enable this critical milestone. The commissioning of the imaging mode of the GRAVITY instrument with the ATs had progressed according to plan by the end of the year; imaging with the UTs and the GRAVITY astrometric mode with the ATs will be tackled early in the coming year.

Early in 2015 the first unit of the 4 Laser Guide Star Facility (4LGSF) was brought to Yepun (UT4), which had already undergone a major upgrade so as to be able to receive the Adaptive Optics Facility (AOF). The 4LGSF is the first major deliverable of the AOF. The laser guide star units take advantage of a new solid-state Raman fibre laser technology and each unit delivers more than 20 watts of continuous output power to generate an artificial star at about 90 kilometres altitude. By creating and observing such a bright point of light, the turbulence in the layers of the atmosphere above the telescope can be probed. This information is then used to adjust deformable mirrors in real time in order to correct most of the disturbances caused by the movement of the atmosphere and to create diffraction-limited images.

The heart of the AOF will be the large deformable secondary mirror that is planned to be installed on UT4 in the last quarter of 2016. Despite the fact that the deformable secondary mirror is not due to arrive until 2016, in August 2015 the AOF team was able to demonstrate a crucial step towards steering the deformable secondary mirror with four laser guide stars in the near future. Using the newly installed GRound-layer Adaptive optics Assisted by Lasers (GRAAL) module for the High Acuity Wide field *K*-band Imager (HAWK-I) instrument, the artificial laser guide star produced by the first laser guide star unit was acquired and the light could be fed to the wavefront-sensing system.

Obsolescence projects

The 8-metre coating unit remained out of operation during the year, which is a major concern for the observatory because of the continuous degradation of the quality of the aluminium coatings on the VLT mirrors. After one year of intensive testing and analysis of the root cause of the problems, the observatory placed a contract for the complete refurbishment of the coating unit with the Danish company Polyteknik AS. This will require extensive work, which has started according to plan. The first production coating of a UT mirror is expected for mid-2016, after the refurbishment is completed and the coating unit recommissioned.

Another ongoing obsolescence project at Paranal is to align the VLT emergency stop and safety chain system with current safety standards, which have evolved considerably since the construction of the VLT. For this purpose, the existing installations are being upgraded using Siemens safety programmable

ESO/R. West

Part of the array of 20-centimetre telescopes of the hosted Next-Generation Transit Survey at Paranal.

logic controllers and by replacing part of the relay system. The project was initiated by Paranal in June 2012 and then developed, delivered and commissioned by the Directorate of Engineering. UT2 was the first telescope to be upgraded in collaboration with Paranal in November 2013. UT1 and UT4 followed this year under the lead of Paranal and with the support of Paranal's engineering service provider MT Mecatronica SpA. The upgrade of UT3 is planned to follow in June 2016. The new programmable logic controller-based safety chain system also allows seamless integration with the critical safety systems of the 4LGSF on UT4.

The absence of electronics spares for the primary mirror (M1) cells of the UTs had early been identified as one of the highest risks for the availability of the VLT. Consequently, an obsolescence project was initiated to replace the custom-made M1 cell electronics with commercial off-the-shelf electronics that ensures the long-term availability of spares. Again, the project was initiated by Paranal in August 2012 and then developed and delivered by the Directorate of Engineering. Critical systems were installed and tested on UT1 in November 2014; complete systems were deployed on UT4 in September 2015. UT3 is planned for June 2016 to be followed by UT2 during the next M1 coating period.

Hosted telescopes at Paranal

The Next-Generation Transit Survey (NGTS) telescope is the first hosted telescope project supported at the Paranal site. The NGTS comprises 12 units, each consisting of a 20-centimetre telescope coupled to a large-format, deep-depleted CCD camera with the prime objective of detecting transiting Neptune-sized planets orbiting K and M stars brighter than $V = 13$. Construction in the valley below the VISTA peak was completed in 2014 and science operations started in June 2015. The hosting of the NGTS at Paranal is cost-neutral to ESO since all construction and running costs are reimbursed by the NGTS consortium. In return for hosting the project, the ESO community receives high-level data products produced by the NGTS that will become available through the Science Archive Facility. The NGTS agreement foresees the completion of the project by the end of 2018.

A second hosted telescope project, SPECULOOS (Search for habitable Planets Eclipsing ULtra-cOOl Stars), is complementary to the NGTS and will carry out a photometric survey designed to discover Earth–sized planets transiting the brightest southern ultra-cool stars. The SPECULOOS observing facility consists of four 1-metre robotic telescopes equipped with CCD cameras operating in the very near infrared. The installation of SPECULOOS next to the NGTS had started by the end of the year. The terms of the SPECULOOS agreement are along the same lines as for the NGTS and completion of the project is foreseen by the end of March 2021.

La Silla Observatory

The La Silla Observatory continued to operate successfully according to the streamlined operations model. The La Silla 2010+ model supports the continued operations of the two major telescopes and their instrumentation, i.e., the ESO 3.6-metre telescope with HARPS and the NTT with SOFI (SOn oF ISAAC), EFOSC2 and visitor instruments.

The NTT remains one of the best 4-metre-class telescopes in the southern hemisphere, providing excellent image quality and high efficiency with negligible technical downtime, but remains equipped with two aging facility instruments, EFOSC2 and SOFI, which were commissioned in 1990 and 1998, respectively. Recognising the continued demand for the NTT in the scientific community and the need to seek new instrumentation or another scientifically competitive use of the telescope, seven projects were down-selected from 19 letters of interest following a call for ideas in 2014. The down-selected projects were invited to present detailed scientific–technical proposals by mid-February 2015. As a result, two proposals were invited to proceed directly to the OPC for scientific evaluation and scheduling of their proposals with the existing EFOSC2 and SOFI instruments.

Five detailed proposals were received for the construction of new instruments for the NTT. Following an internal scientific-technical evaluation, the medium-resolution (R = 5000) optical and near-infrared (0.4–1.8 μm) spectrograph SOXS (SOn of X-shooter) was selected as the future workhorse instrument at the NTT. SOXS addresses in particular — but not exclusively — the needs of the time-domain research community. In addition, the high-speed, triple-beam imager ULTRACAM was offered for up to 25% of the NTT time in exchange for cash contributions to the NTT operations. Negotiations with the SOXS and ULTRACAM consortia had been initiated by the end of the year. In addition, the NIRPS (Near Infra Red Planet Searcher) project has been invited to evaluate the option of becoming the red arm of HARPS on the ESO 3.6-metre telescope; this instrument combination would create the most powerful optical–near-infrared high-precision radial velocity machine in the southern hemisphere.

The HARPS spectrograph was upgraded with a set of octagonal fibres to further improve its radial-velocity accuracy and throughput. In particular, the light-scrambling properties of octagonal fibres have been found to be superior to those of circular fibres. The installation and commissioning of the fully re-engineered laser frequency comb for HARPS as an ultra-stable wavelength reference has progressed, but could not be completed as planned.

The La Silla Observatory further continued to support scientific projects at other hosted telescopes, i.e., the 2.2-metre MPG/ESO telescope, the 1.54-metre Danish telescope, the Swiss 1.2-metre Leonhard Euler telescope, the Rapid Eye Mount (REM) telescope, Télescope à Action Rapide pour les Objets Transitoires (TAROT-S), the 1-metre ESO Schmidt telescope, TRAnsiting Planets and PlanetesImals Small Telescope (TRAPPIST), and the ESO 1-metre telescope. Two new telescope projects, BlackGEM and the Multi-site All-Sky CAmeRA (MASCARA) are under discussion for hosting at La Silla.

APEX

In its tenth year of science operations, APEX continued to operate in a quasi-continuous 24-hour operation mode, maximising the exploitation of the exceptional conditions available at the site. In 2015 a total of 265 days and nights were scheduled for science observations with APEX, out of which 210 could actually be used, with more than 4471 hours of on-sky science time — the highest number of hours achieved with APEX so far.

The APEX project is a partnership between the MPIfR (Bonn, Germany, 50% share), ESO (27% share) and the Onsala Space Observatory (OSO, Sweden, 23% share). In view of the continued success of the project, the APEX partners have recently extended their agreement to 31 December 2017 with a provision for a further extension. Corresponding discussions about a potential five-year extension of the APEX Agreement until 2022 have commenced and will be concluded following a critical external review of the project in early 2016.

The competitiveness of APEX in the era of a fully operational ALMA strongly depends on its instrumentation capabilities and therefore on the results of the ongoing and future receiver developments at the APEX partners. In this context OSO and ESO delivered the Swedish-ESO PI receiver for APEX (SEPIA) during the year. SEPIA currently hosts an ALMA Band 5 receiver (160 to 210 GHz) adapted for APEX. In this project ESO contributed the pre-full-production ALMA Band 5 cartridge and the local oscillator as part of the warm cartridge assembly,

The SEPIA instrument installed at APEX.

The SEPIA instrument installed at APEX.

while OSO designed and built the optics, the cryostat and the complete integrated system.

The delivery and commissioning of SEPIA was completed in early 2015 — just in time to harvest the first scientific results with Band 5 before it becomes available at ALMA. The SEPIA instrument can host up to three ALMA-type receivers. To take advantage of this opportunity ESO has developed an agreement with the Netherlands Research School of Astronomy (NOVA) to build a dual polarisation, double sideband Band 9 receiver (610 to 720 GHz) to be installed in SEPIA in early 2016. The replacement of this double sideband Band 9 receiver by a dual polarisation, sideband-separating Band 9 receiver and the construction of a third receiver band for SEPIA is planned to become part of the instrumentation plan for the possible extension of the APEX project to 2022.

The new ArTeMiS bolometer arrays, an ESO PI project, and the APEX Millimetre-wave Kinetic Inductance Camera (A-MKIDS), an MPIfR project, are still being commissioned. The start of science operations is now expected in 2016.

Time-lapse exposure of APEX observing at night.

C. Durán/ESO

A. Tudorica/ESO

The Visible and Infrared Survey Telescope for Astronomy and the magnificent landscape that surrounds the Paranal Observatory.

Data Management and Operations

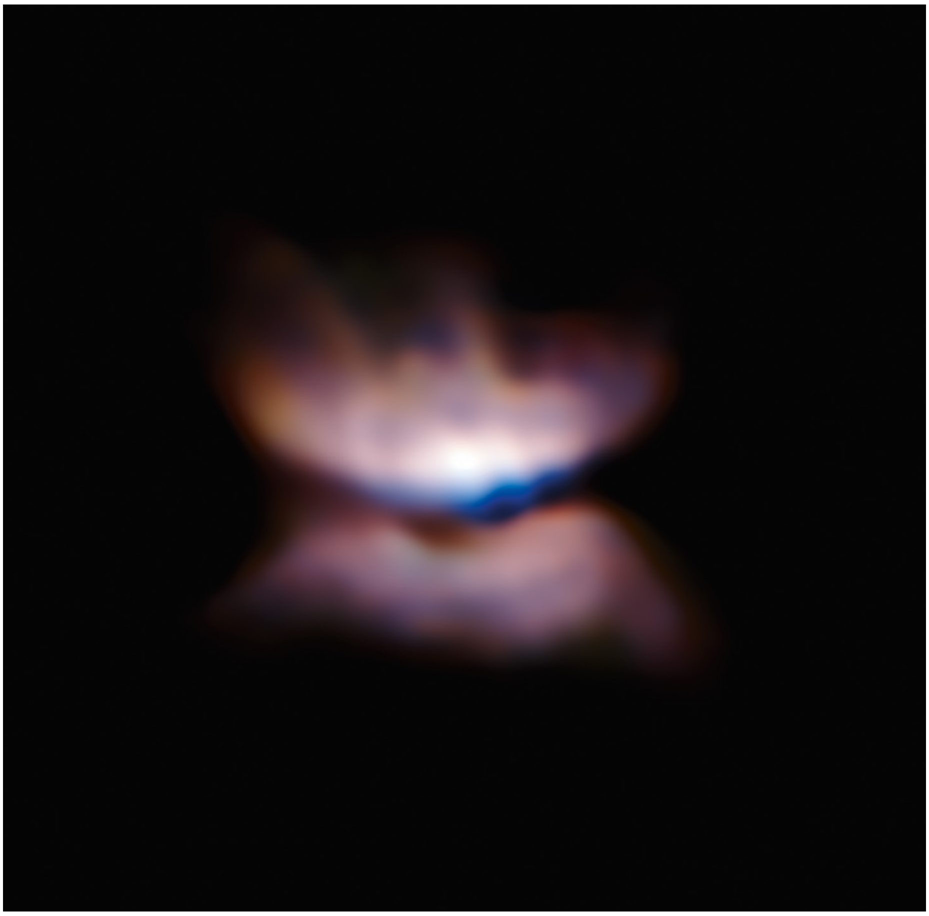
The Data Management and Operations Division is responsible for off-site operations and user support for the La Silla Paranal Observatory. The division enables our community to maximise the science return from the ESO facilities, offering an integrated end-to-end operations approach. A coherent development programme of the dataflow system accommodates the requirements of new instruments and facilities, enabling their integration into operations.

User Support

The User Support Department provides an interface between users of the La Silla Paranal Observatory facilities and ESO. It is responsible for the ESO Users Committee, organising the travel of visiting astronomers to the observatory sites in Chile, and supports primarily, but not exclusively, the preparation of Service Mode observations and their follow-up. The department drives the development of requirements and oversees the implementation of observation support tools, as well as monitoring the effectiveness of Service Mode operations with suitable metrics.

Some of the results based on the core activities of the User Support Department in 2015 can be summarised in a few numbers: supported observing runs (897 new Service Mode runs, including Normal, Large, Public Survey and Director's Discretionary Time runs); helpdesk tickets handled by the department (2427); and visiting astronomer travel arrangements to the observatory sites in Chile — 293 for La Silla, 241 for Paranal and 29 for APEX — similar numbers to 2014.

SPHERE and PIONIER are new additions to the Paranal suite of instruments offered to the whole user community in 2015, while the VLTI interferometric instrument MIDI was decommissioned. SPHERE entered operation in April 2015, following Science Verification, which completed 28 out of 40 programmes, and partially completed eight further programmes, in the first quarter of 2015. SPHERE already has the fourth largest number of allocated Service Mode runs on the VLT, behind the workhorse instruments FORS2, X-shooter and UVES. After the refurbishment of the VLTI, the former visitor instrument PIONIER was offered in Service Mode in October 2015 for the first time. This transition to operations as an ESO instrument was marked by a high demand from the community and 42 Service Mode runs were supported, thus bringing a VLTI instrument among the top four VLT instruments for the first time, in terms of scheduled Service Mode runs.

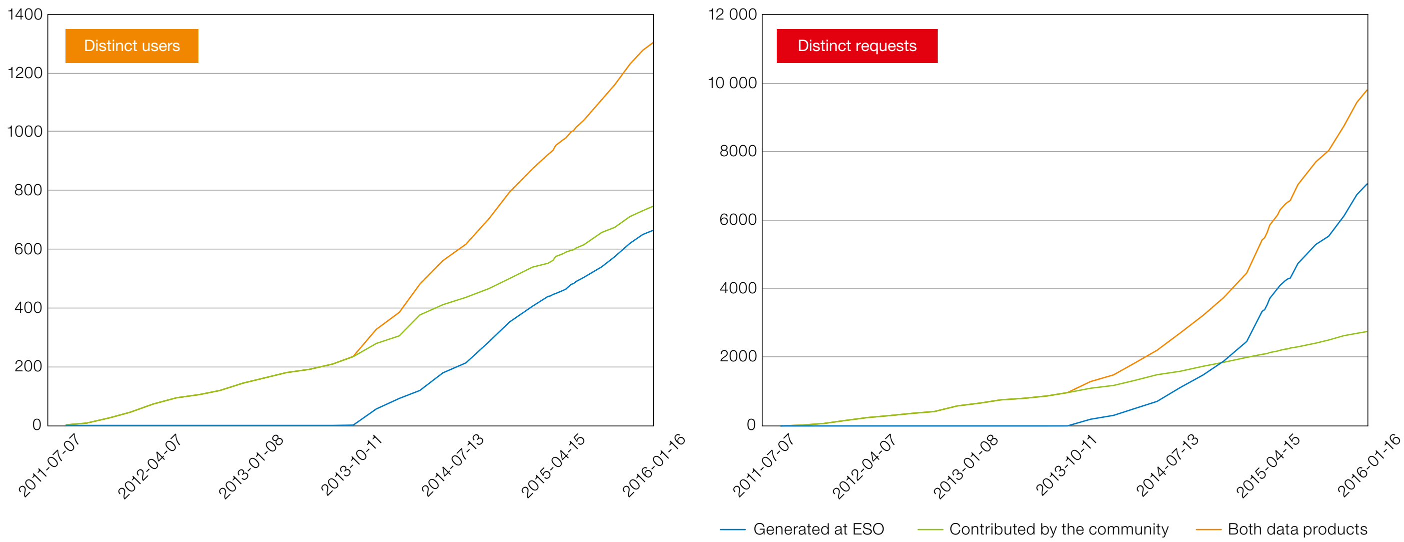


ESO/P. Kervella

A sharp visible-light image of the red giant star L_2 Puppis taken with SPHERE in ZIMPOL mode.

The La Silla Paranal Observatory is carrying out 14 Public Surveys. The User Support Department supports their implementation, monitors observational progress and reports to the ESO Survey Team. In 2015, two new Public Surveys started in Visitor Mode using VIMOS, while the two ongoing Public Spectroscopic Surveys (Gaia-ESO and the Public ESO Spectroscopic of Transient Objects [PESSTO]), received review recommendations to proceed with their final and fifth year of operations. In October 2015 the VISTA Variables in the *Vía Láctea* (VVV) became the first Public Survey to fully complete its observations. The completion of this productive survey was timely, coinciding with the ESO workshop, "Rainbows on the Southern Sky: Science and legacy value of the ESO Public Surveys and Large Programmes", and with the new call for letters of intent for Public Surveys on VISTA.

During 2015 the operations concepts for the upcoming instruments, and for ESPRESSO, GRAVITY, the Adaptive Optics Facility and the 4-metre Multi-Object Spectroscopic Telescope (4MOST) in particular, were examined. Requirements for the evolution of the tools for preparing, executing and reporting observations that are necessary to efficiently integrate these instruments into VLT end-to-end operations were identified, and included in a project that is evolving the Phase 2 tools in line with the mid-term VLT dataflow strategy.



Access to archived data products as a function of time. In both panels the green line displays access to products contributed by the community (deployed since 25 July 2011), the blue line shows access to products generated at ESO (deployed 10 September 2013), and the orange line is for access to both types of products.

The Garching Remote Access Facility became operational in September 2015. This facility enables ESO personnel to remotely connect to instrument workstations in the VLT control building at Paranal. This facility is operated by the User Support Department and is a clone of a similar remote access room located on the Vitacura ESO premises in Santiago. Shortly after commissioning, it was used for remote technical and engineering activities on the wide-field camera OmegaCAM at the VST and SPHERE, and in support of GRAVITY and commissioning the AOF.

Back-end operations

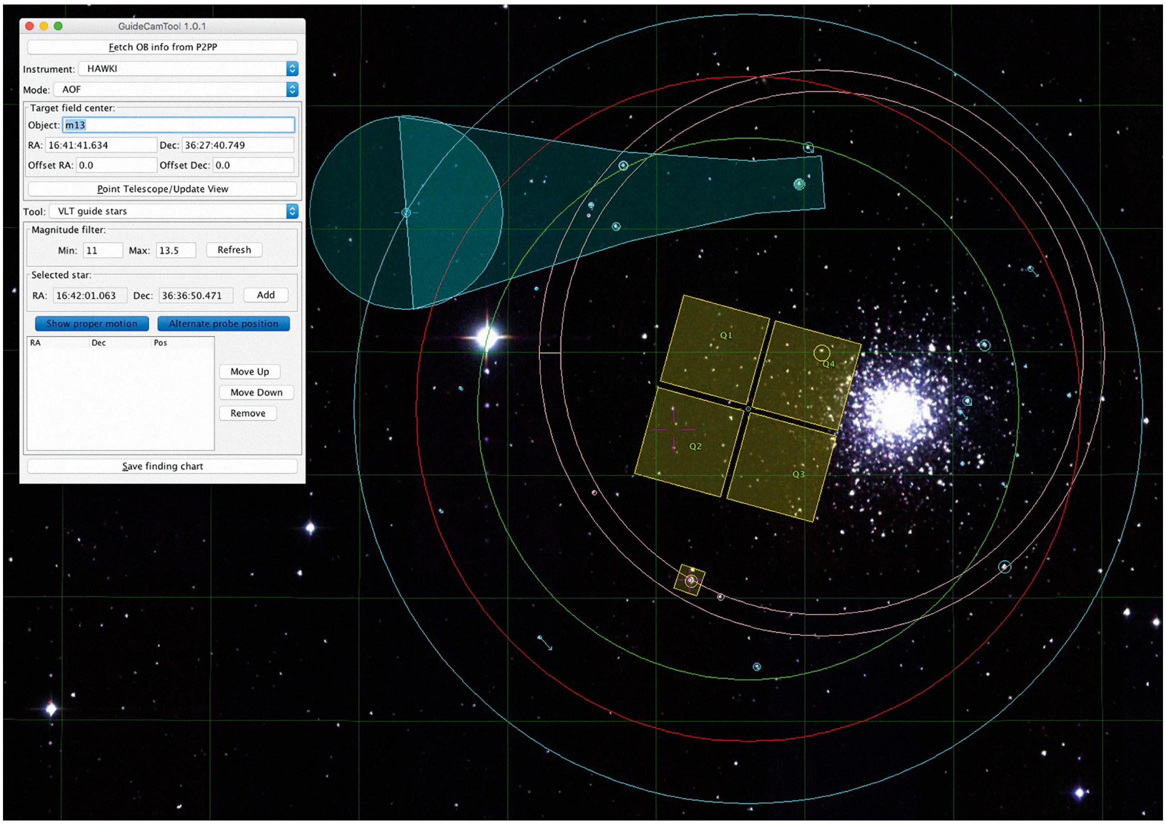
Providing the best science data is at the core of ESO's mission to enable major science discoveries from our community. Much of the activity in 2015 was directed towards making the tools to process data so that science information can be extracted and made available to users, or providing already processed data from which this information can be readily extracted.

A new version of the *Reflex* software tool was released. This new version significantly improves user control over the data processing and the ability to customise the processing to match specific needs. In particular, new capabilities have been added: to browse and interact with the intermediate and final products; to automatically create executable scripts to re-execute the processing; and enhanced book-keeping that allows for more flexible and powerful execution scenarios (for example, to process all previously failed datasets using new parameters). Also, the data-processing software made available to the science community is continually being enhanced, enabling the data to be better exploited. In 2015, enhanced data-processing tools for several VLT instruments, most notably MUSE, KMOS, FORS2 and VIMOS spectroscopy, were developed and released.

In parallel, development of the ESO Science Archive Facility as a science resource continues, both in terms of content and user services. An improved version of the user service that associates the calibrations, needed to remove the signatures imprinted on the science signal by the Earth's atmosphere and by the measurement apparatus, to the science files, and hence reveals the science signal itself, was deployed.

Processed data that can be used immediately for scientific measurements are directly available from the Science Archive Facility. This service relieves users of the need to perform their own data processing. The Science Archive Facility is populated with processed data through two channels. For one channel, data-processing pipelines are run at ESO for selected instrument modes to generate products that are free from instrumental and atmospheric signatures and calibrated in physical units. They cover virtually the entire data history of the corresponding instrument modes and are generated without knowledge of specific science cases, with checks in place to identify quality issues with the products. For the other channel, the community contributes data products generated with processing schemes optimised to serve specific science cases and that have, in most cases, been used in refereed publications. These contributed datasets, which are validated in a joint effort between the providers and ESO before ingestion into the archive, often include advanced products such as source catalogues, stacked or mosaicked images and spectra.

Both the data products contributed by the community and those generated at ESO are in great demand by science archive users (see plots above). Since the first data products were published in July 2011, and up to the end of 2015, in excess of 1300 unique users have accessed products of either origin. For comparison, this is more than one and a half times the number of PIs and Co-Investigators of the Public Surveys currently running at ESO and, in the same period of time, the archive had almost 3500 unique users accessing raw data.



Adaptive optics tip-tilt star selection tool for HAWK-I/GRAAL in use.

Dataflow projects

Dataflow applications and services supporting the end-to-end VLT dataflow cover the proposal submission system (Phase 1), observation specification and execution (Phase 2), archiving and retrieval of raw frames, data reduction, the ingestion of data products including catalogues (Phase 3) and their publication and exploration. These services ensure the astronomical value of the products delivered to our user community and a high operational efficiency and effectiveness, both in Garching and at the observatory. In 2015 a number of software solutions were finalised and brought into operation:

- The unified GuideCamTool for the VLT Mid-Infrared Imager Spectrometer (VISIR), VIMOS and HAWK-I/GRAAL was released to the public. This is a Java desktop application supporting the selection of VLT guide stars, adaptive optics tip-tilt stars and the production of finding charts.
- Laser collision detection in the Service and Visitor Mode Observing Tools was finalised, deployed on Paranal and is fully operational.
- Due to obsolescence, the old, Remedy-based La Silla night-reporting solution was decommissioned and replaced by a modern web application, advancing night reporting on La Silla to the same level as Paranal. The new system logs the downtime and the execution of observing blocks automatically, and computes detailed instrument-specific statistics.
- With the help of a new *archiveReplicator* solution, the content of the entire ESO primary archive was replicated to the Max Planck Computing & Data Facility, a process that took roughly nine months. From 2016 onwards, data will be archived simultaneously, not only to our in-house primary and secondary archives (using spinning disk), but also to the Max Planck Facility (using tapes), improving data safety by ensuring that data is stored on different media and at different locations.
- A new ambient site monitor web display was commissioned in the Paranal control room. Its counterpart in Garching displays both Paranal and La Silla data and is publicly accessible at www.eso.org/asm.

A mid-term strategy in the VLT dataflow is to reduce the need for desktop tools and instead move to web-based solutions, allowing for silent bug-fixing and the incremental release of new features, without the need for users to repeatedly download new versions. Likewise, the aim is to increasingly expose our front-end domains via programmatic web interfaces, enabling users to bypass ESO user interfaces — such as the Phase 2 tool — and produce content — such as observing blocks — in their preferred fashion. As a first step, a comprehensive Phase 2 Visitor Mode programmatic interface has been specified, implemented and published, which allows consortia to build instrument-specific tools through this interface. As an example, ESPRESSO will benefit from carrying out dynamic reprioritisation to optimise observing strategies for exoplanet hunting.

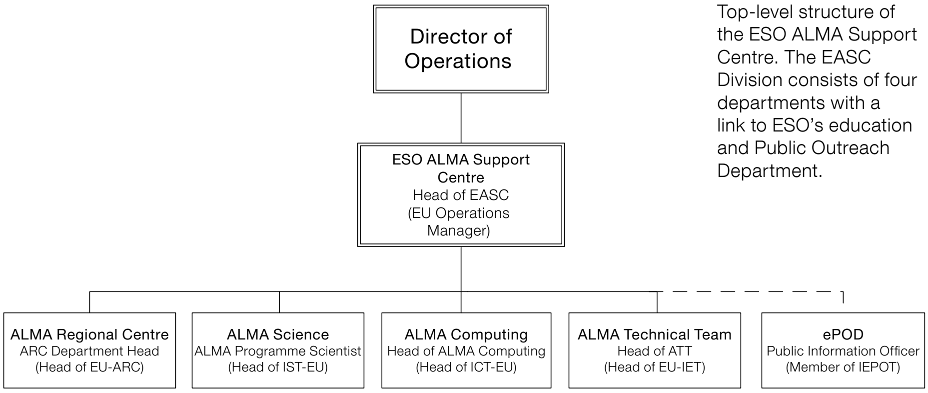
Lore, one of ALMA's two transporters, carries an antenna to a new location on the Chajnantor Plateau.

Enrico Sacchetti/ESO

ALMA and the ESO ALMA Support Centre

ALMA, the Atacama Large Millimeter/submillimeter Array, is a large interferometer operating at wavelengths ranging from 0.3 to 9.6 millimetres. ALMA was constructed between 1999 and 2014 through an international collaboration between ESO, North America and East Asia in cooperation with the Republic of Chile. The ALMA Observatory comprises 66 high-precision antennas with state-of-the-art receivers located on the Chajnantor Plateau at 5000 metres above sea level in the district of San Pedro de Atacama, in the Chilean Andes. The 12-metre-diameter antennas can be placed in configurations with reconfigurable baselines ranging from 15 metres to 16 kilometres. Resolutions as fine as 0.005 arcseconds can be achieved at the highest frequencies, a factor of ten better than the HST at optical wavelengths.

The ESO ALMA Support Centre is ESO's offsite operations unit for ALMA and a division in the Directorate of Operations. It is one of the three ALMA Support Centres, which are based at the three ALMA Executives in Europe, North America and East Asia to support the JAO and ALMA onsite operation. The EASC comprises the ALMA Regional Centre, ALMA offsite technical maintenance and development support, and ALMA science and outreach (see organigram). The high-level scientific representation and scientific guidance of the European ALMA project are provided by the European Programme Scientist, who acts in close collaboration with the VLT and E-ELT Programme Scientists to exploit the scientific synergies with ESO's other major programmes. The EASC is the face of ALMA for the European scientific community and the international ALMA partners for ALMA operations. It is an important component for the success of ALMA, both for its performance as a scientific instrument and for ESO as a partner in the ALMA project.



Top-level structure of the ESO ALMA Support Centre. The EASC Division consists of four departments with a link to ESO's education and Public Outreach Department.

View of ALMA on the Chajnantor Plateau at 5000 metres above sea level.

ESO/A. Caproni

ESO/Rigotti + Simunovic Arquitectos

ALMA Residencia design. General view of the array of buildings. The large building in the foreground contains the dining room, kitchen and leisure facilities and is accompanied by six dormitory buildings.

ESO/A. Caproni

Construction of the ALMA Residencia started in February 2015 and was in an advanced state by the end of 2015.

ESO/W. Wild

One of the six dormitory buildings of the ALMA Residencia.

ALMA Residencia

The construction of the ALMA Residencia started in February 2015, after the design phase and once the construction contract had been tendered. The Residencia is ESO's last deliverable to the international ALMA project.

Given the harsh desert environment, remote location and shift work (both day and night) for the ALMA staff, the Residencia is designed to provide a pleasant onsite environment for staff and visitors who come from as many as 20 countries worldwide. The design was undertaken by the Finnish architects Kuovo & Partanen and then adapted to the Chilean market by Rigotti & Simunovic Arquitectos, a Chilean firm of architects.

The Residencia has two main zones: common areas and dormitory areas. The design uses a modular concept so that more accommodation can be added if necessary. Initially there will be 120 rooms extending across six buildings. The main building includes a kitchen and dining room with enough space to accommodate half of the residents at the same time. Leisure facilities, such as a library, cafeteria, lounge, spa with gym, small swimming pool, sauna and barbecue area, are also part of the main building.

During 2015, construction work progressed according to plan and the Residencia is on track for delivery in 2016. The first dormitory buildings have been erected and the central building is proceeding well. Two webcams have been installed at the Operations Support Facility (OSF) to take pictures every ten minutes from two different perspectives, and images are available in real time at www.eso.org/public/teles-instr/alma/residencia/.

The ALMA Regional Centre in Europe

Since July 2015, the European ALMA Regional Centre (ARC) has been fully integrated into the EASC. The ARC continues to provide comprehensive user support to the European community, strengthen the European ALMA community, and broaden access to ALMA science. Since the start of ALMA Early Science in 2011, the ARC has been working to make ALMA accessible to all European astronomers and optimise the scientific return. It also provides expert assistance to the commissioning of ALMA and the optimisation of its capabilities, and provides tools to the users and the observatory, all of which contributes to making ALMA work.

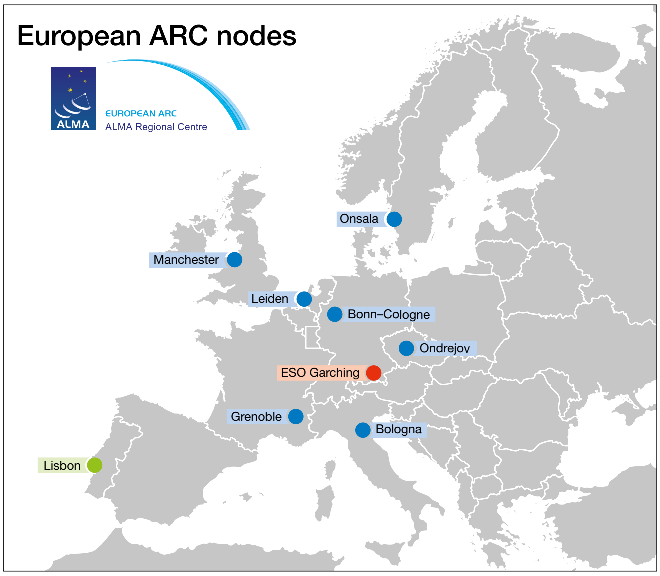
The European ARC is unique in the ALMA partnership for having a distributed network of ARC nodes, with the ESO node coordinating the activities and working in close contact to the ALMA Observatory. The ARC nodes have close ties with their communities (active research environments), host many of the millimetre/submillimetre experts in Europe, and are actively involved in commissioning ALMA and optimising the array's capabilities.

In 2015, the European ARC was heavily engaged with the entire Level 2 Quality Assurance process covering ALMA data for European PIs — amounting to 138 + 347 (Cycle 1 + Cycle 2) scheduling blocks out of 173 + 446 (Cycle 1 + Cycle 2) recommended for observations. The remaining scheduling blocks have either not been observed or the data did not pass the quality criteria. As in 2014, this activity involved full calibration and imaging of the data, verification of the quality criteria, and, where these were fulfilled, standardised packaging and preparation for delivery.

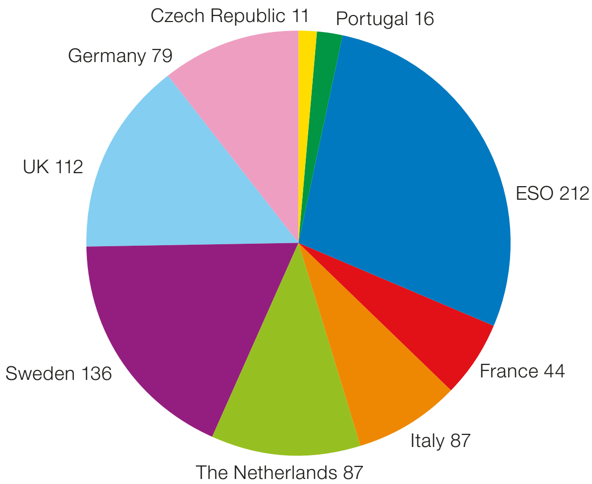
The data processed in 2015 comprised the complete fraction of the European projects of the ALMA Cycle 2 data, carryover data from ALMA Cycle 1 and the first datasets taken at the beginning of Cycle 3 during the long-baseline campaign. The calibration was partially helped by the newly introduced ALMA data reduction pipeline. The work was reasonably evenly spread between ESO and all the European ARC nodes. In total almost 35 trained analysts contributed.

Scientific impact of ALMA observations

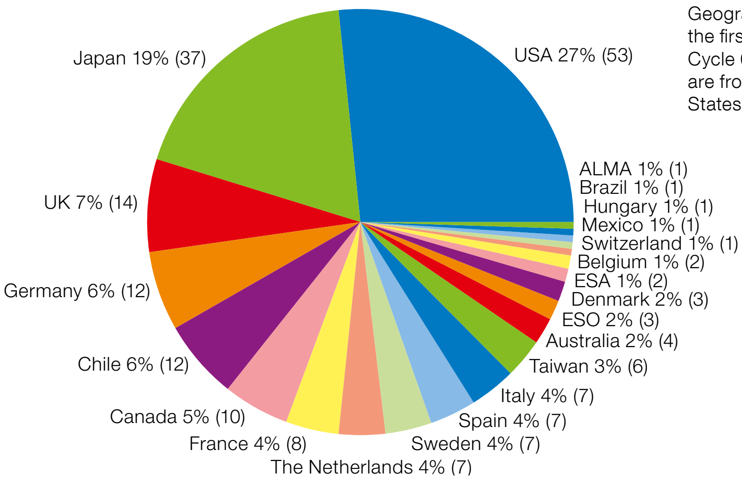
The time was right in 2015 to have a first look at the scientific impact of ALMA observations. In particular, the analysis examined publications that made use of data from ALMA's very first observing cycle, which ran through 2011–2012 with the last dataset becoming public in 2013. The study was possible because authors of scientific publications making use of ALMA data are obliged to mention the data that they have used in those publications. Staff at the ESO Library then extract this information and enter it into a publication database, which also provides the links between the publications and the data used. Among the most remarkable findings is the fact that 7% of all ALMA publications appear in the high-impact journals *Nature* or *Science*.



The ALMA Regional Centre in Europe is a distributed network consisting of the central node at ESO (red), seven nodes in different countries (blue), and a centre of expertise in Portugal (green).



The contributions of the various parts of the EU ARC network to the Level 2 Quality Assurance effort in 2014 and 2015. Numbers represent Member Observation Unit Sets (MOUS), i.e., separately processable datasets (made up of one or more execution blocks).



Geographical distribution of the first authors of ALMA Cycle 0 publications. 40% are from ESO Member States and ESO.

Furthermore it was revealed that ALMA publications appear very fast after the data have been made available to the PIs: typically it takes them only 1.4 years to write a first publication. It was also found that publications using ALMA are cited frequently by authors from other publications. So far each ALMA publication has been cited about ten times per year. Finally, the analysis showed that data from an ALMA project typically leads to several publications. On average, so far, two publications result from a single ALMA programme, and there is one ALMA programme that has already led to 13 publications. To summarise, it was found that ALMA is indeed fulfilling its promise as a transformational facility for the observation of the Universe in the submillimetre.

ALMA Technical Team

The ALMA Technical Team (ATT) is the part of the EASC that is responsible for off-site technical support and hardware development projects. In 2015, the ATT provided support, specific knowledge and assistance to the ALMA Observatory in the areas of antennas, antenna transporters, front ends, calibration devices, back end, correlator and site infrastructure (in particular for the antenna stations and the power system).

The full range of ALMA-wide maintenance plans has been developed. The implementation plan for the JAO-led Integrated Engineering Team (IET), i.e., the combination of the engineering teams of the three ALMA Executives and the JAO, was issued in May 2015. The ATT at ESO is the European part of the IET (also called IET-EU). It has provided remote (off-site) maintenance and onsite support for the ESO deliverables throughout 2015, including:

- All warranty actions relating to the antennas were followed up with the ALMA construction consortium, AEM, in Europe and onsite to ensure high antenna availability. The AEM antenna integration area has been cleaned up, and the AEM office containers and the assembly hall were purchased by ESO. The AEM site has been handed over to the JAO. Tier 3 maintenance tasks in the antennas were taken care of, including missions to the site as necessary. A reliability issue was found on the brake system that showed lubricant leaks on some antennas. The manufacturer has identified the root cause and recommended improvements to the maintenance procedures.
- The ALMA Technical Team at the EASC provided spares for the AEM antennas. ESO staff supported AEM in warranty activities with some onsite missions.
- A Band 7 cryostat test bench was commissioned at the Operations Support Facility in September by engineers from ESO and the Institut de Radioastronomie Millimétrique. During the same mission, two Band 7 cold cartridges were repaired.
- The refurbishment campaign, started in 2014, of the amplitude calibration devices continued as a joint effort with the JAO. The ATT contributed with dedicated missions to the OSF and hired manpower in Chile. By the end of 2015, 67 units had been refurbished.
- Contracts in Europe placed by the EASC/ATT are running for off-site maintenance of digitisers, digitiser clocks and correlator tunable filters.

ALMA Computing

The ALMA computing team at the EASC is responsible for developing and maintaining several software subsystems for the ALMA Observatory in the areas of archive services, common infrastructure, observing preparation, observatory interfaces, telescope calibration and software engineering and quality management. The team also contributes significant resources to groups led by other ALMA partners, namely in the areas of CASA, the Common Astronomy Software Applications package, the science pipeline and integration testing.

A particular focus is on science operations tools. These range from the ALMA Observing Tool (used by Principal Investigators to create observing proposals) and the Phase 1 Manager (a suite of online tools used by the proposal review panels), to tools that directly support the operators and astronomers at the observatory during the full lifecycle of observing projects. In addition, the user interfaces that allow astronomers from the worldwide ALMA community to keep track of their observing projects are being maintained. A new addition to the latter category is presented in the following.

SnooPI — Intuitive project-tracking for Principal and Co-Investigators — is the latest software application that has been developed for the ALMA community. It allows Principal and Co-Investigators to follow their projects from the moment the proposal review process is complete, tracking the project's evolution through observing, data reduction and quality assurance until the last data products have been archived and delivered. SnooPI (or Snooping Project Interface) is a web-based application and can be viewed on almost any computer or tablet; it opens with a dashboard summary view of observing projects, scheduling blocks, Helpdesk tickets and recent news, and can then expose increasing levels of detail, down to the individual executions. SnooPI supersedes the PI view of ALMA's Project Tracker; from now on the Project Tracker will focus exclusively on the needs of ALMA staff.

ALMA development

The ALMA partnership foresees continuous upgrades and the development of new software, front ends (for example, additional receiver bands) and other hardware or system capabilities during the operations phase. In 2015, two projects were (co-) funded by ESO: adding Band 5 to all ALMA antennas, and a fibre connection from ALMA to the rest of the world. In addition, a number of development studies were carried out.

Band 5 receivers for all ALMA antennas

The main development project currently being carried out by ESO is to equip all ALMA antennas with Band 5 receivers. The cold cartridge assemblies are designed and produced by a European consortium of NOVA (the Netherlands) and the Group for Advanced Receiver Development (Chalmers University, Sweden). The project is proceeding as planned with the expected delivery of all 73 receivers to Chile before the end of 2017. The warm cartridge assemblies will be delivered by

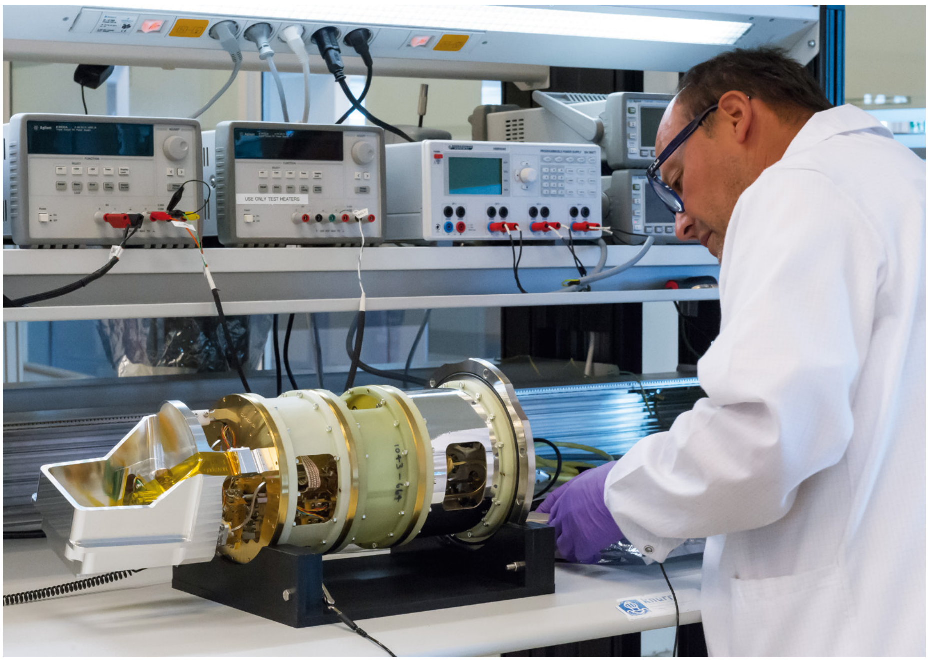
NRAO. ESO is also responsible for supplying all the required auxiliary equipment for the Band 5 receivers.

The integration of Band 5 cartridges into ALMA antennas, which started in May 2015, has been progressing very well. By the end of 2015, 14 cartridges had been delivered to Chile, of which 12 were integrated into front ends and tested at the Front End Integration Centre at the OSF. All Band 5 receivers installed in the front ends met specifications. In particular, the sensitivity, sideband rejection ratio and polarisation purity performance are all well within the tight specifications. At the end of 2015, 12 antennas with Band 5 receivers were available at the Array Operations Site. Engineering Verification for most of these has been completed, with no issues found. An important milestone was met on 7–8 July 2015 when the first fringes with the Band 5 production cartridges were achieved (see ESO announcement ann15059). On 31 July, using three antennas equipped with Band 5, successful phase closure was achieved on sky.

ESO has managed a number of contracts to deliver the necessary auxiliary components for the Band 5 receivers:
– The contract for the production of the bias modules and the cartridge power distribution systems, including the test benches for their testing and verification, awarded to the company Abengoa (Spain), has been completed. All bias modules and cartridge power distribution systems have been delivered to Chile and accepted.
– Optical windows have been produced by Alpes Precision (France) and delivered to the OSF. Most of these windows have already been assembled; the remaining installation will be completed at the OSF by ESO staff in the first quarter of 2016.
– Photomixers have been produced by the UK Rutherford Appleton Laboratory and delivered to NRAO for integration with warm cartridge assemblies.

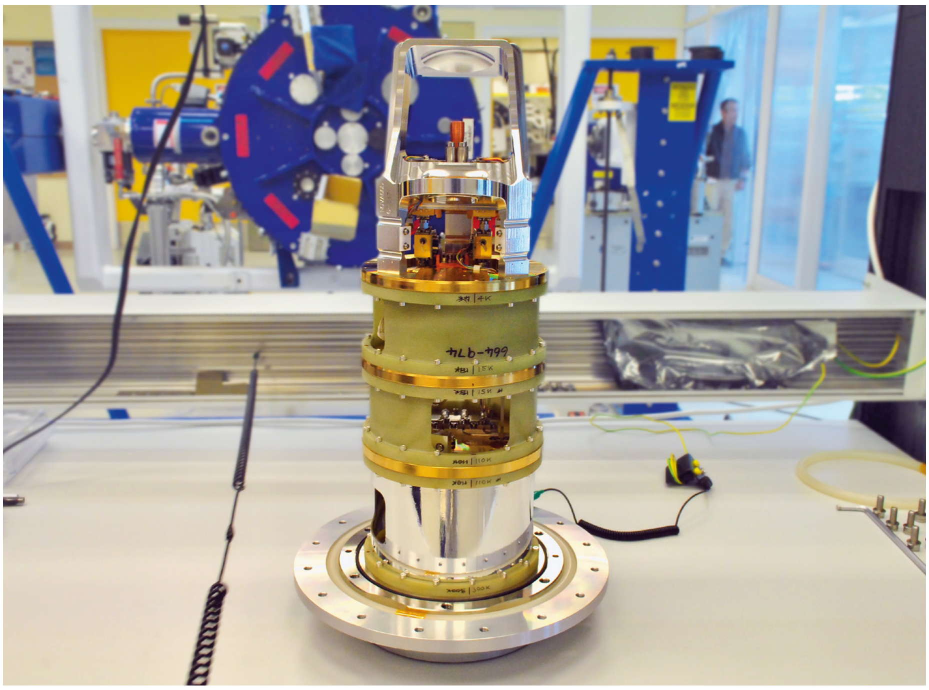
Optical fibre connection for ALMA

The optical fibre project, led by the JAO with contributions and co-funding by ESO and NRAO, provides a fast network connection between the ALMA Observatory and Santiago. After completion of the construction, the corresponding permits and formal handover to ALMA were pursued in 2015. The system has been used in testing mode with 100% functionality.



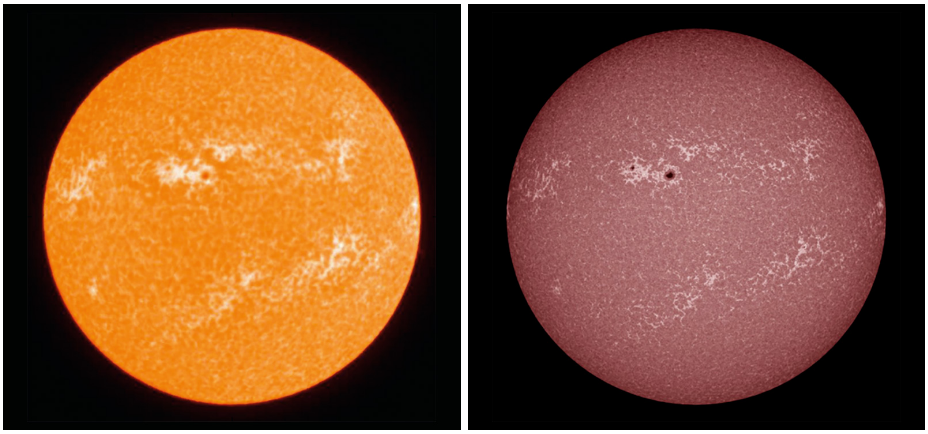
Testing of a Band 5 receiver cartridge at the ALMA OSF before integration into a front end cryostat.

ESO/A. Caproni



A Band 5 receiver cartridge at the OSF ready for integration into an ALMA front end (visible in the background) with all the other Bands (3 to 10).

ALMA (ESO/NAOJ/NRAO), N. Tabilo



ALMA (ESO/NAOJ/NRAO)

NASA/SDO and AIA science team

ALMA single-dish Band 9 test image (left), obtained as part of the December 2015 Solar Campaign, compared with a simultaneous 170 nm ultraviolet image from Solar Dynamics Observatory Atmospheric Imaging Assembly (right).

Development studies

Major progress was achieved by several of the ESO ALMA upgrade studies during 2015.

mmVLBI: The study, led by the MPIfR, on the possibility of operating millimetre Very Long Baseline Interferometry (mmVLBI) with ALMA as a station of the Global mmVLBI array network was successfully carried out and concluded in 2015. Operational concepts were discussed at an international meeting held in Bologna in January 2015 and further refined throughout the year with the various stakeholders. Three-millimetre VLBI capabilities with ALMA will be offered in Cycle 4 (starting in October 2016) as part of the Global mmVLBI array network.

Solar observing modes: Steady progress was made through 2015 in order to allow the release of solar observing modes. As a result of these efforts, solar single dish and interferometric continuum observations of the Sun in Bands 3 and 6 (3 mm and 1.3 mm) will be offered as part of ALMA Cycle 4. Additional work is required to also offer spectral line, polarisation and other frequency band observing modes; some of these will be addressed in 2016 as part of the current study agreement with the Ondrejov Czech ARC node. The figure shows a single dish ALMA test image of the Sun obtained in the December 2015 Solar Campaign with Band 9.

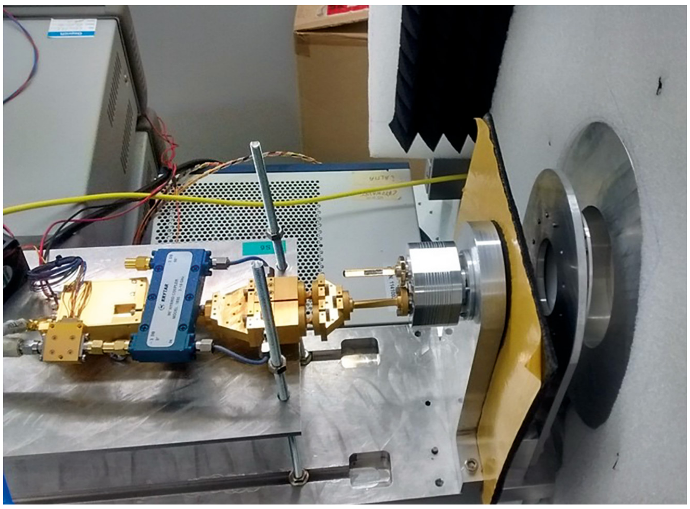
Band 2–3 components: In 2015, as part of a collaboration between ESO, the University of Manchester, the UK Science and Technology Facilities Council (STFC), the Italian Istituto Nazionale di Astrofisica (INAF), the University of Chile, and NAOJ, room temperature testing and validation of passive components for a new-concept broadband receiver covering the frequency range from 67 through 116 GHz was carried out at ESO. The figure to the right shows the assembled testbed in the ESO laboratory.

Next generation digitisers: In a study led by the Laboratoire d'Astrophysique de Bordeaux, a new generation of digitisers for ALMA are being designed and tested. In 2015 an investigation of the available technologies on the market, as well as preliminary design and simulation concepts, were undertaken. The detailed design and possible prototyping of a broadband, fast, and easier to maintain next generation digitiser for ALMA will be explored in 2016.

Cryocooler operations: The Rutherford Appleton Laboratory (STFC, UK) is investigating the possibility of improving the energy consumption of the ALMA receiver cryostats, with the aim of achieving a more cost-effective cooling of the receiver cartridges. Possible routes to optimise the operations of the cryocoolers have been identified, and will be tested in the operational environment in 2016.

Data analysis software: The first release of the myXCLASS software integrated with CASA 4.5 has been prepared for testing. This release contains direct access to the MAGIX optimisation algorithms and an initial version of the line identification functionality. Future releases will include upgraded versions of the line identification routines and an interface to the radiation transfer module ARTIST.

Integrated alarm system: A study for the design of an integrated alarm system for ALMA, led by ESO with the participation of the JAO and the North American and East Asian ALMA Executives, is being carried out in collaboration with experts from ESA. The goal of the new system is to have a more direct overview and diagnostics of all the ALMA operations subsystems from the OSF control room. This will allow more accurate and faster diagnostics and thus more rapid resolution of problems or failures.



Band 2–3 passive components on a room-temperature testbed: horn, orthomode transducer and down converter assembly. The infrared filter, lens and the opening to mimic the cryostat window are on the right side of the picture.

ESO/A. Ghizzi Panizza (www.albertoghizzipanizza.com)

ALMA antennas reflected in a pool of water on the Chajnantor Plateau.

Programmes

ESO/G. Hüdepohl (atacamaphoto.com)

Instrumentation for the La Silla Paranal Observatory

The year was a remarkably productive one for the Directorate of Programmes. In particular, major progress has been made on Phase 1 of E-ELT construction: as well as the completion of the road to Armazones and the platform, several major industrial contracts are underway. The agreements for the first three E-ELT instruments — MICADO (Multi-Adaptive Optics Imaging Camera for Deep Observations), HARMONI (High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph) and METIS (Mid-infrared E-ELT Imager and Spectrograph), and the MAORY (Multi-conjugate Adaptive Optics RelaY) system – have all been signed. The Technology Development Programme is now well underway and is aimed at securing the technologies that are needed for the future. For the Paranal Instrumentation Programme, progress has been made across the board on all projects, including a massive effort to prepare the VLT Interferometer for the arrival of GRAVITY, which culminated in first fringes with the GRAVITY instrument in October, and unprecedented fringe-tracking performance with the Auxiliary Telescopes in November.

The flattened mountaintop of Cerro Armazones that will host the 39-metre European Extremely Large Telescope.

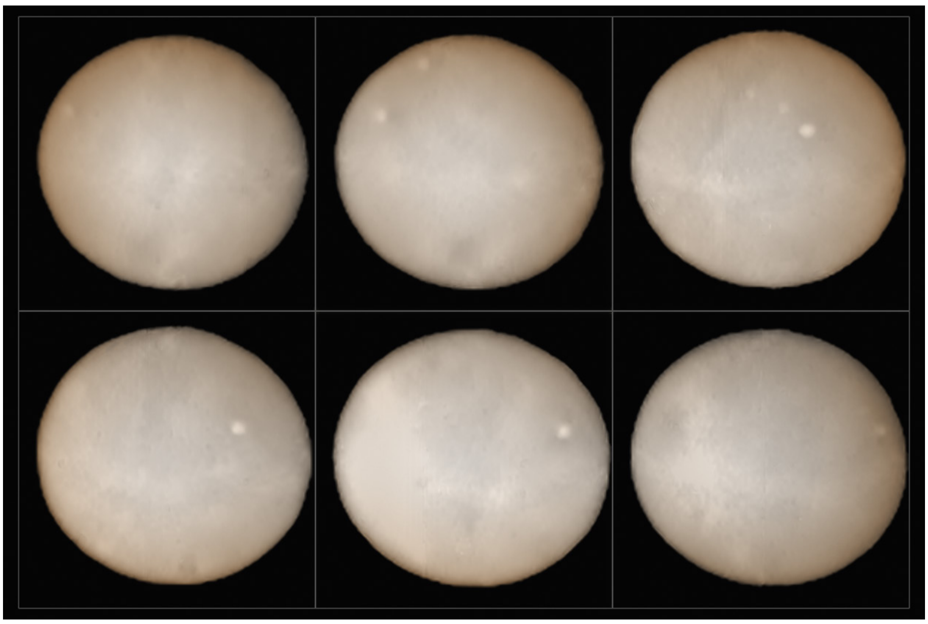
Paranal instrument commissioning

Following commissioning in 2014, SPHERE carried out an extensive Science Verification programme in early 2015 and was offered to the community for open time observations, starting in April 2015. SPHERE was also used for about 50 nights of Guaranteed Time Observations (GTO) throughout the year. Two major interventions to SPHERE took place in May and November 2015. In May, the active toric mirror was replaced, and a new deformation mechanism was installed, which provides a greater range to compensate for the temperature-dependent shape of the high-order deformable mirror. In November, SPHERE was upgraded to the VLT2014 software, and the adaptive optics loop frequency increased from 1200 to 1380 hertz, providing better correction in conditions of fast seeing changes.

SPHERE continues to perform very well and is scientifically very productive. The superb spatial resolution — better than 20 milliarcseconds at optical wavelengths, and imaging contrast better than 10^{-6} at a few tenths of an arcsecond in the near infrared — has led to a number of spectacular results and discoveries. Prominent examples include spatially resolving the surfaces of nearby giant stars and the detailed imaging of structure in circumstellar debris discs. More than one hundred stars have already been checked for the presence of giant planets.

GRAVITY is a second generation VLTI instrument (PI: Frank Eisenhauer, MPE Garching), which combines signals from four telescopes in the *K*-band. GRAVITY will measure the astrometric separations of objects located within the 2-arcsecond field of view of the VLTI with a precision of 10 microarcseconds and will enable spectroscopic imaging. Following the successful Provisional Acceptance Europe (PAE) process, the associated beam combiner instrument was shipped to Paranal, re-assembled in the integration hall and moved to its final destination, the renovated VLTI laboratory. Two commissioning runs of the beam combiner instrument took place before the end of the year, and the instrument has demonstrated its unprecedented ability to fringe track with high sensitivity. The GRAVITY project also includes four adaptive optics correctors for the VLT UTs, which are being integrated at the Max Planck Institute for Astronomy (MPIA). The first will be shipped to Paranal at the beginning of 2016.

This set of images, taken two weeks apart using the SPHERE instrument, shows the two hemispheres of Ceres and provide the best ground-based observations of this dwarf planet.



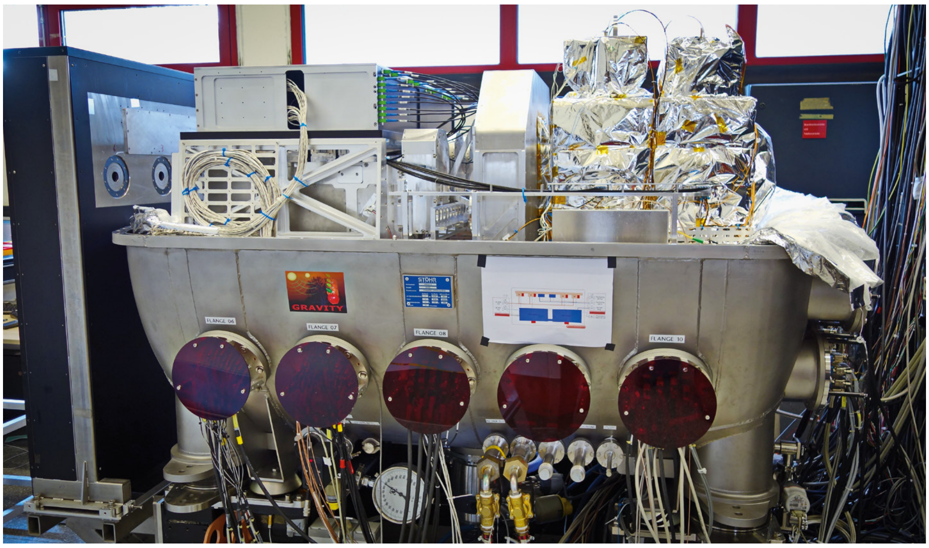
ESO, B. Yang and Z. Wahhaj

Instrument upgrades

VISIR has been upgraded with the new AQUARIUS detector and a long-slit spectroscopic mode, which have increased the observing time efficiency significantly. The upgrade also included the acquisition and commissioning of a water vapour radiometer to optimise observations by real-time monitoring of the atmosphere. The observed excess low frequency noise from the AQUARIUS detector has been mitigated by introducing faster chopping with the VLT secondary mirror (M2). VISIR has been offered for science observations with imaging, and low- and high-resolution spectroscopy from Period 95 (April 2015). The upgrade will be completed after the sparse aperture sampling and burst modes are commissioned early in 2016.

KMOS underwent scheduled maintenance of the pick-off arms in February 2015. An initial set of four arms with a new bearing design was installed in 2014. These arms were qualified during operations, and the decision was then taken to replace the bearings in the remaining twenty arms. The renovation of the arms and the on-sky recommissioning were carried out by a joint team from the consortium and ESO. As anticipated, KMOS was returned to, and remains in, a fully operational state. It continues to be in high demand by the user community.

The Cryogenic high-resolution InfraRed Echelle Spectrograph (CRIRES) is undergoing a major upgrade, led by ESO in collaboration with a consortium of four institutes: Thüringer Landessternwarte; Institut für Astrophysik, Göttingen; Institute of Astronomy, Uppsala and INAF Osservatorio di Arcetri. The upgrade includes a new gas cell to achieve a radial velocity precision of 2–3 metres per second, to search for superEarth-mass planets in the habitable zone of M-dwarf stars, and a novel polarimetric unit that can be used to characterise stellar magnetic fields in low-mass objects. A cross-disperser will increase the simultaneous wavelength coverage by about a factor of ten, and three new HAWAII 2RG detectors will accommodate the new spectral format. This general refurbishment will prolong the life of the instrument.



MPE/GRAVITY team

The GRAVITY beam combiner instrument during assembly at the Paranal Observatory.

The upgrade project (CRIRES+) passed its optical Final Design Review in June 2015, allowing long-lead items to be procured in good time, and in September it passed the Preliminary Design Review. The outcome of these reviews added two items to the original scope: the polarimetric unit will now include linear polarisation (in addition to circular), operating from *Y*- to *K*-band; and a Fabry-Perot interferometer will be added to the calibration unit for non-simultaneous high-precision wavelength calibration. To accommodate sufficient in-laboratory testing and the repair of the warm optics, the delivery of CRIRES+ to Paranal has been delayed. It is now planned to ship the instrument to Paranal by the end of 2017, with installation planned for early 2018.

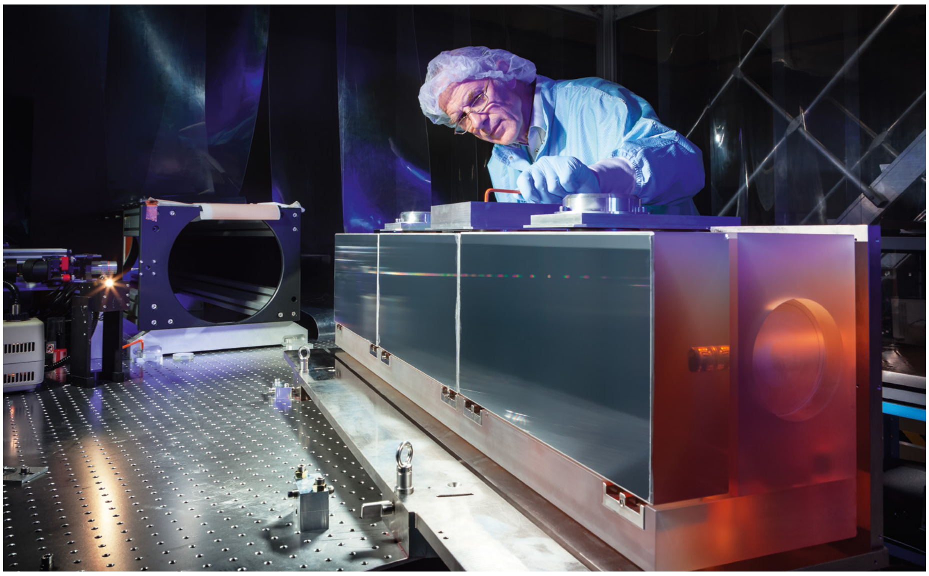
MUSE has been operated smoothly for over a year in wide-field mode without adaptive optics support. Major effort went into optimising the detector stability and minimising the readout noise. The cabling and connectors for all the 24 detectors have been optimised. One of the spectrographs needed an initial re-alignment. MUSE awaits the implementation of the Adaptive Optics Facility before commissioning of the ground layer adaptive optics assisted mode and the narrow-field mode can take place.

Instruments under construction

The second generation VLTI instrument MATISSE is a four-way beam combiner for the *L*- to *N*-band (PI: Bruno Lopez, Observatoire de la Côte d'Azur). It will provide closure phase imaging and spectroscopy at interferometric resolution of a wide range of targets, including asteroids, young stellar objects and active galactic nuclei. During the integration and verification phase at the Observatoire de la Côte d'Azur in 2015 first fringes were achieved in the laboratory, but there were also a number of severe problems with the air-conditioning system, resulting in serious damage to the detector electronics due to condensation. The repair of the electronics, the improvement of the air-conditioning system and more detailed planning for the remaining test and acceptance period have resulted in a delay of 12 months. Provisional Acceptance Europe is now planned for mid-2017.

ESPRESSO, an ultra-stable high-resolution optical spectrograph for the VLT (PI: F. Pepe, Université de Genève), received most of its hardware during 2015. In February the delta-Final Design Review, focused on the coudé train optomechanics, was granted with actions. The vacuum vessel, accepted at the end of 2014, was moved to the temporary integration site in February 2015 and proven to be airtight down to 10^{-5} millibar. All the spectrograph optics, with the exception of the main collimator, have been received by the consortium. The

ESO/M. Zamani



The diffraction grating for the ESPRESSO spectrograph under test in the cleanroom at ESO Headquarters.

optical bench has also been completed and shipped to Geneva. The echelle grating, although it has a low efficiency, has been fully aligned at ESO Headquarters, validating the alignment tools and procedure. A grating with improved efficiency is expected to be delivered in 2016.

Tests of the engineering and science blue CCDs have been completed with good results, and testing of the science red CCD continues. Both the blue and the red cameras have been delayed and are on the project's critical path. The front-end unit has been fully integrated and aligned at Merate. By the end of 2015 the installation of the coudé trains had been prepared and all the coudé train interfaces have been installed at Paranal. Provisional Acceptance Europe for the spectrograph is expected in the second half of 2016.

Instruments in design

The Multi-Object Optical and Near-infrared Spectrograph (MOONS) is a 0.8 to 1.8 μm multi-object spectrometer designed to work at the Nasmyth focus of the VLT. The instrument will have 1000 fibres patrolling a total field 25 arcminutes in diameter. There will be two spectral resolving powers: $R \sim 4000$ spanning the full near-infrared wavelength range and a higher resolution mode which gives $R \sim 9000$ in the *I*-band window and $R \sim 20\,000$ in a region in the *H*-band window. The lower resolution mode is optimised for measuring galaxies with redshifts greater than one and the higher resolution mode is optimised for stellar surveys. MOONS has two main parts: the rotating front end, which is at the focal plane and houses the fibre positioners, acquisition system and the metrology system for the fibres; the second part is the cryogenic spectrograph, which houses the spectrograph optics, volume phase holographic gratings and detectors. The two parts are connected by fibres. The MOONS Preliminary Design Review was held in October 2015 and the project expects to begin the final design phase in early 2016.

4MOST will be a world-class facility for fibre-fed multi-object spectroscopy and will be installed on VISTA. Its unique capabilities result from the combination of a large field of view, medium and high spectral resolutions in the visible range for both Galactic and extragalactic applications with very high multiplex capabilities. During 2015, the 4MOST project received positive recommendations from the ESO governing bodies. A major milestone was passed in June when Council approved the GTO plan for the 4MOST consortium. The agreement and the accompanying documents are being finalised for an official kick-off early in 2016.

The Enhanced Resolution Imager and Spectrograph (ERIS) will be a new infrared facility for the *J*- to *M*-band (1–5 μm) at the VLT UT4 Cassegrain focus. It will feed both an infrared imager (NIX) and the SPectrometer for Infrared Faint Field Imaging (SPIFFI) for SINFONI with adaptive optics corrected wavefronts. ERIS will use the deformable mirror of the Adaptive Optics Facility, as well as one of its lasers, to improve both the spatial resolution and sky coverage compared to the current NACO and SINFONI instruments. After a six-month hiatus in 2014, the project was re-established as a consortium-led project, down-scoped in some technical areas in order to accelerate the project and make it more feasible, while minimising the impact on the scientific requirements. The consortium is led by the Max Planck Institute for Extraterrestrial Physics (MPE, Garching, PI: Richard Davies). Further consortium partners are the UK-ATC in Edinburgh providing NIX, the INAF Osservatorio di Arcetri designing the adaptive optics and the Osservatorio di Teramo building the calibration unit, as well as Swiss Federal Institute for Technology (ETH Zürich) for the NIX detectors. Progress in 2015 was good, and the Preliminary Design Review will take place in February 2016 as planned.

Infrastructure projects

Adaptive Optics Facility

The AOF made good progress during 2015 as activities in Paranal for the commissioning of systems intensified, while system tests are nearing completion in Garching.

The GRAAL module has been completely tested in Garching and both the natural guide star on-axis mode, important for engineering tests of the deformable secondary mirror, and the ground layer correction modes performed in line with expectations. After its successful PAE, GRAAL was shipped to Paranal. The Ground Atmospheric Layer Adaptive optics for Spectroscopic Imaging (GALACSI) system was also tested successfully and the final test report shows again that it meets specifications. The results from the first test of the GALACSI narrow-field mode are very encouraging.

The AOF laser unit#1 was fully tested in 2014 and after a thorough review, shipment was authorised in January 2015 and the unit was installed at Paranal. Superb results were obtained on sky for all the critical specifications of this system: the positioning of the laser star on the sky, spot size, return flux, etc. In October 2015 a combined test with GRAAL (which was installed and tested on UT4 the previous summer) and laser unit#1 was conducted on UT4. Much was learned from these tests and very useful results were obtained that allowed the systems to be fine-tuned in preparation for the full AOF commissioning in 2017. In December 2015, the 4LGSF systems passed PAE and the remaining three laser units are now being installed on UT4. The upgrade of the astronomical site monitoring system is nearly complete and ready to be switched to the new database that includes parameters from the new hardware (slope detection and ranging, Differential Image Motion Monitor and multi-aperture scintillation sensor) and also new displays for visualisation.

The VLTI laboratory.

VLTI

A very extensive upgrade of the VLTI infrastructure was undertaken in 2015, coordinated by a VLTI facility project. The upgrade lasted eight months and its primary purpose was to prepare for the second generation instruments GRAVITY and MATISSE. This upgrade has impacted most of the areas of the VLTI — telescopes, instruments and subsystems of the interferometer.

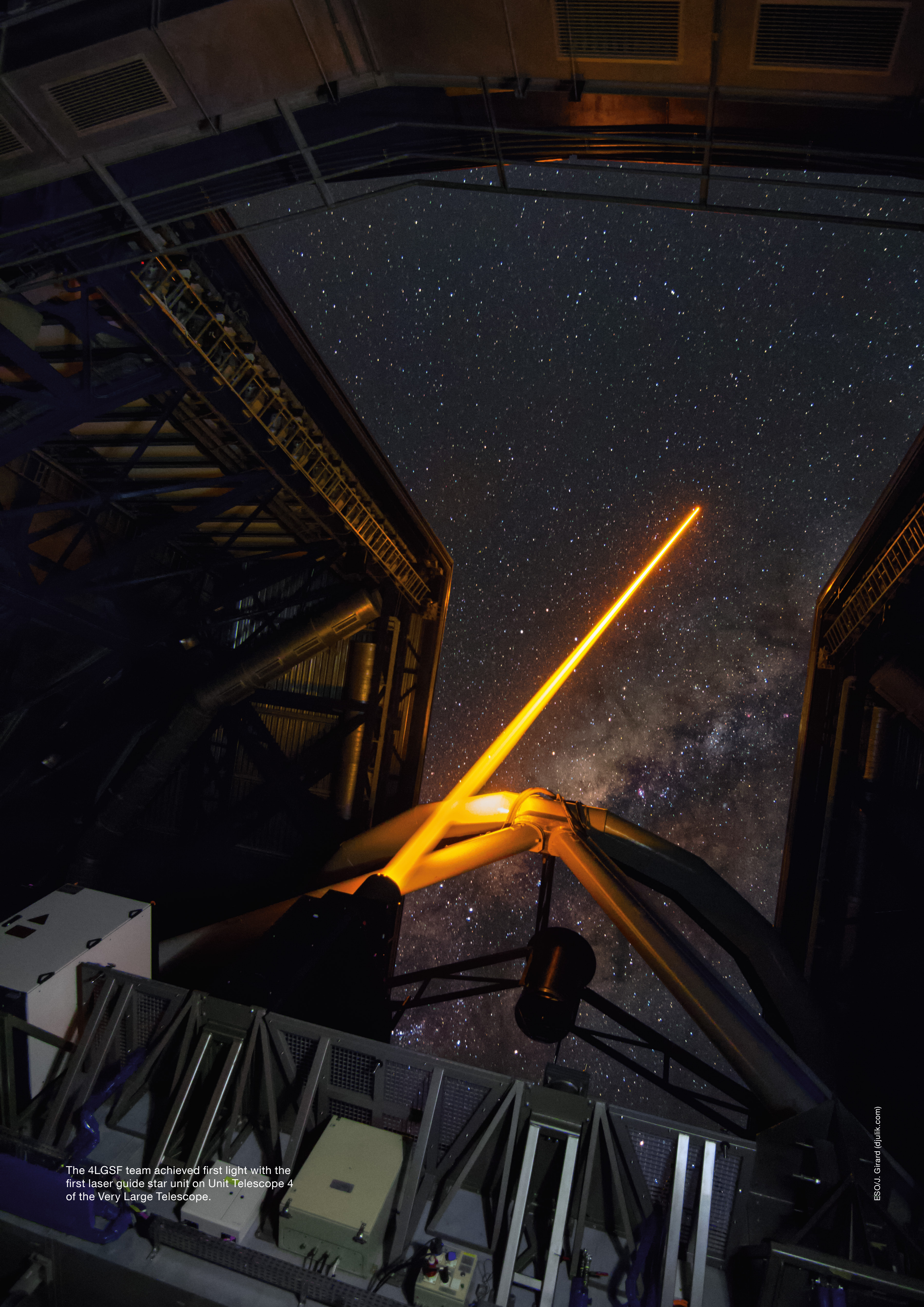
The new Auxiliary Telescope service station, located on the Paranal platform close to the VLTI building, was delivered in April 2015 and used for the upgrades to the ATs. This makes carrying out maintenance work on the ATs much more straightforward. Each of the four ATs was upgraded with a star separator, guiding camera and sensor in the period from April to August. The AT star separators have been in operation since October 2015. A refurbishment of the coudé train optics is planned and a contract was signed with the Polish optical company Solaris Optics to deliver five sets of AT coudé trains in September 2016. The New Adaptive Optics Module for Interferometry (NAOMI), which will deliver adaptive optics to the ATs, passed its Preliminary Design Review in May and an agreement with the Institut de Planétologie et d'Astrophysique de Grenoble was approved in December for the production of the corrective optics and the integration of three of the four systems. The last one will be produced by ESO. The Final Design Review will be held in the fourth quarter of 2016 and the first system is expected to be delivered to Paranal by the end of 2017.

The second generation fringe tracker project had its Phase A review in June 2015. The conclusion of the review was to propose the use of the GRAVITY fringe tracker for MATISSE. A project to cover this activity was officially launched with dedicated manpower and budget in December.

La Silla instruments

In 2012 a consortium composed of ESO, Instituto de Astrofísica de Canarias (IAC, Spain) and Federal University of Rio Grande do Norte, Brazil (UFRN), concluded a contract with Menlo Systems GmbH to provide the turn-key laser frequency comb system for HARPS. The laser frequency comb allows a series of precisely equally-spaced and stable spectral lines to be provided for spectrograph wavelength calibration. The laser frequency comb for HARPS was installed and commissioned at the ESO 3.6-metre telescope in April. The laser frequency comb system has shown very good performance, but did not reach the specified level of reliability and the running time for the unsupervised system needs to be improved.

Following a very successful call for ideas, two instruments have been selected for design and construction for the NTT and the ESO 3.6-metre telescope: SOXS is a proposal led by INAF (PI: S. Campana, Osservatorio Astronomico di Brera) to build a small X-shooter for the NTT. NIRPS, the Near Infra Red Planet Searcher (PI: C. Melo, UFRN), will be an infrared HARPS, to be hosted at the ESO 3.6-metre telescope. Negotiations for defining the agreements with the consortia have begun and these instruments will be entirely funded by the community, with minimal ESO participation. With their installation, ESO will be primarily devoting the two main telescopes at La Silla to transient object spectroscopy and searches for exoplanets and their characterisation.



The 4LGSF team achieved first light with the first laser guide star unit on Unit Telescope 4 of the Very Large Telescope.

ESO/J. Girard (djulik.com)

Inside the Mirror Maintenance Building at Paranal Observatory where the 8.2-metre mirrors of the VLT are cleaned and recoated.

D. Schreiner and S. Degezelle/ESO

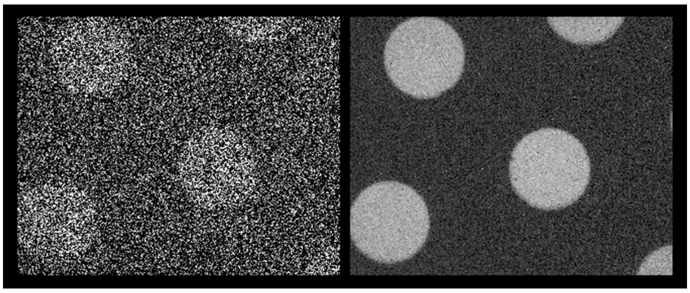
Technology Development

The technology development initiative is aimed at nurturing and securing the technologies that ESO will need to successfully conduct its scientific programme in the future. This new approach adds to the significant developments that already occur within the scope and funding of individual instrument and telescope projects. The aim is to have a longer-term view and to tackle riskier developments, while working closely with European industry and institutes in a collaborative spirit.

D. Lopez/IAC

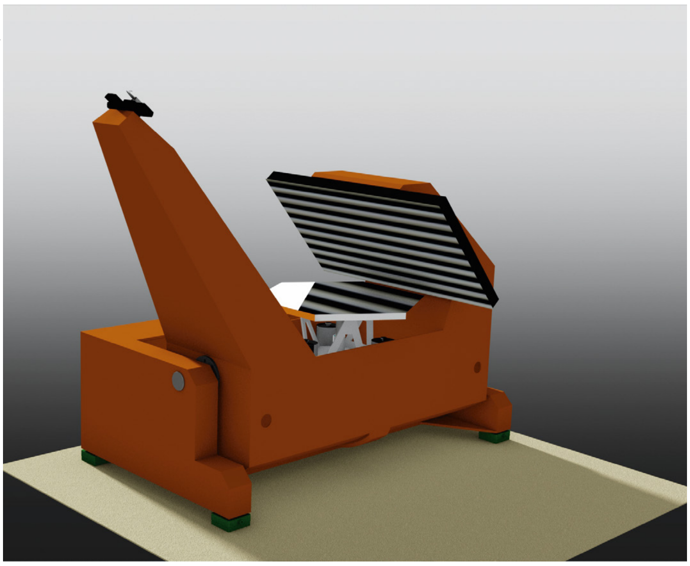
Laser Launch Telescope in the dedicated dome at the Observatorio de el Teide, propagating the laser beam during night-time observations.

Unsurprisingly, the first set of challenges and developments come from the E-ELT, although it is envisioned that these will also be important for enhanced performance of new instruments at the VLT. It is important that progress is made in the coming years in a number of areas if the telescopes and instruments are to achieve their full potential.



Test images of a screen taken with the SAPHIRA electron avalanche photodiode array device. Noise performance is so good that individual photon events can be seen in the left panel. Right panel shows the image after multiple frames are added together.

Adaptive optics has become an indispensable tool for ground-based astronomy in the optical/infrared. In the case of the E-ELT, it is critical for many of the science cases and for the telescope to achieve its maximum impact. However, the technology for a number of adaptive optics components is still relatively immature and their availability is limited.



MicroEpsilon

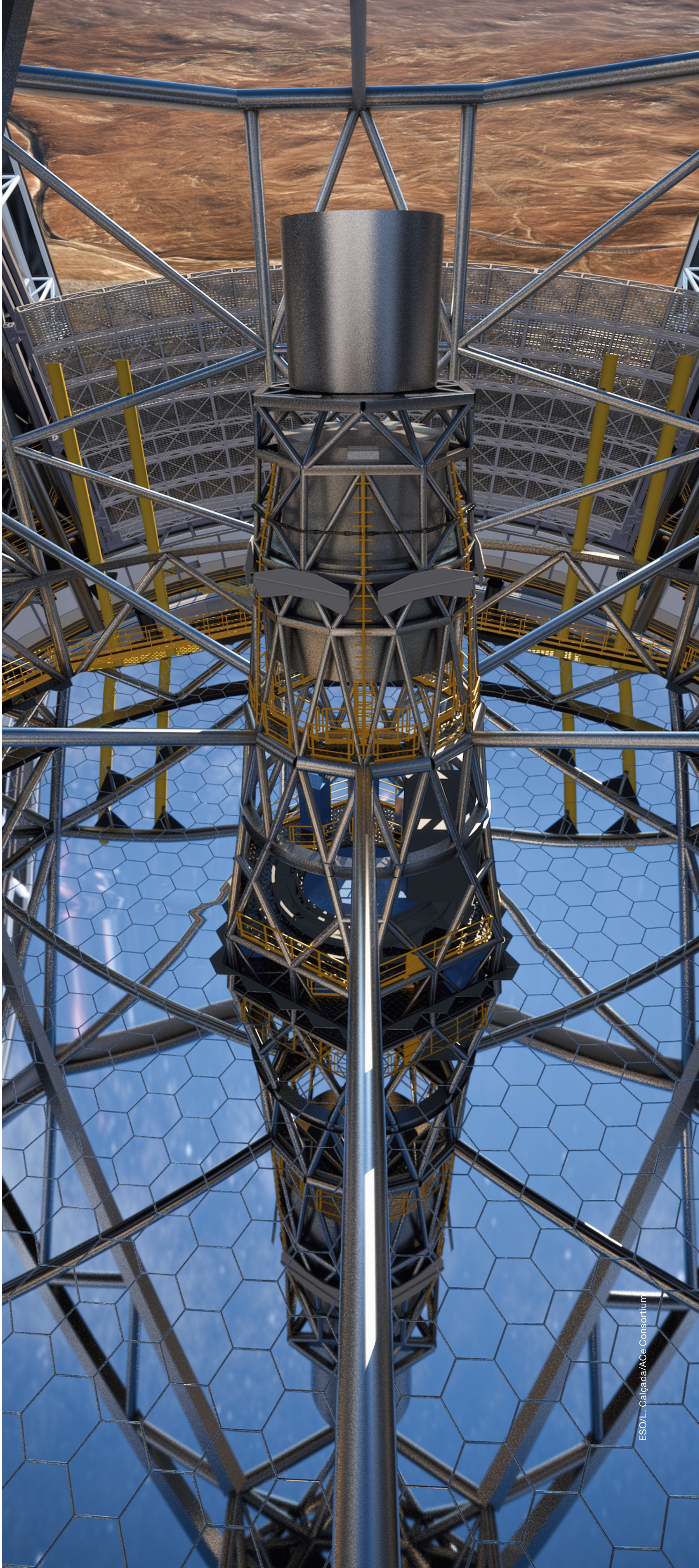
Conceptual design for measuring relative optical surface deformations of an E-ELT segment by deflectometry.

One critical component for a successful adaptive optics system is a fast, low-noise visible or infrared detector array, to be used for real-time measurements of the distortions in the wavefront of the incident radiation, so that these can be corrected with a deformable mirror. ESO has been advancing these detectors for both the visible and the infrared wavelength ranges. For the visible, a development programme using complementary metal oxide semiconductor (CMOS) technology is ongoing with e2v (Chelmsford, UK). The infrared development has been with SELEX (Southampton, UK) and has been particularly successful in 2015, leading to electron avalanche photodiode arrays, which can achieve sub-electron read noise at readout rates of hundreds of hertz. An electron avalanche photodiode array is already in use in the GRAVITY instrument for the VLT.

The deformable mirror itself, working at the level of performance required for astronomy, is a difficult and expensive component. In 2015 ESO made important steps in securing a European source of supply for its future needs. A collaborative project with CILAS (Orléans, France) and the US Thirty Meter Telescope project improved the precision and reliability of the manufacture of the deformable mirror actuator. In addition a call for tender was launched to identify new technologies for the manufacture of high-order deformable mirrors. An excellent response from European companies was received. Multiple contracts for seed funding should be launched in 2016.

The third critical adaptive optics technology is that of sodium lasers, used to create artificial guide stars 90 kilometres above the Earth. These artificial guide stars act as reference sources for the wavefront sensing and correction process. ESO has had wonderful success in the past with the development of a new generation of 22-watt Raman fibre lasers (Toptica, Munich, Germany), which have largely removed the risk in this area. However, there is still work to be done in optimising the laser parameters and understanding how bright the artificial guide star will be as a function of such parameters as laser polarisation, time of year and angle of the geomagnetic field. ESO has been conducting a campaign of observations in collaboration with the Instituto de Astrofisica de Canarias at El Teide Observatory on Tenerife. A great deal of data was obtained during the year and is currently being analysed.

The determination of a mirror's true shape remains a challenging problem. This will be particularly acute on the E-ELT, where the very large number of primary segments will require efficient and accurate testing. During 2015 two studies were financed to investigate one particularly promising technique known as deflectometry, in which a test pattern is imaged with great accuracy after reflection by the mirror under test. Final results are expected in early 2016.



Artist's rendering of the primary mirror and central structure of the European Extremely Large Telescope.

European Extremely Large Telescope

The year 2015 marks the start of E-ELT construction. Exactly nine months after the green light to begin work was given by ESO Council in December 2014, a set of very important contracts and agreements was signed for the procurement of the complex and critical optomechanical parts to be installed on the E-ELT: namely the unit for the quaternary mirror (M4), its thin mirror and the first three science instruments. This major achievement has been the result of several years of intense efforts both inside ESO and in fruitful collaboration with the scientific community from the Member States. It has allowed the existing momentum to be retained, in spite of the slower-than-expected progress of Brazil's ratification of its ESO membership, and has secured the option to keep first light in 2024, a key element for the scientific success of the E-ELT.

This year also marked the completion of the major site preparation activities, with the construction of the access road and the flattening of the top platform of Cerro Armazones. This work was performed by the Chilean company ICAFAL, under a contract signed with ESO in December 2013. At the peak of activities, during the first quarter of the year, the contractor's base camp at Armazones was running at full capacity (around 250 beds), including a kitchen and canteen for food service. The access road extends about 24 kilometres from the B710 public road, has a width of about 11 metres and a steepest gradient of about 8%. It is fully equipped with road signs, markings, safety barriers, rock retention meshes, etc. It now takes less than 30 minutes to drive from Paranal to the summit of Armazones. The platform measures about 150 by 300 metres and has been levelled. It is ready to welcome the future dome and main structure contractor who should mobilise onsite in 2017.

Another significant onsite preparatory activity is the connection to the Chilean electrical grid by the Chilean Company SAESA under a contract signed in mid-2014. Following design work, an environmental impact declaration was submitted and most of the necessary material and equipment (power transformers, main protection relays, high voltage isolator, etc.) were procured in 2015. The grid electricity supply is expected to start in late 2017.

G. Hüdepohl (atacamaphoto.com)/ESO

The flattened peak of Cerro Armazones, the future home of the European Extremely Large Telescope, before completion of the access road.

Industrial contracts

The first two industrial contracts to be placed covered the M4 adaptive mirror, a key element for the performance of the giant telescope whose image quality would otherwise be drastically limited by atmospheric turbulence. Reosc (France) is to produce the very fragile 1.95-millimetre thick, 2.4-metre-diameter glass shells. The full mirror is made out of six petals. The contract foresees the delivery of 12 petals in total, thus providing a complete set of spare petals for maintenance reasons. By the end of the year, the design successfully passed its final review and the Zerodur blanks were ordered by Reosc from SCHOTT.

AdOptica (Italy) was awarded the contract for the complete M4 adaptive support system. The deformable M4 is a 2.4 by 2.5 metre elliptical mirror system consisting of the mirror petals, the actuators and the control systems that can correct for the image distortion caused by the turbulence of the Earth's atmosphere in real time, as well as contribute to correcting for the minor elastic deformation of the telescope structure caused by thermal changes, gravity and wind. The corrected optical system will produce images almost as sharp as those taken from space. The mirror is controlled by 5316 contactless actuators. AdOptica has developed a modular concept based on replaceable control bricks for ease of maintenance. These also make adjusting the mirror elements more straightforward.

In addition to these hardware contracts, a number of smaller, but important, contracts were signed during the year. Those included the licences to develop the data distribution system for the telescope and the instrument control system (Real Time Innovations, USA); a framework contract (with the company ISQ, Portugal) to assist the ESO Quality Assurance team in providing reviews and audits both of contractors and within ESO. Another framework contract (with Critical Software, Portugal) will provide independent software validation and verification for the various components of the telescope control system developed at ESO and by contractors.

Progress with E-ELT instrumentation

In the latter part of the year, the joint efforts of ESO and the scientific community in the Member States led to the signature of the agreements for the design and construction of the first light instruments: MICADO, HARMONI and METIS. The preliminary design study for a laser tomography adaptive optics module was also initiated, as part of the HARMONI agreement.

Signing of a contract with the French optics company Reosc for the M4 shell mirrors for the E-ELT.

- MICADO is the Multi-Adaptive Optics Imaging Camera for Deep Observations with the E-ELT. It will work in combination with the laser guide star multi-conjugate adaptive optics system MAORY, to provide diffraction-limited imaging over a wide (about 1 arcminute) field of view, covering the 0.8–2.5 μm wavelength range. MICADO will be able to resolve the internal structure of distant high-redshift galaxies, to study individual stars in the Milky Way and nearby galaxies, and, using a coronagraph, to discover and characterise exoplanets. A key driver for the instrument design is the astrometric accuracy needed to precisely measure the orbits of stars around the central black hole in the Galaxy as a test of general relativity. In addition to its imaging capabilities, MICADO will also include a single-slit spectroscopic mode to obtain the spectra of compact objects. A consortium made up of institutes located in Germany, the Netherlands, France, Austria and Italy will build the instrument.
- HARMONI is a workhorse integral field spectrograph, operating over a large wavelength range (*V*- to *K*-band), with many different spatial scales, from diffraction-limited to seeing-limited and moderate to high spectral resolving power (5000 to 20 000). It is designed to work in conjunction with several different adaptive optics systems at the E-ELT: single conjugate adaptive optics and laser tomography adaptive optics will be provided by a dedicated facility. It is capable of 3D spectroscopy, providing a spectrum for every pixel in the field of view, enabling the spectroscopic study of a range of targets from exoplanets to stars, and from local to very high redshift galaxies. HARMONI will be crucial in furthering our understanding of galaxy formation and evolution across the entire history of the Universe. HARMONI is being built by institutes located in the UK, France and Spain.
- MAORY is the Multi-conjugate Adaptive Optics RelaY for the E-ELT and it uses six laser guide stars to correct for atmospheric turbulence. It will feed sharpened images to the MICADO imager, and has an auxiliary port available for a future instrument. It is being built by institutes in Italy and France.
- METIS is designed for imaging and medium-resolution spectroscopy over the full wavelength range of the *L*-, *M*- and *N*-bands (3–14 μm), and high-resolution integral field spectroscopy in *L*- and *M*-bands (3–5.3 μm). METIS will be able to detect cool objects, such as young planetary systems still embedded in gas and dust. It will be built by institutes located in the Netherlands, Germany, France, UK, Belgium, Switzerland and Austria.

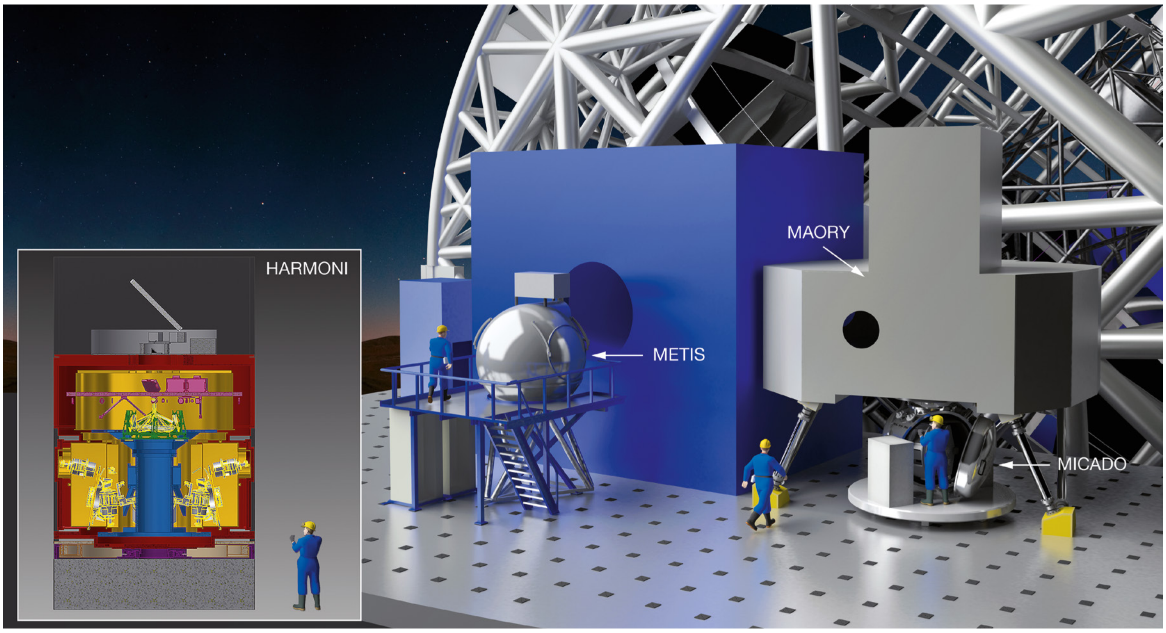
An important activity within the E-ELT Science and Instrumentation Project at ESO has been to specify the technical requirements and statements of work for these instruments and to closely follow the progress and activities of the consortia.

A contract was signed with the AdOptica consortium in Italy for the final design and construction of the adaptive unit for the fourth mirror of the E-ELT.

Adaptive mirror unit prototype for the E-ELT under test at AdOptica.

ESO/AdOptica

NOVA/METIS/MAORY/MICADO/HARMONI



Artist's impression of the location of the first E-ELT instruments, METIS, MAORY and MICADO on the Nasmyth platform. The inset shows the other approved instrument HARMONI.

Furthermore, preparatory activities were initiated for the next two instruments to be installed on the E-ELT: a multi-object spectrograph (MOS) and a high-resolution spectrograph (HIRES). A call for proposals for Phase A studies was launched in mid-2015, resulting in two proposals being received and evaluated by the end of the year.

Another priority for the Science and Instrumentation Project has been the interaction with the scientific community at large. This activity has included: i) coordination with the E-ELT Project Science Team; ii) presentation of the E-ELT programme at conferences and for public outreach; iii) organisation and support of the Science and Technology with E-ELT school at Erice in October to train and inspire the next generation of astronomers, who will be the primary users of the E-ELT.

Dome and main structure

In addition to the contracts that have already been signed, many other procurement activities were pursued throughout the year to prepare for the construction of other major components of the E-ELT. The most significant concerns the large contract for the dome and main structure. The procurement process started in 2012 with the pre-qualification of the tenders. The call for tender, launched in spring 2014, proceeded smoothly through its various phases, ending, after an extension of a few months, with final offers being received in autumn 2015. The recommendation for awarding the contract is to be considered by the extraordinary meeting of the Finance Committee in February 2016. This contract will be the largest contract ever placed in ESO's history!

The dome and main structure contract includes the final design, manufacture, transport, installation and commissioning onsite of the dome, which protects the telescope during the day and against adverse weather conditions, as well as the mechanical structure for the telescope on which the various mirror units and science instruments will be mounted. The E-ELT dome has a footprint of about 115 metres and a height of 80 metres. It has two large opening slit doors that present similar engineering challenges to that of large stadium roofs. In a concept similar to that used by the VLT, a large number of louvres can be opened or closed depending on the wind conditions and direction to provide optimum flushing inside the dome, while avoiding excessive wind pressure on the primary mirror. The telescope main structure is located on a 54-metre-diameter, 10-metre-high concrete pier and has a total moving mass of about 3000 tonnes. The altitude axis is located 33 metres above ground level to ensure that the primary mirror is above the main layer of ground turbulence. As a result, the back of the secondary mirror is at a height of about 62 metres. In 2012 it was decided to combine the work for these two large moving structures (the dome and telescope) into one single contract to facilitate and expedite the critical onsite construction phase, currently planned from 2017 to 2023.

Optics and optomechanics

In the area of optomechanics, the year began with the start of two parallel contracts with VDL (the Netherlands) and CESA (Spain) for the primary design and qualification of the primary mirror (M1) segment support. The contracts consist of a design phase followed by the production of engineering models and testing. The progress on both contracts has been as expected, with completion in the last quarter of 2015 of the Preliminary Design Review for both.

Other preparatory activities have been the completion of tests by ESO of the prototype edge sensors delivered by MicroEpsilon (Germany) and by Fogale (France), as well as several alternative design prototypes for the position actuators delivered by Physik Instrumente (Germany) and CESA (Spain). These components are key elements in the control of the phasing of the primary mirror segments. The edge sensors measure the relative position of each segment with respect to its neighbours, while the position actuator moves the segments with nanometric precision.

Very good progress has been made with the preparation of what is expected to be the second-largest E-ELT contract, for M1 segment polishing. Intensive exchanges took place with representatives for the relevant industries through requests for information and preliminary inquiries. This led to a consolidated set of specifications, culminating in the launch of a competitive call for tender in December 2015. The M1 segment polishing contract will be unique in terms of the scale of the processing chain: a total of up to 931 segments (including spare segments) will need to be polished to a precision of about 30 nanometres wavefront error at rate of about 20 segments per month.

In parallel, the combined effects of engineering activities and discussions with industry led to good progress towards procuring the other optomechanical units, in particular the difficult, highly aspheric 4-metre secondary mirror (M2) and its cell. In November 2015 an Industry Day that focused on M2 and M3 cell procurement took place at ESO. This event allowed ESO to present the items to be procured to a group of interested companies. It also allowed industry to become familiar with the scope of these contracts and enabled an open exchange on technical points. The request for information was completed by the end of the year.

Very good progress has been made towards defining the overall procurement strategy and the conceptual design of the pre-focal station, which forms the interface between the telescope and instruments. This critical item contains the Nasmyth wavefront sensors required to perform all the on-sky wavefront sensing, as well as the phasing and guiding cameras. It also contains the flat relay mirrors for redirecting the beams towards the Nasmyth lateral foci and the coudé focus. The design is being drafted.

Systems engineering

In terms of overall systems engineering and technical coordination, a decisive step forward has been made towards defining the interface between the telescope and instruments, and on the preparation of the documents for the award of the agreements for the construction of the individual instruments. This was achieved in tight collaboration with the consortia and has led to a set of common requirements documents that will provide the framework for technical coordination in future.

In the first half of 2015, all the systems engineering procedures (management of requirements, configuration, documentation and verification) were finalised, documented and put into practice. These will be continually improved and updated in the light of experience. Most of the technical budgets related to the system performance were released early in 2015 and translated into subsystem requirements as needed. The few remaining second-priority budgets for power supply, cooling power and heat dissipation were updated and released later in the year.

An important systems engineering activity has been the consolidation, throughout the year, of the Level 1 Technical Requirements that collects the high-level engineering requirements at system level in answer to the top-level requirements held by the Programme Scientist. This is a fundamental document for proper requirements management.

On the more technical side, the Systems Engineering team coordinated the work of the newly created Performance Analysis and Verification Working Group with a view to proactively analyse and simulate technical issues associated with identified technical risks.

In the area of the telescope control system, the design of the M1 local control system, which will eventually control the 798 primary mirror segments in tip, tilt and piston, continued after passing its Preliminary Design Review in late 2014. The effort concentrated on the analysis of the M1 focus mode control, entailing analysis of edge sensor noise propagation and calibration requirements and the strategies to be executed after the M1 mirror segments are exchanged. Drafting of the control software requirements as well as trade-off/prototyping of the M1 cell power distribution and control system are also both underway.

Control systems

In readiness for the launch of the E-ELT instrument agreements, a set of instrument control system requirements was prepared. The documents include requirements for the interface between instrument wavefront sensors and adaptive optics controllers and the telescope actuators (via the central control system), instrument control system hardware and software standards and common requirements.

The Instrument Control System Framework project, an internal ESO deliverable for use in the construction of instrument control systems, was reviewed and re-baselined in order to match available long-term resources in-house. The project is now ready to honour its deliverables to the instrument consortia for use in the construction of the instrument control systems.

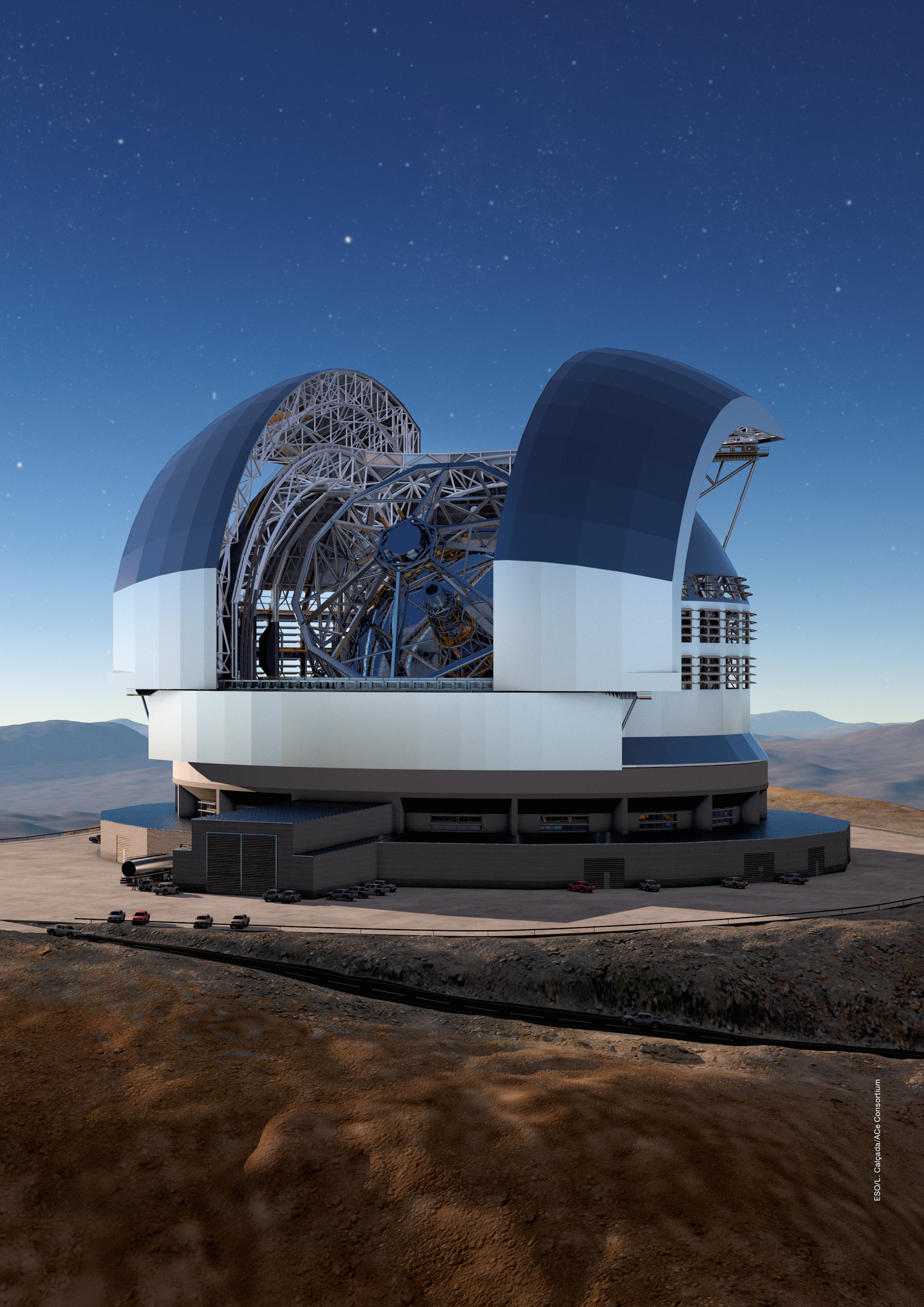
Finally, the design and construction of the E-ELT control model has progressed very well, with requirements established, room and laboratory space allocated and hardware purchased and assembled. An automatic test environment has been developed for unit and integration level testing of control systems. A first version of the control model is on track for the end of 2015 and will be available to test and carry out a quality assessment on the in-house and procured control systems (commencing with the M4 control system software deliveries in 2016).

Build-up of teams

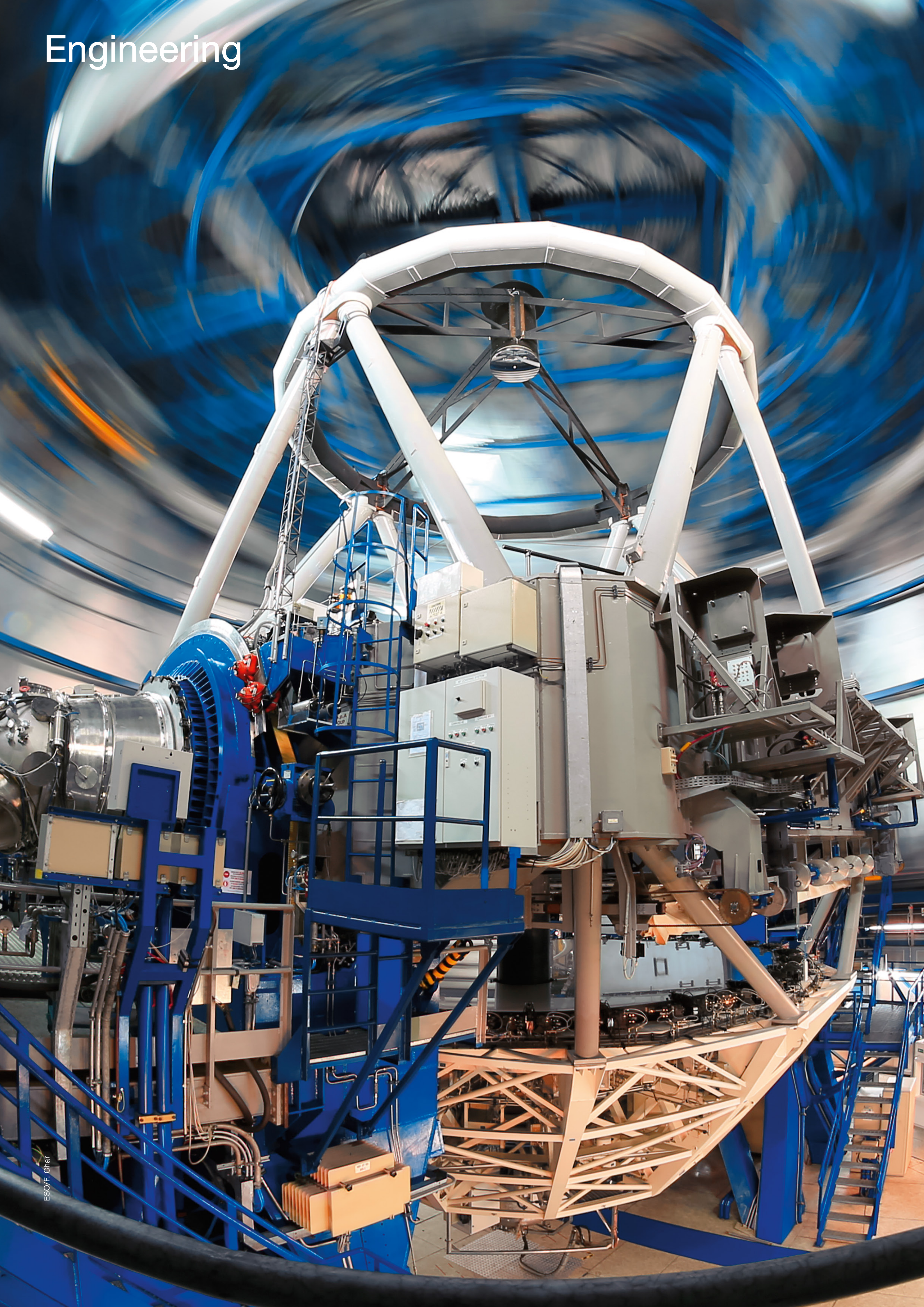
On the organisational side, 2015 has been used to make fine adjustments to the managerial structure and processes to cope with the challenges of the programme. Two key positions, the Programme Scientist and the Programme Controller, which were left vacant early in 2015 due to departure or re-assignment, were filled. With the approval for construction, it was time to finalise in detail the final phases of the construction on site, assembly, integration and verification and also to consolidate the entire schedule. The dates at which the various components need to be delivered to Armazones, the required infrastructure, as well as a detailed schedule of the M1 segment integration process have been defined. This was fundamental to confirm the feasibility of planned first light. Furthermore, the managerial interface between the construction activities and the start of operations by La Silla Paranal Observatory staff has been discussed and fine-tuned together with management. A number of basic documents were updated, such as the work breakdown structure, risk management plan, cost and schedule control concept, to reflect adjustments in the processes and the sharing of responsibilities.

In addition to the regular reporting to the governing bodies, the first two meetings of the recently created E-ELT Managerial Advisory Committee were held in February and December. This committee is composed of experienced managers of large scientific projects in astronomy and physics on the ground and in space. Its mandate towards the Director General and Council is to "provide appropriate and timely management oversight and advice to assist in the delivery of the E-ELT". After careful inspection of the programme's status, the two E-ELT Managerial Advisory Committee meetings resulted in very positive feedback on the way the E-ELT programme is being driven, both by the governing bodies and the programme team. They emphasised the importance of keeping to an aggressive schedule to deliver the E-ELT on time to enable the crucial synergy with the James Webb Space Telescope and to keep the ESO Member States at the forefront of ground-based astronomy.

An artist's rendering of the European Extremely Large Telescope in the Chilean Atacama Desert.


ESO/L. Calçada/ACe Consortium

Engineering



ESO/F. Char

The Directorate of Engineering provides engineering resources and services to all ESO programmes as well as to the operations teams at the observatory and at ESO Headquarters.

During 2015 ESO technicians and engineers contributed to the development of La Silla-Paranal instruments and observing facilities as well as to maintaining all existing ones. Highlights have been the integration of the 4LGSF and the upgrade of the VLTI infrastructure. The Directorate has also been working at full speed on preparing the statements of work for the E-ELT and E-ELT instrument contracts.

Many of the activities carried out by the Directorate of Engineering are under the governance of the Directorates of Programmes or Operations and are reported in the corresponding sections.

In addition, the Directorate is responsible for the development and maintenance of engineering standards used by all projects. Two proposals for update of standards were reviewed by the Engineering Standards Control Board. The set of standard components for chilled medium cooling systems was updated with a reviewed list of components, and the mechanical engineering analysis standard was revised for application to E-ELT contracts. New standards in preparation, for instance, related to the use of commercial-off-the-shelf CCD cameras, were presented to the Board. The Directorate continued to maintain the laboratories, workshops and integration halls, as well as develop test facilities for detectors.

Mechanical Engineering Department

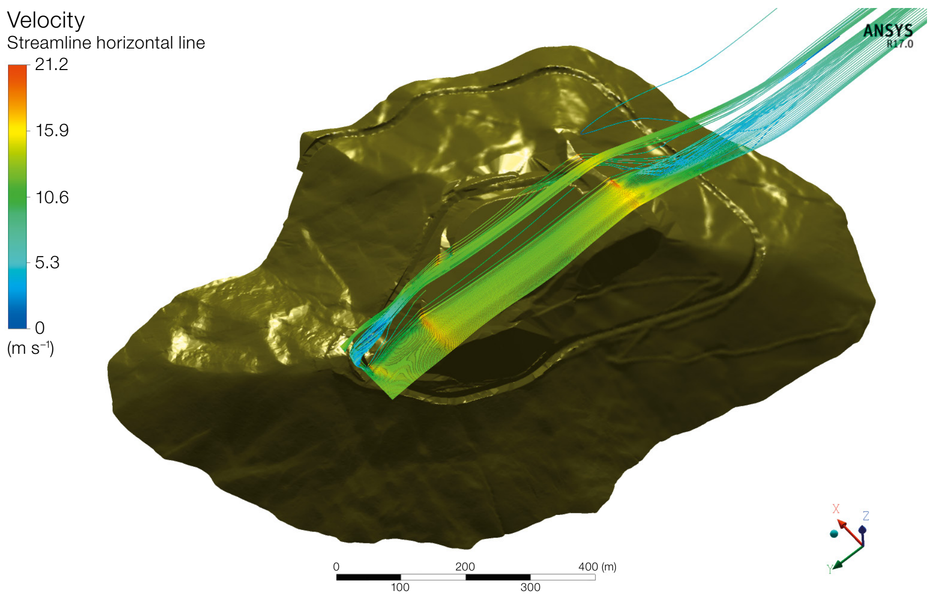
The department provides mechanical engineering support to all ESO projects. It consists of three groups: the Telescopes and Large Structures Group; the Instruments and Cryo Systems Group; and the Structural Analysis Group. Department members are responsible for the definition, design, analysis, procurement and assembly of mechanical, optomechanical, cryogenic and vacuum systems for advanced telescope and instrumentation systems.

Chief among the year's activities were the preparation, consolidation and justification of requirements for several major E-ELT procurements. These included design volume and interface drawings between the main structure, the mirror cells and mirrors, and structural analyses and performance simulations at subsystem and system level to define quantitative and feasible performance requirements. Design concepts for a new E-ELT pre-focal station within the framework of the Optical Control Project were developed. This activity included studies of telescope wavefront sensors, sensor arms, supporting structures, drive and bearing concepts, and cable wrap systems, as well as analysis of important subsystems and interface forces. Computational fluid dynamics simulations that took into account the current topology of Cerro Armazones were carried out in order to investigate the impact of the road step on the intensity of the turbulence.

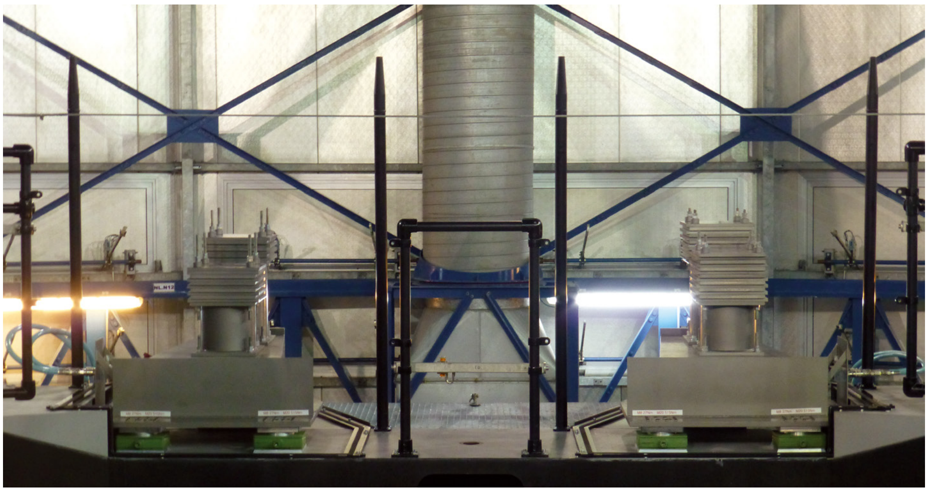
Expertise was provided to the Maintenance Support and Engineering Department in Paranal in order to investigate the failure of the rotation mechanism drive wheel in UT4 and the cracks appearing in some welds of the enclosure box structures. In close collaboration with the Maintenance Support and Engineering Department, a measurement and analysis campaign was initiated to identify the reasons for these failures and define measures to prevent their occurrence in future.

The department supported a large number of ongoing Paranal instrumentation programme and technology development projects, such as ESPRESSO, CRIRES+, MATISSE, the SPIFFI-upgrade, GRAAL and GALACSI. Significant contributions were made to the commissioning of the first unit of the 4LGSF project on UT4. This comprised design, analysis, test, packing, shipment and integration, as well as the design and installation of a safety railing on the centrepiece. The project upgrading the VLTI infrastructure was supported by setting up models and drawings of the four UT coudé rooms and several technical rooms in the UT basements, with both the installed and planned equipment.

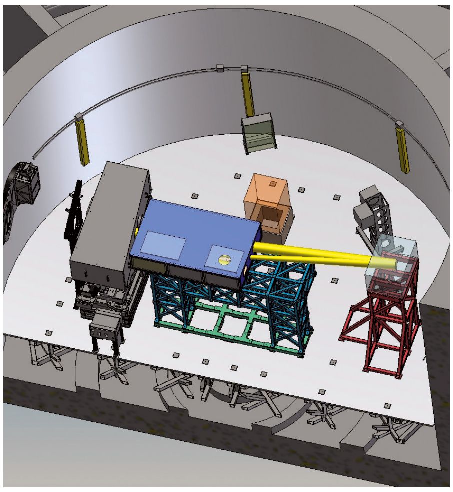
Simulation of wind velocity streamlines on Cerro Armazones, including the effect of the road.



ESO's Very Large Telescope Unit Telescope 4 (Yepun) in operation; the walls of the dome are seen rotating around the telescope structure.



Safety railing installation for the 4LGSF on the UT4 centrepiece.



3D computer-aided design model of the UT coudé room layout.

Engineering support was provided to Paranal by aligning the GRAVITY metrology boxes at the secondary mirror spiders for all the ATs, and UT3 and UT4, using the FARO laser tracker. Acceptance, integration and test procedures and cryo-vacuum support were provided during the installation of the GRAVITY beam combiner instrument in Paranal's new integration hall and subsequently in the VLTI laboratory. The CIAO wavefront sensing system design was followed up, the wavefront sensor cryostats were assembled, tested and delivered, including cryo-vacuum support and consulting. The design of NAOMI's mechanical hardware and test facility was supported. An emergency intervention to VISIR was supported in Paranal with the aim of eliminating the mechanical flexure discovered during long exposures. An issue with the focusing mechanism of the spectrometer detector was also investigated and the instrument pupil re-aligned. The instrument was re-installed at UT3 and successfully commissioned.

The department operates the mechanical workshop and laboratory facilities in the technical building, manages the stockkeeping of standard components and technical gases and provides maintenance and operations support to the detector test facilities. It also operates several computerised engineering tools, for example, the ANSYS finite element program, the mechanical computer-aided design system (3D modelling, 2D drafting) and the Project Data Management system for the configuration control of engineering documentation of all ESO projects.

Electronics Department

The department is responsible for the definition, design and manufacturing of control electronics, detector systems and subsystems for all telescopes and instruments, as well for verifying electrical compliance for all ESO projects. The wide variety of skills available in the department means that its engineers and technicians have contributed to almost all projects running at ESO. At management level, we have worked to develop a clear staffing and competence development plan.

Electronics Engineering Group

Together with the Paranal team, the group continued to develop and implement the obsolescence management work plan, successfully upgrading the safety chain systems on UTs 1 and 4. The MACAO obsolescence project was completed with the final validation of the newly developed avalanche photodiode counter boards and successful on-sky tests of the new high voltage amplifier boards. Another major milestone was the successful final test campaign of the replacement boards for the MACCON^{tm} motion controller boards that had been developed inhouse.

As part of the refurbishment of NACO, a real-time computer test environment was developed in Garching. A prototype system for the replacement of the VLTI alignment beacon was successfully tested in December and will be produced in mid-2016. The remaining three laser guide star units of the 4LGSF have passed their PAE and support was provided with the VLT deformable secondary mirror. As part of the VLTI infrastructure upgrade, the engineering team, together with the workshop, completed two critical missions to fix the relay optics structure on AT2 and install a new relay optics structure on AT1. As a result, all the ATs were fully operational by the end of the VLTI upgrade.

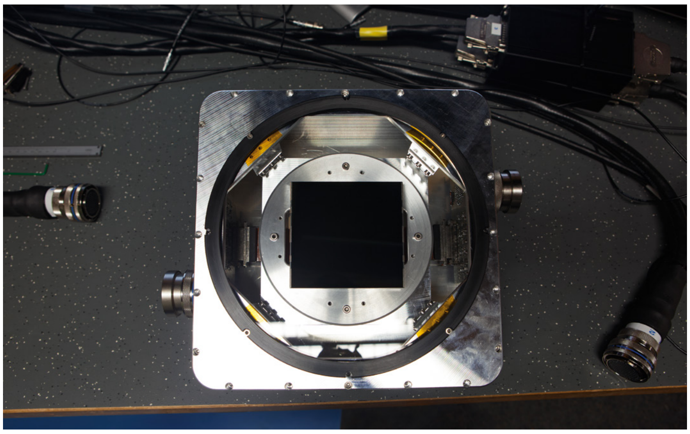
Compliance Engineering Group

The group was deeply involved as a regular support partner to all ESO programmes. In addition to contributing to many specifications and participating in several design reviews and bidder proposals, electromagnetic compatibility tests and safety compliance and analysis work were undertaken. Major progress was made with the activities associated with the connection of ESO to the Chilean power grid, and a major milestone was reached during the 23–26 November Santiago meeting.

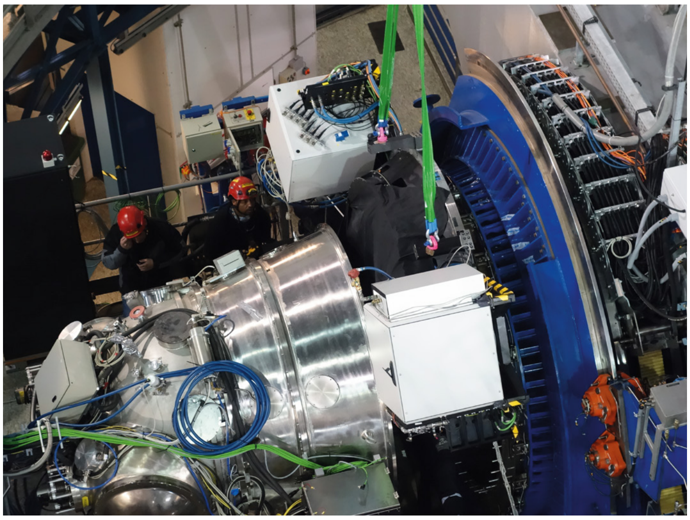
Detectors Group

The group has made many successful deliveries and completed a number of upgrades to projects during the reporting year. One example involving the current instrumentation was the service mission to the MUSE instrument, which successfully improved detector noise performance and the long-term bias stability. All the detector systems for the GRAVITY wavefront sensors were also successfully delivered, and the performance goals in terms of frame rate, low noise and quantum efficiency were achieved or surpassed. An internal study for detector control in the E-ELT era was carried out and its recommendations were accepted, namely that a further development of the new generation controller was considered the best option for the first light E-ELT instruments. Development of the Selex Avalanche Photodiodes for High-speed Infra Red Applications (SAPHIRA) detector has continued and this detector is now routinely achieving sub-electron noise performance.

The MOONS project passed its Preliminary Design Review milestone with an agreement on the types of detectors for both the infrared arm and the visible arm, where the choice for the latter is the first fully depleted detector at ESO. The detectors for ESPRESSO are currently being tested; these detectors are one of the largest monolithic CCDs available. The CRIRES+ science detectors were also successfully put into operation in readiness for final project delivery. The MATISSE detectors were installed in their instrument cryostats at the laboratory in Nice. Development of the natural guide star detector, an optical detector for wavefront sensing, continues apace with the successful testing of a revised design, and initial designs for a compact controller to operate the new detector. Finally, all adaptive optics wavefront sensing cameras were successfully delivered to the appropriate projects.


ESO/ESPRESSO Consortium/e2v

A test chip of the e2v 9k × 9k 10 μm pixel CCD to be installed in ESPRESSO.



Installation of GRAAL on UT4. HAWK-I is the shiny metallic structure on the left while the blue part on the right is the Nasmyth A adapter/rotator. GRAAL is the black structure lying in between.

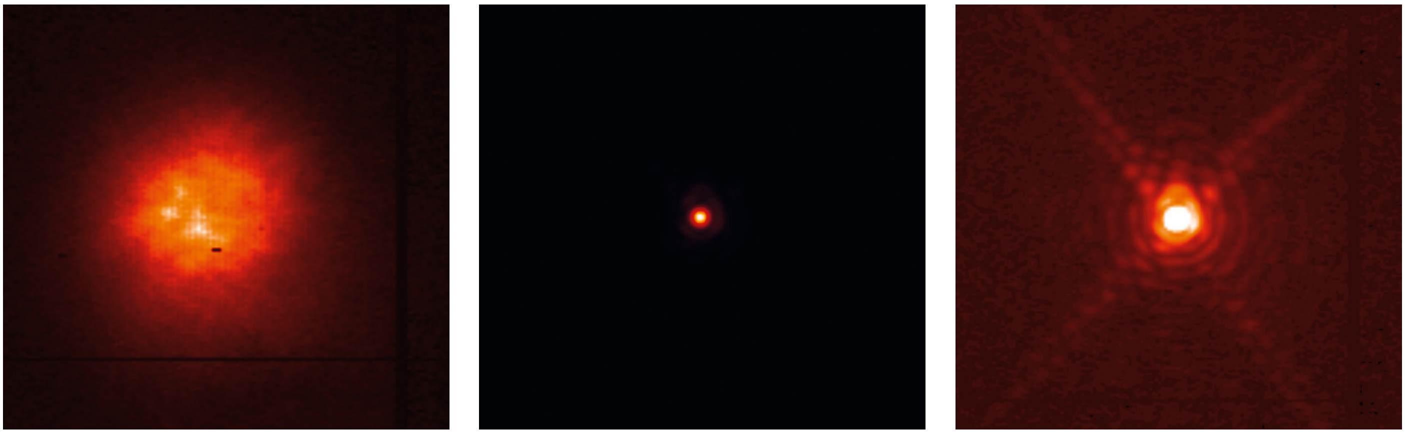
Systems Engineering Department

The department comprises four groups that each focus on different areas: adaptive optics; instrument systems; systems analysis; and systems engineering processes and standards. The four groups together cover all the essential systems engineering functions, including disciplinary integration and technical coordination, system architectural design and systems analysis. The department's services are employed in adaptive optics, instruments, telescopes and infrastructure projects and contribute prominently to the projects described in Programmes (p. 54).

Adaptive Optics

The installation on UT4 of GRAAL, the adaptive optics module developed to provide ground layer adaptive optics correction for the HAWK-I infrared imager continued. The aim is to reduce the diameter of the star images to improve the limiting magnitude reached by the instrument, in addition to enhancing the science case where higher resolution is critical. The anticipated gain is similar to that achieved by selecting a better site for the telescope. GRAAL was moved to Paranal and after reassembly and verification in the new integration hall, GRAAL was installed on UT4 between the Nasmyth A adapter/rotator and HAWK-I. In the meantime, the first laser guide star unit of the 4LGSF was also installed and commissioned in April 2015. During the night of 20 October, GRAAL acquired the laser guide star for the first time and was able to centre it within the 5-arcsecond field of view of one of its wavefront sensors.

GALACSI system testing progressed in Garching. For the first time, an adaptive optics correction based on tomography using four wavefront sensors looking at four laser guide stars in different directions was demonstrated using the Adaptive



Images recorded using ASSIST. Left: Seeing-limited image; centre: adaptive optics corrected image using tomography; right: same adaptive optics corrected image but saturated to show the Airy rings and diffraction pattern of the ASSIST spider. Experimental conditions: seeing 0.65 arcseconds at 500 nm; high flux; tip-tilt and focus delivered by the high order wavefront sensor; field of view 1.5 arcseconds; Strehl ratio larger than 73% at 1.6 μm.

Secondary Simulator and Instrument Testbed (ASSIST), the AOF test facility in Garching. The four laser guide stars are located at the corners of a square, 10 arcseconds from the GALACSI optical axis. Using tomography algorithms, the aberrations are reconstructed in the volume above the telescope and then projected onto a single deformable mirror located in the pupil, providing aberration correction in a given direction within the narrow GALACSI field of view. A tomographic reconstructor has been developed and used to close the adaptive optics loop in GALACSI.

Instrument Systems

The group provides technical system and project management leadership for instrument projects at ESO. Together with the instrument scientists, members of the group lead or support instrumentation projects in various roles, either as system engineers or project managers, for instruments built by external consortia and at ESO. Currently ten different instrumentation projects — seven for Paranal and three for the E-ELT programme — are supported at different phases of their life cycle. Examples are the second generation VLT instruments ESPRESSO and MATISSE, which are currently under construction, the second generation instrument ERIS, which is being designed, and the adaptive optics system for the ATs, NAOMI.

Two further instruments, CRIRES+ and MOONS, are on the way towards their Final Design Reviews. In preparation, prototypes of grating wheels for CRIRES+ were tested in the laboratory and close-out calibration tests were finished. MOONS underwent a major redesign of the optics after the Preliminary Design Review, reducing the weight by several hundred kilograms. Both instruments will have their Final Design Reviews in 2016.

Systems Analysis

The group's activities are focused on the E-ELT and VLTI programmes. For the E-ELT, the group coordinates the Performance Analysis and Validation team and is developing and consolidating the wavefront control strategy. It is helping to firm up the technical specification for the E-ELT's subsystems by analysing the sensitivity to tolerances of the optical performance at the focal plane, referenced to the wavefront control baseline. The team also supports E-ELT systems engineering in identifying and mitigating technical risks. It is collaborating with the Optical Control Project in the definition of the Nasmyth platform architecture and its control equipment. Finally, the team plays a leading role in specifying the wavefront control interfaces between the telescope and the instruments.

A significant amount of effort has been devoted to improving the beam quality control with CIAO for GRAVITY, in collaboration with the MPIA, Heidelberg. The technical difficulty for CIAO is the optical registration of this narrow-field system (2-arcsecond diameter) with its client instrument, involving a dozen non-common path optical elements over a distance greater than 100 metres. Instead of using a K-mirror to compensate for the optical rotation of the deformable mirror, the group proposed and developed an alternative control strategy for CIAO: the optical rotation of the wavefront corrective assembly, mounted on the azimuth platform, is compensated by updating the control matrices dynamically. The control strategies were validated in the Heidelberg laboratory in December 2015 and the first system was declared ready for deployment at the coudé focus of UT1.

Systems Engineering Processes and Standards

The group provided a significant amount of the systems engineering effort to the E-ELT programme, in particular to the management of the systems engineering activities. Once the procedures defining the engineering processes were finalised and put in place in 2014, and after a significant reorganisation within E-ELT engineering, the focus has moved steadily towards coordinating the technical activities. This refers mainly to consolidating the E-ELT system-level requirements, then flowing these requirements down to the subsystems, validating the procurement documentation for several subsystems and finally identifying and resolving any system-level issues. During 2015 the Processes and Standards Group has also played an important role in communicating the principles and benefits of systems engineering within ESO, giving short seminars on some of the key processes involved in engineering activities, such as the management of requirements and interfaces, configuration and documentation management and verification.

Optical Engineering Department

The department supports ESO's projects in the area of optical design for telescopes and instruments, active optics and wavefront control, metrology for telescope alignment, laser guide stars, optical fibre technology, integration and testing of instruments. It also manages the optics laboratories and the integration facilities.

Two studies investigated the feasibility of using deflectometry to test the active support systems beneath the E-ELT segments in the laboratory for different inclination angles. Deflectometry analyses the reflection of a regular black and white pattern by a surface. Distortions in the pattern yield information about the surface deformations, in this case, the segment surface. The method has been widely applied in industry, but so far only to detect imperfections on the scale of a few micrometres, whereas the application to segments requires accuracies of the order of 10 nanometres. The method seems to be feasible for this application, provided that a few key components are sufficiently stable. Distances between the optical elements of the telescope can be measured with an accuracy of the order of 50 μm with laser trackers and a new technology called multiline interferometry. Whereas a laser tracker sequentially measures the distances from the device to a number of targets, the multiline interferometer can measure several dozens of distances between the ends of optical fibres and the corresponding targets continuously and simultaneously. First tests in the laboratory achieved an accuracy of 0.5 μm per metre. The application of these technologies will deliver the necessary data to control the relative positions of the optical elements and thereby, during observations, improve the stability of critical parameters such as the telescope plate scale.

Daniel López/IAC

The transportable laser guide star system in operation on Mount Teide, Tenerife.

A test of the method of multi-wavelength shearing interferometry has proved that inter-segment pistons and tilts as small as 10 nm and 1 arcsecond, respectively, can easily be detected. This could provide a solution to the problem of calibrating the edge sensor steps locally at the E-ELT primary mirror intersegment borders. These encouraging results led to a recommendation for a follow-up collaboration between ESO and the Bremen Institute for Applied Beam Technology (BIAS, Bremen) with two goals. The first is to prove the feasibility of simultaneous multi-wavelength measurements to optimise the system's accuracy and robustness under real telescope conditions, which include vibrations and variations of the sensor to segment orientations. The second goal is to demonstrate that by extending the measurement to the full segment surface, errors in the measured segment steps due to segment misalignments can be disentangled from errors due to segment distortions.

A new method of focal-plane wavefront sensing, which analyses the diameters and ellipticities of star images in the science image, has been successfully tested on OmegaCAM on the VST in September 2015 during two technical nights, using the Garching Remote Facility. This method is based on analytical optical aberration theory. It may also find application in the processing of data from the curvature wavefront sensor in 4MOST (on VISTA).

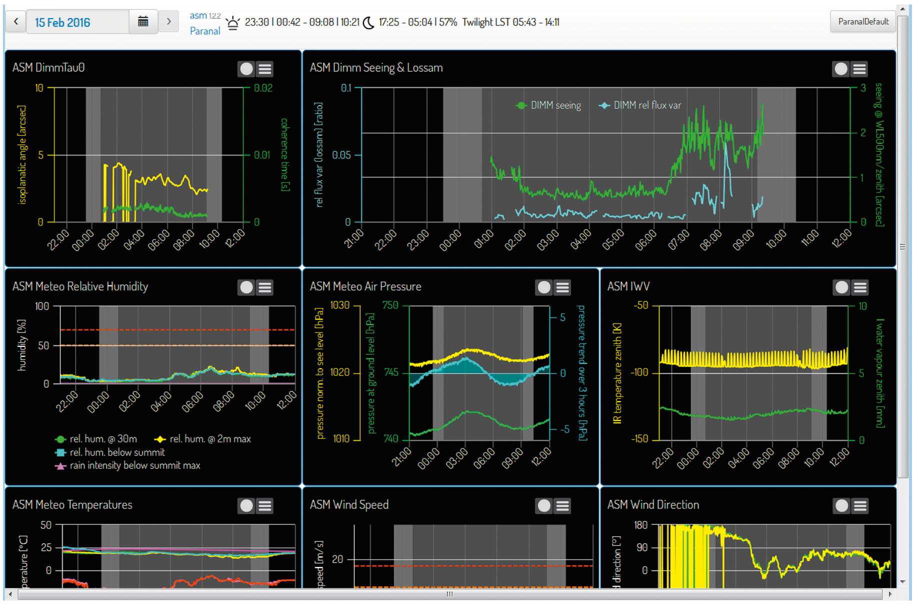
In the area of laser guide stars, the four laser guide star units for the AOF passed PAE and the first laser guide star unit was installed on UT4. The PARLA laser test bench has been completed and is being used to support the PARLA laser, run sodium gas cell experiments and train Paranal and Garching laser staff. The acquisition of seasonal laser guide star return flux data has continued on Mount Teide, Tenerife, and an initial comparison between observed return flux and numerical simulations showed good agreement. Finally the department has made major contributions to the integration of the AOF and 4LGSF, to the development of MOONS and NAOMI, as well as to the VLTI upgrade.

Control Software and Engineering Department

Members of the department are involved in specifying, analysing, designing, implementing, verifying and maintaining control systems and are responsible for the development of control software for (optical and radio) telescopes and astronomical instruments over the full software lifecycle.

The Standard Platform for Adaptive Optics Real Time Applications (SPARTA) was designed to use some specific hardware in order to fulfil the demanding requirements of the adaptive optics instruments. By 2015, some of these electronics boards had reached the end of their availability. This awareness triggered an investigation to verify whether the existing obsolescence plan for SPARTA is still valid under the latest assumption that SPARTA will be supporting four instruments (SPHERE, GALACSI, GRAAL and ERIS).

The investigation confirmed the general strategy of relying on spare parts for the full lifetime of these instruments. It was confirmed that no re-design of SPARTA with different hardware is needed from today's perspective. However, calculations based on the mean time between failure information received from the vendor of the boards, and our experience with the failure rate of the available boards (the oldest ones are already around ten years old), showed that the quantity of available spares might be not sufficient, especially if instruments remain in use longer than the minimum planned ten years. For example, the predicted status of the VPF1 board showed that two electronics boards could be unusable. As a consequence, two additional VPF1 boards and one CSW1 board were ordered before they became unavailable, and have in the meantime arrived at ESO. With this additional hardware, the operation of the four instruments using SPARTA should be assured, at least from the point of view of SPARTA hardware.



The new web interface to the data from the astronomical site monitor (www.eso.org/asm).

After more than 20 years of regular releases, the VLT Software continues to be maintained. The newest hardware introduced with the current and future generation of instruments needs to be supported, while also fighting against the obsolescence of older hardware. In that respect, to satisfy the ever-growing demand for computing power of larger imaging sensors, it was decided to take full advantage of the 64-bit capabilities of modern central processing units. This move was made in two steps. Firstly, with the 2014 VLT Software release, a 64-bit version of the Linux operating software was introduced, while the VLT Software and the application code was still being generated in 32-bit mode. This gradual transition allowed the existing code to be thoroughly analysed in order to identify as many potential issues as possible before the actual porting exercise. The second step then occurred with the 2015 release of a full 64-bit version of the VLT Software itself, and all applications using it. A pre-release version, intensively tested in Garching, followed by a few test nights in early 2015 in Paranal with onsite support of several colleagues from Garching, allowed the good behaviour of the new 64-bit version of the VLT Software to be verified. Interoperability with older installations still based on 32-bit versions could also be confirmed.

Science Operation Software Department

The remit of the department covers all science operation software for the end-to-end operations of the ESO observatories, ALMA and the E-ELT. The department is composed of three groups dealing with dataflow infrastructure, pipeline systems and software engineering.

The Dataflow Infrastructure Group develops tools for proposal submission, observation preparation and execution, archive ingestion and retrieval, data organisation and execution of data reduction pipelines. Some highlights of 2015 included a rollout of the ALMA quality assurance tool AQUA for data quality; improvements to the usability of the ALMA Request Handler and of the archive software quality and release process; release of the VLT Unified GuideCam Tool; a new web interface for the astronomical site monitor display; and support for laser collision detection within the VLT Dataflow System Observing Tool.

The Pipeline Systems Group deals with the scientific processing of data, the estimation of data quality with the exposure time calculators and the measurement of data quality. Highlights of 2015 included the parallelisation of the CASA data reduction system for ALMA by the High Performance Computing Team; final release of the scientific data reduction workflow platform ESO *Reflex* 2.8; and the first public release of the RPM Package Manager and MacPorts based packages for VLT data reduction pipelines. A new pipeline was delivered to support Service Mode for the VLTI instrument PIONIER and science data product upgrades of VIMOS and FORS were released. The image quality convention in all the exposure time calculators was improved and the sky radiance model in spectroscopy and near-infrared imaging exposure time calculators was upgraded.

The Software Engineering and Quality Group provides the tools necessary to support the development processing, testing, integration and release of scientific operation software. The VLT and ALMA test infrastructure was migrated to a new continuous integration platform based on Jenkins. The new system supports release build, metrics for code analysis, regression testing, and automated deployment including some web applications. The software configuration control and issue reporting systems (JIRA) were both upgraded. The group also played a major role in the definition of the independent software verification and validation processes for the E-ELT.

Information Technology Department

The department is responsible for the day-to-day information technology (IT) operations in Chile and Garching as well as the delivery of the agreed-upon services to all sites.

A large IT contract for the out-tasking of operational functions to Comarch in Chile and Garching was implemented and many ESO instruments and facilities arriving at Paranal were supported. Major upgrades and projects include building the Garching Remote Facility, instrument support for GRAVITY and GRAAL, and IT upgrades such as the video conference system, implementation of one IT ticketing system for all sites, and upgrades of the telephone and Remedy system at the observatories.

The surroundings of the interacting galaxy NGC 5291.

P. Horálek/ESO

Green and red airglow and Galactic star formation regions over the La Silla Observatory.

Administration

ESO/Ernst A. Graf

The Directorate of Administration organises ESO's administration in Garching and in Chile. Its functions include human resources, financial services, contracts and procurement services, the running of the facility, logistics and transport, safety coordination, Enterprise Resource Planning services, fundraising activities and the operation of the ESO Guesthouse. The ESO Supernova Planetarium & Visitor Centre project is also conducted by the Directorate. The Director of Administration provides support to the Director General in external relations activities and functions, and represents ESO at ALMA's Head of Administration meetings, and in CERN Pension Fund matters. The Administration Office deals with arrangements for the Finance Committee meetings.

Highlights of the year included the groundbreaking for the ESO Supernova Planetarium & Visitor Centre and the successful negotiations for many E-ELT contracts.

Aerial photograph showing the construction of the ESO Supernova Planetarium & Visitor Centre at ESO Headquarters.

The construction work for the building of the ESO Supernova Planetarium & Visitor Centre, a donation from the Klaus Tschira Stiftung, started in February 2015 at the site of ESO Headquarters in Garching. A groundbreaking event took place, attended by the donor, the planners and architects, as well as authorities and officials from the institutes on the Garching campus. The building is scheduled to open to the public in the second half of 2017. The project is made possible by a cooperation with the Heidelberg Institute for Theoretical Studies, and ESO will run the facility.

In 2015, the ESO Guesthouse in Santiago celebrated its 50th anniversary. It has served many astronomers on their way to and from the ESO observatories.

After the construction of the E-ELT was approved in December 2014, the first E-ELT contracts were placed in 2015, including the contracts for the M4 mirror and the final design and construction contract for the M4 unit that will support the mirror. All other procurements are progressing according to schedule.

ESO's Enterprise Resource Planning system received several enhancements in 2015. These included the implementation of a flexi-time module, an integrated performance management and personnel development tool and a supplier portal, which will go live early in 2016.

Safety provided conformity assessment advice during the tendering process for the E-ELT dome and main structure, and in the Preliminary Design Review of some critical subsystems. The cooperation with the Directorate of Engineering, particularly where electrical engineering, electronics and associated functional safety aspects are concerned, ensures that adequate safety-related resources are available to the project.

A significant number of VLT/VLTI instrumentation projects are in the process of undergoing Preliminary Acceptance Europe reviews. Although these projects started under previous compliance requirements, their level of safety awareness and adherence to compliance rules is encouraging. This trend is expected to continue in 2016, where more Paranal instruments are due for milestone reviews, and subsequently to spread to the E-ELT's instrument projects.

The symbolic groundbreaking ceremony for the ESO Supernova Planetarium & Visitor Centre. From left to right: Patrick Geeraert, Christoph Göbel, Dietmar Gruchmann, Klaus Tschira, Tim de Zeeuw, Manfred Bernhardt and Patrick Roche.

Finance and Budget

Financial Statements 2015

Accounting Statements 2015
(in €1000)

Statement of Financial Position	31.12.2015	31.12.2014
Assets		
Cash and cash equivalents	55 053	22 045
Inventories, receivables, advances and other current assets	22 960	23 066
Non-current assets	1 105 209	1 069 676
Total Assets	1 183 222	1 114 787
Liabilities		
Short-term borrowing	0	0
Payables, advances received and other current liabilities	84 239	65 261
Non-current liabilities	529 373	504 281
Total Liabilities	613 612	569 542
Accumulated surpluses/deficits	545 245	641 538
Pension fund loss/gain	969	– 98 157
Other changes in net assets	– 765	–
Net surplus/deficit for the year	24 161	1 864
Total Net Assets	569 610	545 245
Total Liabilities and Net Assets	1 183 222	1 114 787

Statement of Financial Performance	2015	2014
Operating Revenue		
Contributions from Member States	197 898	151 086
Contributions to special projects	12 289	9 213
In-kind contributions	8 405	7 506
Sales and service charges	2 067	2 333
Other revenue	598	662
Total Operating Revenue	221 257	170 800
Operating Expenses		
Installations and equipment	1 625	1 705
Supplies and services	44 103	47 670
Personnel expenses	83 700	68 081
Depreciation of fixed assets	66 510	60 446
Other operating expenses	1 123	839
Total Operating Expenses	197 061	178 741
Net Surplus/Deficit from Operating Activities	24 196	– 7 941
Financial revenue	4 942	2 495
Financial expenses	5 043	1 000
Net Surplus/Deficit from Financial Activities	– 101	1 495
Non-periodic and extraordinary revenue	66	8 310
Non-periodic and extraordinary expenses	0	0
Net Surplus/Deficit from Non-periodic and Extraordinary Activities	66	8 310
Net Surplus/Deficit for the Period	24 161	1 864

Cash Flow Statement	2015	2014
Cash Flow		
Net receipts	212 682	173 615
Net payments	– 179 674	–135 778
Net Cash Flow from Operating Activities	33 008	37 837
Net Cash Flow from Financing Activities	0	–20 000
Net Cash Flow = Net Increase/Decrease in Cash and Cash Equivalents	33 008	17 837

Budgetary Reports 2015
(in €1000)

Income Budget	Actual	Budget
Contributions from Member States	179 137	179 800
Income from third parties and advances received	26 079	23 543
Other income	1 510	1 293
Consolidated entities	560	701
Total Income Budget	207 286	205 337

Expenditure Budget		
Programme	59 257	78 739
Technical infrastructure and production	7 488	8 558
Operations	72 681	72 274
Science support	8 649	8 005
General activities	25 001	25 736
Financing cost	32	52
Consolidated entities	673	739
Total Expenditure Budget	173 781	194 103

Budget for 2016
(in €1000)

Income Budget	2016 (Approved)
Contributions from Member States	188 919
Income from third parties	20 058
Other income	1 217
Consolidated entities	700
Total Income Budget	210 894

Expenditure Budget	2015 (Approved)
Programme	105 747
Technical infrastructure and production	8 843
Operations	74 847
Science support	9 428
General activities	26 587
Financing cost	34
Consolidated entities	755
Total Expenditure Budget	226 241

The External Auditors, Tribunal de Contas de Portugal*, have expressed their opinion that the financial statements for 2015 give a true and fair view of the affairs of the organisation.

The accounting statements for 2015 show a positive result of 24.2 million euros against 1.9 million euros in 2014. This amount was entirely generated from operating activities. A small negative impact from financial activities was compensated by an equal positive impact from extraordinary activities.

The net assets of the organisation at 31 December 2015 amount to 569.6 million euros.

The cash flow in 2015 was positive by 33.0 million euros. Payments increased in comparison to 2014, mainly as a result of the ramping up of the E-ELT Phase 1, with large payments for the road and platform. Receipts also increased due to the contributions from Poland, additional advance funding from Member States for the E-ELT and funds from the Klaus Tschira Stiftung for the new ESO Supernova Planetarium & Visitor Centre. The cash position at 31 December 2015 was 55.1 million euros.

ESO Council approved the budget for 2016 in December 2015. The approved 2016 expenditure budget amounts to 226.2 million euros. The increase in comparison to 2015 mainly reflects the E-ELT Phase 1, as well as the remaining construction of the ESO Supernova Planetarium & Visitor Centre. It also covers commitments for the current Paranal instrumentation programme and for the ALMA Residencia.

The 2016 approved income budget amounts to 210.9 million euros. This includes the regular contributions from the European Member States, income from third parties and partners, and other income, as well as additional income for the E-ELT from all Member States and funding from the Klaus Tschira Stiftung. Conditional income from Brazil will be added as soon as their ratification procedure is completed.

* Antonio José Avérous Mira Crespo (Judge of the Portuguese Court of Auditors), Maria da Luz Carmezim (Head of Audit Department), Filomena Maria de Oliveira Rolo (Auditor), Nuno Martins Lopes (Auditor).

The ALMA Santiago Central Office at night.


R. Wesson/ESO

Human Resources

Enrico Sacchetti/ESO

ESO/L. Calçada

ESO/M. Alexander

The Human Resources (HR) Department manages all services provided to members of personnel in connection with their employment at ESO, starting from the definition of applicable policies to the execution and conclusion of employment contracts. Within this remit, HR manages the following tasks:
– planning, definition and execution of overall policies and strategies for personnel resources;
– coordination of recruitment and selection procedures;
– employment contracts;
– support to employees with regard to the implementation of the applicable rules, regulations and contractual terms;
– maintenance and storage of personnel records;
– occupational health and welfare;
– social security matters;
– training and professional development;
– family matters connected with employment contracts, including day-care and provision of education at the European School Munich;
– performance management;
– payroll;
– travel settlements.

ESO staff engagement survey

A staff engagement survey was rolled out on 8 June 2015 by Towers Watson. The survey used the same questionnaire as in 2011, albeit with minor changes and amendments, and including additional questions for staff members working in the matrix. The survey results were made available during an all-hands meeting with the Director General and Towers Watson on 29 October. The conclusions from the survey are under discussion.

Review of regulations for ESO Local Staff members in Chile

A working group has been formed by the Director of Administration with representatives from HR, local staff and the unions at Paranal and La Silla. The task of the working group is to review the present regulations for ESO Local Staff Members in Chile in conjunction with developments in Chilean labour law.

Regular Review – Conditions of employment for ESO International Staff Members

In accordance with the ESO Staff Rules and Regulations, a Regular Review is initiated by Council, or by the Tripartite Group established by Council, to review the nature of the employment conditions, and benchmark, collate and analyse relevant data in comparison with other organisations or private industries.

A working group comprising members from the Tripartite Group, the International Staff Committee and Human Resources was set up and met regularly throughout 2014 and 2015. Twelve reference organisations were asked about:
– real movement in the net remuneration for the period 2006–2013;
– basic salary levels as per 2013;
– remuneration, social security and social conditions for fellows and PhD students;
– comparison of allowances, indemnities, reimbursements and other payments;
– working time and social conditions; and
– annual indexation of basic pay.

A report was presented to the ESO Director General in October 2015 and its proposed recommendations will be submitted for approval by the Standing Advisory Committee, the Tripartite Group, the Finance Committee and Council in 2016.

Munich Dual Career Office

Human Resources is in regular contact with the Munich Dual Career Office to support the spouses of international employees during their job search in the Munich area.

Girls' Day at ESO Headquarters

On 23 April 2015, ESO opened its doors to 50 female school students, aged between 10 and 17, to give them an insight into science and technology professions within the organisation, and thereby encourage them to choose such careers in the future. The students participated in an extensive engineering and astronomy programme composed of numerous hands-on workshops.

Recruitment, selection and reassignment

During the year, 43 vacancy notices were published, prompting a total of 1172 applications. The number of completed recruitment campaigns according to contract type were:

Contract type	No. of campaigns	No. of applications
International Staff Members	33	692
Local Staff Members	9	272
Fellows	1	208

All positions were advertised on the ESO Recruitment Portal. For International Staff positions, notifications were sent 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. In addition, prominent advertisements for selected positions were placed in appropriate specialist publications and on recruitment web pages. All ESO advertisements contain a statement regarding ESO's commitment to equal opportunities.

Within the ESO Fellowship Programme, out of 208 applicants, six were recommended for fellowships in Garching and six for Chile. Furthermore, four candidates were awarded ESO Studentships in Europe and two in Chile.

Online interviewing

Human Resources implemented a new recruitment concept, the aim of which is to screen and shortlist candidates more successfully before inviting them for face-to-face interviews, thereby reducing recruitment and travel costs. This new technique invites candidates to answer a set of pre-defined questions via a video link that can be viewed by recruitment board members at any time from anywhere.

PhD programme for engineers

HR, together with the Directorate of Engineering, implemented a new PhD programme for engineers, and the first PhD student from the programme joined in October 2015.

Employee relations and communications

Human Resources continues to have regular consultations and discussions with the International Staff Committee and the unions in Chile.

Collaboration and representation of HR

During two meetings in 2015 the Tripartite Group dealt mainly with matters related to the Staff Rules and Regulations, the Progressive Retirement Programme, the Regular Review, the flexible working time tool and the salary adjustment formula.

HR continued to participate in regular meetings with the HR Advisory Group of the Joint ALMA Observatory in order to discuss and resolve personnel issues of common interest.

HR represented ESO at the International Career Day in Lausanne in March 2015, with the aim of increasing the number of Swiss staff members at ESO and refreshing ESO's relationship with the Federal Department of Foreign Affairs in Switzerland.

Following a request from ESA, HR responded to the ESA review on contractual benefits and conditions for fellows.

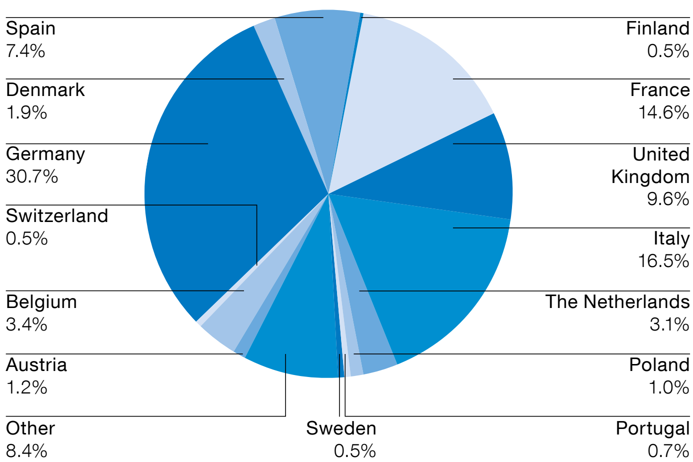
Human Resources also collaborated in and contributed to the audit of the three projects funded by the European Commission (EVALSO, OPTICON and ASTRONET).

Performance management and professional development

An electronic performance management and professional development document process was introduced in 2015. This process was rolled out to several test groups during the 2015 annual performance review and it will be assessed in 2016.

Learning and professional development

Human Resources continued to deliver a wide range of development activities according to the Training Catalogue and the Fellows' Development Programme.



Distribution of International Staff Members by nationality as of 31 December 2015.

In 2015 learning and professional development has seen a strong trend towards individualising development needs within the organisation, i.e., an increasing number of development activities have been designed and rolled out to targeted departments specifically.

Flexible working time tool and policy

A new flexible working time tool was rolled out in May 2015. The accompanying flexible working time policy allows staff members to freely organise their working time within a framework of flexible working hours, provided that operational needs are met. Furthermore, staff members can accrue up to 16 flexi-hours of credit or debit. Participation in the flexi-time model is voluntary. The model will be reviewed by the end of 2016.

Health and welfare and social security

CERN Pension Fund

The annual CERN Pension Fund information meeting took place at ESO Headquarters in September 2015.

Health insurance

Vanbreda International changed its name to Cigna as of 1 February 2015. New Cigna membership cards were made available to eligible staff, and the Enterprise Resource Planning (ERP) and Cigna databases were updated with regard to the dependency status of staff.

In September 2015 several amendments to the health insurance scheme were made at the annual meeting with Cigna in order to adjust and update the medical coverage to the needs and/or the developments regarding health care in the Member States.

HR advice and administration

HR also handles a wide spectrum of personnel-related activities. As an integral part of this service, a variety of pertinent documents, circulars and processes have been reviewed during 2015.

An electronic settlement process for travel claims and education claims is under development and will be introduced in 2016.

Staff departures

The departures of staff in 2015 fall into the following categories:

Reasons	Staff Member	Local Staff Member
Resignation	12	7
Expiry of contract	4	–
Retirement	2	1
Mutual agreement	1	–
Death	–	1
Dismissal (Probation period)	1	–
Total	20	9

The Prawn Nebula (also known as Gum 56 and IC 4628), a southern star formation region.

List of Staff

As of 31 December 2015

Director General

Tim de Zeeuw

Director General Support

Laura Comendador Frutos
Fernando Comerón
Maria Gabriela Gajardo
Nikolaj Gube
Priya Nirmala Hein
Isolde Kreutle
Elena Llopis Liske
Claus Madsen
Enikő Patkós
Douglas Pierce-Price
Jasna Razmilic
Diego Rioseco
Jane Wallace
Jeremy Walsh

Emeritus Astronomers

Thijs de Graauw
Robert Fosbury
Sandro D'Odorico
Massimo Tarenghi

Directorate of Administration

Patrick Geeraert

Patricia Adriazola
Andres Oldemar Arias
Angela Arndt
Katalin Baltayne Korompay
Jean-Michel Bonneau
Renate Brunner
Marcela Campos
Karina Celedon
Claudia Silvina Cerda
Mercedes Chacoff
Pauline Conlon
Amal Daire
Alain Delorme
Evelina Dietmann
Andrea Dinkel
Sabine Eisenbraun
Willem Eng
Alicia Garafulich
Alain Gilliotte
Rebonto Guha
Manuela Gunka
Robert Hamilton
Charlotte Hermant
Georg Junker
Nathalie Kastelyn
Katarina Kiupel
Maria Francisca Labayru
Katjuscha Lockhart
Rodrigo Lorca
Qiao Yun Ma
Maria Madrazo
Alessandro Martis
Alejandra Mena
Katarzyna Meyer
María Angélica Moya
Christian Muckle
Hélène Neuville
Claudia Ober
Betül Özener
Ester Oliveras
Ernesto Orrego
Thomas Penker
Florence Perrault
Leonel Pizarro
Mauricio Quintana
Fabian Reckmann
Mario Riedel
Jürgen Riesel
Rosa Ivonne Riveros
Francky Rombout
Elke Rose
Marcia Saavedra
Johannes Schimpelsberger
Heidi Schmidt
Maria Soledad Silva
Erich Siml
Roswitha Slater
Alexandra Specht
Steffi Steins
Orsolya Szécsényi
Arnoldus Gregorius Tromp
Lone Vedsø Marschollek
Maritza Vicencio
Michael Weigand

Directorate of Engineering

Michèle Péron

José Antonio Abad
Roberto Abuter
Matteo Accardo
Eric Allaert
Emmanuel Aller Carpentier
Domingo Álvarez Méndez
Paola Amico
Luigi Andolfato
Javier Eduardo Argomedo Zazzali
Gerardo Ávila
Pascal Ballester
David Bargna
Pablo José Barriga Campino
Domenico Bonaccini Calia
Sylvain Bonnefond
Henri Bonnet
Roland Brast
Martin Brinkmann
Paul Bristow
Iris Bronnert
Enzo Brunetto
Blanca Camucet
Alessandro Caproni
Sandra María Castro
Cecilia Cerón
Alberto Maurizio Chavan
Anne-Laure Cheffot
Gianluca Chiozzi
Emanuela Ciattaglia
Mauro Comin
Livio Condorelli
Ralf Dieter Conzelmann
Paula Cristina Correia dos Santos
Claudio Cumani
Sebastian Deiries
Bernard-Alexis Delabre
Françoise Delplancke-Ströbele
Nicola Di Lieto
Canio Dichirico
Martin Dimmler
Robert Donaldson
Dario Dorigo
Reinhold Dorn
Mark Desmond Downing
Philippe Duhoux
Jorge Dupeyron
Christophe Dupuy
Sebastian Elias Egner
Siegfried Eschbaumer
Michael Esselborn
Sylvie Feyrin
Gert Finger
Gerhard Fischer
Vincenzo Forchi
Robert Frahm
Christoph Frank
Armin Gabasch
Fernando Gago
César Enrique García Dabó
Daniel Gaytan
Christoph Geimer
Rodrigo Gesswein
Paolo Ghiretti
Bruno Gilli
Percy Glaves
Andreas Glindemann
Juan Carlos González Herrera
Justo Antonio González Villalba
Thomas Grudzien
Ivan Maria Guidolin
Carlos Guirao Sanchez
Stéphane Jean Roger Guisard
Pablo Gutierrez Cheetham
Ronald Guzman Collazos
Wolfgang Hackenberg
Andreas Haimerl
Peter Hammersley
Jochen Haucke
Gerald Hechenblaikner
Florian Heissenhuber
Guy Hess
Renate Hinterschuster
Ronald Holzlöhner
Stefan Huber
Georgette Hubert
Evi Hummel
Derek James Ives
Olaf Iwert
Gerd Jakob
Bogdan Jeram
Paul Jolley
Andreas Jost
Yves Jung
Dimitrios Kalaitzoglou
Markus Kasper
Lothar Kern
Mario Kiekebusch
Jean Paul Kirchbauer
Barbara Klein
Maurice klein Gebbinck
Jens Knudstrup
Franz Koch
Johann Kolb
Maximilian Kraus
Hervé Kurlandczyk
Przemyslaw Kurowski
Paolo La Penna
Mervi Johanna Lampinen
Uwe Lange
Miska Le Louarn
Samuel Lévêque
Steffan Lewis
Paul Jonathan Lilley
Jean-Louis Lizon à L'Allemand
John Lockhart
Simon Lowery
Christian Lucuix
Lars Kristian Lundin
Pierre-Yves Madec
Antonio Ramón Manescau Hernández
Alisdair Manning
Enrico Marchetti
Juan Antonio Marrero Hernández
Stewart McLay
Leander H. Mehrgan
Serge Menardi
Samantha Milligan
Andrea Modigliani
Christophe Moins
Antonio Ignacio Molina Conde
Michael Müller
Michael Naumann
Lothar Noethe
Sylvain Oberti
Ralf Palsa
Moreno Pasquato
Jérôme Paufique
Marcus Pavez
Federico Pellegrin
Martine Peltzer
Lorenzo Pettazzi
Thomas Pfrommer
Duc Thanh Phan
Werther Pirani
Dejan Popovic
Eszter Pozna
Marco Quattri
Jutta Quentin
Mathieu Reinquin
Roland Reiss
Javier Reyes
Robert Ridings
Jesús Rodríguez Ulloa
Calle Rosenquist
Goncalo Sérgio Santos Tomás
Marc Sarazin
Marcus Schilling
Christian Schmid
Dominik Schneller
Babak Sedghi
Paola Sivera
Christian Sönke
Fabio Sogni
Heiko Andreas Sommer
Jörg Stegmeier
Stefan Ströbele
Marcos Suárez Valles
Dieter Suchar
Helmut Tischer
Mirko Todorović
Sebastien Tordo
Arno Van Kesteren
Elise Vernet
Jakob Vinther
Andrew Wright
Michèle Zamparelli
Stefano Zampieri

Joint ALMA Observatory

Pierre Cox

Itziar De Gregorio Monsalvo
William Dent
Diego Alex García
Serge Guniat
Tracey Hill
Jorge Ibsen
Rüdiger Kneissl
Stéphane Leon Tanne
Massimiliano Marchesi
Sergio Martin
Gautier Mathys
Lars-Åke Nyman
José Parra
Neil Matthew Phillips
David Rabanus
Armin Silber
Giorgio Siringo
Russell Smeback
Donald Tait
Baltasar Vila Vilaro
Eric Villard
Nicholas Whyborn

Directorate of Operations

Andreas Kaufer

Sergio Abadie
Margarita Acuña
Gregorio Aguilera
Claudio Agurto
Bernardo Ahumada
Javier Alarcón
Jaime Alonso
José Luis Álvarez
Nicolás Álvarez
Paola Andreani
Jimmy Arancibia
Iván Aranda
Juan Pablo Araneda
Pablo Arias
Maria Adriana Arrau
Oriel Alberto Arriagada
Karla Aubel
Francisco Azagra
Rodrigo Badinez
José Baez
Pedro Baksai
Giacomo Beccari
Juan Beltran
Thomas Bierwirth
Andrew Biggs
Israel Blanchard
Maxime Boccas
Henri Boffin
Carlos Bolados
Pierre Bourget
Stéphane Brillant
Erich Bugueno
Francisco Caceres
Luis Alejandro Caniguante
Michael Cantzler
Robin Capocci
Rubén Cárcamo
César Cárdenas
Giovanni Carraro
Duncan Castex
Mónica Castillo
Roberto Castillo
Susana Cerda
Claudia Cid
Lodovico Coccato
Franco Colleoni
Alex Correa
Alejandra Cortés
Angela Cortés
Carlos De Breuck
Willem-Jan de Wit
Diego Del Valle
Nausicaa Delmotte
Álvaro Díaz
Mariano Díaz
Eva Montserrat Díaz Catalá
María Díaz Trigo
Danuta Dobrzycka
Adam Dobrzycki
Reinaldo Donoso
Javier Duk
Michael Dumke
Cristian Elao
Marcela Estefanía Espinoza
Lorena Faundez
José Figueroa
Giorgio Filippi
Erito Flores
Nathalie Fourniol
Michel Frantz
Wolfram Freudling
Eloy Fuenteseca
Dimitri Gadotti
Sergio Gaete
Julien H. V. Girard
Andrés González
Edouard González
Jaime González
Javier Andrés González
Leonardo González
Sergio González
Patricia Guajardo
Carlos Guerra
Juan Carlos Guerra
Jonas Haase
Juan Pablo Haddad
Nicolas Haddad
Boris Häußler
Pierre Haguenauer
Reinhard Hanuschik
Evanthia Hatziminaoglou
George Hau
Juan Pablo Henriquez
Cristian Herrera
Cristian Herrera
Pascale Hibon
Michael Hilker
Gerhard Hüdepohl
Rodrigo Huerta
Christian Hummel
Wolfgang Hummel
Elizabeth Humphreys
Valentin Ivanov
Nestor Jiménez
Ismo Kastinen
Thomas Klein
Carlos La Fuente
Francisco Labraña
Robert Alexander Laing
Cédric Ledoux
Alfredo Leiva
Marcelo Lopez
Fernando Luco
Felipe Mac-Auliffe
Gianni Marconi
Pedro Mardones
Christophe Martayan
Stéphane Marteau
Mauricio Martínez
Eduardo Matamoros
Andrea Mehner
Angel Mellado
Antoine Mérand
Alberto Micol
Steffen Mieske
Sabine Möhler
Palle Møller
Francisco Miguel Montenegro-Montes
Alex Morales
Ivan Muñoz
Juan Carlos Muñoz-Mateos
Sangeeta Mysore
Julio Navarrete
Mark Neeser
Hernan Nievas
Francisco Olivares
Rodrigo Olivares
Juan Osorio
Juan Carlos Palacio
Laurent Pallanca
Ricardo Nelson Parra
Rodrigo Javier Parra
Diego Parraguez
Ferdinand Patt
Eduardo Peña
Isabelle Percheron
Juan-Pablo Perez-Beaupuits
Monika Petr-Gotzens
Dirk Petry
Oliver Pfuhl
Jorge Pilquinao
Juan Pineda
Andres Pino
Aldo Pizarro
Emanuela Pompei
Sébastien Poupar
Matteo Pozzobon
John Pritchard
Andrés Ramírez
Christian Ramírez
Suzanna Randall
Claudio Reinero
Marina Rejkuba
Jörg Retzlaff
Claudia Reyes
Miguel Riquelme
Leonel Rivas
Thomas Rivinius
Chester Rojas
Pascual Rojas
Martino Romaniello
Cristian Romero
Rodrigo Romero
Silvio Rossi
Felix Alberto Rozas
Laura Ruiz Zorrilla
Francisco G. Ruseler
Fernando Salgado
Ariel Sanchez
Stefan Sandrock
Sebastian Sanhueza
Eleonora Sani
Pierre Sansgasset
Jorge Santana
Ivo Saviane
Erich Schmid
Linda Schmidtobreick
Ricardo Schmutzer
Nicolas Schuhler
Fernando Selman
Waldo Siclari
Peter Sinclaire
Nicolas Slusarenko
Alain Smette
Gerardo Smith
Jonathan Smoker
Christian Spille
Thomas Stanke
Christian Stephan
Michael Fritz Sterzik
Felix Stoehr
Sandra Strunk
Thomas Szeifert
Lowell Tacconi-Garman
Richard Tamblay
Gie Han Tan
Mario Tapia
Pedro Toledo
Karl Torstensson
Konrad Tristram
Josefina Urrutia
Guillermo Valdes
Elena Valenti
José Javier Valenzuela
Karen Vallejo
Mario Van Den Ancker
Eelco van Kampen
Pierre Vanderheyden
José Velásquez
Paulina Venegas
Sergio Vera
Ignacio Vera Sequeiros
Arthur Vigan
Jorge Vilaza
Zahed Wahhaj
Rein Warmels
Wolfgang Wild
Markus Wittkowski
Burkhard Wolff
Pavel Yagoubov
Véronique Ziegler
Gerard Zins
Elena Zuffanelli
Martin A. Zwaan

Directorate of Programmes

Adrian Russell

Robin Arsenault
Fabio Biancat Marchet
Claudio Cabrera
Mark Casali
Marc Cayrel
Frédéric Derie
Philippe Dierickx
Roberto Gilmozzi
Frédéric Yves Joseph Gonté
Peter Murray Gray
Christoph Haupt
Volker Heinz
Norbert Hubin
Lieselotte Jochum
Florian Kerber
Bertrand Koehler
Nicholas Charles Kornweibel
Ignacio Lopez Gil
Pascal Martínez
Katia Montironi
Bianca Neureiter
Luca Pasquini
Jean-François Pirard
Gero Rupprecht
Valérie Saint-Hilaire
Stefano Stanghellini
Josef Strasser
Roberto Tamai
Mauro Tuti
Gianluca Verzichelli

Directorate for Science

Robert Julian Ivison

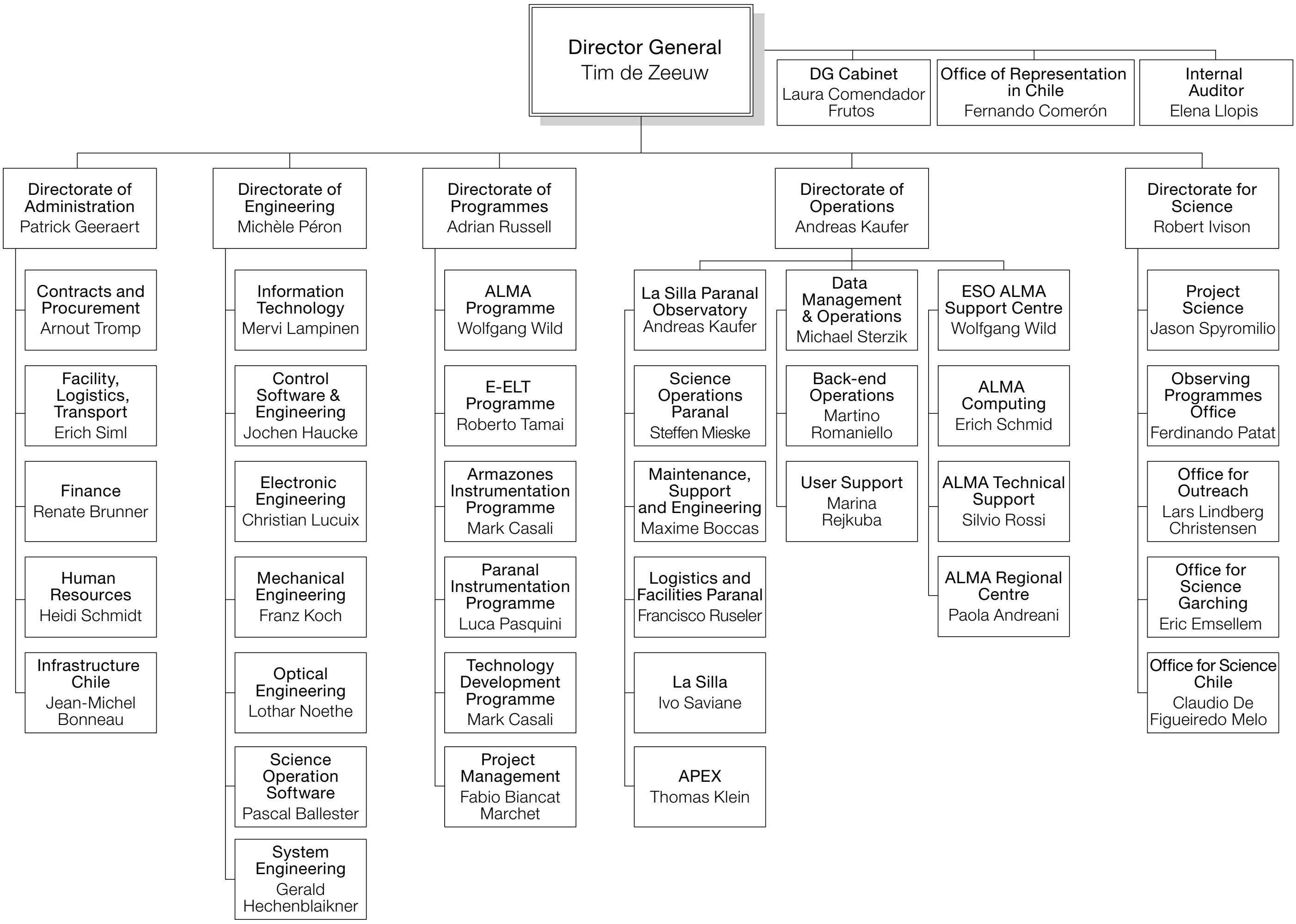
Adriano Agnello
Rebeca Aladro
Susana Almagro García
Julian David Alvarado Gomez
Joseph Anderson
Mathias André
Maryam Arab Salmani
Fabrizio Arrigoni Battaia
Vinodiran Arumugam
Daniel Asmus
Dietrich Baade
Callum Bellhouse
Jean-Philippe Berger
Matthieu Bethermin
Dominic Bordelon
Jutta Boxheimer
Pamela Bristow
Ivan Cabrera Ziri Castro
Stella-Maria Chasiotis-Klingner
Roxana-Adela Chira
Lars Lindberg Christensen
Aleksandar Cikota
Michele Cirasuolo
Silvia Cristiani
Joana Mafalda da Cruz Carmo Martins
Rebecca Davies
Izan de Castro Leao
Annalisa De Cia
Claudio De Figueiredo Melo
Suhail Dhawan
Bruno Dias
Richard Ellis
Eric Emsellem
Steve Ertel
Tamar Faran
Maud Muriel Galametz
Alexandre Gallenne
Adam Ginsburg
María Eugenia Gómez
Luis Goncalves Calçada
Oscar A González
Uta Grothkopf
Jason Harley Grunhut
Adrien Guerou
Nicolas Guillard
Claudia Patricia Gutiérrez Avendaño
Lizette Guzman
Olivier Hainaut
Naama Hallakoun
Johanna Hartke
Xavier Haubois
Richard Hook
Renate Elisabeth Hoppe
Petr Horálek
Bernd Husemann
Gaitee Hussain
Katharina Immer
Yara Lorena Jaffe Ribbi
Narges Jamialahmadi
Edmund Janssen
Paulina Jirón
Evelyn Johnston
Tania Johnston
Hans-Ulrich Käufl
Darshan Kakkad
Tomasz Kaminski
Muhammet Emin Karabal
Wolfgang Kerzendorf
Robert Klement
Martin Kornmesser
Anja Krause
Harald Kuntschner
Alexis Lavail
Bruno Leibundgut
Jorge Lillo Box
Gaspare Lo Curto
Hau-Yu Lu
Vincenzo Mainieri
Wing Shan Man
Michaël Marsset
Jorge Martins
Anna Faye McLeod
Melissa McClure
Silvia Meakins
Julien Milli
André Müller
Carl Mundy
César Muñoz
Koraljka Muzic
Belinda Annette Nicholson
Maria Theresa Nilsson
Iván Oteo
Paolo Padovani
Ferdinando Patat
Céline Péroux
Adele Plunkett
Gergely Popping
Francesca Primas
Suzanne Ramsay
Javier Adrián Rodón
Francisco Rodríguez
Paula Valentina Rodríguez
Amanda Schmidt
Markus Schöller
Christine Schulz
Elyar Sedaghati
Raquel Yumi Shida
Ralf Siebenmorgen
Jason Spyromilio
Andra Stroe
Francisco Surot Madrid
Agnieszka Sybilska
Stefan Taubenberger
Matthew Taylor
Marco Tazzari
Leonardo Testi
Svea Teupke
Hideki Umehata
Laura Ventura
Joël Daniel Roger Vernet
Ruud Visser
Karina Theresia Voggel
Frédéric Vogt
Ke Wang
Linda Watson
Julien Woillez
Siyi Xu
Bin Yang
Sarolta Zahorecz
Zhiyu Zhang
Herbert Zodet

A pool, plants and ping-pong table cater to the relaxation needs of astronomers and engineers at the Paranal Observatory.

P. Horálek/ESO

Organigram

Organisational Structure December 2015



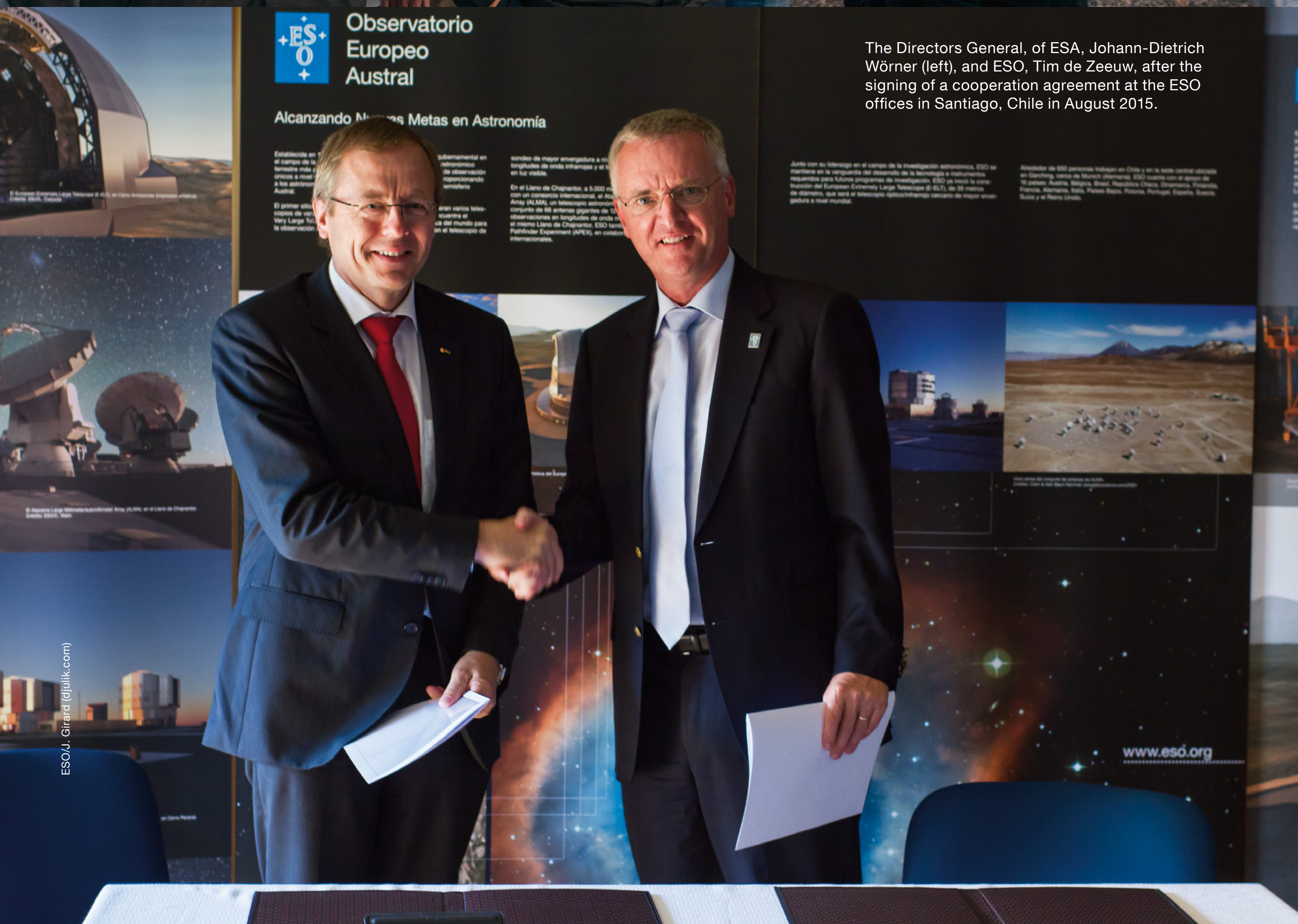
An ESO staff member relaxes and enjoys the view of the Chilean Atacama Desert at the award-winning Paranal Residencia.

ESO/S. Brunier

Director General Support

ESO/Juan Pablo Astorga

The Prime Minister of Italy, His Excellency Mr Matteo Renzi (centre), visited Paranal Observatory in October 2015.



ESO/J. Girard (djulik.com)

The Directors General, of ESA, Johann-Dietrich Wörner (left), and ESO, Tim de Zeeuw, after the signing of a cooperation agreement at the ESO offices in Santiago, Chile in August 2015.

The Cabinet of the Director General, the Office of the Representation in Chile and the Internal Audit Office work together to support the Director General. The Cabinet brings together a number of expert areas that are necessary to ensure ESO's function as an intergovernmental organisation. These include the areas of legal and international affairs, internal communication, corporate risks and intellectual property management, the Council Secretariat and Cabinet and Protocol Office. Within these areas of expertise, the Cabinet additionally supports the ESO Council, the Finance Committee and the ESO Management Team, as appropriate, in the development and implementation of ESO's overall strategy.

Cabinet members are also tasked to forge and maintain ties with ESO Member States. At the same time, Cabinet members participate in meetings of the Council, Finance Committee, Tripartite Group, several Council and Finance Committee working groups as well as representing ESO on external boards, such as the Square Kilometer Array Board, or participate in negotiations with external institutions, such as the Cherenkov Telescope Array.

In the 2014 Annual Report, the Cabinet reported on two of its major tasks during the year — the detailed negotiation of the Polish Accession Agreement and the finalisation of the Trilateral Agreement concerning operations at ALMA. The year 2015 saw the successful culmination of these efforts, with Poland becoming ESO´s 15th Member State on 8 July 2015 and the signature of the ALMA Agreement by all ALMA partners on 15 December 2015 in Tokyo.

Legal Affairs

The Legal Affairs team made a substantial contribution to finalising the ALMA Trilateral Agreement. On the basis of this agreement, the negotiations of the ALMA Management Agreement between the three ALMA Executives (Association of Universities Inc., ESO and NAOJ) have significantly progressed. This agreement will set out the manner in which the executives will work together to make ALMA a world-class scientific endeavour.

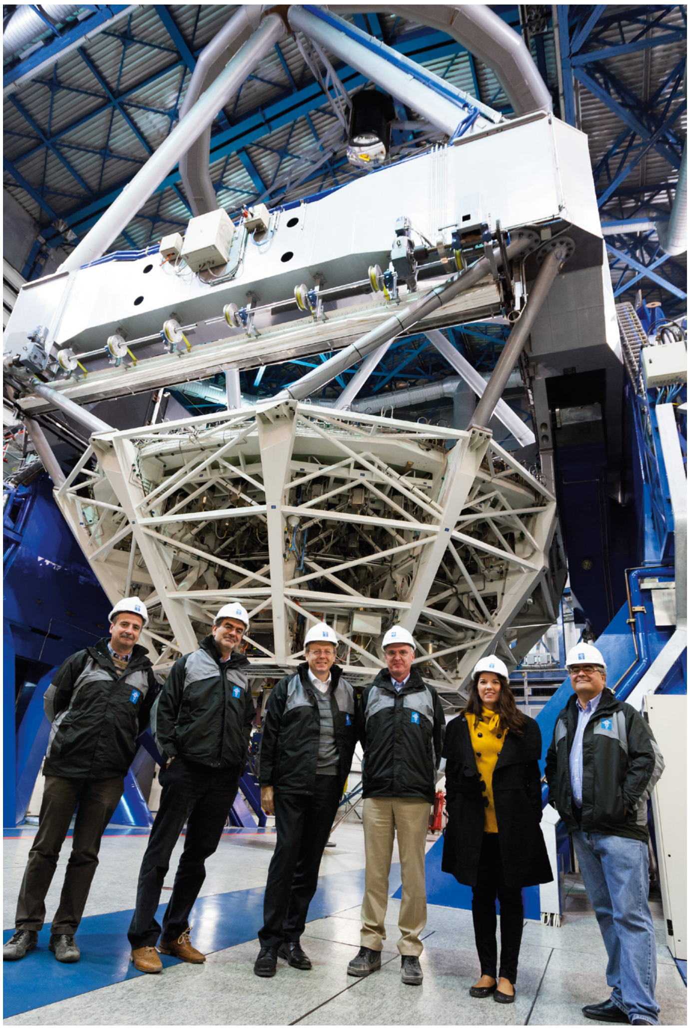
Further developments in 2015 were the approval by Council and signature of two general framework agreements with the ESA on 20 August 2015 and with CERN, on 17 December 2015, concerning mutual cooperation and exchange of information with regard to scientific investigation, research and technological development. Corresponding implementation agreements will be negotiated and concluded in the future for specific cooperation activities with ESA and CERN.

At its 136th meeting Council approved the conclusion of the agreement concerning the publication of the *Astronomy & Astrophysics* journal between ESO and astronomical institutes from 23 countries, which had been negotiated over many months under the leadership of the ESO Cabinet. The main goal of this agreement is to establish clear roles and responsibilities for ESO, the institutes and the A&A Board of Directors for the continuing publication of the journal.

Apart from providing assistance in all legal matters to the ESO Representation in Chile during 2015, the Legal Affairs team in Chile actively supported ESO projects in all relevant areas pertaining to Chile, and in particular the E-ELT project. Foremost examples were the ongoing process for the connection of Armazones and Paranal to the Chilean national electricity grid and the environmental impact study for the construction of a gas pipeline to the ALMA site.

As part of its permanent tasks, the Legal Affairs team provided legal support to the Directorate of Administration, in particular the Human Resources and Contracts and Procurements Departments on various legal matters, such as the interpretation of and update to the ESO Staff Rules and Regulations, labour law cases or complex contractual questions.

Tim de Zeeuw, ESO Director General (left), Katsuhiko Sato, NINS President (centre), and F. Fleming Crim, NSF Assistant Director (right, on behalf of France Córdova, NSF Director), at the ceremony where the ALMA Trilateral Agreement between ESO, the National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS), was signed.



On the day after the signature ceremony between the two organisations, the Director Generals of ESO and ESA, visited the VLT and other facilities at ESO's Paranal Observatory. In this image, from left to right: Fernando Comerón (ESO's Representative in Chile), Fabio Favata (Head of the ESA Programme Coordination Office), Johann-Dietrich Wörner (ESA Director General), Tim de Zeeuw (ESO Director General), Laura Comendador Frutos (ESO Head of Cabinet of the Director General), and Álvaro Giménez (ESA Director of Science and Robotic Exploration).

International Affairs

The most significant event in 2015 for the International Affairs team was without doubt the deposit by Poland of the instrument of ratification regarding its accession to ESO at the French Ministry of Foreign Affairs on 8 July 2015. The efforts by Brazilian astronomers, supported by ESO, to further the ratification process in Brazil continued. An important milestone was reached on 14 May, when the Brazilian Senate approved the ratification proposal. However, by year's end, the final signature by the President of Brazil was still pending.

Meanwhile, Irish astronomers, supported by the ESO Cabinet, made considerable progress regarding ESO membership. On 26 March 2015, an ESO Information Day took place at Trinity College in Dublin. The participants included Irish astronomers, representatives of Irish companies and various advisors to the government. Later in the year, on 3–4 December 2015, the Irish Ambassador in Santiago, Justin Harman, accompanied by Irish astronomer Tom Ray, visited Paranal, and on 8 December, the Irish government published its new Strategy for Science, Technology and Innovation, *Innovation 2020*, which announced that the Irish government intends to "initiate negotiations with ESO for Ireland's membership options". Informal discussions between the Irish Office of Science, Technology and Innovation within the Department of Jobs, Enterprise and Innovation and the ESO Cabinet commenced shortly thereafter to prepare for the official negotiations.

Astronomers in Norway also took important steps towards bringing their country into ESO. In support of this goal, an ESO delegation visited Oslo on 27–28 October 2015. Meetings were held at the Science Ministry and at the University of Oslo, where a colloquium was presented by the Director General. This event was attended by representatives of the Research Council of Norway and the Norwegian Space Centre, university staff astronomers and students. Furthermore, representatives of hi-tech companies were in the audience.

In the course of the year, informal discussions took place between ESO and a number of other countries with a view to strengthening their ESO links, including Armenia, Hungary, Israel and Mexico.

ESO continued its involvement in the EIROforum partnership. Among the topics addressed during 2015 — and to which ESO provided significant input — was the question of the long-term sustainability of research infrastructures, a topic that is high on the agenda of both the European Commission and of the G7 Group of Senior Officials. Furthermore, a number of EIROforum partners are elaborating a proposal under the H2020 Framework Programme, which will potentially lead to substantial European Union funding for targeted research and development in the field of imaging technologies.

As a permanent observer at the United Nations Committee for the Peaceful Uses of Outer Space, ESO attended the relevant sessions in February and June 2015. ESO has also joined the International Asteroid Warning Network, established at the recommendation of the Committee and endorsed by the United Nations General Assembly.

Internal Communication

The Internal Communication Office continued to run the internal announcements and weekly internal newsletter, which are the official channel for internal ESO-wide news. Almost 400 announcements were published during the year. Following an effort to encourage news from the observatory sites, a greater number of such articles were published in 2015, in particular from Paranal. These included reports on instrument commissioning,

The workshop entitled Public Awareness of Research Infrastructures — Expectations — Experiences — Examples was hosted at ESO in June 2015.

news about the people at Paranal, and a series of astronomical topics from Paranal Science Operations.

The Coffee with the Director General events, which provide an informal forum for staff to ask questions and give feedback to senior management, continued in 2015. In Chile, a total of 14 events aimed at all staff were arranged in Vitacura, Paranal, La Silla and at APEX. In Garching, the events have evolved towards more focused discussions, targeted at (but not exclusive to) specific directorates, with the Director General and the relevant director in attendance. Five events took place in Garching, for the Directorates of Administration, Programmes, Engineering and the Directorate for Science, and for the Data Management and Operations Division.

In Vitacura, a new series of informal talks, Astronomy for Everyone, started. These were given by fellows and students, in Spanish, and were aimed at non-experts. Eight such talks took place during the year, covering a wide range of topics including astronomical observations from an aircraft, Earth's place in the Universe, and how astronomical research can lead to spinoff products in everyday life. In Garching, another talk in the What ESO Really Does series took place, on the ESO Fellowship and Studentship programmes.

The Internal Communication Office also coordinated the 2015 ESO Annual Overview, which took place on three half-days from 23–25 March 2015 at all ESO sites. Speakers from across the organisation presented topics selected from ESO's entire programme. The talks were intended to be accessible to a wide audience, covering a broad range of scientific, technical, operational, and administrative themes. This year, for the first time, a presentation skills training course was offered to help the overview speakers prepare for their talks, and video recordings of the overview were made available for the benefit of staff who were unable to attend the sessions.

Risk and intellectual property management

In early 2015 ESO's insurance broker Marsh and the property underwriter QBE made an accompanied site visit to Paranal and ALMA to survey certain risks and discuss improvements, as necessary, relating to property insurance. QBE issued some recommendations as a result of the visit, which are currently in the process of being implemented.

ESO's contract for non-life insurance brokerage services with Marsh reached the end of its initial three-year term in July 2015 (the contract is for 3+2 years). As ESO was satisfied with the services of Marsh, the two-year extension was granted, continuing the contract with Marsh until July 2018. A new tender for brokerage services will be issued at the end of 2017.

Intellectual property and knowledge transfer activities at ESO continued with modest but rewarding actions. Two royalty-based license agreements on the Lizon cryostat know-how were concluded in 2015 with a Spanish (FRACTAL) and a French (SDMS) company. The ESO patent on a blackbody calibration standard for the submillimetre frequency range was finally granted in the US (Patent No. 9182298), Japan (Patent No. 5738813) and Canada (Patent No. still to be issued) in 2015. The inventor of the patent is Pavel Yagoubov. The know-how for both of these is available for licensing.

The implementation of ESO's Data Classification Policy, published in 2013, continued in 2015. The major milestone in this area was the decision to make public many Council and Finance Committee documents in the future: they are currently available at www.eso.org/public/about-eso/committees.html.

Office of the Representation in Chile

The first, albeit virtual, visit of the Chilean President, Her Excellency Michelle Bachelet, to ESO took place on 6 June 2015 through a video conference between Paranal and the Chilean pavilion at Expo Milan 2016. In the course of this event President Bachelet announced that the Italian Prime Minister, His Excellency Matteo Renzi, would visit Paranal. The visit took place in October and included an overnight stay at the observatory. Other high-level contacts between ESO and current or former high officials of the Chilean government included: the meeting between the Director General and the former Chilean President Sebastián Piñera in April; and the attendance of the Minister of Economy, Luis Felipe Céspedes, at the dinner for the Committee of Council by the Embassy of Sweden in Chile in October 2015.

ESO is cooperating with initiatives led by the Chilean Government to promote the outstanding qualities of the night sky in the north of Chile, such as a project to declare the observatory sites as Human Heritage by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in coordination with other international observatories, and a study concerning the coordination of astrotourism on a nationwide scale. ESO has also collaborated with the Foundation Imagen de Chile to promote astronomy and its related technologies. These are examples of cooperation between ESO and its host state that extend to other contexts, as is reflected by the high demand for the funding of Chilean projects by the ESO–Chilean Government Joint Committee, which once again received a record number of applications in 2015, amounting to 42.

The start of E-ELT construction opens up possibilities for Chilean industry and engineering companies to become involved in this project, as specified by the agreement signed in 2011 between ESO and the Government of Chile for the establishment of the E-ELT. Information events have continued to take place to raise awareness of the project both among Chilean companies and among companies from ESO Member States with presence in Chile. ESO also contributed to the organisation of the third Astroengineering Conference organised by the Chilean Ministry of Economy in November 2015.

Chile continues to be an important venue for ESO's international relations beyond those with the host state. High-level visits to the ESO sites in Chile this year included the Parliamentary Secretary of State for Science and Technology of Germany, Stefan Müller; a delegation from the Christian Social Union, the political party currently in government in Bavaria, from the Bavarian parliament; Austrian delegations to their national and European parliaments; the Spanish Secretary of State for Science and Technology, Carmen Vela; the Chief Scientific Adviser to the UK Foreign Office, Robin Grimes; the UK Government Chief Scientific Adviser, Sir Mark Walport; the Rector of the University of Oslo, Petter Ottersen; the Rector of the University of Ankara, Erkan Ibis; and a delegation of the National Science Foundation/National Science Board, composed of Fleming Crim, Carl Lineberger, and Ruth David. The observatories have also hosted visits by the ambassadors of several Member States: Patrick de Beyter (Belgium), Josef Rychtar (Czech Republic), Jesper Fersløv Andersen (Denmark), Justin Harman (Ireland), Aleksandra Piątkowska (Poland), Jakob Kiefer (Sweden), Edgar Dörig (Switzerland), and Fiona Clouder (United Kingdom). In this regard the publication by the ESO Representation of a monthly newsletter specifically addressed to the diplomatic missions in Chile, begun in August 2015, has been instrumental in reinforcing this important communication channel for ESO activities.

ESO/Expo Milano 2015

Above: Screenshot of Her Excellency Michelle Bachelet, President of Chile, during a video conference with Paranal Observatory from Expo Milan.

Below: ESO Director General Tim de Zeeuw presented ESO to members of the German Federal Parliament at a Parliamentary Evening in Berlin in February 2015.

Internal Audit

The internal audit is an independent, objective assurance and consulting activity designed to add value and improve the organisation's operations. During 2015, the Internal Audit Office provided support to the external auditors in the performance of their duties and delivery of reports to the Director General. Other regular activities during the year were the audit certificate for ESO partners as well as various audit certificates for EU-financed projects.

The Internal Audit Office also performed several other audits, including the audit of procurement by external staff and an analysis of the rights within the ERP software.

ESO/Stuart Bebb

The signing ceremony at Oxford University of the agreement for the design and construction of the HARMONI instrument for the E-ELT.

ESO and a consortium of institutes around Europe signed an agreement at Leiden University in September 2015 for the design and construction of the E-ELT infrared instrument METIS.

ESO's Very Large Telescope on Cerro Paranal, Chile.

John Colosimo (colosimophotography.com)/ESO

Committees

The Member State flags outside ESO Headquarters. The construction information board of the ESO Supernova Planetarium & Visitor Centre is also on display.

ESO/M. Zamani

Council

As ESO's main governing body, Council determines the policy of the organisation with regard to scientific, technical and administrative matters. Both Council and the Committee of Council (the informal body of Council) normally meet twice during the year: however, in 2015 there were two extraordinary Council meetings, which took place in conjunction with the March and October Committees of Council. The first ordinary Council meeting of the year was kindly hosted by the Portuguese delegation in Lisbon on 10–11 June 2015, with the second taking place on 8–9 December 2015 in Garching. For the Committees of Council, the March meeting was held at the Leiden Observatory on 3–4 March 2015, where the delegates were warmly welcomed by their Dutch colleagues. The second meeting took place at the ESO Offices in Santiago on 7–8 October 2015, from where the delegations were able to visit the ESO sites, including La Silla, Paranal, Armazones and ALMA. All meetings were chaired by the Council President, Patrick Roche.

During the March meeting, Council approved the composition of the New Member States Working Group and the Strategic Working Group, which had both changed due to the departure of some delegates from Council.

At the June meeting, the Belgian delegation confirmed that they had converted their *ad referendum* vote concerning the resolution regarding the E-ELT construction in two phases to a positive vote. This means that there is now a full complement of 14 positive votes for the E-ELT programme, which is thus firmly supported by all delegations. The Council President and the ESO Director General gave an update on a number of ongoing events and actions and the respective Directors and Heads of Department presented feedback on all aspects of ESO's programme, including the status of La Silla, Paranal, the E-ELT and ALMA. In conjunction with the ALMA programme, feedback was provided by Xavier Barcons from the ALMA Lessons Learned Committee, which had concluded its study. Approval was given to the Director General to sign, on behalf of ESO, the ESA–ESO Cooperation Agreement, which had recently been agreed.

The Annual Report, the Financial Statements for 2014 and the External Audit Report were all unanimously approved. Discharge was granted to the Director General, and the external auditors were warmly thanked for their hard work over the past twelve months. GTO was agreed for 4MOST and the E-ELT instruments. Prior to closing the meeting, Jan van de Donk, who was retiring from Council, was thanked for his valuable contributions during his time as a member of the Dutch delegation.

In October, a short extraordinary Council meeting took place. This allowed Council to warmly welcome the Polish delegation to their first meeting following the completion of their accession to ESO on 8 July 2015. During the meeting, the *Astronomy and Astrophysics* (A&A) Journal Agreement was unanimously approved, as well as the CERN–ESO Cooperation Agreement.

The final Council meeting of the year took place in Garching. Following the regular updates regarding the ESO programme, feedback was provided on the status of the E-ELT programme by the Chair of the E-ELT Management Advisory Committee, in the light of their meeting earlier in the month. Elections took place for appointments to the various ESO Committees, including the ALMA Board, Finance Committee, Observing Programmes Committee, Scientific Technical Committee and the Tripartite Group. The re-appointment of the Council President and Vice President for a second term was confirmed. A number of matters concerning human resources were discussed, including the Regular Review, and the start of a progressive retirement scheme within the organisation was approved by Council. As part of the discussions related to finance, approval was given for the ESO Budget and the scale of contributions, both for 2016. An updated VLT–GTO policy was approved by Council, as was GTO for the NAOMI system and the Band 9 receiver project at APEX. In conclusion, Council expressed its appreciation to Martin Steinacher, a departing member of the Swiss delegation, who was taking up a new post, for his dedication and contributions during his long association with ESO.

Council and Committee of Council 2015

President	Patrick Roche (United Kingdom)
Austria	Daniel Weselka João Alves
Belgium	Sophie Pireaux Christoffel Waelkens
Czech Republic	Jan Palouš (Vice President) Jan Buriánek
Denmark	Cecilie Tornøe Uffe Jørgensen
Finland	Antti Väihkönen Jari Kotilainen
France	Laurent Vigroux Denis Mourard
Germany	Thomas Roth Thomas Henning
Italy	Giovanni Bignami Matteo Pardo
The Netherlands	Jan van de Donk/Mirjam Lieshout-Vijverberg Konrad Kuijken
Poland	Konrad Dębski Marek Sarna
Portugal	Pedro Carneiro Paulo Garcia
Spain	Fernando Ballestero Rafael Bachiller
Sweden	Catarina Sahlberg Hans Olofsson
Switzerland	Martin Steinacher Willy Benz
United Kingdom	Colin Vincent Simon Morris

Finance Committee

Finance Committee 2015

Chair	Colin Vincent (United Kingdom)
Austria	Sabine Hertgen (Vice-chair)
Belgium	Alain Heynen
Czech Republic	Pavla Katzová Pavel Křeček (as of August 2015)
Denmark	Cecilie Tornøe
Finland	Sirpa Nummila
France	Patricia Laplaud
Germany	Gisela Schmitz-DuMont
Italy	Giampaolo Bologna
The Netherlands	Mirjam Lieshout-Vijverberg Thijs Geurts (as of July 2015)
Poland	Konrad Dębski (as of September 2015)
Portugal	Filipa Baptista Coelho
Spain	Inmaculada Figueroa
Sweden	Johan Holmberg
Switzerland	Astrid Vassella
United Kingdom	Maggie Collick

The ESO Finance Committee is charged with the general responsibility of advising Council on all matters of administrative and financial management. In 2015, it held one extraordinary and two ordinary meetings, all of them chaired by Colin Vincent. At these meetings, the delegates received regular updates and information on the status of the programmes, the CERN Pension Fund, the procurement statistics and industrial return coefficients.

At its 141st meeting in May 2015, the Finance Committee recommended to Council for approval a few personnel-related matters, the financial statements for 2014 and the external audit report, which included the granting of discharge to the Director General. Among other contracts, the first collaboration agreements for instruments and contracts for the E-ELT were approved.

The 142nd extraordinary meeting in September 2015 focused on financial and personnel matters. The Finance Committee discussed the preliminary budget figures for 2016, taking into account indexation, and a possible option to secure exchange rates. Other topics were the Regular Review and the presentation of a progressive retirement programme.

The progressive retirement programme was recommended to Council at the 143rd Finance Committee meeting in November. At this meeting, the delegates also recommended to Council the scale of contributions for 2016, the ESO Budget for 2016, a small change to the salary adjustment formula and the securing of exchange rates. They also approved a number of contracts for the La Silla Paranal Observatory, ALMA and the E-ELT.

In total, the Finance Committee approved 17 contracts exceeding €500 000, one amendment to an existing contract and four single-source procurements exceeding €250 000. Two financial issues were approved by written procedure.

After ratification of the Accession Agreement, Poland nominated a delegate to the Finance Committee, who, for the first time, attended the meeting in September 2015.

ESO/M. Zamani

At a ceremony at ESO Headquarters on 10 December 2015, an agreement was signed between ESO and an international consortium, represented by the INAF President Nicolò D'Amico, for the design and construction of the MAORY adaptive optics system for the E-ELT.

Scientific Technical Committee

The Scientific Technical Committee 2015

Chair	Sofia Feltzing (Sweden)
Austria	Franz Kerschbaum
Belgium	Hans Van Winckel (LSP)
Czech Republic	Stephane Vennes (LSP)
Denmark	Jes K. Jörgensen (ESAC)
Finland	Alexis Finoguenov (LSP)
France	Anne-Marie Lagrange (ESC Chair)
Germany	Matthias Steinmetz (ESC)
Italy	Livia Origlia
The Netherlands	Eline Tolstoy (LSP)
Poland	Grzegorz Pietrzyński
Portugal	André Moitinho (LSP)
Spain	Almudena Alonso-Herrero (ESC)
Switzerland	Michael R. Meyer (ESAC)
United Kingdom	Ian Smail (ESAC)
Chile	Neil Nagar

Members at Large
Rachel L. Akeson (USA, ESAC)
Warrick Couch (Australia)
John D. Monnier (USA, LSP Chair)
Eva Schinnerer (Germany, ESAC Chair)
Gillian Wright (UK, LSP)

Observer

Brazil	Marcos Perez Diaz

The Scientific Technical Committee advises the Council and the Director General on policy matters of scientific and technical importance and on scientific priorities for projects and programmes. It met for ordinary meetings at ESO Headquarters on 21–22 April 2015 (STC85) and 20–21 October 2015 (STC86), with a high fraction of new members and presided over by a new Chair, Sofia Feltzing. STC86 was the first STC meeting with a Polish member (Grzegorz Pietrzyński) in attendance. The STC was comprehensively briefed on a broad range of regular activities as well as specific projects requiring their recommendation. Before the plenary STC sessions, meetings of the STC subpanels for ALMA (the European ALMA Science Advisory Committee, ESAC), the E-ELT (E-ELT Subcommittee, ESC) and La Silla Paranal Observatory subcommittee (LSP) were held. The subpanel chairs delivered summaries from their respective panels to the STC. During all discussions, attention was paid to conflicts of interest arising from the involvement of individual STC members in the project under consideration. For its 86th meeting, the STC Chair and the Director for Science developed a modified scheme for the agenda, allowing more time for discussion. A new format for the fact sheets was also developed.

85th STC meeting

The STC recommended that ESO complete the negotiations for the E-ELT instruments MAORY, MICADO, HARMONI, METIS and the laser tomography adaptive optics module. HARMONI and MICADO were confirmed as first-light instruments, with METIS to follow. The STC provided strong encouragement to cap both capital expenditures and Guaranteed Time Observation awards by exploring options for simplifying/descoping instruments, as long as the impact on scientific potential is not critical.

For ALMA, the STC supported ESO's efforts to encourage the JAO to quickly fill the position of ALMA Observatory Scientist. ALMA's increased observing efficiency was noted, but the STC saw room for further improvements, to be pursued with a high priority. More meaningful and clearer metrics of the observatory's efficiency were requested. High priority should also be given to automatic checks of observing proposals for the duplication of targets. The executability of proposals should be more strongly reflected in their ranking.

The STC was particularly pleased with ESO's report on the lessons learned from PRIMA (the VLTI Phase Referenced Imaging and Micro-arcsecond Astrometry instrument) and how they will be applied in other projects, including the E-ELT. On the occasion of the decommissioning of the VLTI Mid-Infrared instrument MIDI, the STC congratulated all involved for the 15 years of success that have led to an important legacy of scientific results.

In view of the aging of NACO, the STC expressed strong support for the ERIS project and the partnership that ESO has built with an external consortium. At the same time, ESO was encouraged to start defining a more capable instrument that can better exploit the power of the Adaptive Optics Facility. The development of an adaptive optics master plan was suggested.

The STC was pleased to learn about the exciting scientific perspectives resulting from the numerous responses to the call for proposals for new NTT instruments at La Silla. The STC endorsed the proposal that, for an interim period, ULTRACAM be hosted at the NTT. For the new facility instrument, the development of SOXS was recommended, with the proviso that at least 50% of the observing time should be available for the community at large. The STC noted that the proposals received for new NTT instruments did not provide the hoped-for reduction in the financial burden on ESO and encouraged ESO to look into this matter.

The significant amount of work that had gone into the Scientific Prioritisation Report was much appreciated by the STC, and it strongly suggested that the document be regularly reviewed and updated so that it always provides up-to-date scientific guidance. The STC found it very important that the priorities of the community had been captured by the community poll carried out by ESO. It suggested that the stewardship of the document be given a broad basis and that a VLT instrumentation roadmap be developed for discussion at the next STC meeting.

The suggestion by ESO for a new call for proposals for VISTA Public Surveys was supported. Furthermore, the STC recommended that the sharing of 4MOST fibres between the community and Guaranteed Time Observers be conducted in as transparent a way as possible and the community be informed about policies and procedures well in advance of first light. The STC also welcomed the move towards remote operations and diagnostics from Santiago as a means to reduce costs and improve the work-life balance of staff.

86th STC meeting

The STC welcomed the new VLT–GTO policy and emphasised the need to continue to make GTO awards in return for contributions of labour from institutes, as this has been an enormous success in engaging the community in ESO's mission. It was considered vital that this process continues. The new policy, which fixes the number of GTO nights in the call for proposals, was seen to be in line with this goal. Cash contributions from consortia could serve the same purpose but should be reviewed with care to avoid imbalance. The STC also recommended that the ceiling on the fraction of GTO observations in any one semester be increased to 15% for each VLT Unit Telescope. The cost to completion was seen as a valuable metric that should be included in all future project proposals to be discussed by the STC.

A request to ESO for a decommissioning plan for VLT/VLTI instruments reaching the end of their scientific or technical life expectancy was made. The STC expressed the wish to be involved in the identification of the instrument to be displaced by CRIRES+ when it returns to Paranal after the upgrade in Garching.

The STC was very pleased with the progress accomplished by the AOF, the reconfiguration of the VLTI laboratory, and the achievement of first fringes by GRAVITY. It requested a draft of a VLTI scientific priorities document for discussion at STC87 and emphasised the need to fill the post of VLTI Programme Scientist after Jean-Philippe Berger leaves ESO.

The presentation of ERIS by its Principal Investigator was perceived very positively, and it was suggested that similar presentations to the STC should be considered for E-ELT instruments. For the latter, it was perceived as important in Phase A that consortia are provided with a clear description of the process that establishes the final Top Level Requirements and scientific objectives to be used for the design.

The STC repeated their identification of an urgent need for the JAO to release a mmVLBI operations plan well before the call for proposals for ALMA Cycle 4. It also encouraged ESO to propose that the JAO undertake a public Band 5 Science Verification programme. The STC welcomed the plan to strengthen the formal cooperation between the various ARC nodes, including the specialisation of the nodes and the resulting support of a broader community by each node. It advocated a strong role for the ALMA Observatory Scientist.

The STC supported the proposal that ESO enter into detailed negotiations with the MASCARA and BlackGEM project teams, which have both enquired whether ESO can host their observing equipment at its observatories. MASCARA would monitor the whole sky at high cadence to detect exoplanets transiting bright stars, while the BlackGEM array of small telescopes would search for optical counterparts of gravitational wave events.

D. Schreiner and S. Degezelle/ESO

View out of the ALMA Array Operations Site Technical Building.

Observing Programmes Committee

The Observing Programmes Committee 2015

Alvio Renzini (Chair)
Henk Hoekstra (Vice-Chair)

Micol Bolzonella
Xavier Bonfils (P96)
Fabio Bresolin (P97)
Alessandro Bressan
Marcio Catelan
Pierre-Alain Duc (P97)
Jesus Falcon-Barroso (P96)
Fabrizio Fiore
Malcolm Fridlund
Gianfranco Gentile (P97)
Miwa Goto (P97)
Henk Hoekstra
Peter Jonker (P96)
Elina Lindfors (P97)
Suzanne Madden
Simona Mei (P96)
Joanna Mikolajewska (P97)
Reynier Peletier (P96)
Philipp Richter (P97)
Nicola Schneider (P96)
Rita Schulz (P97)
Ignas Snellen
Ben Stappers (P96)
Roland Walter (P96)

Nina Hatch (member at large P96)
Samuel Boissier (member at large P96)
Andrea Merloni (member at large P97)

During its meetings in May and November 2015, the Observing Programmes Committee evaluated the proposals submitted for observations to be executed in Periods 96 (1 October 2015 to 31 March 2016) and 97 (1 April 2016 to 30 September 2016). The number of proposals for observations with the ESO telescopes in each of these two periods was 960 and 1023, respectively.

The fraction of submitted proposals (excluding Large Programmes) is 19.3%, 18.6%, 31.3% and 30.7% for A, B, C and D categories, respectively. In terms of requested time the fractions are 21.9%, 17.9%, 31.5% and 28.7%. This turns into a slight shift towards stellar science (categories C and D) from extragalactic science (categories A and B). The OPC categories are specified in full at http://www.eso.org/sci/observing/phase1/p98/opc-categories.html.

FORS2, which is mounted on Antu (UT1), remained the VLT instrument receiving the largest amount of requested observing time (489 nights), as in previous periods. X-shooter on Kueyen (UT2) with 377 nights and MUSE (322 nights) on Yepun (UT4) were just behind. Thanks to the combined presence of FORS2, NACO and KMOS, Antu is the most popular UT, with a ratio between the requested and available time, or pressure, of 5.8, followed by Yepun (pressure 5.4). The return of VISIR and the start of SPHERE operations have led to a pressure increase for Melipal (4.9), evening out the loads on the four VLT Unit Telescopes. The breakdown of requested and allocated time by telescope and instrument is tabulated on p. 25.

The presence of PIONIER at the VLT Interferometer continued to generate considerable interest in the community. This near-infrared interferometric visitor instrument, designed for imaging and fed by four telescope beams, received requests for 146 nights, of which 52 were allocated.

For the survey telescopes (VISTA and the VST), the OPC reviewed 16 open-time proposals for VISTA and ten for the VST, of which eight and nine were scheduled, respectively.

On La Silla, HARPS and EFOSC2 remained in high demand.

Within the framework of the continuing agreement between ESO and ESA for a joint telescope time allocation scheme for coordinated observations with the VLT and the XMM-Newton, proposals for such observations were again invited in 2015. ESO received only one application in Periods 96 and 97, which did not qualify for the allocation of telescope time. Time at both facilities was granted to three joint proposals evaluated by the XMM–Newton Observing Time Allocation Committee.

Targets of Opportunity

Despite the stricter criteria applied to Target of Opportunity programmes as of Period 86, the number of Target of Opportunity proposals submitted in 2015 remained similar to previous years. For Periods 96 and 97 the OPC evaluated 46 and 48 proposals respectively, of which 18 and 17 were scheduled, for a total of about 470 hours. FORS2 is the most requested instrument for Target of Opportunity observations (about 242 requested hours), followed by X-shooter and UVES. These three instruments were allocated 43% of the Target of Opportunity time. A significant amount of Target of Opportunity time was allocated to the two survey telescopes (110 hours, 23.4%), for programmes dedicated to the identification of the counterparts of gravitational wave sources.

Calibration Programmes

Calibration Programmes are intended to allow users to complement the existing coverage for the calibration of ESO instruments. They are principally evaluated by comparing the expected potential enhancement to the science outcomes in the future, compared with the immediate return of science proposals directly competing for the same resources in the current period. In 2015 (Period 97 only) one Calibration Programme was submitted. The proposal was recommended for implementation by the OPC.

Large Programmes

Large Programmes are projects requiring a minimum of 100 hours of observing time that have the potential to lead to a major advance or breakthrough in the relevant field of study. The execution of Large Programmes is spread over several observing periods with a maximum duration of four years for observations carried out with the La Silla telescopes and two years on the VLT/VLTI and APEX.

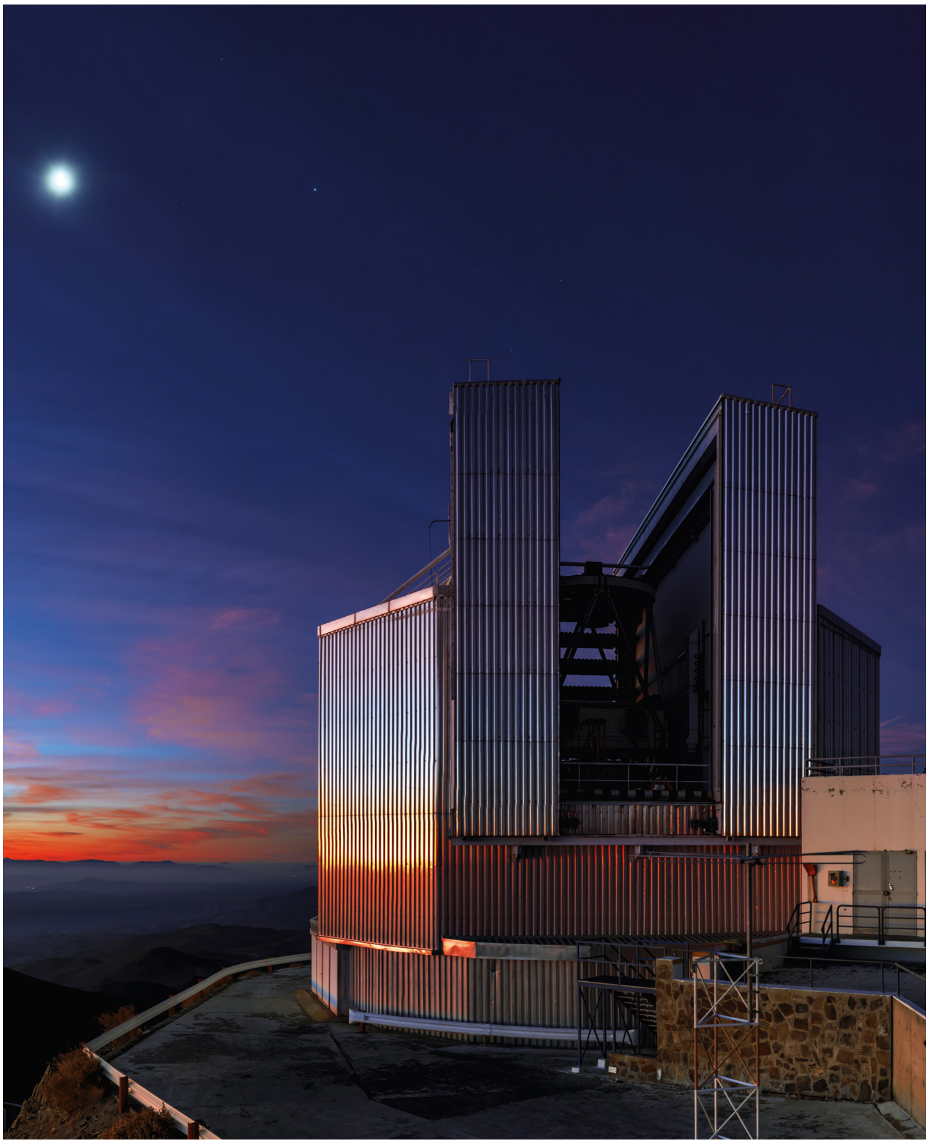
A total of 51 Large Programme proposals were received in 2015: 28 in Period 96 and 23 in Period 97. Following the OPC's recommendations, six new Large Programmes were implemented in Period 96, and three in Period 97. The trend towards using a large fraction of the science time on the La Silla telescopes for the execution of Large Programmes, encouraged by ESO and embraced by the community in recent years, has continued. The total allocations to new and ongoing Large Programmes in Periods 96–97 at the ESO 3.6-metre telescope and NTT were 152 and 159 nights, respectively. These correspond to 47% and 43% of the available science time at these two telescopes (these figures include PESSTO, to which 90 nights per year are allocated at the NTT).

Public Spectroscopic Surveys

The two Public Spectroscopic Surveys, both on UT3 with VIMOS and approved in Period 94, entered full operation. These surveys, extending to Period 100 (October 2017–March 2018), add to those approved in Period 88: namely PESSTO, on the NTT with EFOCS2 and SOFI, and Gaia-ESO (on UT2 with FLAMES [Fibre Large Array Multi Element Spectrograph]). The request for a one-year extension to both PESSTO and the Gaia-ESO surveys was granted in Period 97.

Director's Discretionary Time

Proposals requesting Director's Discretionary Time may be submitted throughout the year for programmes that present a level of urgency incompatible with the regular proposal cycles handled by the OPC. In 2015 the ESO user community submitted 95 Director's Discretionary Time proposals. After taking advice from an internal committee comprising ESO staff astronomers, the Director General approved 56 proposals for implementation. The total amount of requested Director's Discretionary Time was about 580 hours.



ESO/B. Tafreshi (twanight.org)

Sunset behind the NTT at the La Silla Observatory.

Users Committee

The Users Committee 2015	
Chair	Hans Kjeldsen (Denmark)
Austria	Bodo Ziegler
Belgium	Emmanuel Jehin
Czech Republic	Michaela Kraus
Finland	Eija Laurikainen
France	Philippe Delorme
Germany	Maria-Rosa Cioni
Italy	Stefano Covino
The Netherlands	Matthew Kenworthy
Portugal	David Sobral
Spain	María Rosa Zapatero Osorio
Sweden	Kirsten Kraiberg Knudsen (Vice-chair)
Switzerland	Damien Ségransan
United Kingdom	Stephen Smartt
Chile	Thomas Puzia

The 39th annual meeting of the Users Committee was organised by the User Support Department at ESO Headquarters on 27 and 28 April 2015. The meeting serves as a means of exchanging information between ESO and representatives of its astronomical community, and a way to channel input from the community about ESO operations and user interfaces, via this advisory body, to the Director General.

The meeting had a similar format to previous years. During the first day, the Users Committee was informed about ESO's status and latest news in a series of presentations. The Director General provided an update on the entire ESO programme in his opening talk, which was followed by reports from operations departments. The proposal from the Head of the Observing Programmes Office to involve the Users Committee in the selection of OPC members was welcomed and endorsed by the Users Committee, as this strengthens its advisory role. In a special presentation, the Director for Science informed the Users Committee about the scientific priorities resulting from the ESO2020 process. The Users Committee expressed interest in continuing its participation in this process. The first day of the meeting ended with a review of the past year's Users Committee recommendations to ESO, followed by an open discussion that covered a variety of topics from scientific pipelines, observing efficiency and programme completion, to remote observing and publications based on ESO data.

The second day of the meeting was fully dedicated to the topic ESO Science Archive Facility: Status and evolution of content and user services. Two expert users, Celine Péroux (France) and Christopher Wegg (Germany) presented their experience with the Science Archive Facility, describing scientific projects that were enabled by it, while the Head of the Back-end Operations Department described ESO's priorities for the evolution of archive content and services. Overall the users are satisfied with the increase in science-ready and highly processed data in the science archive, and the Users Committee recommended that work on the Science Archive Facility continues and intensifies, as archival research is becoming an increasingly important mode of astronomical research. Additional recommendations that serve to guide priorities for the development of different operational areas were discussed at the end of the meeting.

The contacts between ESO and the Users Committee were not limited to this one meeting. During a mid-term telecon in November, ESO updated the Users Committee on the progress of its recommendations. Furthermore, Users Committee representatives participated in the time allocation and data management working groups, and the newly elected Users Committee chair, Stefano Covino, reported about the users' experiences at the Paranal instrumentation second generation Lessons Learned Review, in which he had participated.

ESO Acknowledgement: VST/Omegacam Local Group Survey

The disc of old stars and some young star formation regions imaged in the nearby dwarf galaxy IC 1613 with OmegaCAM on the VLT Survey Telescope.

Outreach

This year work on the operational parts of the forthcoming ESO Supernova Planetarium & Visitor Centre moved from the planning to the implementation phase. As a result, the work of ESO's education and Public Outreach Department (ePOD) broadened further. In particular the areas of education, planetarium productions and relations with the local and national (German) communities now play a more important role. At the same time, the core outreach areas are being maintained, with special attention being given to innovative ways of communicating astronomy.

Significant progress with the ESO Supernova Planetarium & Visitor Centre was achieved, covering all aspects that are included in the planned programme of activities: management, exhibition, planetarium, education, promotion, merchandise, print products etc. Bringing together this large outreach, exhibition and planetarium infrastructure has been the biggest challenge of the year, although it has also been a welcome opportunity to think out of the box, and to implement innovative solutions that also benefit ESO's "ordinary" outreach work. As an example, ESO implemented a content delivery network (in collaboration with the content delivery network CDN77). All of ESO's web videos and images are now held in 31 data centres throughout the world. This gives users, particularly those in the Americas, Asia and Australia, much faster access to ESO content, and also makes the direct delivery of planetarium shows possible.

Press activities

Forty-nine press releases were issued during the year — a significant increase on the previous year and a larger fraction of them were science releases than in the past. The news releases covered a good mix of results from all ESO facilities, including important science results demonstrating the full power of ALMA. Many science results from the two survey telescopes, as well as their beautiful images, were also released.

Following the successful installation of MUSE and SPHERE during 2014, science results from these two most recent instruments on the VLT were also published during the year. In addition two new facilities were announced — the Next-Generation Survey Telescope at Paranal and the new SEPIA camera on APEX.

An ESO Picture of the Week was issued for each week of the year. This continued the popular series of beautiful photographs of the ESO telescopes and their surroundings, as well as detailed astronomical images and many views of the night sky. Pictures of the Week also continue to be a very valuable channel through which to report on news items that do not necessarily require a full press release or announcement.

During the year ESO received almost a hundred formal interview requests from the media worldwide, resulting in impressive media coverage.

The ESO Supernova Planetarium & Visitor Centre

The groundbreaking ceremony for the ESO Supernova Planetarium & Visitor Centre took place on 24 February at ESO Headquarters. This event marked the beginning of the main construction phase of the facility. Eight months later, an informal ceremony for the construction workers celebrated the substantial progress achieved. By this time the remarkable architecture of the building had become apparent.

The portfolio of products for the planetarium community has been expanded significantly. The world's first full-length fulldome planetarium movie that is freely

The 10 000th free image was uploaded to the ESO image archive on 30 September 2015. This montage shows a small selection.

Dust and gas in the star formation region Messier 17.

available for planetarium use, *From Earth to the Universe*, was released in standard 4k fulldome format. This is now available for the planetarium community worldwide to download and use. Several other shows are in production and more than 150 planetarium clips and mini-shows were available for download by the end of the year. ESO is the first, and so far only, producer of planetarium material to be fully open for free download, providing high-quality content, especially to small planetariums.

Two teacher-training workshops were held this year in collaboration with our educational partners, the Deutsches Museum in Munich and Haus der Astronomie in Heidelberg. In collaboration with teachers, content for ten curriculum-linked educational workshops, together with supporting material has been developed for teachers to use.

In collaboration with the exhibition planner Design & Mehr, work on the several hundred individual exhibition items is in progress. The first test panels have been designed and implementation of the thirteen themes has started. Texts are being written in English and German, the two languages of the centre.

The operational model of the ESO Supernova Planetarium & Visitor Centre relies heavily on collaboration, and a team of volunteers has also been established, with ten of them actively contributing to the development so far. An ESO Supernova Planetarium & Visitor Centre coordinator was also appointed in the last quarter of the year.

Publications

In total 73 publications or items of merchandise were produced during 2015. This corresponds to a total of 1013 pages of publications, a slight decrease in comparison with previous years. Examples of ePOD products are brochures, the ESO Calendar, stickers, merchandise, electronic posters and periodicals. Preparations for some of the ESO Supernova Planetarium & Visitor Centre print products have been undertaken.

The logo of the ESO Supernova Planetarium & Visitor Centre was unveiled during the groundbreaking ceremony that marked the beginning of the main construction phase of the facility.


Teacher training session organised by the ESO Supernova Planetarium & Visitor Centre, Universe Awareness and the Deutsches Museum, delivered by Cecilia Scorza (front right). The Supernova coordinator, Tania Johnson, can be seen at the back.


A group photo of the 24 teachers who are now a part of the ESO Supernova Teacher Network.

Audiovisuals

The ESOcast video podcast series has continued successfully and a moderate but constant upward trend in the iTunes ranking reflects its increasing popularity. A new welcome video for weekend visitors at the Paranal and La Silla Observatory sites has been made.

The online video and image archive is the backbone of ePOD's audiovisual content distribution and is growing at an ever-increasing rate. Rich content, quick

Left: Poster of ESO's first in-house produced fulldome planetarium movie, *From Earth to the Universe*.

Right: An exhibition featuring photographs and videos showing the Atacama Large Millimeter/submillimeter Array — *ALMA, exploring our cosmic origins* — opened in Santiago.

access, ease of use, and cross-platform formats are the main characteristics of the archive.

The crowdsourcing of subtitle translations is proceeding well with more than 260 volunteer translators contributing. The number of volunteer translators for ESO's fulldome shows is also gradually increasing.

Exhibitions and events

In terms of exhibitions and events, the year was more active than 2014 with a number of activities set up in Chile and Europe. In June, the President of Chile, Her Excellency Michelle Bachelet, visited the Chilean Pavilion at Expo Milano and joined a live video conference with ESO's Representative in Chile, Fernando Comerón, the Director of the Energy, Science and Technology & Innovation Division of the Chilean Ministry of Foreign Affairs, His Excellency Gabriel Rodríguez, and Chilean astronomer María Teresa Ruiz, all of whom were speaking from the platform of the Paranal Observatory.

ESO exhibitions also visited Ireland, Poland, Switzerland, Spain and the USA.

Web and software development

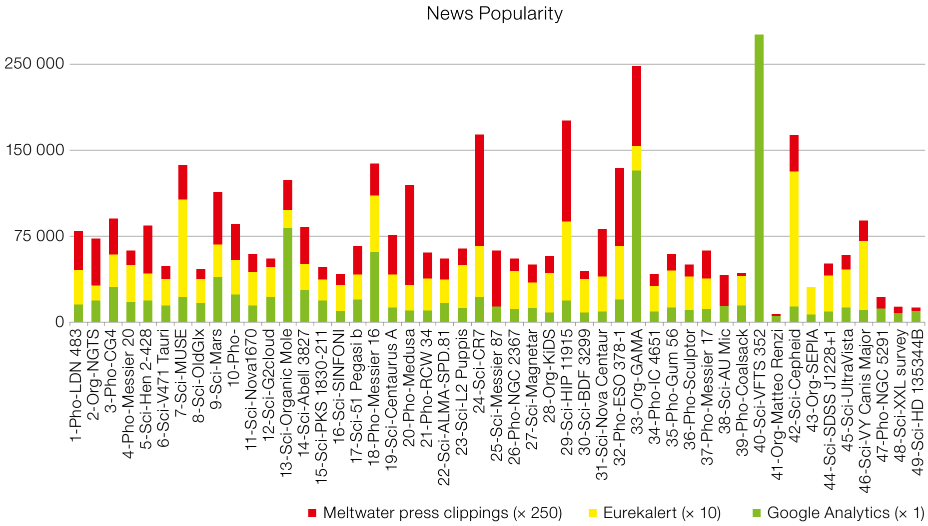
All the ePOD servers (web, database, etc.) were migrated to the latest IT standard, and are now installed and configured with standard profiles. This simplifies the replacement or re-installation of systems.

The infrastructure for the kiosks available at ESO Headquarters was rewritten from the ground up with a focus on stability and flexibility even in the event of a slow network or network outages. This is a first step towards the installation of kiosks at the Chile sites. The updated kiosks also make full use of the screen resolutions, improving readability.

The main database servers were migrated to PostgreSQL, which resulted in an important improvement in performance, in particular with some of the most complex queries. It also improved the data consistency and bugs, which had gone undetected, have now been fixed.

The Portal to the Universe website was upgraded to the latest version of Djangoplicity and brought in line with the other sites, making future development easier. A new design for spacetelescope.org was implemented using modern responsive technologies. A lot of the work previously done for eso.org was reused, whilst giving the site its own visual identity.

The ESO mini-sites (public versions of eso.org translated into 19 languages) were updated, also taking account of modern responsive technologies. Numerous new pages went online, making ESO more visible worldwide. Over 1500 images and videos were made publicly available in high resolution, many of them with captions written in several different languages and an advanced metadata system, which allows integration with external platforms and easy access via external searches.



The relative popularity of the 49 ESO press releases in 2015. Google Analytics measures the number of visitors to the news release web page on www.eso.org. Eurekalert counts how many journalists followed the news release link on the Eurekalert website (a news aggregation and distribution site for journalists). Meltwater is an electronic press clippings service; the metric is the number of online newspaper articles about a particular news release. These three metrics have widely different values and have been scaled to the range of Google Analytics values. The most popular releases were eso1540 (on the double star system VFTS 352), eso1533 (Slow death of the Universe), eso1529 (Jupiter twin discovered around solar twin) and eso1542 (VISTA finds new component of the Milky Way).

Media, VIP and weekend visits in Chile

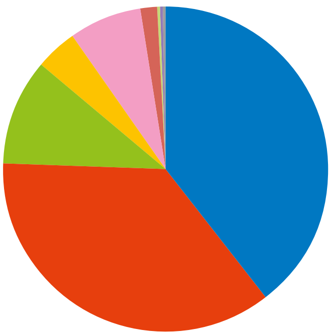
Many prestigious media outlets visited the sites in Chile, including the international channel of RAI (Radiotelevisione italiana, Italian National TV), Telewizja Polska SA (Polish TV), Radio France International, CCTV (the main channel in China, with an audience of an impressive one billion). The Swiss 3D movie company NVP3D visited the ESO observatories, co-led by former Swiss delegate to the Council, Georges Meylan, to produce a high-resolution 3D movie. Finally, the renowned astrophotographer Miguel Claro visited Paranal and the ALMA Observatory and took some impressive high quality images. The impact of the media visits remains very high, with a total audience estimated to be of the order of hundreds of millions.

The public weekend visits to La Silla and Paranal attracted 7262 people, maintaining roughly the same level as in 2014.

ESO Science Outreach Network

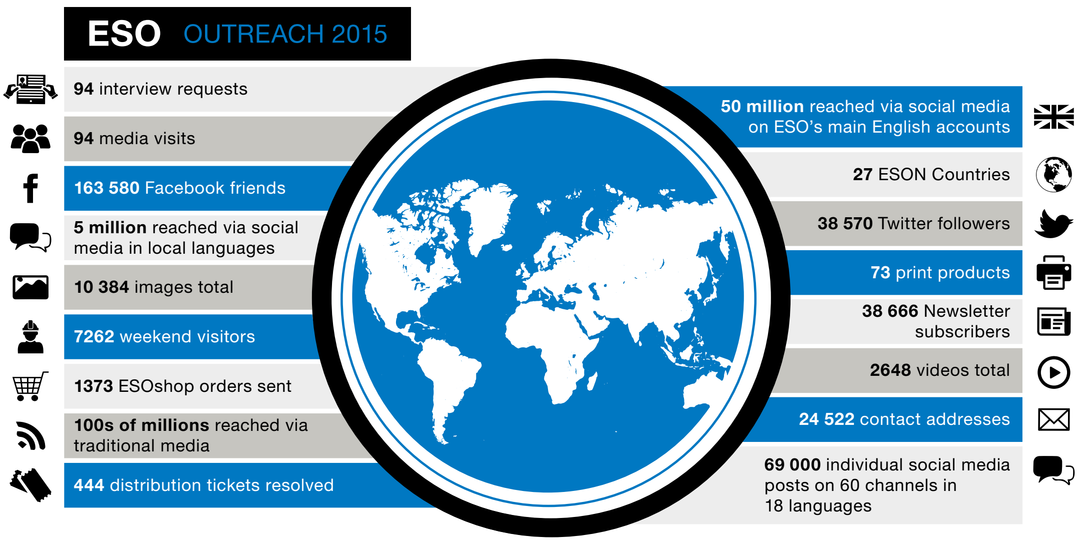
To raise the profile of ESO in the Member States and beyond, ePOD continues to manage the ESO Science Outreach Network (ESON). This consists of outreach specialists, press officers and educators in the ESO Member States and beyond. They act as direct, local contacts with the media and organise the translation of ESO-related information into their local languages. In total, ESON operates in 27 countries (including 16 ESO Member States), with information in 19 different languages (including English). The press releases, as well as most pictures of the week, and announcements, are translated into 18 different languages.

ESON also includes volunteers in other countries, who disseminate astronomical news and information about ESO. Furthermore, an ongoing fruitful collaboration with the EU Universe Awareness programme results in additional versions for children, issued as Space Scoops, which are also available in several languages.



The distribution of the 8.9 million web visits in 2015 for the ESO, HST and IAU outreach websites.

Above: Representatives from ESON member states gather for a group photo outside ESO Headquarters in Garching, Germany. They met on 22 May 2015 for the ESO Science Outreach Network meeting 2015.



Key figures relating to ESO's outreach activities in 2015.

In 2015, almost 30% of the web pages viewed on eso.org were translated by ESON.

Community coordination and distribution

The distribution and promotion systems ran smoothly through 2015. ESO's products, such as the 2016 ESO Calendar and *The Messenger*, are being distributed globally and are promoted to appropriate groups carefully selected from a large address database. Several improvements were made to the database to account for new distribution rules and contact groups were continuously updated.

ESO has continued to develop its presence in all of the most popular social media networks using the latest social media tools available. Over 1500 messages were posted on Facebook and Twitter alone, attracting millions of visitors. Each message was translated into about 18 languages and posted on about 60 local channels, resulting in a total of about 69 000 individual posts. All social media channels use the same workflows, tracking systems and software platforms.

Volunteers became even more important to the outreach team, helping us in particular with the ESO Supernova Planetarium & Visitor Centre and the translation of social media messages.

Partnerships continued to play an important role. ESO supported several competitions, such as Photo Nightscapes (organised by the French astronomy magazine *Ciel & Espace*), the AstroCamera competition (organised by the Polish Hewelianum Centre) and Insight Astrophotographer of the Year (organised by the Royal Observatory Greenwich in the UK). The ESO Astronomy Camp, held in partnership with Sterrenlab, saw its third successful year.

ESO/M. Claro

Twilight at the Paranal Observatory.

Calendar of Events

January

The Next-Generation Transit Survey achieves first light at Paranal Observatory.

Construction contract for the ALMA Residencia awarded to the consortium L y D - Axis, consisting of Constructora L y D S.A. and Axis Desarrollos Constructivos S.A.

Signing of parallel contracts with CESA (Spain) and VDL (the Netherlands) for the design and production of qualification models for the mirror segment support system for the E-ELT primary mirror.

ESO Workshop on ESO in the 2020s. ESO Garching, 19–23 January.

February

ESO Workshop on Baryons at Low Densities: The Stellar Halos around Galaxies. ESO Garching, 23–27 February.

Groundbreaking ceremony for the ESO Supernova Planetarium & Visitor Centre in Garching, beginning the main construction phase.

Meeting with members of the German Federal Parliament, organised in collaboration with the Committee on Education, Research and Technology Assessment.

March

Decommissioning of MIDI after 11 years of operation.

ESO Workshop on Ground and Space Observatories: A Joint Venture to Planetary Science. ESO Vitacura, 2–5 March.

Committee of Council and 134th Council meeting, Leiden, the Netherlands.

Unveiling of a plaque commemorating the 1954 Leiden Statement, which paved the way for the creation of ESO.

ALMA Board meeting, Vitacura.

María Ignacia Edwards selected for the ESO Art & Science Residency.

Annual Overview (internal review).

ESO Workshop on Dissecting Galaxies Near and Far. ESO Vitacura, 23–27 March.

April

Industry event at ESO Garching for Spanish companies seeking to participate in E-ELT construction.

Meetings on ALMA Community Days 2015: Preparation for Cycle 3 and Joint ALMA-Herschel Archival Workshop. ESO Garching, 13–17 April.

ESO Workshop on Satellites and Streams in Santiago. ESO Vitacura, 13–17 April.

Completion of first commissioning of the HARPS laser frequency comb on the ESO 3.6-metre telescope.

85th STC meeting.

APEX Board meeting.

ALMA Early Science Cycle 3 application deadline closes with 1582 proposals for observing time.

Activities as part of nationwide German Girls' Day at ESO Garching.

39th Users Committee meeting.

The first Olivier Chesneau Prize (established by ESO and the Observatoire de la Côte d'Azur) awarded to ESO Fellow Julien Milli.

First light of the 4LGSF with the first of four 22-watt laser guide star units on UT4.

May

141st Finance Committee.

96th Observing Programmes Committee meeting.

June

Exoplanet Focus Meeting for the Chilean Scientific Community. ESO Vitacura.

135th Council meeting.

4th EIROforum School on Instrumentation ESI 2015 (co-hosted with Eurofusion). ESO Garching, 15–19 June.

Workshop on Let's Group. The Life Cycle of Galaxies in their Favorite Environment. Max Planck Institute for Astrophysics, Garching, 16–19 June.

Meeting on Public Awareness of Research Infrastructures — Expectations — Experiences — Examples. Organised by the Association of European-level Research Infrastructure Facilities (ERF-AISBL). ESO Garching, 18–19 June.

Signing of contract with the AdOptica consortium in Italy for the final design and construction of the M4 unit of the E-ELT.

European Week of Astronomy and Space Science. La Laguna, Tenerife, Spain, 22–26 June.

Open House Day, part of The Long Night of Science (Lange Nacht der Wissenschaften), ESO Garching.

Unveiling ceremony for plaque commemorating the signing of the Leiden Statement, which laid the groundwork for the ESO Convention of 1962. The plaque was unveiled by the Dutch State Secreteary for Education, Culture & Science, Sander Dekker accompanied by the President of Leiden University, Carel Stolker.

July

Workshop on Early E-ELT Science: Spectroscopy with HARMONI. Oxford University Museum of Natural History, 29 June–3 July.

ESO Industry Day in Warsaw, Poland.

ESO Workshop on Stellar End Products: The Low Mass – High Mass Connection. ESO Garching, 6–10 July.

Contract signed with the French optics company Reosc, a subsidiary of Sagem, Safran group, to manufacture the deformable shell mirrors for the E-ELT M4 unit.

Poland's membership of ESO completed with the instrument of ratification being deposited at the French Ministry of Foreign Affairs in Paris on 8 July.

Industry event for Chilean businesses in Antofagasta, co-organised with the Chilean Government.

Joint ESO, MPA, MPE, Technische Universität München Excellence Cluster Workshop on Theoretical and Observational Progress on Large-scale Structure of the Universe. ESO Garching, 20–24 July.

August

IAU General Meeting and workshops, Honolulu, Hawaii, USA, 3–14 August.

The Director General of ESO and the Director General of ESA, Johann-Dietrich Wörner, sign a cooperation agreement at ESO Vitacura on 20 August.

September

European Radio Interferometry School 2015. ESO Garching, 6–10 September.

Signing of agreements with consortia of European institutes to design and construct the MICADO camera and spectrograph, the HARMONI spectrograph and METIS, an infrared camera and spectrograph, three of the first light instruments for the E-ELT.

ESO/G. Huedepohl

On 28 and 29 September 2015, ESO's Paranal Observatory welcomed the British rock guitarist, singer, songwriter and astrophysicist, Brian May, here shown in one of the domes of the VLT. Famed for being the lead guitarist of the legendary rock band Queen, May also has a passion for astronomy.

ESO Workshop on Astrobiology and Planetary Atmospheres. ESO Vitacura, 28 September–2 October.

British rock guitarist, singer, songwriter and astrophysicist, Brian May, visited Paranal.

142nd Finance Committee meeting.

October

The exhibition *ALMA, exploring our cosmic origins*, opened at the Espacio Fundación Telefónica, Santiago, Chile.

Astronomy week at the Chilean ExpoMilan Pavillion organised by Massimo Tarenghi, ESO Astronomer Emeritus.

ESO Workshop on Rainbows on the Southern Sky: Science and Legacy Value of the ESO Public Surveys and Large Programmes. ESO Garching, 5–9 October.

87th Committee of Council meeting.

First fringes with GRAVITY and four ATs.

Workshop on Science and Technology with E-ELT. Erice, Sicily, 8–20 October.

Winners of third ESO Astronomy Camp bursaries announced.

86th Scientific Technical Committee meeting.

The Prime Minister of Italy, His Excellency Matteo Renzi, visited Paranal Observatory on 24 October.

APEX Board meeting, MPIfR, Bonn.

November

143th Finance Committee meeting.

First observations with the Swedish–ESO PI receiver for APEX (SEPIA), for detection of water and other molecular emission at 1.4–1.9 mm.

97th OPC meeting.

ALMA Board meeting, Vitacura.

ESO Information Day held in São Paolo, Brazil.

ESO/ESA Workshop on Science Operations 2015: Science Data Management. ESO Garching, 24–27 November.

December

At the launch of *Innovation 2020* in Dublin, the Prime Minister of Ireland, Enda Kenny, sets out Ireland's intention to negotiate ESO membership.

136th Council meeting.

Agreement signed with an international consortium for the design and construction of the MAORY adaptive optics system for the E-ELT.

ESO and CERN sign a cooperation agreement.

Signing of ALMA Trilateral Agreement in Tokyo between ESO, the National Science Foundation and the National Institutes of Natural Sciences.

The Milky Way and the Magellanic Clouds over
the Residencia, at the Paranal Observatory.

P. Horálek/ESO

Glossary of Acronyms

4LGSF	4 Laser Guide Star Facility (VLT)
4MOST	4-metre Multi-Object Spectroscopic Telescope (Proposed new spectroscopic instrument for VISTA)
A&A	Journal, *Astronomy & Astrophysics*
A&ARv	Journal, *Astronomy and Astrophysics Review*
AEM	ALMA construction consortium
AGN	Active Galactic Nucleus
AJ	*The Astronomical Journal*
ALMA	Atacama Large Millimeter/submillimeter Array
AMBER	Astronomical Multi-BEam combineR (VLTI instrument)
A-MKIDS	APEX Millimetre-wave Kinetic Inductance Camera
AMUSING	All-weather MUse Integral field Nearby Galaxies survey
AN	Journal, *Astronomische Nachrichten*
ANSYS	Finite element analysis system
Antu	VLT Unit Telescope 1
AOF	Adaptive Optics Facility
APEX	Atacama Pathfinder Experiment
APEX-2A	APEX heterodyne receiver
APEX-SZ	Atacama Pathfinder EXperiment Sunyaev-Zel'dovich Instrument
ApJ	*Astrophysical Journal*
ApJS	Journal, *Astrophysical Journal Supplement Series*
AQUA	ALMA quality assurance tool
AQUARIUS	Mid-infrared detector array (VISIR)
ARA&A	Journal, *Annual Review of Astronomy and Astrophysics*
ARC	ALMA Regional Centre
ArTeMiS	Architectures de bolometres pour des Telescopes a grand champ de vue dans le domaine sub-Millimetrique au Sol (APEX)
ARTIST	Adaptable Radiative Transfer Innovations for Submillimetre Telescopes
ASSIST	Adaptive Secondary Setup and Instrument Simulator (AOF test bench)
ASTRONET	EU scheme for astronomy to step up cooperation and coordination of research activities carried out at national or regional level in the Member States and Associated States
AT	Auxiliary Telescope for the VLTI
ATT	ALMA Technical Team
au	Astronomical unit (Earth-Sun distance)
BIAS	Bremen Institute for Applied Beam Technology
BlackGEM	Telescope array searching for optical counterparts of gravitational wave sources
CARS	Close AGN Reference Survey
CASA	Common Astronomy Software Applications (ALMA)
CCD	Charge Coupled Device
CCTV	China Central Television
CDN77	Content delivery network
CERN	European Organization for Nuclear Research
CESA	Compañía Española de Sistemas Aeronáuticos S.A. (Spain)
CHAMP+	Carbon Heterodyne Array of the MPIfR (APEX)
CHEOPS	CHaracterising ExOPlanet Satellite (ESA)
CIAO	Coudé Infrared Adaptive Optics system (VLT)
CO	Carbon monoxide
CONDOR	CO N+ Deuterium Observations Receiver (APEX)
CONICA	High-resolution near-infrared camera (VLT, NACO)
CRIRES	Cryogenic InfraRed Echelle Spectrometer (VLT)
CRIRES+	Planned upgrade to CRIRES
CSW1	SPARTA electronics board containing switches and transceivers
DG	Director General
e2v	Detector company (Chelmsford, UK)
EASC	European ALMA Support Centre
E-ELT	European Extremely Large Telescope
EFOSC2	ESO Faint Object Spectrograph and Camera 2 (NTT)
EIROforum	Organisation consisting of the eight scientific European international organisations devoted to fostering mutual activities
EM&P	Journal, *Earth, Moon, and Planets*
ePOD	education and Public Outreach Department
ERIS	Enhanced Resolution Imaging Spectrograph (VLT)
ERP	Enterprise Resource Planning
ESA	European Space Agency
ESAC	European Science Advisory Committee (for ALMA)
ESC	E-ELT Subcommittee
ESI	EIROforum School on Instrumentation
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
ESON	ESO Science Outreach Network
ESPRESSO	Echelle SPectrograph for Rocky Exoplanet- and Stable Spectroscopic Observations (VLT)
ETH	Swiss Federal Technical Institute (Zürich)
EU	European
EU-IET	European part of the IET (ALMA)
EVALSO	Enabling Virtual Access to Latin American Southern Observatories
EWASS	European Week of Astronomy and Space Science
ExA	Journal, *Experimental Astronomy*
FARO	Laser tracker manufacturer
FEROS	Fibre-fed, Extended Range, Échelle Spectrograph (2.2-metre)
FINITO	Fringe-tracking Instrument of NIce and TOrino (VLTI)
FLAMES	Fibre Large Array Multi Element Spectrograph (VLT)
FLASH	First Light APEX Submillimetre Heterodyne receiver
FORS2	FOcal Reducer/low dispersion Spectrograph 2 (VLT)
G7	Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States
Gaia	Astrometric satellite (ESA)
GALACSI	Ground Atmospheric Layer Adaptive Optics for Spectroscopic Imaging (AOF)
GmbH	Gesellschaft mit beschränkter Haftung, German limited liability company
GRAAL	GRound-layer Adaptive optics Assisted by Lasers (AOF)
GRAVITY	AO assisted, two-object, multiple-beam-combiner (VLTI)
GTO	Guaranteed Time Observing
GuideCam	Unified target acquisition preparation tool for all ESO instruments
H2020	Horizon 2020 EU Research and Innovation programme
HARMONI	First light integral field spectrograph for the E-ELT
HARPS	High Accuracy Radial Velocity Planetary Searcher (3.6-metre)
HAWK-I	High Acuity Wide field *K*-band Imager (VLT)
HEDP	Journal, *High Energy Density Physics*
HIRES	Proposed E-ELT high-resolution spectrograph
HR	Human Resources
HST	NASA/ESA Hubble Space Telescope
IAC	Instituto de Astrofísica de Canarias
IAU	International Astronomical Union
ICAFAL	Ingeniería y Construcción S.A., Chilean construction company
Icar	*Icarus*, Planetary science journal
ICT	Integrated Computing Team (ALMA)
IEPOT	Integrated Education and Public Outreach Team (ALMA)
IET	Integrated Engineering Team (ALMA)
INAF	Italian National Institute for Astrophysics
ISAAC	Infrared Spectrometer And Array Camera (VLT)
IT	Information Technology
JAO	Joint ALMA Observatory
Jenkins	Java open source continuous integration tool
JIRA	Proprietary issue tracking product
JMoSp	Journal, *Journal of Molecular Spectroscopy*
KMOS	*K*-band Multi-Object Spectrograph (VLT)
Kueyen	VLT Unit Telescope 2
LABOCA	Large APEX Bolometer CAmera

LAOG	Laboratoire d'Astrophysique de Grenoble
LGSF	Laser Guide Star Facility (VLT)
LMU	Ludwig Maximilians University, Munich
LSP	La Silla Paranal Subcommittee
M#	Mirror #
MACAO	Multiple Application Curvature Adaptive Optics
MACCON	Motion controller manufacturer
MAGIX	Modeling and Analysis Generic Interface for eXternal numerical codes
MAORY	Multi-conjugate Adaptive Optics RelaY (E-ELT)
MASCARA	Multi-site All Sky CAmeRA (La Silla)
MATISSE	Multi AperTure mid-Infrared SpectroScopic Experiment (VLTI)
Melipal	VLT Unit Telescope 3
METIS	Proposed mid-infrared imager and spectrograph (E-ELT)
MICADO	Adaptive optics imaging camera (E-ELT)
MIDI	Mid-infrared Interferometric Instrument (VLTI)
mmVLBI	Millimetre very long baseline interferometry
MNRAS	Journal, *Monthly Notices of the Royal Astronomical Society*
MOONS	Multi Object Optical and Near-infrared Spectrograph (VLT third generation)
MOS	Proposed multi-object spectrograph (E-ELT)
MOUS	Member Observation Unit Sets (ALMA)
MPA	Max Planck Institute for Astrophysics
MPE	Max Planck Institute for Extraterrestrial Physics
MPG	Max-Planck-Gesellschaft
MPIA	Max Planck Institute for Astronomy
MPIfR	Max Planck Institute for Radio Astronomy
MUSE	Multi Unit Spectroscopic Explorer (VLT)
myXCLASS	Tool within XCLASS that calculates synthetic spectra
NACO	NAOS-CONICA (VLT)
NAOJ	National Astronomical Observatory of Japan
NAOMI	Adaptive optics system for the ATs (VLTI)
NAOS	Nasmyth Adaptive Optics System (VLT)
NASA	National Aeronautics and Space Administration
NewA	Journal, *New Astronomy*
NewAR	Journal, *New Astronomy Reviews*
NGC	New General Catalogue
NGTS	Next-Generation Transit Survey (Paranal)
NIRPS	Near Infra Red Planet Searcher
NIX	Infrared imager (VLT)
NOEMA	NOrthern Extended Millimetre Array
NOVA	The Netherlands Research School for Astronomy (Nederlandse Onderzoekschool voor Astronomie)
NRAO	National Radio Astronomy Observatory
NSF	National Science Foundation (US)
NTT	New Technology Telescope (La Silla)
NVP3D	Nicolet Vidéo Productions 3D, Swiss 3D movie company
OmegaCAM	Wide-field camera (VST)
OPC	Observing Programmes Committee
OPTICON	Optical Infrared Coordination Network for astronomy
OSF	ALMA Operations Support Facility
OSO	Onsala Space Observatory
P#	Observing Period
P&SS	Journal, *Planetary and Space Science*
PAE	Provisional Acceptance Europe
PARLA	Laser source for the LGSF
PASJ	Journal, *Publications of the Astronomical Society of Japan*
PASP	Journal, *Publications of the Astronomical Society of the Pacific*
PESSTO	Public ESO Spectroscopic Survey of Transient Objects
PhRvL	Journal, *Physics Review Letters*
PI	Principal Investigator
PIONIER	Precision Integrated Optics Near-infrared Imaging ExpeRiment (VLTI)
PIONIER-3D	PIONIER at its new location in the VLTI laboratory
PLATO	PLAnetary Transits and Oscillations of stars (ESA)
PRIMA	Phase-Referenced Imaging and Micro-arcsecond Astrometry facility (VLTI)
RAI	Radiotelevisione italiana. Italian television channel
REM	Rapid Eye Mount telescope (La Silla)
SABOCA	Shortwave Apex BOlometer Camera
SAESA	Chilean Electrical company
SAPHIRA	Selex Avalanche Photodiodes for Highspeed Infra Red Applications (GRAVITY)
SEPIA	Swedish-ESO PI receiver for APEX
SFR	Star formation rate
SHFI	Swedish Heterodyne Facility Instrument (APEX)
SINFONI	Spectrograph for INtegral Field Observations in the Near Infrared (VLT)
SnooPI	Snooping Project Interface, an intuitive project tracking tool for Principal and Co-Investigators (ALMA)
SOAR	Southern Astrophysical Research 4-metre telescope
SOFI	SOn oF Isaac (NTT)
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOXS	SOn of X-shooter (NTT)
SPARTA	Standard Platform for Adaptive Optics Real Time Applications (AOF)
SPECULOOS	Search for habitable Planets Eclipsing ULtra-cOOl Stars (Paranal)
SPHERE	Spectro-Polarimetric High-contrast Exoplanet Research instrument (VLT)
SPIFFI	SPectrometer for Infrared Faint Field Imaging (SINFONI, VLT)
STC	Scientific Technical Committee
STFC	UK Science and Technology Facilities Council
STIS	Space Telescope Imaging Spectrograph (HST)
STRAP	System for Tip-tilt Removal with Avalanche Photodiodes (STRAP)
TAROT-S	Télescopes à Action Rapide pour les Objets Transitoires South (La Silla)
telbib	ESO Library telescope bibliography database
TRAPPIST	TRAnsiting Planets and PlanetesImals Small Telescope (La Silla)
UFRN	Universidade Federale do Rio Grande do Norte, Brazil
UK	United Kingdom
UK-ATC	UK Astronomy Technology Centre
ULTRACAM	High-speed camera (VLT UT3:P74–79; NTT: P85–87)
UNESCO	United Nations Educational, Scientific and Cultural Organization
UT	VLT Unit Telescopes 1–4: Antu, Kueyen, Melipal and Yepun
UVES	UV-Visual Echelle Spectrograph (VLT)
VDL	Van Der Leegte Groep, the Netherlands
VIMOS	VIsible MultiObject Spectrograph (VLT)
VISIR	VLT Mid-Infrared Imager Spectrometer
VISTA	Visible and Infrared Survey Telescope for Astronomy
VLA	Jansky Very Large Array
VLBI	Very Long Baseline Interferometry
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer
VPF1	SPARTA electronics board for LGS wavefront control and processing
VST	VLT Survey Telescope
VVV	ESO Public Survey VISTA Variables in the *Vía Láctea*
WFI	Wide Field Imager (MPG/ESO 2.2-metre telescope)
XCLASS	eXtended CASA Line Analysis Software Suite
XMM-Newton	X-ray Multi-Mirror satellite (ESA)
X-shooter	Wideband ultraviolet-infrared spectrograph (VLT)
Yepun	VLT Unit Telescope 4
ZEUS	Redshift (*z*) Early Universe Spectrometer (APEX)
ZIMPOL	Zurich Imaging Polarimeter (SPHERE mode)
Z-spec	Millimetre-wave spectrograph (APEX visitor instrument)
μm	Micrometre

ESO Europe

Headquarters
Karl-Schwarzschild-Straße 2
85748 Garching bei München
Germany
Phone +49 89 320 060
Fax +49 89 320 2362
information@eso.org
www.eso.org

ESO Chile

ESO Vitacura
Alonso de Córdova 3107
Vitacura
Casilla 19001
Santiago de Chile
Chile
Phone +56 2 2463 3000
Fax +56 2 2463 3101

La Silla Paranal Observatory
La Silla Site
IV Región
Chile
Phone +56 2 2464 4100
Fax +56 2 2464 4101

La Silla Paranal Observatory
Paranal Site
II Región
Chile
Phone +56 55 2435 100
Fax +56 55 2435 101

APEX Sequitor Base
Ayllo de Sequitor, Parcela 85
San Pedro de Atacama
II Región
Chile
Phone +56 55 2448 200
Fax +56 55 2448 221

APEX Chajnantor Site
II Región
Chile
Phone +56 55 2448 299

ESO La Serena Office
Avenida Panorámica No. 4461
Sector Aeroparque La Florida
Casilla 567
La Serena
Chile
Phone +56 51 2272 601
Fax +56 51 215 175

Guesthouse
Rey Gustavo Adolfo No. 4634
Las Condes
Santiago
Chile
Phone +56 2 2208 4254
Fax +56 2 2228 9333

ESO Antofagasta Office
Avenida Balmaceda 2536
Office 504
Edificio “Don Guillermo”
Antofagasta
Chile
Phone +56 55 2260 032
Fax +56 55 2260 081

ESO is a partner in the international ALMA project

ALMA Santiago Central Offices
Alonso de Córdova 3107
Vitacura
Casilla 763 0355
Santiago
Chile
Phone +56 2 2467 6100
Fax +56 2 2467 6101

ALMA Operations Support Facility
Kilómetro 121
Carretera CH 23
San Pedro de Atacama
Chile
Phone +56 2 2467 6416

ALMA Array Operations Site
II Región
Chile

Cover: A typical observing night for the Very Large Telescope at the Paranal Observatory.
Credit: P. Horálek/ESO

All images are courtesy of ESO unless otherwise indicated.

Edited by the DG Cabinet.

Produced by the education and Public Outreach Department.

ESO 2015
ISSN 0531-4496


www.eso.org